2023 PEREGRINE FALCON MIGRATION STUDIES AT ASSATEAGUE ISLAND, MD

CONDUCTED UNDER:

AINS (NPS) SCIENTIFIC RESEARCH AND COLLECTING PERMIT ASIS-2023-SCI-0008
ASSATEAGUE STATE PARK (MD) USE AGREEMENT
USGS-BRD MASTER BANDING PERMIT 20127
MARYLAND SCIENTIFIC COLLECTING PERMIT 55662

by

EARTHSPAN
In partnership with The Peregrine Fund
14990 Honodel Road
Waynesboro, PA 17268
Phone (775) 781-3844
www.earthspan.foundation

Michael A. Yates
William S. Seegar, PhD
B. James Dayton

16 December, 2023

ABSTRACT

As part of a continuing research program, field studies were conducted on the Peregrine Falcon, Falco peregrinus. This report focuses on our 53rd annual study, which was conducted on the northern (MD) portion of Assateague Island, MD/VA, and includes information on joint research initiatives with our parallel study at South Padre Island, TX. Observations and captures by unit effort were the 17th and 11th lowest, respectively for this long-term study. Between 25 September and 18 October, the Survey team expended 220 man-hours in the field, recording 149 sightings of peregrines and capturing 36 different individuals. Three of the falcons captured were previously banded. The 149 sightings included 24 observations of individuals previously captured during the survey. We also obtained 36 blood samples and 32 cloacal swabs from captured peregrines, along with associated feather samples for current and future collaborative studies. We recommend that the survey be continued indefinitely.

INTRODUCTION

The presence of Peregrine Falcons on Assateague Island, Maryland each autumn was confirmed by falconers in 1938. Most of these were tundra peregrines (*Falco peregrinus tundrius*), a migratory Arctic nesting subspecies. Some few individuals of the subspecies *Falco peregrinus anatum* also occurred on Assateague in the fall. These peregrines were known to breed on rock faces in the eastern United States.

Catastrophic declines in global peregrine populations after the mid-1940s were attributed to widespread use of chlorinated hydrocarbons (such as DDT) as agricultural pesticides after World War II (Hickey 1969). Food chain contamination resulted in high levels of DDE (the principal metabolite of DDT) in the tissues of peregrines, which caused the formation of thin eggshells and increased reproductive failures. *F.p. anatum* was extirpated east of the Mississippi River and only remnant populations survived elsewhere in temperate North America. By the late 1960s *F.p. tundrius* was also in rapid decline, and both subspecies received endangered species status in 1970.

Diverse efforts were undertaken to study, monitor and augment peregrine populations. Enderson (1969) advocated coastal surveys as population indices in migrating peregrines. Assateague Island, as a major focal point of the autumn tundra peregrine migration, had been visited for the preceding three decades by falconers, bird banders and scientists. In 1970 the Department of the Army initiated a program to monitor the tundra peregrine and to develop new technologies to assist in the study of highly migratory threatened, endangered and sensitive species. The Assateague survey was thus established, and a similar effort was begun at Padre Island, TX in 1977. At Assateague our data could be related to records kept by previous researchers for over 30 years (Ward et al. 1988, Fig. 1). The program rapidly expanded to include research in diverse geographic regions to assess all aspects of the natural history of the tundra peregrine, and specifically the issues associated with global contaminants and pathogens affecting their population dynamics. We have used blood sampling to assess contaminants (Henny et al. 1988, 1996, 2009, Seegar et al. 2015, Barnes et al. 2019), emerging pathogens (Dusek 2005, Redig and Goyal 2012), parasites (Taft et al. 1998), and genetics (Longmire 1988, Morizot 1988, Longmire et al. 1991, Johnson et al. 2010,). In addition to investigations referenced in the Methods section, we have studied habitat use during migration (Seegar and Ray 1979), prey selection by peregrine age class (Ward and Laybourne 1985), and distribution of band recoveries (Yates et al. 1988). The principals, working under the Earthspan banner at Assateague and Padre since 1994, have developed new and innovative technologies to examine migration and wintering biology (Fuller et al. 1995, Seegar et al. 2003). The results dramatically extend our knowledge of this macropredator on migration and during its wintering period in the Neotropics.

North American peregrine populations rebounded markedly after the U.S. ban of DDT for agricultural use in 1972. Relying heavily on standardized data from this study, the U.S. Fish and Wildlife Service (USFWS) in 1994 removed *F.p. tundrius* from the List of Endangered Species; *F.p. anatum* followed in 1999.

METHODS

In 2006-2023 we surveyed only the northern (MD) portion of the island. Our 2023 study area on Assateague Island, MD, included Assateague Island National Seashore (National Park Service) and Assateague State Park (Maryland Department of Natural Resources). During the survey period the island was traversed each day from sunup to sundown by one team in a four-wheel-drive vehicle. Only vehicle failure, high wind, flood tide, or other condition that would place study subjects or personnel in jeopardy constrained survey operations. All raptors observed were recorded according to species, time, location and activity at time of sighting.

An attempt was made to capture peregrines encountered that were not identified through color marking as duplicates, and that were found in areas conducive to trapping. Capture methods are described by Ward and Berry (1972). Unbanded peregrines were fitted with a U.S. Geological Survey (USGS) lock-on band (size 6 for males, 7a for females) and processed according to current research protocols before release at the capture site. Past protocols have included recording weight and body measurements, collecting small feather samples (Parrish et al. 1983, Barnes et al. 2019), pollen samples from plumage, ~2ml blood samples (as described by Redig 1993), cloacal and pharyngeal swabs, affixing color-coded alpha-numeric bands (Ward 1975), and attaching conventional VHF (Cochran 1985) and pulse-coded (Howey et al. 1984) transmitters. Between 1993 and 2012 we also deployed Platform Transmitter Terminals (PTTs) and Cellular Transmitter Terminals (CTTs) on 25 peregrines. The former are tracked and located globally by polar orbiting satellites (Fuller et al. 1995) and the latter by GSM cellular towers. Before each falcon was released its head and crop were marked with a harmless red dye. This identifies the individual as one already sampled during the survey and precludes recapture attempts; it fades quickly over a three-week period. In the evening field notes were transcribed, samples processed and equipment repairs made.

RESULTS AND DISCUSSION

Between 25 September and 18 October, the survey team of Mike Yates and Bill Seegar expended 220 man-hours in the field, recording 149 sightings of peregrines and capturing 36 different individuals (Table 1). Three of the falcons captured were previously banded. The 149 sightings included 24 observations of individuals previously captured during the survey. We include these other known duplicates in tables and discussion to allow more direct comparisons among our data and those from pre-survey Assateague counts (dating from 1939) and other projects where protocols do not allow identification of duplicates.

Sightings per 10 man-hours were the 17th lowest and captures 11th lowest among our 53 survey years (Table 2), a disappointing continuance of our recent downturn in numbers. A major concern has been that populations are adversely affected by the Highly Pathogenic Avian Influenza (HPAI) outbreak of 2021-23. Counts at our Padre Island (TX) survey have sharply declined, particularly in spring, and a long-term survey on Alaska's Yukon River has also shown a concurrent decrease. We know that HPAI is almost invariably fatal to peregrines that become exposed. We looked at raptor counts from other East Coast sites (Table 5) for perspective on our results. North of us is Cape May, NJ and south of us are Kiptopeke, VA and FL Keys. Although those fixed sites with vast viewscapes record more peregrines on favorable migration days and our most productive days are those that retard migration or reduce flight altitudes through wind and/or precipitation, it can be instructive to compare peregrine observations temporally and collectively. Their 2023 results provide little insight on our anemic numbers at Assateague, but they are somewhat reassuring.in terms of any nosedive in migratory tundra peregrine numbers. While Cape May's seasonal observations slightly declined, healthy increases in observations at Kiptopeke and FL Keys were recorded.

Age and sex demographics of sighting and capture are detailed in Tables 1 and 3. Juveniles sighted per 10 man/hours were 4.72, our 10th lowest number since 1979 and well below our 53-year average of 7.20. Adults sighted per 10 man-hours were only .64, our 3rd lowest since 1977 and roughly half our 53-year average of 1.26. While 2023 was a very poor showing of adults at Assateague, the percentage of adults relative to overall sightings identified by age was not alarmingly low. We captured three previously-banded peregrines this fall, all marked as nestlings from the eastern population established through captive breeding and release. One juvenile male had been banded in NJ on 14 June 2023, and another in VA on 6/3/23. We await word from the

USGS on the provenance of a juvenile female. During the survey only 56 merlins (*Falco columbarius*) were observed, a continuation of anemic numbers that have spiraled downward in recent years. The peak of merlin migration normally precedes our Peregrine Survey dates.

Sightings and captures by sector are detailed in Table 4. On the Maryland Beach productivity by unit effort was (as expected) below that on the McCabe Tract. The 12-mile Over-sand Vehicle (OSV) Zone from the Virginia border north sees very intensive public use. OSVs on this sector are a limiting factor for the occurrence, observation and particularly the capture of peregrines. Reduced prospect for productivity leads to less Survey time devoted to the Maryland Beach. We spent an increased 36% of our time there in 2023 due to multiple tide-related closures of all or part of the OSV zone to the public, and productivity improved as expected. We thank the Seashore for its recognition that we will safely use a closed beach and be its eyes and ears thereon.

As usual, we operated only on the beachfront of the McCabe Tract due to the presence of the federally threatened and Maryland endangered plant Sea Beach Amaranth (*Amaranthus pumilus*). This had little or no impact on results, as most resting peregrines there are on or near the beachfront. The McCabe Tract is generally more productive in terms of capture success than the Maryland Beach; that is to be expected because of the prohibition on public use by OSVs. Although visitor foot traffic increases yearly on McCabe's, this still proved the case. We devoted 60% of our time there in 2023, with higher numbers of falcons observed and captured by unit effort than on the Maryland Beach.

Because of its very narrow beachfront, development and public use, the Assateague State Park is seldom utilized by migrating peregrines. Its primary value to the Survey is for efficient travel between potentially productive sectors during periods when few people are using the State Park beachfront. Only 11 of the survey's 5,928 captures have occurred on the State Park. The Access Road is utilized only for travel between the McCabe Tract and Maryland Beach and offers no possibility for anything more than observations.

Historically our migration is characterized demographically by an early preponderance of adult females and juvenile males. When large numbers of juvenile females arrive, we see fewer juvenile males and even fewer adult females in the mix, and the migration's peak is upon us. As migrant counts begin their decline a few more adult females appear and the number of individuals of any age/sex becomes ever more dependent upon favorable weather conditions. That scenario was not evident in 2023, with few adults and only minor surges in juvenile demographics. The 2023 migration at Assateague was atypical as a whole, with a predominance of the north winds that assist peregrines in migrating rather than resting on the Assateague beachfront. A review of archived weather data from the Ocean City airport confirmed that anecdotal impression. Of our 24 Survey days, only three had winds with no northerly component, and only four had winds with any of the southerly component that tends to retard migration and make falcons more available for capture. In addition, several days boasted northerly winds in the 19-27 MPH range. Peregrines put many miles behind them and are reluctant to stop on such days, and the techniques necessary to safely capture them are generally futile.

The Survey's peregrine numbers at Assateague are reduced over the past several years, but most studies elsewhere indicate no decline in populations. The island itself has become less hospitable to most migrating raptors, as evidenced by our own observations. We previously commented on reduced numbers of merlins over the years. Only 28 northern harriers (*Circus hudsonius*) were observed in 2023, and previously abundant numbers of migrating kestrels (*Falco sparverius*) were reduced to 7 this year. The factors that affect migratory peregrines' use of Assateague can effectively limit many other raptors as well.

One possible factor in reduced peregrine and other raptor observations at Assateague has been evolving over time, with implications that threaten the island's long-term status as a magnet for southward migrating tundra peregrines. As the mid-Atlantic coastline to the north has been incrementally developed, there are progressively fewer places a migrant can rest and feed. With little appropriate habitat, many individuals may either divert offshore or inland to bypass development and not return to the coast by the time they pass Assateague. For those in a position to utilize the island, the intense visitation and public use of beachfront habitats are a deterrent. Once extensive sand levels created by frequent ocean washover (Fox Hill and Little Fox Levels in Maryland, Wash Flats in Virginia) were lost through anthropogenic management, and the beachfront became key to peregrine use during migration. Public use of the Seashore beach is intense on many days, and on some weekends in fall we can count over 100 OSVs traversing the beach. Under such conditions, migrants attempting to use the beachfront are soon displaced. Migration patterns could also be changing in response to beachfront development and use. It is interesting to note that in 2023 Cape May and Assateague (coastal) numbers declined, while Kiptopeke (interior bayshore) and FL Keys (converged coastal and interior migrants) both increased. Could a larger proportion of migrants be bypassing the traditional coastal route?

The dramatic increase in presence of Bald Eagles (*Haliaeetus leucocephalus*) we have been observing over the past couple of decades is also demonstrably affecting survey results. In 2019 we observed many more Bald Eagles (364) than peregrines (135), a 210% increase in eagle observations over 2017. This year our 213 sightings exceeded those of peregrines by a 1.43:1 ratio. In earlier survey years eagles encountered were shy and usually gave us a wide berth. Now many are so habituated to human proximity as to display no concern when we pass within 20 meters. They are tame and aggressive; we regularly observe them teaming to rob Ospreys (*Pandion haliaetus*) of prey, and sometimes observe them in pursuit of peregrines with or without prey. They interfere in our capture attempts, we must always be mindful of their actual or potential presence, and it is likely that such presence also reduces the number of peregrines utilizing the immediate area.

All this being said, when conditions are right peregrines will still utilize Assateague in significant numbers on migration. On those days, island visitors and eagles will not deter them and those displaced by one or the other will quickly find another niche close by.

We fielded no PTTs or CTTs on peregrines during the survey. These technologies comprise an invaluable tool in identifying critical habitats and in pinpointing and mitigating global sources of contaminants and pathogens affecting peregrines and the other Neotropical migrants with which their life histories are so irrevocably intertwined. We have tracked 22 Assateague migrants via PTT and three via CTT, and plan to continue their use in the future when funding levels allow.

Resident Peregrines: In 1980 captive-bred peregrines of mixed subspecies were first released from a “hack tower”, a tall platform constructed on the Virginia portion of Assateague. In 1981 a pair took up residence, produced young, and remained on territory during the fall migration of tundra peregrines. Residents were present during the 1981-2004 surveys, and we witnessed aggression towards migrants in varying degrees. Other individuals of the newly established eastern race have at times taken territories on the north and south ends of the island and have been observed defending these territories. It has been clear that the artificial establishment of this coastal population has resulted in many agonistic encounters for migratory peregrines in the autumn. A resident was present on the McCabe Tract in 2016 and we documented one territorial encounter with a migrant; no resident peregrines were identified during the 2017-2023 surveys.

Blood Sampling: We collected blood samples from 36 captured peregrines for our archive and eventual use in collaborative studies. By example, in 2015 we published the results of a study with the Peregrine Fund and the University of Connecticut (Seegar et al. 2015) associated with the Deepwater Horizon (DWH) MC 252 oil spill. In April 2010 a catastrophic explosion ripped through an offshore oil rig; eleven workers were killed and a massive release of crude oil fouled the Gulf of Mexico and associated coastal habitats. Oil spill-related injury to wildlife is of major concern, and our investigation dealt directly with the effects of this event on the Tundra Peregrine Falcon. The Gulf oil spill posed an especially high risk to the tundra peregrine population in North America; Earthspan research has determined most of the population (≥80%) passes through the Gulf States during its annual fall and/or spring migrations. As predators at the top of the food chain, peregrines are particularly susceptible to toxins and contaminants concentrated at lower trophic levels. Polycyclic Aromatic Hydrocarbons (PAHs), components of the DWH oil spill, are known to cause a variety of adverse eco-toxicological impacts. Zuberogoitia et al. (2006) found that a 2002 oil tanker sinking off NW Spain “…clearly resulted in increased rates of (peregrine) adult mortality and reduced fertility…" The Peregrine Falcon is a recognized environmental sentinel species, and it is established that: 1) peregrines are susceptible to acute toxicity from PAHs; 2) PAHs are lethal to developing peregrine embryos; 3) PAHs form DNA adducts in several avian species; and 4) PAHs cause heritable genetic mutations in birds. Furthermore, immediate hazards loom during semiannual migrations through contact contamination and accumulation of oil when large numbers of falcons capture and consume prey in oil contaminated Gulf Coast habitats. Tundra peregrines migrating southward at Assateague in 2010 could not yet have been exposed to DWH contaminants, and juvenile peregrines in subsequent years could only have been exposed through any contaminants borne by their mother or by contaminated migratory prey species they ingested to the north. The samples we collected at Assateague and Padre Islands (along with those previously archived) comprised an invaluable resource in demonstrating the utility of non-lethal blood sampling to assess effects of contaminants. Results showed a marked increase in both the levels of PAHs present and their composition (a transition to crude oil-based compounds) in the year following the spill, followed by a return to near baseline components.

Highly Pathogenic Avian Influenza monitoring: In a 2015 collaboration with Dr. Tom Gidlewski and Meredith Grady from the USDA APHIS National Wildlife Research Center, we contributed blood and cloacal swab samples from our Assateague and Padre Island surveys for analyses in their Highly Pathogenic Avian Influenza (HPAI) in Raptors of the US project. This effort contributes to the conservation of raptors, knowledge of the epidemiology of HPAI, heightened national surveillance efforts and understanding of potential impacts on populations. The recent spread of HPAI viruses into North America and their tendency to reassort generates concerns and questions of the risks to agriculture, zoologic collections, wildlife and, potentially, human populations. As researchers have pointed out, robust, targeted surveillance programs among wild birds and poultry, modeling of the movements of HPAI-infected wild birds, and experimental research studies will provide the knowledge required for intelligent policy and management decisions (Hall et al. 2015). The USDA conducted initial analyses of 274 serum samples collected in 2015 from all species of raptors (including 109 peregrine samples we provided from Assateague and Padre Islands). Samples were analyzed using the IDEXX Multi-S ELISA to detect influenza A antibodies, and the only raptor samples that tested positive for influenza A antibodies were one peregrine from Assateague and one from Padre.

We began a collaboration in December 2022 with Arnaud Van Wettere (DVM, MS, PhD, DACVP) at the School of Veterinary Medicine, Utah State University. Entitled Prevalence of Avian Influenza A Virus Antibodies in Migrating North American Peregrine Falcons, it is summarized thus:
An outbreak of highly pathogenic avian influenza (HPAI) virus H5N1 started in the fall of 2021. The scale of this outbreak is unprecedented; it is the largest and most prolonged to date in the USA. Raptors are known to be particularly susceptible to HPAI, with most succumbing within a few days post infection. Given that Peregrine Falcons often prey on bird species known to carry the virus asymptomatically (e.g., waterfowl, gulls, shorebirds), they are at a higher risk of exposure to the virus than most raptor species. While a small number of wild Peregrine Falcons and falconry birds that succumbed to HPAI virus infection have been found during this outbreak, data on how many falcons survive infection is lacking. Studies during past outbreaks have shown that very few falcons (<0.1%) have antibodies to avian influenza virus. However, past HPAI outbreaks occurred in the fall and/or winter and disappeared in early summer with the return of warm temperatures. Therefore, exposure to the virus of Peregrine Falcons that migrate to Central and South America for the winter was likely limited. As this outbreak started in the fall of 2021 but persisted during the summer and fall 2022, Peregrine Falcons are more likely to have been exposed to HPAI virus than in past outbreaks. The goal of this study is to detect evidence of exposure to avian influenza virus. The presence of antibodies to avian influenza virus will be evaluated in the plasma of Peregrine Falcons captured during the fall and spring of 2021-2022 and the spring of 2023 to determine how many Peregrine Falcons have developed an immune response against the virus. Determining the prevalence of antibodies against avian influenza virus will provide documentation of exposure to the virus in migrant Peregrine Falcons and indicate whether some falcons survived infection.

We tested 442 peregrine samples and 6 were positive for influenza A antibodies. For spring and fall 2021 which is the period before the HPAI outbreak started, the combined number of positives is 1 out of 237 birds (0.42%, similar to past studies). For Spring 2022, Fall 2022, and Spring 2023 (the outbreak period) the combined number of positive birds is 4/204 (1.96%). A single individual sampled in both 2021 and 2022 accounted for two of the positives, so was removed from the 2022-23 results. The number of birds with antibodies remains very low, but higher than reported in past surveys. The percentage of peregrines with antibodies in past studies in the US was 1/472 (0.2%) in 2006 to 2010, and 2/299 (0.67%) in 2001 to 2004, and 2 of 109 falcons (1.83%) during the large outbreak of 2014 to 2015. The encouraging news is that AI exposure is not invariably fatal to peregrines, although most succumb rapidly. We also infer that serology metrics in peregrines do relate to the scale of outbreaks, which has grown considerably at present. This autumn we also collected 32 cloacal swabs from captured peregrines for analyses.

Genetic analyses: In a collaboration initiated with Drs. Sandra Talbot (USGS) and Jeff Johnson (The Peregrine Fund) we provide red blood cell samples for continued genetic analyses. Dr. Talbot's focus is completing DNA level analyses of peregrine samples acquired at Assateague and Padre Islands. Utilizing samples collected from past surveys, we will investigate methods that will help us: 1) describe the composition of the migratory population using a molecular probe that will identify birds to population of natal origin; 2) assess the relative contribution of various breeding populations to the migratory populations at Assateague and Padre; 3) examine how changes in weather patterns and migratory patterns influence the size of the migratory populations; and 4) possibly draw conclusions about changes in the size of breeding populations. In 2007 Johnson and Dr. David Mindell presented a conference poster assessing the temporal genetic stability of migrating Peregrine Falcons sampled at Padre Island, TX between the years 1985-2007. Further analyses were published in Johnson et al. (2010).

Mercury concentrations among migrant Peregrine Falcons: We collected feather samples from captured peregrines during the Survey. In an ongoing collaboration with Joe Barnes (USFWS) and Chris DeSorbo (BioDiversity Research Institute), we have continued to sample feathers and provide blood for mercury contaminant analyses. This work draws from research by Barnes and Gerstenberger (2015) looking at mercury in feathers of a non-migratory population of peregrines in southern Nevada and in their avian prey, correlating peregrine mercury levels with prey in order to use peregrines as an indicator species of broader environmental contamination. AMAP (2011) has highlighted concerns about increasing mercury levels in the Arctic, primarily from anthropogenic sources and augmented by melting of permafrost, and Ambrose et al. (2000) identified mercury as a contaminant of concern specifically for peregrines breeding in Alaska due to trends in egg burdens and the general increasing trends in Arctic biota. Climate warming may remobilize and increase methylization of mercury, thus increasing ecosystem and human exposure. In addition, by incorporating molt patterns (Hunt et al. 1975, White et al. 2013) into our sampling protocol, we are assessing annual and cumulative mercury exposure in adult peregrines.

We published current findings (Barnes et al. 2019) in the Journal of Raptor Research; the abstract reads: "We document concentrations of total mercury (THg) in feathers of Peregrine Falcons (*Falco peregrinus*; hereafter peregrines) collected during autumn migration at South Padre Island, Texas, and Assateague Island, Maryland, from 2009–2015. We detected THg in all sampled fourth primary (p4; range ¼ 0.44–37.46 μg/g) and axillary feathers (range¼ 0.09–62.68 μg/g). We found no significant difference in THg concentrations between hatch-year (HY) peregrines by study site. Mean THg concentrations were greater in both feather types of after-hatch-year peregrines than of HY peregrines, but concentrations in p4 feathers of second-year peregrines (mean ¼ 14.9 μg/g) were significantly greater than those of after-second-year individuals (mean¼ 8.5 μg/g). Pooling samples from HY birds across both sites and all years, we found no significant differences between the concentrations in the axillaries of females (mean¼ 2.4 μg/g) vs. males (mean¼ 2.2 μg/g), nor between the two feather types. The concentration associated with toxic effects in peregrines is unknown; however, peregrines have recently experienced broad population expansion across the presumed breeding area of the birds we sampled, and the THg concentrations we measured were lower than those in an apparently healthy breeding population in the southwestern USA. We documented widespread THg exposure in peregrines migrating from the northern latitudes of North America, but additional research is needed to assess trends of mercury exposure in the face of increasing global anthropogenic release of mercury into the environment and the release of long-term sequestered mercury in melting permafrost because of climate change."

Stable Isotope Research: We maintain feather collections from juvenile falcons at Padre for future stable isotope analyses to continue research initiated by Dr. Nancy Clum of the Wildlife Conservation Society. Dr. Clum's research assessed the feasibility of using stable isotopes as a means of identifying natal origins of migrant birds. If successful, this technique may allow us to: 1) evaluate the relative importance of different breeding habitats to populations of tundra peregrines; 2) identify the dominant trophic position of tundra peregrines; and 3) identify any temporal patterns of migration related to breeding habitat. Isotope data will be combined with data on plumage and morphological variation, which have also been suggested to vary geographically among peregrine populations. In addition, future comparative analyses of isotopic signatures of Gulf and East Coast HY falcons have potential to reveal the effects of continental weather patterns on juvenile tundra peregrines.

SUMMARY, CONCLUSIONS, RECOMMENDATIONS

Productivity was reduced in 2023, and questions remain about the stability of migratory peregrine populations. We conducted important sampling for associated studies. The tundra peregrine made a significant recovery and was removed from the list of endangered species, yet continued monitoring of populations is imperative. Because of this survey's continuity and standard method for data collection it has become an essential tool in that effort. During the past 53 years we have expended over 21,000 hours in the field, observing nearly 21,000 peregrines and capturing 5,928 individuals. Our database includes sightings of every other raptor we have observed on the Island since 1970. Standardized survey protocols have been used during the course of the study, and more than 90% of all observations have been recorded by three experienced individuals.

In 2008 our database allowed us to provide an Expert Declaration on the Draft Environmental Assessment and Management Plan for Take of Migrant Peregrine Falcons in the United States for Use in Falconry. Among other points, we concluded that the standardized average number of migrating peregrines we observed at Assateague over the preceding 30 years (updated here through 2023 in Fig. 1) was essentially the same as that seen more than six decades earlier (1939-1944), before DDT had serious adverse effects on the reproductive potential of the peregrine in North America. Our work at Assateague and Padre Islands represents the bulk of Tundra Peregrine Falcons banded within the continental United States since the establishment of the Bird Banding Laboratory by the Department of the Interior. Furthermore, our database constitutes the longest continuous monitoring study of this falcon in the Americas. Long-term studies such as ours are essential to monitoring the stability of wildlife populations, particularly in light of rapid changes that may occur due to contaminants, infectious diseases, habitat loss, climate change and other factors. By the long-term and standardized nature of our studies, we have established levels of observation in stable populations that will quickly raise future concerns if not achieved over a several year period. In addition, the availability of data meticulously collected by falconer/citizen scientists since 1939 and represented in Figure 1 effectively extends our database to >80 years.

As outlined above, our work with satellite and GSM-received telemetry will allow for continued research to elucidate previously undescribed aspects of the tundra peregrine's wintering biology and continental migration and to identify critical habitats. Given available technologies, Assateague currently remains a viable laboratory in which to study and address present and future issues of concern to peregrines, other Neotropical migrants, and all humanity. We have addressed contaminants (DDE, PAHs) and emerging infectious pathogens (West Nile Virus, Avian Influenza) in partnership with U.S. Government entities. We maintain and yearly augment an archive of blood samples that is invaluable in assessing such emerging threats. In addition, the new race of eastern peregrines introduced from captive stocks is encountered routinely on the island. Our continued observations on this race and its interactions with migrating tundra peregrines should be an invaluable asset when future management decisions are considered.

Accordingly, we recommend that this study continue into the foreseeable future without significant changes in 1970-2023 protocols.

ACKNOWLEDGMENTS

The work at Assateague was possible only through substantial donations from Bob Berry's Wolf Creek Charitable Foundation and the Dwight S. Haldan Family Charitable Foundation. Kevin Taylor helped in the field and generously provided secure storage for our equipment trailer. We thank Ruth Mutch, the Grasslans Charitable Foundation, The Peregrine Fund, the American Honda Motor Company, Chris Pfister and Susan Lasher, Pete Widener, the Rockwell Foundation, and the North American Falconers' Association for support enabling Earthspan's survey at South Padre Island, TX. Thanks are also due Dr. Jeff Johnson and the

University of Wyoming's Robert and Carol Berry Biodiversity Conservation Center for curating the Earthspan blood archive, and to Chris Parish and all our collaborators at The Peregrine Fund. We are indebted to Superintendent Hugh Hawthorne, Bill Hulslander, and Tami Pearl of the Assateague Island National Seashore, and to Angela Baldwin of the Assateague State Park. These stewards of the resource are staunch advocates of our research. We also wish to thank those who assisted us in the field for long hours or in other significant ways, including Janis/Jim/King/Jane Seegar, Karen/Amy/Jeff/Helena/Aiden/Lyric Yates, Twig Craighead George, Donna Leonard, Estelle Elliott, Robin Zimmerman, Richard Dallam, Allen Sklar, April and Ralph Hooper, Jack Cibor, Matt Olear, John Harrell, Seth Roy, Blake Henke, Scott Ward, Mark Fuller and Gregg Doney.

LITERATURE CITED

AMAP. 2011. Arctic monitoring and assessment programme assessment 2011: mercury in the Arctic. Arctic Monitoring and Assessment Programme, Oslo, Norway.

Ambrose, R.E., A. Matz, T. Swem, and P. Bente. 2000. Environmental contaminants in American and arctic peregrine falcon eggs in Alaska, 1979-95. Technical Report NAESTR-00-02, U.S. Fish and Wildlife Service, Northern Alaska Ecological Services, Fairbanks, AK. 67pp.

Barnes, J.G., G.E. Doney, M.A. Yates, W.S. Seegar and S.L. Gerstenberger. (2019) A broadscale assessment of mercury contamination in Peregrines across the northern latitudes of North America. J. Raptor Res. 53(1):1–13

Barnes, J.G. and S.L. Gerstenberger. 2015. Using feathers to determine mercury contamination in Peregrine Falcons and their prey. J. Raptor Res. 49:43–58.

Cochran, W.W. 1985. Ocean migration of Peregrine Falcons: Is the adult male pelagic?. Pp. 223-237. In M. Harwood [ed.]. Proceedings of hawk migration conference IV. Hawk Migration Assoc. of North America. Rochester, NY, 24-27 March 1983.

Dusek, R.J., E.K. Hofmeister, W.S. Seegar, M.A. Yates, T.L. Maechtle, and B.J. Dayton. 2005. Prevalence of West Nile Virus in Peregrine Falcons. Poster presentation, proceedings of Raptor Research Foundation annual meeting, Green Bay, WI.

Enderson, J. H. 1969. Coastal migration data as population indices for the Peregrine Falcon. Pp. 275-278 in Peregrine Falcon Populations: their biology and decline (J. J. Hickey, ed.). Madison, Univ. of Wisconsin Press.

Fuller, M.R., W.S. Seegar, and P.W. Howey. 1995. The use of satellite systems for the study of bird migration. Israel Journal of Zoology 41:243-252.

Hall, J.S., R.J. Dusek, E. Spackman. 2015. Rapidly Expanding Range of Highly Pathogenic Avian Influenza Viruses. Emerg. Infec. Dis. • www.cdc.gov/eid • Vol. 21, No. 7, July 2015

Henny, Charles J., Michael A. Yates and William S. Seegar. 2009. Dramatic declines of DDE and other organochlorines in spring migrant peregrine falcons from Padre Island, Texas, 1978–2004. J. Raptor Res. 43(1):37–42.

Henny, C.J., W.S. Seegar and T.L. Maechtle. 1996. "DDE Decreases in Plasma of Spring Migrant Peregrine Falcons, 1978-94." Journal of Wildlife Management 0:342-349.

Henny, C. J., K. E. Riddle, and C. S. Hulse. 1988. Organochlorine Pollutants in Plasma of Spring Migrant Peregrine Falcons from Coastal Texas, 1984. pp. 423-427 in Peregrine Falcon Populations: their management and recovery. (T. J. Cade et al., eds.). The Peregrine Fund, Inc.

Hickey, J.J. (ed.) 1969. Peregrine Falcon Populations: their biology and decline. Madison, Univ. of Wisconsin Press.

Howey, P., D.R. Witlock, M.R. Fuller, W.S. Seegar, and F.P. Ward. 1984. A computerized biotelemetry and data logging system. Pp. 442 - 446 in Proceedings of the 8th International Symp. on Biotelemetry. H.R. Kimmich and H.J. Klewe, eds. International Society on Biotelemetry, Nijmegen, Netherlands.

Hunt, W. G., R. R. Rogers, and D. J. Slowe. 1975. Migratory and foraging behavior of Peregrine Falcons on the Texas Coast. Can. Field-Nat. 89: 111 - 123.

Johnson, J.A., S.L. Talbot, G.K. Sage, K.K. Burnham, J.W. Brown, T.L. Maechtle, W.S. Seegar, M.A. Yates, B. Anderson, D.P. Mindell. 2010. The Use of Genetics for the Management of a Recovering Population: Temporal Assessment of Migratory Peregrine Falcons in North America. PLoS ONE 5(11): e14042. doi:10.1371/journal.pone.0014042

Longmire, J. L., R. E. Ambrose, N. C. Brown, T. J. Cade, T. L. Maechtle, W. S. Seegar, F. P. Ward, and C. M. White. (1991) Use of sex-linked minisatellite fragments to investigate genetic differentiation and migration of North American populations of the Peregrine Falcon. Pp. 217-229 in DNA Fingerprinting: Approaches and Applications. (T. Burke, G. Gaudenz, A.J. Jefferies and R. Wolff, Eds.) ISBN 978-3-0348-7.

Longmire, J. L. 1988. Identification and development of breeding population-specific DNA polymorphisms within the genome of the Peregrine Falcon. pp. 779-788 in Peregrine Falcon Populations: Their Management and Recovery. (T.J. Cade, J. H. Enderson, C. G. Thelander, and C. M. White, Eds.) The Peregrine Fund, Inc.

Morizot, D. C. 1988. Biochemical genetic variability in Peregrine Falcon populations. pp. 773-778 in Peregrine Falcon Populations: Their Management and Recovery. (T.J. Cade, J. H. Enderson, C. G. Thelander, and C. M. White, Eds.) The Peregrine Fund, Inc.

Parrish, J.R., D.T. Rogers, Jr., and F.P. Ward. 1983. Identification of natal locales of Peregrine Falcons (*Falco peregrinus*) by trace element analysis of feathers. Auk 100:560-567.

Redig, P.T. 1993. Medical management of birds of prey. The Raptor Center at the University of Minnesota, St. Paul, MN.

Redig, P. T. and S. M. Goyal. 2012. Serologic evidence of exposure of raptors to influenza A virus. Avian Diseases, 56(2):411-413.

Seegar, W.S., M.A. Yates, G.E. Doney, J.P. Jenny, T.C.M. Seegar, C. Perkins, M. Giovanni. 2015. Migrating Tundra Peregrine Falcons accumulate polycyclic aromatic hydrocarbons along Gulf of Mexico following Deepwater Horizon oil spill. Ecotoxicology 24(5): 1102-1111.

Seegar, W.S., M. Yates, and T. Maechtle. 2003. Research and Monitoring of Migratory Peregrines. In Return of the Peregrine. T.J. Cade and W. Burnham, eds. The Peregrine Fund, Boise, Idaho.

Seegar, W.S and T. Ray. 1979. Habitat use patterns of the Peregrine Falcon during autumn migration on Maryland and Virginia barrier islands. Unpubl. rep., U.S. Army, Edgewood Research, Development and Engineering Center, Maryland.

Taft, S.J., R.N. Rosenfield, W.S. Seegar and T.L. Maechtle. 1998. “Paucity of hematozoa in Peregrine Falcons (Falco peregrinus) in West Greenland and Coastal Texas.” Journal of the Helminthological Society of Washington 65:111-113.

Ward, F.P. 1975. Colored and numbered tarsal bands as an aid to raptor demographic studies. Pp. 98-102 *In* Proceedings of the North American Hawk Migration Conference. Syracuse, New York.

Ward, F. P., and R. B. Berry. 1972. Autumn migrations of Peregrine Falcons on Assateague Island, 1970-71. J. Wildlife Mgmt. 36: 484-492.

Ward, F.P., and R.C. Laybourne. 1985. A difference in prey selection by adult and immature Peregrine Falcons during autumn migration. Pp. 303-309 *in* Conservation Studies on Raptors, ICBP Tech. Publ. No. 5 (I. Newton and R.D. Chancellor, Eds.). London, Brit. Mus. (Nat. Hist.).

Ward, F. P., K. Titus, W. S. Seegar, M. A. Yates, and M. R. Fuller. 1988. Autumn migrations of Peregrine Falcon populations at Assateague Island, Maryland/Virginia, 1974-1984. pp. 485-495 in Peregrine Falcon Populations: their management and recovery. (T. J. Cade et al., eds.). The Peregrine Fund, Inc.

White, C.M.,T.J. Cade, J.H. Enderson. 2013. Peregrine Falcons of the World. Linx Edicions. Bellaterra, Barcelona.

Yates, M. A., K. E. Riddle, and F. P. Ward. 1988. Recoveries of Peregrine Falcons migrating through the eastern and central United States, 1955-1985. pp. 471-483 in Peregrine Falcon Populations: their management and recovery. (T. J. Cade et al., eds.). The Peregrine Fund, Inc.

Zuberogoitia, Inigo, J. A. Martinez, A. Iraeta, A. Azkona, J. Zabala, B. Jimenez, R. Merino, G. Gomez. 2006. Short-term effects of the prestige oil spill on the Peregrine Falcon (Falco peregrinus) Marine Pollution Bulletin 52 (2006) 1176–1181.

TABLE 1.

ASSATEAGUE AUTUMN PEREGRINE SURVEY
2023 TOTALS (EXCLUDING RESIDENTS, INCLUDING RESIGHTS)

	Observed	Captured	Recaptured	resighted
Juvenile male	23	13	1	1
Juvenile female	81	20	5	16
Adult male	3	1	-	-
Adult female	11	2	1	-
Unidentified	31	-	-	-
Total	149	36	7	17

TABLE 2.
ASSATEAGUE AUTUMN PEREGRINE SURVEY
1970-2023 TOTALS (EXCLUDING RESIDENTS, INCLUDING RESIGHTS)

	Man-hours expended	Peregrines sighted	Peregrines sighted/10 man-hours	Peregrines captured	Peregrines captured/10 man-hours
1970	310.0	66	2.13	23	.74
1971	222.1	120	5.40	35	1.58
1972	325.7	41	1.26	8	.25
1973	360.7	136	3.77	47	1.30
1974	360.3	59	1.64	22	.61
1975	332.5	186	5.59	40	1.20
1976	336.2	176	5.23	48	1.43
1977	468.2	209	4.46	75	1.60
1978	436.2	259	5.94	64	1.47
1979	427.4	598	13.99	127	2.97
1980	451.1	512	11.35	110	2.44
1981	564.7	347	6.15	89	1.58
1982	632.3	591	9.35	121	1.91
1983	637.2	562	8.82	116	1.82
1984	724.9	547	7.55	150	2.07
1985	683.0	483	7.07	147	2.15
1986	704.1	838	11.90	230	3.27
1987	607.4	327	5.38	112	1.84
1988	671.7	409	6.09	132	1.97
1989	601.2	813	13.52	203	3.38
1990	509.3	659	12.94	248	4.87
1991	630.3	743	11.78	227	3.60
1992	558.8	340	6.08	116	2.08
1993	593.2	595	10.03	192	3.24
1994	557.3	467	8.38	133	2.39
1995	485.4	525	10.82	139	2.86
1996	374.3	568	15.17	192	5.13
1997	516.5	889	17.21	254	4.91
1998	556.3	999	17.96	261	4.69
1999	504.3	560	11.10	179	3.55
2000	536.8	522	9.73	155	2.89
2001	507.3	404	7.96	115	2.27
2002	513.8	350	6.81	116	2.26
2003	518.7	572	11.03	155	2.99
2004	477.3	489	10.25	147	3.08
2005	388.2	439	11.31	126	3.25
2006	238.3	173	7.26	66	2.77
2007	171.5	222	12.94	78	4.55
2008	206.0	380	18.45	123	5.97
2009	196.7	356	18.10	124	6.30
2010	194.6	457	23.49	135	6.93
2011	212.3	325	15.31	77	3.63
2012	214.9	344	16.01	98	4.56
2013	28.8	9	3.12	5	1.73
2014	218.8	480	21.94	136	6.22
2015	162.2	89	5.48	40	2.47
2016	189.4	317	16.74	97	5.12
2017	212.8	279	13.11	65	3.06
2018	214.6	165	7.69	48	2.24
2019	213.5	135	6.32	37	1.73
2021	250.4	242	9.66	63	2.52
2022	209.9	264	12.58	46	2.19
2023	220.4	149	6.75	36	1.63
Total	21,440	20,786	9.69	5,928	2.76

TABLE 3.
ASSATEAGUE AUTUMN PEREGRINE SURVEY
1970-2023 SIGHTINGS BY AGE CLASS (EXCLUDING RESIDENTS, INCLUDING RESIGHTS)

	Adults sighted	Adults sighted/10 man-hours	Juveniles sighted	Juveniles sighted/10 man-hours	Percent adults
1970	8	.26	50	1.61	13.79
1971	8	.36	97	4.36	7.62
1972	7	.21	23	.71	23.33
1973	18	.50	110	3.04	14.06
1974	13	.36	40	1.11	24.53
1975	14	.42	153	4.60	8.38
1976	14	.42	121	3.60	10.37
1977	18	.38	167	3.57	9.73
1978	32	.73	199	4.56	13.85
1979	35	.82	501	11.72	6.53
1980	42	.93	408	9.04	9.33
1981	57	1.01	235	4.16	19.52
1982	64	1.01	454	7.18	12.35
1983	48	.75	408	6.40	10.53
1984	77	1.06	406	5.60	15.94
1985	60	.87	353	5.17	14.53
1986	111	1.58	630	8.95	14.97
1987	73	1.20	178	2.93	29.08
1988	90	1.34	249	3.71	26.55
1989	131	2.18	580	9.65	18.42
1990	93	1.83	494	9.70	15.84
1991	70	1.11	553	8.77	11.23
1992	70	1.25	239	4.28	22.65
1993	76	1.28	440	7.42	14.73
1994	56	1.00	340	6.10	14.14
1995	53	1.09	413	8.51	11.37
1996	50	1.34	445	11.89	10.10
1997	120	2.32	650	12.58	15.58
1998	90	1.62	821	14.76	9.88
1999	97	1.92	418	8.29	18.83
2000	90	1.68	352	6.56	20.36
2001	67	1.32	294	5.80	18.56
2002	112	2.18	191	3.72	36.96
2003	65	1.25	415	8.00	13.54
2004	81	1.70	340	7.12	19.24
2005	53	1.37	324	8.35	14.06
2006	39	1.64	119	4.99	24.68
2007	33	1.92	160	9.33	17.10
2008	30	1.46	315	15.29	8.70
2009	62	3.15	264	13.42	19.02
2010	32	1.64	368	18.91	8.00
2011	34	1.60	253	11.92	11.80
2012	62	2.88	252	11.73	19.75
2013	1	.34	8	2.77	11.10
2014	36	1.65	395	18.05	8.35
2015	19	1.17	65	4.01	22.62
2016	40	2.11	231	12.20	14.76
2017	24	1.13	221	10.39	9.79
2018	41	1.91	97	4.52	29.71
2019	13	.61	97	4.54	11.82
2021	27	1.07	188	7.51	12.56
2022	20	.95	182	8.67	9.90
2023	14	.64	104	4.72	11.86
Total	2,690	1.26	15,410	7.20	14.88

TABLE 4.

ASSATEAGUE AUTUMN PEREGRINE SURVEY
2023 PRODUCTIVITY BY SECTOR (EXCLUDING RESIDENTS, INCLUDING RESIGHTS)

	Sighted	Sighted/10 man-hours	Captured	Captured/10 man-hours
McCabe Tract	99	7.48	24	1.81
State Park	-	-	-	-
Access Road	-	-	-	-
Maryland Beach	50	6.36	12	1.53
Total	149	6.75	36	1.63

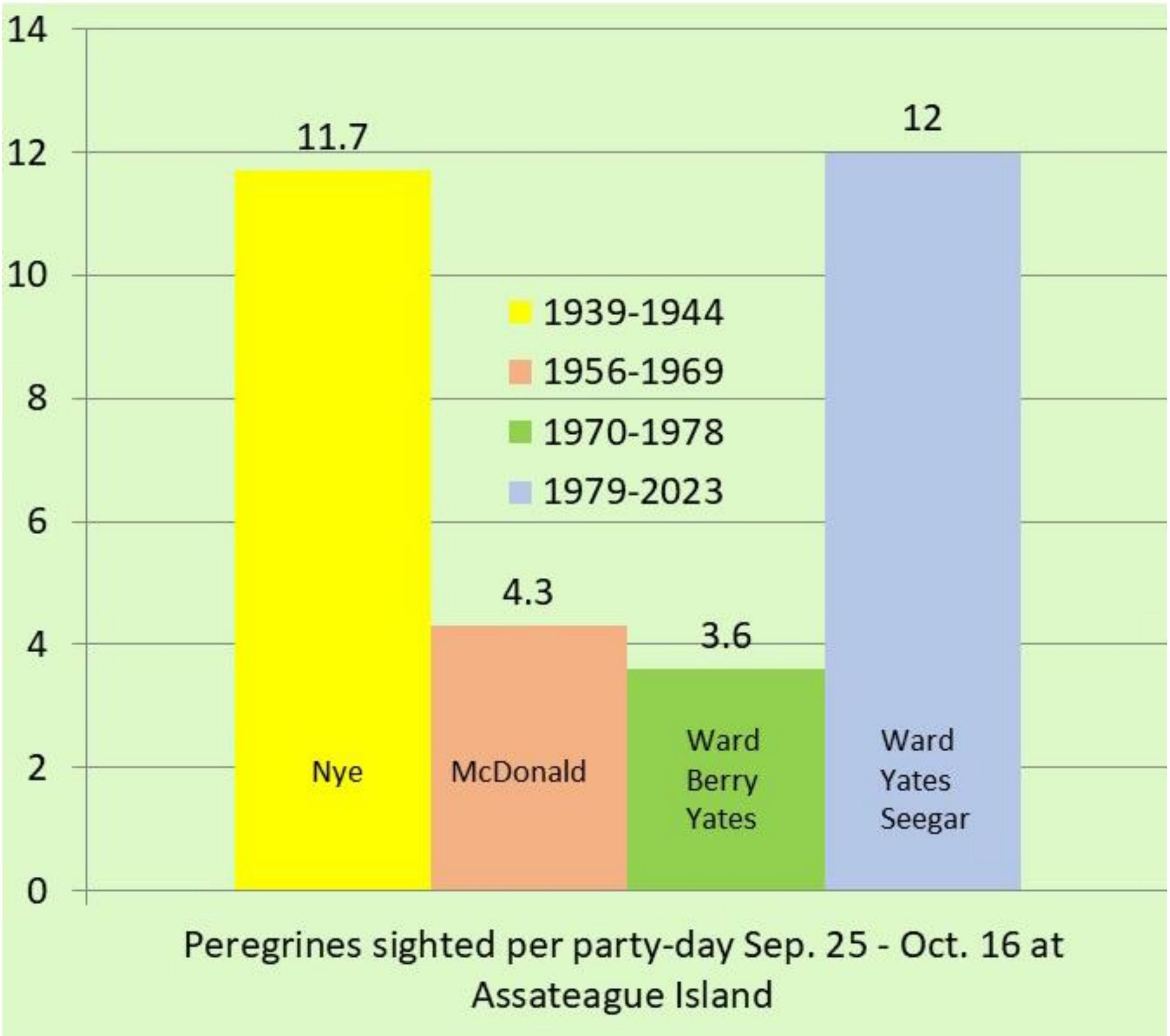
TABLE 5.

2023 PEREGRINE OBSERVATIONS AT EAST COAST SITES

	Cape May	Assateague	Kiptopeke	Florida Keys
23 September	0	*	*	12
24 September	5	*	1	22
25 September	3	5	6	23
26 September	5	1	6	14
27 September	6	2	8	27
28 September	10	11	4	49
29 September	14	10	5	60
30 September	9	8	2	34
01 October	27	3	29	168
02 October	49	9	58	54
03 October	25	5	41	24
04 October	47	5	20	70
05 October	31	9	47	43
06 October	24	11	29	87
07 October	26	5	22	149
08 October	19	5	13	505
09 October	40	8	12	175
10 October	74	7	66	511
11 October	84	11	38	159
12 October	107	4	44	100
13 October	40	2	93	127
14 October	7	15	2	267
15 October	3	6	2	262
16 October	1	1	0	66
17 October	4	2	7	26
18 October	13	4	2	10
19 October	1	*	3	14
20 October	2	*	7	7
21 October	7	*	7	29
22 October	2	*	2	10
23 October	0	*	0	11
2022 Through 29 Nov	921	264	413	2,428
2023 Through 29 Nov	819	149	648	3,289

* Not Observing

FIGURE 1.


14
12
10
8
6
4
2
0
11.7
4.3
3.6
12
1939-1944
1956-1969
1970-1978
1979-2023
Nye
McDonald
Ward
Berry
Yates
Ward
Yates
Seegar
Peregrines sighted per party-day Sep. 25 - Oct. 16 at Assateague Island