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The peregrine falcon in Virginia: Survey of historic eyries and reintroduction effort

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THE PEREGRINE FALCON IN VIRGINIA:
Survey of Historic Eyries and Reintroduction Effort

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APPROVAL SHEET

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ABSTRACT

A survey was conducted of known historic peregrine falcon (_Falco peregrinus anatum_) eyries in Virginia to locate any resident peregrines, determine suitability of the sites for use in the reintroduction effort and quantitatively descibe physical characteristics of the eyries.

Thirteen of twenty-four known sites were visited. No peregrines nor any evidence of recent breeding were found. The sites displayed extreme variability in altitude, height of cliff face, extent of cliff face, and distance to water. Eyries in Virginia showed a tendency to face either northeast of southwest. This result is thought to be an artifact of the local geology.

Density of known eyries is low when compared with other areas. Mean inter-eyrie distance is 43.2 km (n=13). Seven eyries in the Shenandoah Park region average 18.9 km apart. These results suggest that many peregrine eyries in Virginia were never found before extirpation.

Human disturbance was the most common factor causing unsuitability of the sites for use in the reintroduction effort. Six of the thirteen visited sites were suitable for the release of young peregrines by hacking although a more thorough horned owl (_Bubo virginianus_) survey must be undertaken.

Between May 1978 and July 1982, seventy-two peregrines were released in coastal Virginia using a hacking technique. Eighty-nine percent successfully fledged. The known dispersal movements of the released birds are consistant with the wanderings typical of juvenile peregrines. Three pairs of adult plumage peregrines were resident at coastal sites in 1982. One of the pairs successfully nested, producing three young.

A stochastic population growth program was used to estimate current and future reintroducted populations. The model indicates a current Virginia population of 15-23 individuals including 3-7 pairs. Field estimates corroborate this assessment. The model also indicates that a peregrine population constrained by mortality and reproduction estimates found in the literature cannot be self-supportive. Because reproductive output data are more complete, estimates of mortality in the literature may be erroneous.

THE PEREGRINE FALCON IN VIRGINIA:

Survey of Historic Eyries and Reintroduction Effort

INTRODUCTION AND REVIEW

The peregrine falcon (*Falco peregrinus*) is generally regarded as the paragon of raptor evolution. It has impressed man for thousands of years with its near perfection of form. The peregrines' hunting prowess, great speed and exhilarating aerobatics have made it the most prized bird among falconers, past and present. These same attributes have inspired much research on the biology of the peregrine (Bond 1946; Cade 1960; Enderson 1965; Hickey 1942; Herbert *et al*. 1965; Spofford 1950; White 1968a; Beebe 1960).

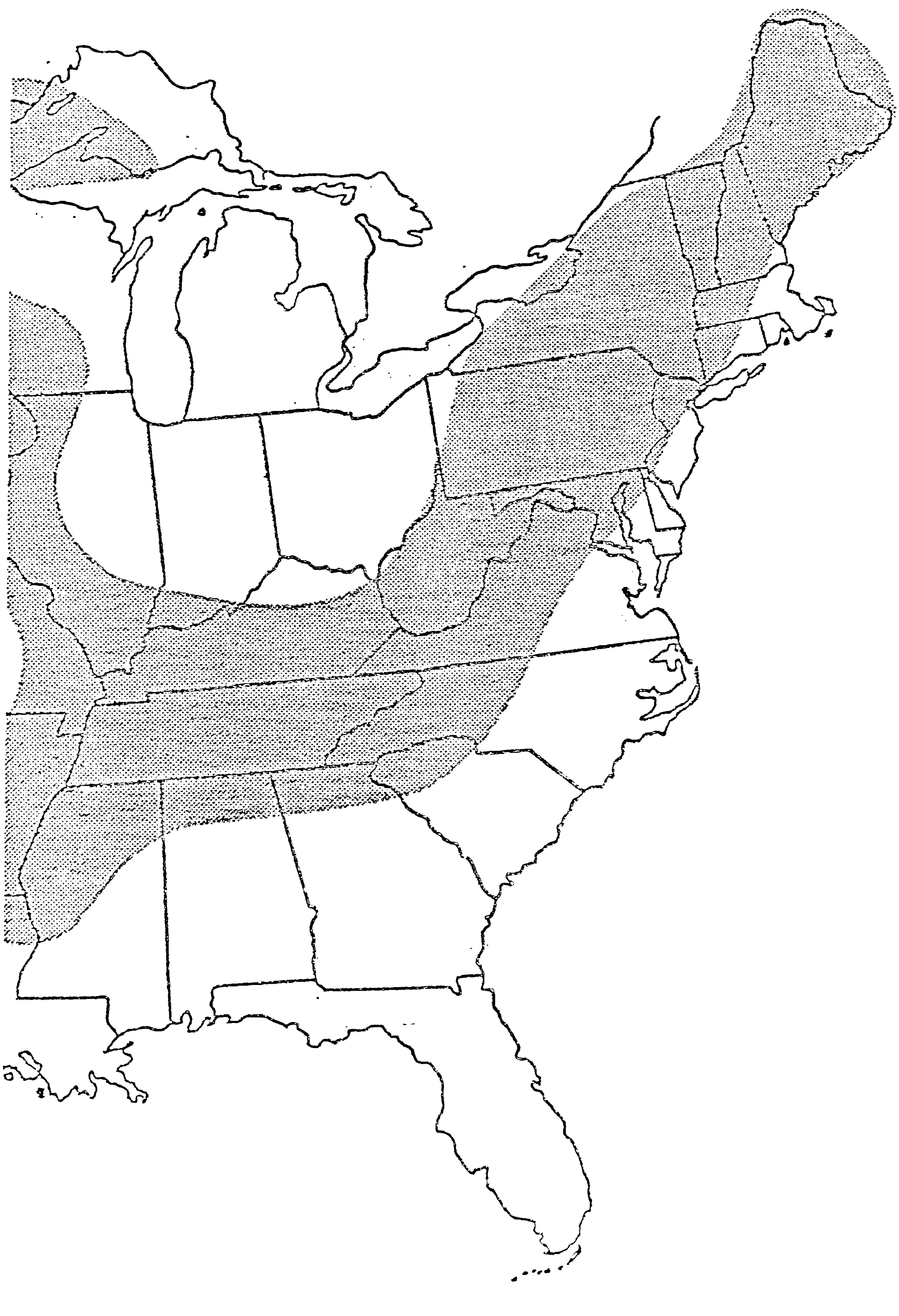
Members of the genus *Falco* possess long, pointed wings, a relatively narrow tail, and are cabable of sustained powerful flight (Brown and Amadon 1968). The peregrine is large relative to most other species in the genus and displays a virtual cosmopolitan breeding distribution (Cade 1982). As expected, this vast range and resulting exposure to diverse biotypes has generated noticeable geographic variation. At least 38 races have been named, but only about 18, depending upon the authority, are presently considered valid (White 1968b). The races differ morphologically and behaviorally in varying degrees.

Three races are described by White (1968 a, b) as inhabiting

North America; _F. p. peali_, _F. p. tundris_ and _F. p. anatum_. _F. p. peali_ is a large, dark, sedentary form inhabiting the island chains of the Pacific Northwest. _F. p. tundrius_ is a paler colored, smaller, highly migratory form with a breeding distribution limited to the nearctic tundra region. _F. p. anatum_ is a large, variably migratory, forest inhabiting race whose range spans the continent, intergrading with _tundrius_ in the north and limited to north-central Mexico in the south. The former breeding range of _F. p. anatum_ in the eastern U. S. is shown in Figure 1. Peregrines that habitually nested in Virginia were considered part of a recognizable subpopulation within the _anatum_ race. This group was called the Appalachian peregrine. Individuals of the Appalachian group were noticeably larger and darker than most western and northwestern _anatum_ individuals (White 1968b; Alva Nye, Fairfax Co. Va., pers. comm.). Despite geographical variation, several basic aspects of peregrine biology are uniform throughout its range.

The preferred nesting site is a ledge or shelf on a cliff face (Bond 1946; Cade 1960). The peregrine is not known to build a true nest but requires a substrate of suitable consistency to permit scraping a shallow cup for the eggs (Cade 1960). North American records document peregrine nest sites in tree holes (Ridgeway 1895; Spofford 1942, 1943, 1945, 1947; Gross 1878), in stick nests built by Ospreys (Jones 1946), Ravens, and Red-tail Hawks (Bond 1946) and on man-made structures (Craighead and Craighead, 1939; Groskin, 1947, 1952). Cade (1960) reports nests found on cutbanks and on the ground. Cliff ledges are by far the

Figure 1. Former Eastern U. S. breeding distribution of *Falco pergrinus anatum*. From Fyfe *et*. al. (1976) *in* Barclay (1980).



most common sites although Hickey (1942) proposed the existence of a tree nesting subpopulation which occured in West Tennessee and throughout the upper Mississippi Valley region prior to 1880. Other individuals have been found nesting in "aberrant" sites worldwide (Hickey 1969) attesting to some behavioral flexibility in this species. Peregrines appear to defend a territory immediately surrounding the nest. They apparently do not defend their hunting territory, probably due to the energy expense involved (Ratcliffe 1980).

"The peregrine is a bird hunter par excellance" (Cade 1982). It is highly specialized, behaviorally and morphologically, to capture other birds in open flight. Many authors discuss at length the various techniques involved (Newton 1979; Radcliffe 1980; Cade 1982). The most spectacular is a vertical plunge which gives the peregrine sufficient speed to overtake and strike quarry from the air. Estimates vary but some workers have reported the maximum velocity of a peregrines' "stoop" at over 200 m.p.h. (Brown and Amadon 1968). Peregrines are catholic in their prey selection. Ratcliffe (1980) reports 136 species taken in Britain. Cade *et al*. (1968) report at least 60 species taken along the Yukon River (Alaska) and estimates that 200 species are utilized on the North American continent as a whole. Several authors indicate a preference for columbiform birds (pigeons and doves) and propose a co-evolutionary scenario (Newton 1979; Cade 1982). Other authors (Herbert and Herbert 1965) describe the coincidence of breeding times of *F. p. anatum* with the northward migration of certain birds i.e. Blue Jay (*Cyanocitta cristata*) and Flicker (*Colaptes auratus*). Prey selection is undoubtably affected by the distribution of prey species which varies over the extensive breeding range of the peregrine. The efficiency of the peregrine is also a much discussed subject. Calculated hunting success of breeding peregrines ranges from 16% (Parker 1979) to 93% (Cade 1982) both samples exceeding 100 observations. Rudebeck (1951) reports a succ ess rate of only 7.5% in peregrines on migration and examines the relation of hunting modes and prey selection. It is generally believed that immature birds are less efficient than adults as hunting is a learned skill to some extent. This is supported by the lengthy post-fledging period during which the young are dependent on the adults.

Peregrines display sexual size dimorphism as do most other raptors. Males average one fourth smaller than females in most linear dimensions (White 1968b). The sexual size dimorphism of raptors is the reverse of that found in most other avian groups, in which males are larger than females, and has been discussed by many workers. The explanations of this phenomenon include differential niche utilization hypotheses (Earhart and Johnson 1970; Storer 1966; Selander 1966) to social dominance mechanisms (Amadon 1975; Cade 1960), and energy storage and "big mother" theories (Newton 1979; Ralls 1976). The strength of each of these arguments compounds the controversy and promotes the consideration that multiple selective factors may be additive in their effect, obscuring the initial selective force.

Historically, workers noted that pre-1940 peregrine populations were uniformly low (relative to other raptors), widely dispersed, yet quite stable (Newton 1979; Ratcliffe 1980; Hickey 1942, 1969; Beebe 1960; Cade 1960). The evidence indicating population stability was multifold:

1) Yearly censuses of nesting pairs per area varied less than 10% (Cade 1960; Walpole-Bond 1914; Hickey 1942; Beebe 1960).
2) The traditional use of nest sites (eyries) over long periods of time has been recognized since medieval times (Hickey 1942; Ferguson-Lees 1951). In fact, it was uncommon for researchers to find recently established nest sites (Hickey 1969).
3) A "floating population" of non-breeders existed within the breeding range. This was deduced by the repeated and sometimes rapid replacement of birds at eyries when one or both resident adults were removed.
4) Peregrines are insulated from vacillations in the number of any one prey species by the high variance of prey in their diet. Some raptor populations fluctuate with the numbers of their main prey species (Galushin 1974) .
5) Life tables calculated from banding recoveries indicate a relatively low adult mortality rate (18-25%) (Enderson 1969).
6) Individual peregrines were known to have productive life spans of up to 20 years (Hall 1955; Herbert and Herbert 1965).

The factors limiting peregrine populations are still somewhat unclear. Food and nest sites are commonly implicated as limiting factors. Their inability to construct typical nests has limited their breeding distribution (Hickey 1969). On the population level, the relationship between peregrines and their prey is probably extremely complex considering the variability in prey species in most regions. The highest densities of breeding peregrines are found on seacoast cliffs near nesting seabird colonies where both nest sites and food occur in abundance.

Cade (1960) found that gyrfalcons (Falco rusticolus) can displace peregrines from nest sites in Alaska and in Great Britain. Ratcliffe (1962) indicates that Golden Eagles (Aquila chrysaetos) do the same. These competitive factors may affect peregrine density somewhat, but the impact on the population level is unknown.

The most widely used population parameter is a breeding pair census. Mean nearest neighbor distance is a common index of density. It varies from less than one mile (Beebe 1960; Ratcliffe 1962) to 9.6 miles (Cade 1960) where peregrines are considered common.

During the late 1930's and 1940's several workers noticed slight declines in some population parameters. Rice (1969) reported that egg collectors and falconers were disturbing large numbers of nest sites in Pennsylvania, Maryland, and Virginia. Herbert and Herbert (1969) observed that the Hudson River eyries were suffering losses to falconers but also to shooting by locals and even park police. The construction of a highway above the palisades also contributed to several eyrie abandonments. It is clear that the peregrine population suffered direct persecution and indirect effects of a growing human population. Suddenly, during the 1950's and early 1960's the peregrine population of Europe and parts of North America suffered a dramatic crash. Hickey (1969) called it "one of the most remarkable recent events in environmental biology". Of 275 known eyries in the eastern United States all nests checked were deserted by 1964 (Burger *et al.* 1969) and the peregrine falcon was considered extirpated as a breeding bird. It is now known that the severe population crash of the 1950's was caused, to some extent, by poisoning from organochloride pesticides developed in the late 1940's. Persistent investigative research by Ratcliffe (1958, 1967, 1970) and Hickey and Anderson (1968) unraveled the mechanisms by which raptor mortality increased and fecundity decreased. Further laboratory and field research corroborated their results (Jeffries *et al.* 1966; Lehner 1969; Peakall *et al.* 1979; Peakall 1974).

The peregrine falcon was placed on the United States Department of the Interior endangered species list and in 1975 the U.S. Fish and Wildlife Service established a recovery team. The team developed a plan to assess and protect historic eyries and re-establish the peregrine through a reintroduction scheme, sponsored in large part by The Peregrine Fund, Ithaca, New York. The Eastern Peregrine Falcon recovery plan (1979) suggests that state natural resource agencies support the management plan within their jurisdiction. The Virginia Commission of Game and Inland Fisheries sponsors the plan in Virginia under contract to the College of William and Mary.

The first section of this thesis attempts to answer questions pertaining to the biology of the presumed extinct peregrine population in Virginia. These questions are:

1) Are breeding peregrines of the anatum race still present in Virginia? Peregrines may have survived in remote areas of the state and may have been missed in other surveys, or some natural repopulation may have occured since the decline of the 1950's.

2) Are any known historic breeding sites of the peregrine suitable for reintroduction or natural reoccupation?

3) Do the historic breeding sites display common characteristics which would allow researchers to choose similar sites for future reintroductions?

The second section of this thesis is a report of the Virginia peregrine reintroduction effort, an estimate of the current population and a computer assisted growth projection.

SURVEY OF HISTORIC EYRIES

EYRIE SURVEY - METHODS AND MATERIALS

In this paper, the term "eyrie" refers to the nest cup and immediately adjacent territory of a peregrine pair or series of pairs. The existence and location of historic peregrine eyries was verified several ways. Sources include the Eastern Peregrine Falcon Recovery Plan (1979), J. J. Murray (1933, 1952), unpublished notes of J. J. Hickey, and personal notes from the egg collection of F. M. Jones. Communication with various persons (see acknowledgements) familiar with Virginia Peregrines revealed several previously undocumented sites.

The sites were visited during the late winter of 1982. The cliffs were examined with 7X, 35 binoculars or a 30X spotting scope from above or below the face. In many cases the faces were climbed. Measurements of height and extent were obtained using a Toko model 22551 triangulator. Compass aspect, defined as the perpendicular to the symmetric chord of the cliff face, was determined to the nearest five degrees using a lensatic compass. Compass aspects were averaged at sites with more than one cliff face. Horizontal distance to nearest water, roads, clearings, and disturbance factors were determined using United States Geological Survey (U.S.G.S.) 1:24,000 scale topographic maps on which eyries had been located. Altitude at the cliff base to the nearest three meters was also noted on these topographic quadrats. Where the cliff base crossed contour lines, median altitude at base was calculated. Substrate was noted at the site and verified using a U.S.G.S. 1:250,000 scale Virginia base geologic map. Inter-eyrie (nearest neighbor) distances were measured to within four hundred meters on a 1:250,000 scale U.S.G.S. base contour map of Virginia. General habitat evaluations were made for the area surrounding the eyries within a 200m radius. Detailed habitat measurements were not taken because of the certain change in habitat values which has occurred since site selection by peregrines. Indications of human activity at or near each site were noted, as were logistical considerations, to assess the suitability of the site for reintroduction or natural occupation. Because horned owls (*Bubo virginianus*) are known predators of unprotected fledgling peregrines, a Johnny Stewart Game Call was used in an attempt to locate horned owl territories near the eyries.

Statistical analysis

Compass aspects were analysed using methods for circular distributions from Zar (1974). Analysis of these parameters using Goodness of Fit Test for circular distributions and Raleighs Test is also from Zar (1974). Site data were summarized using standard descriptive statistics (Sokal and Rohlf, 1969). Scattergram correlation was used as programmed in the Statistical Programs for Social Sciences (SPSS) on the Prime 750. A cluster analysis as programmed in the Statistical Analysis System (SAS) was also used (Helwig and Council, 1979).

EYRIE SURVEY - RESULTS

The existence of twenty-four historical Peregrine eyries was verified. Nesting was inferred at two additional sites (Jones 1933). Table 1 is a summary of the site names, references, and known active years. Thirteen of the sites were inspected. No peregrines nor any evidence of recent breeding were seen at any of the sites. For six sites, only the general location was determined, data were not collected as the actual eyrie could not be located without question. Location information within Virginia was not available at five eyries. The general location and survey status of the eyries is displayed in Figure 2.

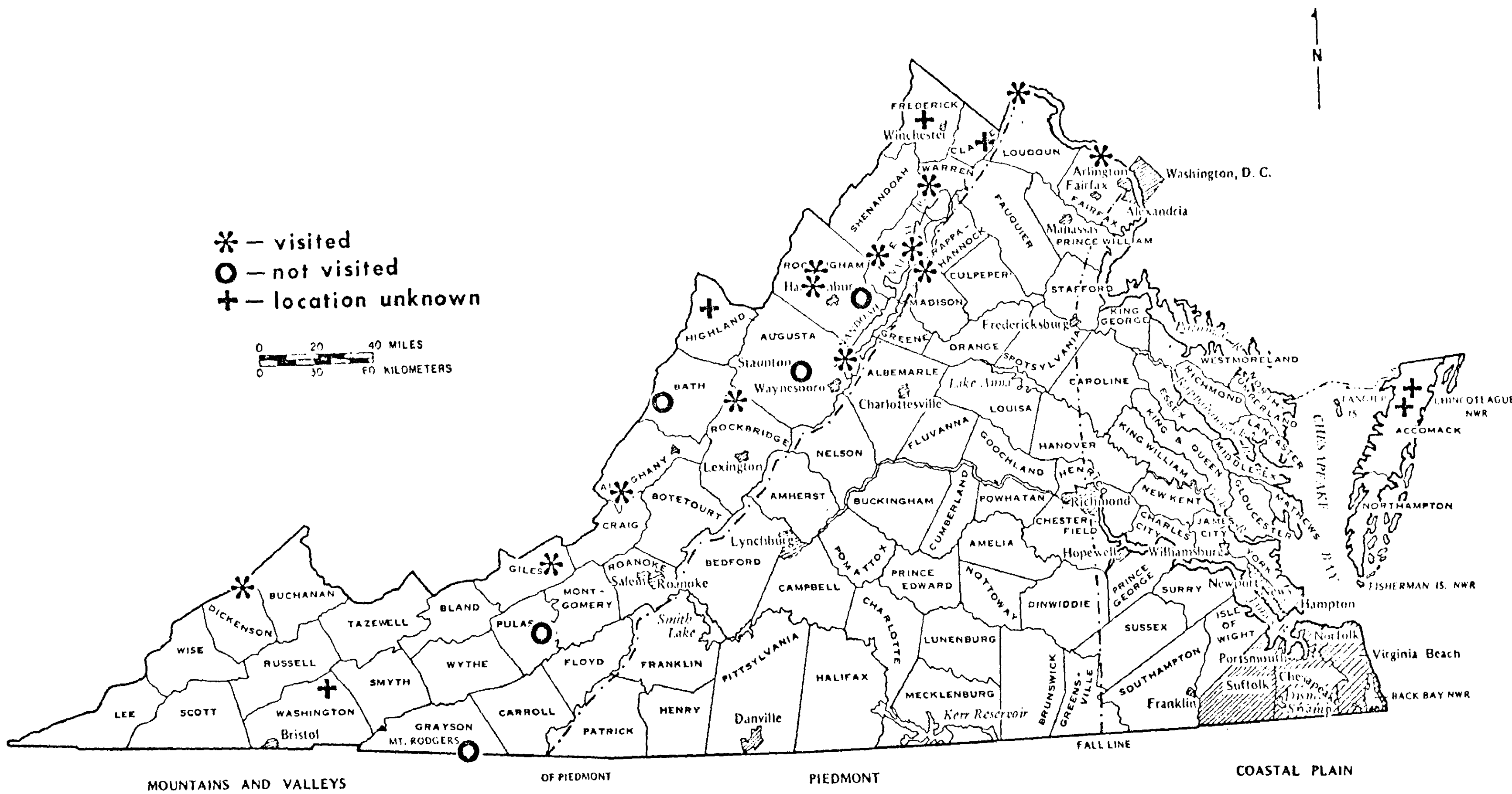
The majority of the eyries are distributed along the mountains from northern to southwest portions of the state. Two sites are described as being coastal. The distribution of known eyries is not uniform within the mountains. A measurement of density, mean inter-eyrie distance, is 43.2 Km (n=13). Seven nests in the Shenandoah Park region average 18.9 km apart. The apparent clumping of eyries in the National Park area probably reflects human observation patterns. Falconers, egg collectors, and birdwatchers were most active in searching for eyries. The Blue Ridge and Shenandoah areas are relativley close to human

Table 1. Historical activity and reference sources of Virginia peregrine eyries.

Site name	Reference	Years known active
Harpers Ferry	Alva Nye (pers. comm.)	1930-1943
Great Falls	J.J. Hickey (notes); Alva Nye (pers. comm.)	1907-1939
Fort Valley	Ava Nye and Steve Grady (pers. comm.)	1955-1961
Old Rag	Ava Nye to Hickey	pre-1936
Staunton	W. A. Wimsatt to Hickey	1938-1939
Rip Rap	Ava Nye (pers. comm.)	1959-1960
Jump Mountain	J. J. Murray (1933), Alva Nye to Hickey	1933
Hot Springs	W. A. Wimsatt to Hickey	1940
Nichols Knob	W. F. Kent to Hickey	1934
Barneys Wall	J. J. Hickey notes	1941*
Radford	J. J. Murray (1952)	pre-1933
Towers	D. Burger (pers. comm.)	1963 or 1964*
Stony Man	A. E. Granier (in litt.) to J. J. Hickey	1925
Independance	W. R. Spoffard to Hickey	1933
Dixon Ridge	F. M. Jones notes	1934-1936
Riven Rock	F. M. Jones notes	pre-1934
Massanutten	Ava Nye (pers. comm.)	pre-1938
Highland Co	F. M. Jones to Hickey	1936
New Market	Sidney Sigwald (pers. comm.)	pre-1950
Coastal #1	F. M. Jones (1946)	1926-1946
Coastal #2	F. M. Jones to Hickey	1926-1946
N. Virginia #1	F. M. Jones to Hickey	1930-1936
N. Virginia #2	F. M. Jones to Hickey	pre-1939
Clinch Mountain	F. M. Jones (1933)	pre-1933*

* long term use implied

Figure 2. Location and survey status of historic eyries.



* — visited
O — not visited
+ — location unknown
0 20 40 MILES
0 30 60 KILOMETERS
N
Washington, D. C.
Alexandria
Arlington
Fairfax
FAIRFAX
Manassas
PRINCE WILLIAM
LOUDOUN
FREDERICK
Winchester
CLA
WARREN
SHENANDOAH
FAUQUIER
RAPPA-HANNOCK
CULPEPER
MADISON
STAFFORD
KING GEORGE
WESTMORELAND
Fredericksburg
ORANGE
SPOTSYLVANIA
GREENE
ALBEMARLE
Charlottesville
Lake Anna
LOUISA
CAROLINE
HANOVER
HENR
Richmond
CHESTER FIELD
Hopewell
HIGHLAND
AUGUSTA
Staunton
Waynesboro
BATH
ROCKBRIDGE
Lexington
NELSON
AMHERST
FLUVANNA
GOOCHLAND
POWHATAN
CUMBERLAND
BUCKINGHAM
AMELIA
CRAIG
BOTETOURT
Lynchburg
BEDFORD
CAMPBELL
APPOMATTOX
PRINCE EDWARD
NOTTOWAY
DINWIDDIE
PRINCE GEORGE
SURRY
SUSSEX
GILES
ROANOKE
Salem
Roanoke
MONT-GOMERY
Smith Lake
CHARLOTTE
LUNENBURG
MECKLENBURG
Kerr Reservoir
BRUNSWICK
GREENS-VILLE
SOUTHAMPTON
Franklin
BUCHANAN
DICKENSON
TAZEWELL
BLAND
PULAS
WISE
RUSSELL
SMYTH
WYTHE
FLOYD
FRANKLIN
PITTSYLVANIA
HALIFAX
LEE
SCOTT
WASHINGTON
Bristol
GRAYSON
MT. RODGERS
CARROLL
PATRICK
HENRY
Danville
KING WILLIAM
KING & QUEEN
ESSEX
RICHMOND
NORTHUMBERLAND
LANCASTER
MIDDLESEX
GLOUCESTER
MATHEWS
NEW KENT
CHARLES CITY
JAMES CITY
Williamsburg
YORK
Newport News
Hampton
ISLE OF WIGHT
Portsmouth
Norfolk
Suffolk
Virginia Beach
BACK BAY NWR
CHESAPEAKE BAY
ACCOMACK
NORTHAMPTON
FISHERMAN IS. NWR
CHINCOTEAGUE NWR
MOUNTAINS AND VALLEYS
OF PIEDMONT
PIEDMONT
FALL LINE
COASTAL PLAIN

population centers and have been utilized for nature watching and recreation much more than the mountains of southwest Virginia.

A "typical" peregrine eyrie can be fabricated using the mean values of characteristics thought to be relevant. This hypothetical eyrie is a vertical sedimentary rock outcrop with 1.7 faces. It is 25.8 m in height, 249.5 m in horizontal extent, 402.1 m from a flowing stream, faces southwest or northeast, and is 627.5 m above sea level. The data are summarized in Table 2.

Table 2. Summary of variable values for Virginia peregrine eyries.

Variable	N	Mean and S.E.	Minimum	Maximum
altitude (m)	15	627.5 ± 85.5.0	18	1152
height of outcrop (m)	13	25.8 ± 5.6	8	73
extent of outcrop (m)	13	249.5 ± 135.9	8	1818
number of cliff faces	13	1.7 ± .24		
distance to water (m)	15	402.1 ± 117.9	1	1360

A summary page for each visited eyrie has been compiled (Appendix Table 7).

It is difficult to demonstrate meaningful or consistent interdependent relationships among the physical characteristics of the nest sites. Comparison of known nest sites with other "unused" cliff sites in Virginia was not attempted because it is unsafe to assume that any one cliff in Virginia was never utilized by peregrines. It is possible that peregrines used many more sites than is currently known. Table 3 illustrates bivariate scattergram correlation analysis of eyrie physical characteristics. Several significant relationships exist. Outcrop height is negatively correlated with the number of faces of the outcrop at the .05 level. The altitude of the site is negatively correlated (.05 level) with the horizontal extent of the outcrop and the altitude is positively correlated (.009 level) with the distance to a body of water.

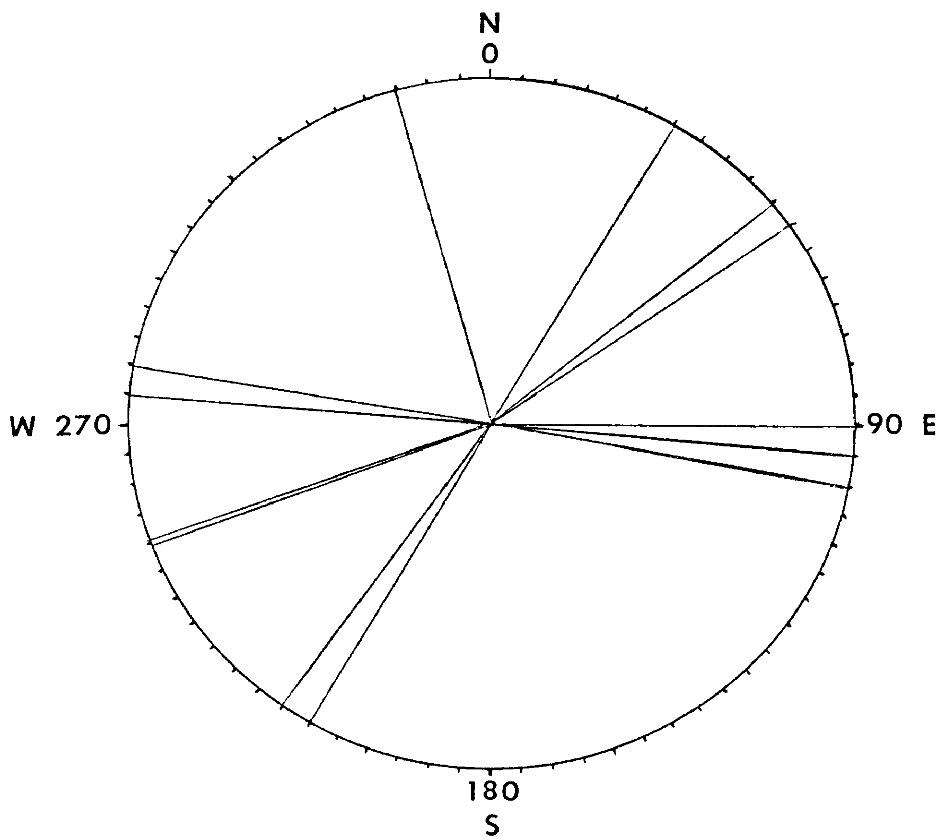
The compass direction the eyries face was determined; data are displayed in Figure 3. Goodness of fit test verifies that the eyries are not uniformly distributed with respect to compass direction (.05 level). Visual inspection of the data reveals a strong tendency towards a bimodal distribution which is best seen by disregarding the 345 degree facing site. The eyries basically face southwest or northeast. Further statistical analysis, including a test for randomness, becomes meaningless because unimodal distribution is an assumption of circular distribution statistics.

The sites can be ranked according to height of cliff and

Table 3. Bivariate scattergram correlations.

Variables	R	Significance level
height vs. altitude	-.28658	.17124
extent	-.05647	.42731
number of faces	-.48583	.04617
distance to water	.15487	.30671
altitude vs. extent	-.48490	.04653
number of faces	-.07688	.40144
distance to water	.59775	.00930
extent vs. number of faces	.29955	.16004
distance to water	-.24639	.20855
number of faces vs. distance to water	-.27624	.18047

Figure 3. Compass aspects of historic eyries.

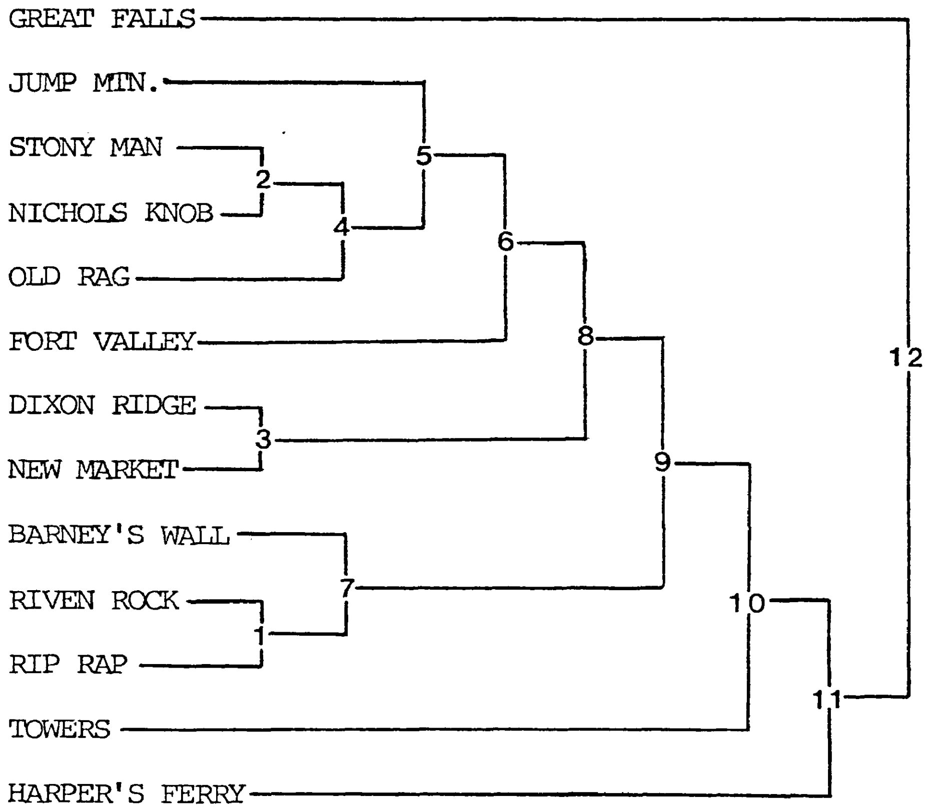

N
0
90 E
180
S
W 270

proximity to suitable hunting areas. Harper's Ferry, Great Falls, Towers, and New Market display above median ranking in these respects. It is interesting to note that three of these four sites also display a longer than average history of known use (Table 1).

Cluster analysis is a program which plots items in "n" dimensional space according to characteristic values and measures the distance between the plotted items. The items can then be paired and grouped in order of similarity (Figure 4). The sites were grouped according to variables thought to be relevant in determining the usefulness of the site for hacking. The variables were altitude, vertical height of cliff, horizontal extent of cliff, distance to water, habitat surrounding site, distance to potential disturbance, and distance to nearest road. The variables were weighted equally. It is assumed that only the first several groupings are meaningful although significant levels cannot be determined. Three main groupings are formed by the seventh amalgamation. Great Falls, Harper's Ferry, and Towers are the terminal groupings. The lowest order groupings involve Riven Rock, Rip Rap, Stony Man, Nichols Knob, Old Rag, and Dixon Ridge, New Market, respectively.

The habitat surrounding most of the sites appears suitable to support horned owls (*Bubo virginianus*). Horned owls are widespread in range and breed in a variety of habitats (Bent 1961). Fort Valley was the only site at which a horned owl was observed. Foul weather probably adversely affected vocal

Figure 4. Cluster analysis showing similarity in physical characteristics of historic eyries.


GREAT FALLS
JUMP MTN.
STONY MAN
NICHOLS KNOB
OLD RAG
FORT VALLEY
DIXON RIDGE
NEW MARKET
BARNEY'S WALL
RIVEN ROCK
RIP RAP
TOWERS
HARPER'S FERRY
1
2
3
4
5
6
7
8
9
10
11
12

responses of owls to the taped calls which were played at the sites. It is possible that the higher altitude sites, Old Rag and Stony Man, are free of horned owl territories.

EYRIE SURVEY - DISCUSSION

Prior Surveys

The first survey of *F. p. anatum* was conducted between 1937 and 1941 (Hickey 1942). Hickey compiled location and history data on all known eyries in eastern North America. Two hundred seventy-five valid eyries were reported. The number of eyries discovered per decade between 1840 and 1940 had increased considerably. Because the "law of diminishing returns" had not not yet reduced the number of eyries being discovered, the author concluded that the actual number of breeding pairs far exceeded estimates by survey. His tenative population estimate for the area south of Canada and east of the Rocky Mountains was 350 breeding pairs. Hickey was of the opinion that most of the eyries were not recently established by peregrines and had simply been unknown by ornithologists before their "discovery".

Hickey noted nine valid sites in Virginia. My study increases the number of known valid sites by fifteen. Assuming a fairly uniform distribution in suitable habitat, relatively few nest sites have been identified in the vast areas of mountainous terrain in southwest Virginia. This leads me to believe that a number of eyries were never found. By rough extrapolation, I estimate the number of breeding pairs present in Virginia before the decline to be between 30 and 45. The knowledge of peregrine eyries and their associated histories was much more complete in the northeastern U.S., ie., New York, Massachusetts, and Pennsylvania. When considering the limited knowledge of peregrine numbers in the southern Appalachians, Hickey's 1942 estimate of the entire eastern population appears decidedly conservative.

Several other surveys have been undertaken since Hickey's 1942 report (Burger et al. 1969; Cade et al. 1970; Fyfe et al. 1976). These more recent surveys concentrated on the sites compiled by Hickey and did not attempt to discover "new eyries" through correspondence and the literature. These surveys did not find any sites occupied by peregrines although they were not complete and some observations were made from distances approaching 1.7 km. Burger (1969) did suspect that one Virginia eyrie (Towers) was active in 1962 due to the freshly whitewashed ledges. These researchers also noted that other raptors (vultures, horned owls) and ravens appeared to be using several deserted peregrine eyries.

Traditional use

The traditional use of eyries is recognized as a fundamental concept in peregrine biology. Hickey (1942) introduced the idea that cliffs functioned as "ecological magnets". He graded cliffs by their size, situation, and their attraction to peregrines. He states that "first class peregrine cliffs are extremely high", usually are extensive, overlook water, and dominate the surrounding terrain. Peregrines are so attracted to these sites that the cliff will be occupied during the breeding season no matter how many birds are removed. Second class cliffs are smaller and the attraction is correspondingly less. Third class sites are marginal, usually temporary, and minor disturbances cause resident peregrines to abandon the site. There are numerous examples of first class sites, the most famous being the cliffs near Cornwall, England where peregrines were persecuted under Royal decree in an attempt to halt losses of messenger pigeons. The population was systematically slaughtered and breeding was curtailed between 1939 and 1945. The population rebounded quickly, probably due to recruitment from other areas. Pairs formed and breeding was attempted on the same ledges that were occupied before the extirpation. Similar occurrences have been reported in this country. A pigeon fancier methodically shot all the territorial adults at Harper's Ferry for years, yet other adults almost immediately took up residency. The removal of all fledglings by falconers at this same site compounded the disturbance yet peregrines continued breeding attempts at this site (Hickey 1942).

Other authors, particularly Cade (1960) recognize the concept of traditional use, but disagree on the importance of the physical structure of the cliff and argue that sites should be classed according to to the history of success at the site. A correlation may exist between the size of a cliff and the success due to the protection that a high inaccessible cliff ledge offers against terrestrial predators. White (1968 b) theorized that longtime eyrie use occurs through "genetic continuity". After looking at many museum skins of resident peregrines he noticed distinct phenotypic similarity of birds collected near each other. He states that an eyrie or local group of eyries could be traditionally maintained by the return of mature adults to their natal eyries and inbreeding within a small localized deme. This hypothesis may only be relevant to several resident demes of peregrines. Herbert and Herbert (1965) cite evidence contrary to White's genetic continuity theory. The Herberts banded large numbers of young peregrines and never observed any banded birds returning to the natal area. They also noticed several nest ledges become reoccupied that were previously used by peregrines. The lapse time between the occupations was 40-50 years, which is longer than the lifespan of any one peregrine. Because dozens of ledges were available that "looked good to human observers" those particular ledges obviously possessed some special attraction. It appeared that traditional use of eyries is fostered several ways; recognition of specific outstanding nest sites, return of adults to "successful sites", and the return of young upon maturity to natal areas to breed.

Northern Appalachian peregrines wintered coastally as far south as Georgia (Herbert and Herbert 1965), while southern Appalachian peregrines probably remained resident near the eyrie throughout the year (Hickey 1969; Spofford 1950). F. M. Jones found paired peregrines at Virginia eyries, Riven Rock, and Dixon Ridge in early February (unpublished notes). Successful or "first class" eyries in Virginia were probably occupied throughout the year, with breeders being replaced upon death, continuing the tradition of peregrine usage at the site. The majority of eyries in Virginia were not found until just prior to the population decline, limiting our knowledge of the site history. It is possible that the discoverers of the eyries (oologists and falconers) hastened the population decline by repeatedly disturbing nesting attempts.

Inter-eyrie distance

The density of formerly nesting peregrines in Virginia appears to be low when compared with other areas. The highest density of known breeding peregrines was found by Beebe (1960) on the coast of the Queen Charlotte Islands, British Columbia. Nest sites of twenty pairs averaged 1.6 km apart. In a two year survey on the Colville River Alaska, Cade (1960) found inter-nest distances of 8 and 11 pairs averaged 11.2 - 15.4 km, respectively. Inland nesting sites of peregrines in Britain have varied from 4.8-10.3 km apart (Ratcliffe 1969). The greatest concentration of known eyries in Virginia, ie., the Shenandoah National Park Region, displays a lower apparent density than reports from other areas and the apparent overall density in Virginia is markedly low. Although it is my opinion that many eyries were never found before the population crash, one must consider other factors. It is possible that the eastern U.S. has never comprised optimal habitat and, therefore, the peregrine population never reached high density. Pre-colonial eastern U.S. consisted mainly of homogeneous climax forest. The peregrine is generally associated with vast open areas, ie. tundra, highland, seacoast, which are suited to the peregrine's style of hunting. Although the eastern woodlands produce abundant potential prey, a large proportion of that prey base could be regarded as inaccessible due to the dense forest cover. Studies of peregrine breeding density, habitat and associated prey abundance have not been attempted.

Compass aspect

Direction of eyrie exposure, as related to protection from the elements, has been proposed as one factor in the selection of nest sites by cliff nesting species (Brown and Amadon 1968) Golden eagles (<u>Aquila chysaetos</u>) show a statistically significant preference for different eyrie exposure directions depending on the latitude of the breeding territory (Mosher and White 1976). The mountains of Virginia display a northeast - southwest orientation. The drainage pattern from these ridges flow basically southeast. The water flow has altered the environment in two ways relative to peregrine biology. Rivers have cut valleys and occassionally steep sided gorges in the mountains. Cliffs associated with these river cuts supply suitable nesting habitat explaining the northeast or southwest exposure directions of Virginia's eyries. The rivers also have cut a swath through the forest creating an opening in the otherwise homogeneous canopy. Nesting peregrines probably hunted the open air space above the river. Prey are favored by an abundance of cover in forested regions and peregrines must take advantage of quarry that ventures across clearings. Cade (1960) describes a hunting technique by which peregrines force their prey into water from which the prey can be easily grasped. Thus, the orientation of the mountain ridges and perpendicular drainage in many cases has determined the compass aspect of the eyries by providing suitable nesting habitat with nearby hunting areas. Thus, it appears that peregrines in Virginia probably do not show a directional preference for eyrie exposure, but the exposure of the nest sites appear to be an artifact of the local geology.

Correlation analysis

The significant relationships deduced from the correlation analysis are only moderately relevant to peregrine nesting biology. One significant correlation shows that the distance to a body of water from the eyrie increases as the altitude of the eyrie increases. This result is an artifact of geology. Obviously, higher altitude areas of a mountain are farther from bodies of water which tend to be located in the valleys. Open bodies of water are postulated as being important hunting areas of forest inhabiting peregrines. Proximity of the eyrie to the hunting area is advantageous as foraging efficiency would be increased by decreasing energy expenditure. But, it appears that proximity to the hunting area may not be a prime consideration in nest site selection by peregrines because they are capable of sustained long-distance flights. Ratcliffe (1980) states that breeding peregrines in Britain are known to travel over 10 miles from the nesting site to hunt. This figure is more impressive when one considers that a successful hunter carries the quarry to the eyrie.

Another significant correlation demonstrates that the horizontal extent of a cliff decreases as the altitude af a site increases. This result is probably an artifact of the decreasing surface area of a mountain from bottom to top. As previously stated, large cliffs are associated with attracting peregrines, but previous writers (Hickey 1942; Cade 1960) refer to height and not extent. Correlation of height with extent did not show a significant relationship in this study.

Evaluations for future use

The release of captive-produced peregrines near historical sites may lead to the reoccupation of those eyries (Eastern Recovery Plan). The hacked peregrines, upon return to their "natal areas" may be attracted to the former eyrie as a suitable nesting site. To be suitable as a hack site, a former eyrie must be free of human disturbance, yet accessible enough that logistic demands do not financially restrict maintenance operations.

The cluster analysis may be useful in making decisions concerning the use of historic eyries for hacking. Occasionally, the success of releasing peregrines depends on the characteristics of the site. The clustering groups together sites which are similar in relevant physical characteristics. If one former eyrie proves to be an outstanding hack site, probably another site similar to it would also prove to be a successful hack site. This analysis does not take into account certain factors such as attendant competence and financial considerations.

The sites were rated as suitable or unsuitable for future releases (Table 4).

Table 4. Suitability of Virginia eyries for release of captive produced peregrines.

Site	Suitable	Unsuitable	Major concern
Harpers Ferry	X		human disturbance
Great Falls		X	human disturbance
Fort Valley	X		
Old Rag		X	human disturbance
Rip Rap		X	"class 3" site
Jump Mountain	X		
Nichols Knob	X		
Barney's Wall		X	human disturbance
Towers	X		
Stony Man	X		human disurbance
Dixon Ridge		X	proximity to habitation
Riven Rock		X	"class 3" site
New Market		X	proximity to major road

according to the proximity of potential disturbance. Two sites are regarded as unsatisfactory due to small (class 3) cliff face size. An important factor in eyrie use appears to be the proximity of civilized areas and the associated disturbance (Hickey 1942). Many of the former peregrine eyries in Virginia have become popular recreation areas for picnickers, rock climbers, hikers, etc. Several of the sites may be suitable if the human use patterns can be modified or restricted. Peregrines begin courtship and territorial defense at this latitude in March. Human use of the eyrie sites is usually at a minimum at that time of year with increasing use in later months. Because many sites with heavy human usage are located on National Park property, it may be possible to protect the eyrie by restricting human use. Ultimately, peregrine occupancy will demonstrate which sites are suitable for breeding. Annual surveys of accessible sites during March would probably reveal territorial birds. Upon the reoccupation of a site steps could then be taken to protect the eyrie from human disturbance.

REINTRODUCTION EFFORT

REINTRODUCTION - MATERIALS AND METHODS

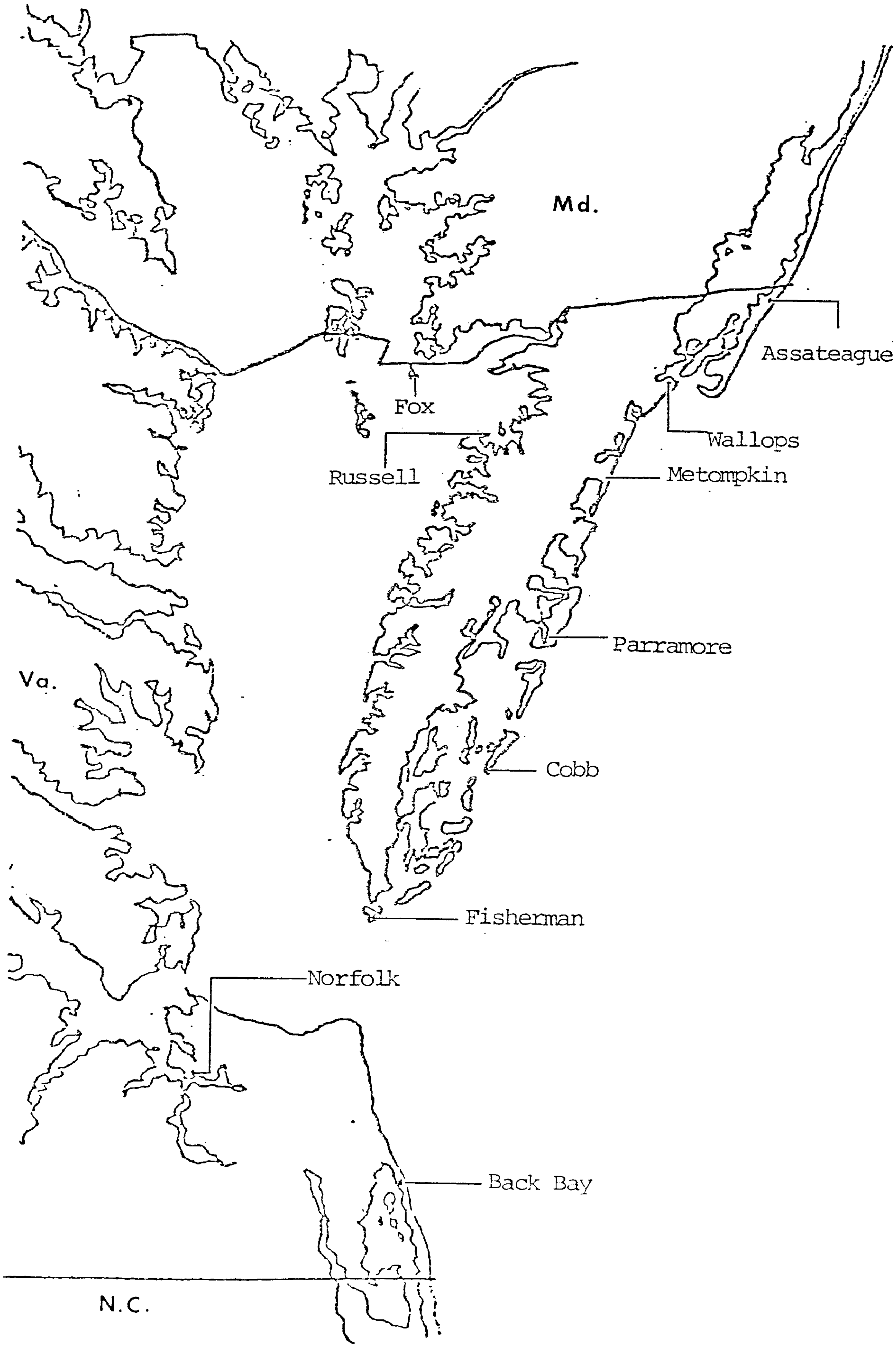
Peregrines are released into the wild using a technique known as hacking. It is a process developed by falconers which allows young hawks to learn flight and hunting skills while still dependent on the falconer for food. In this way the falconer maintains a relationship with the young raptors. The birds are placed in an artificial eyrie, the hack house, and allowed to fledge and learn hunting skills at their own pace. The falconer traps the juvenal hawks before they are totally independent, yet fairly skilled at hunting. The hawks then enter other forms of training. In hacking young peregrines for release, the technique is modified so that no relationship develops between the birds and the attendants and, of course, the peregrines are not trapped for captive training. This modified hack procedure is thoroughly described by Cade and Temple (1977).

Hacking was originally designed for use at or near historic eyrie sites. It was hoped that the birds would return, at breeding age, to the hack site and thus repopulate the old eyries (Recovery Plan 1979). Prior to 1978, the release success in other states (New York, Vermont) was low due to predation by great horned owls (Bubo virginianus). It was then decided that success (number of peregrines dispersed normally) would increase if releases occurred in habitats which horned owls did not frequent. In Virginia, hack sites were established on Coastal or Chesapeake Bay marshes and in an urban setting (Figure 5). Hack sites in marshes consist of an artificial tower; the urban site is a nine story high rooftop. These locations provide open terrain for hunting, a suitable prey base, minimal human disturbance, and safety from predators (Barclay 1980). These sites are permanent and can be used as nest sites by returning birds.

The towers at marsh sites consist of four utility poles vetically arranged in an eight to ten foot square. Each pole is thirty to forty-five feet in length; three to four feet of which extends into the marsh for stability. The poles are secured with a framework of crossmembers and a plank platform is built at the top. All lumber is salt treated for rot-resistance. The artificial nest or hack box (4'x5'x3') is contructed from plywood and placed on the platform. The front of the box is a removable "window" of metal bars. This allows the young birds to orient themselves by surveying the surroundings, yet be safely locked in a protective box. A partition (hide) and food chute apparatus is installed and a substrate of small gravel and several perching blocks are placed in the box. The urban release site has a similar hack box on a platform supported by a wooden scaffold six feet above the building rooftop.

The peregrines for release were produced at the propagation facility of the Peregrine Fund at Cornell University Laboratory of

Figure 5. Hack/breeding sites.



Md.
Assateague
Fox
Wallops
Russell
Metompkin
Parramore
Va.
Cobb
Fisherman
Norfolk
Back Bay
N.C.

Ornithology in Ithaca, New York. Cade _et al._ (1977) describe the facilities and production techniques. Sherrod and Cade (1978) and Barclay (1980) thoroughly detail the release procedure. The following is a broad description of the process. Dates of Virginia releases are in Table 5.

Peregrine chicks were transported from Cornell to the hack sites at approximately thirty days of age. A group of four to seven chicks was placed at each site. Hack attendants on duty at each site provided food, guarded against disturbance, and observed the development of the young birds. Japanese quail (_Coturnix coturnix_) and domestic chickens (_Galus domesticus_) were used for food. Depending on the circumstances of the hack site, the food birds were kept either alive or frozen. The peregrines were released at between forty and forty-five days of age, by the removal of the hack box front allowing the birds to fly at will. Continuous observations were made for about seven days after release. This assured that the exact fate of each bird was known. It also allowed immediate rescue of any birds that incurred problems during or shortly after fledging. Feeding and general observations continued until it was determined that the juvenal peregrines were feeding independently near the site or had dispersed (approximately forty days post-fledging).

All released peregrines were individually marked with numbered aluminum U.S. Fish and Wildlife Service bands. Auxillary plastic bands with alpha-numeric designations large enough for "field observations" were used except on 1980 releases. Two birds released in 1979 carried tail mounted radio transmitters.

REINTRODUCTION - RESULTS AND DISCUSSION

Thirteen releases of captive produced peregrines were conducted from seven release sites in eastern Virginia during 1978-1982. Three sites were used once, three sites were used twice, and a single site was used four times. Thirty-nine males and thirty-three females fledged. The release sites consist of hack towers, as described in the reintroduction methods, excepting Norfolk and 1978 Cobb Island at which releases were conducted from the roof and cupola of respective buildings.

Hacking success is measured by the percentage of released peregrines that become independent with respect to food, and normally disperse from the hack site. This success rate may be biased due to the inherent difficulty in distinguishing mortality from dispersal during the fourth and fifth weeks following release. For consistency, birds not seen after four weeks post release are assumed independent unless individual evaluation or other evidence suggests otherwise. The success rate of peregrine releases in Virginia was 89%. The success and mortality by site and year appear in Table 5. Barclay (1980) determined a 72% success rate of releases in the eastern U.S. from 1975 to 1979.

The greatest cause of known mortality in Virginia is due to

Table 5. Summary of release results.

Release Date	Hack site	Number of young released	Number of young lost	Cause	Number dispersed
6/19/78	Cobb	5	2	storm	3
6/27/79	Cobb	5	0	-	5
5/22/80	Cobb	5	0	-	5
6/1/80	Assateague	5	0	-	5
5/31/80	Fisherman	5	1	unknown	3
			1	followed subadult	
7/26/80	Norfolk	6		congenital defect	5
5/23/80	Cobb	6	0		6
5/30/81	Assateague	6	3	adult harassment	3
6/3/81	Great Fox	6	0		6
5/29/81	Norfolk	4	0		4
5/31/82	Back Bay	7	0		7
6/7/82	Great Fox	6	0		6
6/5/82	Russell	6	0		6
Totals		72	8		64

returning subadult and adult peregrines. In one instance, a released female is believed to have followed a subadult tiercel away from the site (Fisherman Island 1980). The young peregrine is categorized as lost because the subadult was never observed to feed her and she was considered unable to hunt proficiently at her age of disappearance. An adult male of a pair that returned to the Assateague site in 1981 forced three young males away from the site before they were competent hunters. This problem may occur more frequently in the future assuming more peregrines return to towers at which young are being hacked. Occassionally, innocuous interactions do occur between young and returning peregrines.

An important result is the apparent successful evasion of great horned owl range. This is undoubtedly due to the location of hack sites in coastal salt marsh habitat. Horned owl predation was the greatest cause of mortality in Barclay's (1980) report on the eastern release program.

As observed in most avian groups, mortality of first year peregrines is the highest of any age class. Estimates of first year mortality rate of wild peregrine's vary from 55% (Shor 1970) to 80% (Mebs 1960 in Barclay (1980). First year mortality of 70% as calculated by Enderson (1969) is accepted for North American peregrine populations. This first year mortality can be divided into pre- and post-dispersal periods. The post-dispersal period has been commonly thought to be a more difficult time as it requires the young birds to hunt successfully. Post-dispersal young are also prone to encounter more hazards due to their increased range. Pre-dispersal birds however are subject to many dangers. The fledging or first flight is an important phase in avian development and tends to be hazardous. Injuries that occur due to lack of judgement or skill may doom a young peregrine. Data are lacking on the pre-dispersal mortality for wild peregrines, but estimates do exist for a cogener with similar population dynamics. Prairie falcons (Falco mexicanus) in Idaho experience pre-dispersal mortality rates varying from 12-26% (Kochert 1976; Peterson 1976 in Barclay 1980). These figures are minimal estimates as every individual was not accounted for due to the lack of radio telemetry. The low pre-dispersal mortality of Virginia releases (11%) is probably due to several factors, namely, the choice of predator release hack sites and the dedication of hack attendants. In several cases, young peregrines were rescued from predicaments that would have proven fatal if not for human intervention.

We have much less control over post-dispersal mortality of released peregrines. Hunting is an instinctive behavior yet much practice is necessary to perfect the skill. For this reason food is made available to the released peregrines at the sites for up to six weeks post release. A "weaning" process is also employed to further stimulate hunting without risking starvation. Hunting proficiency of hacked birds is possibly enhanced by the amount of practice each bird experiences. The high density of potential prey, especially migrating shorebirds, on the eastern shore of Virginia increases prey encounters.

Human persecution has been and may continue to be an important cause of post-dispersal mortality. One half of the band recoveries in studies by Shor (1970) and Enderson (1969) occurred through shooting. Peregrines released by hacking are unavoidably subject to human contact although techniques are used to minimize the chances of developing human-food relationships. Nevertheless, hacked peregrines are not necessarily wary of humans. Coupled with the large amount of gunning which occurs in the Chesapeake Bay area, losses of peregrines to unscrupulous hunters is a distinct possibility. Only one peregrine shooting is known to have occured in eastern Virginia since 1978. An unbanded individual (implying a wild peregrine) was found shot near Norfolk, Virginia. The possibility exists that more peregrines are being shot and not reported since it is an unlawful activity. After reviewing band recovery data, Barclay (1980) concludes that peregrines hacked in the eastern U.S. are not subject to heavier shooting pressure than wild peregrines. Evidence does exist that the amount of raptor shooting has decreased since 1949 (Newton 1979) possibly due to a more conservation minded public and protective legislation.

Because it appears that, in Virginia, the hacking process results in a considerably lower pre-dispersal mortality rate, the first year mortality of hacked peregrines may well be lower than that of wild peregrines, assuming that both groups experience equal post-dispersal mortality. Modifying Enderson's (1969) calculation for first year mortality, peregrines hacked in Virginia probably are subject to a first year mortality rate approximating 55%.

Returns and sightings

Virginia is within the wintering range of an extant population of peregrines. Peregrines sighted from September through June therefore are possibly birds that are migrating or wintering and not releases. Since the commencement of Virginia peregrine hacking in 1978 summer sightings have dramatically increased attesting to the efficiency of hacking. Hack attendants at the sites are briefed to record details of all extraneous peregrines sighted and irregular visits are made to the hack sites throughout the year to locate returning birds. Birdwatchers and other interested persons in the area sometimes locate territorial peregrines at localities other than hack sites. Only banded peregrines can be identified as individuals and then only under excellent viewing conditions. For this reason most of our sightings are of unidentified peregrines. Peregrines seen between June 1 and August 14 or exhibiting courtship breeding behavior can be safely assumed to be released birds. Due to the Virginia recovery of several Maryland releases, resident peregrines in Virginia cannot be assumed to be Virginia releases. For population considerations, recruitment and loss to other areas, ie. Maryland, New Jersey, etc. is assumed to occur with equal frequency. Appendix Table 8 is a compilation of relevant peregrine sightings. Of note are the naturally formed pairs.

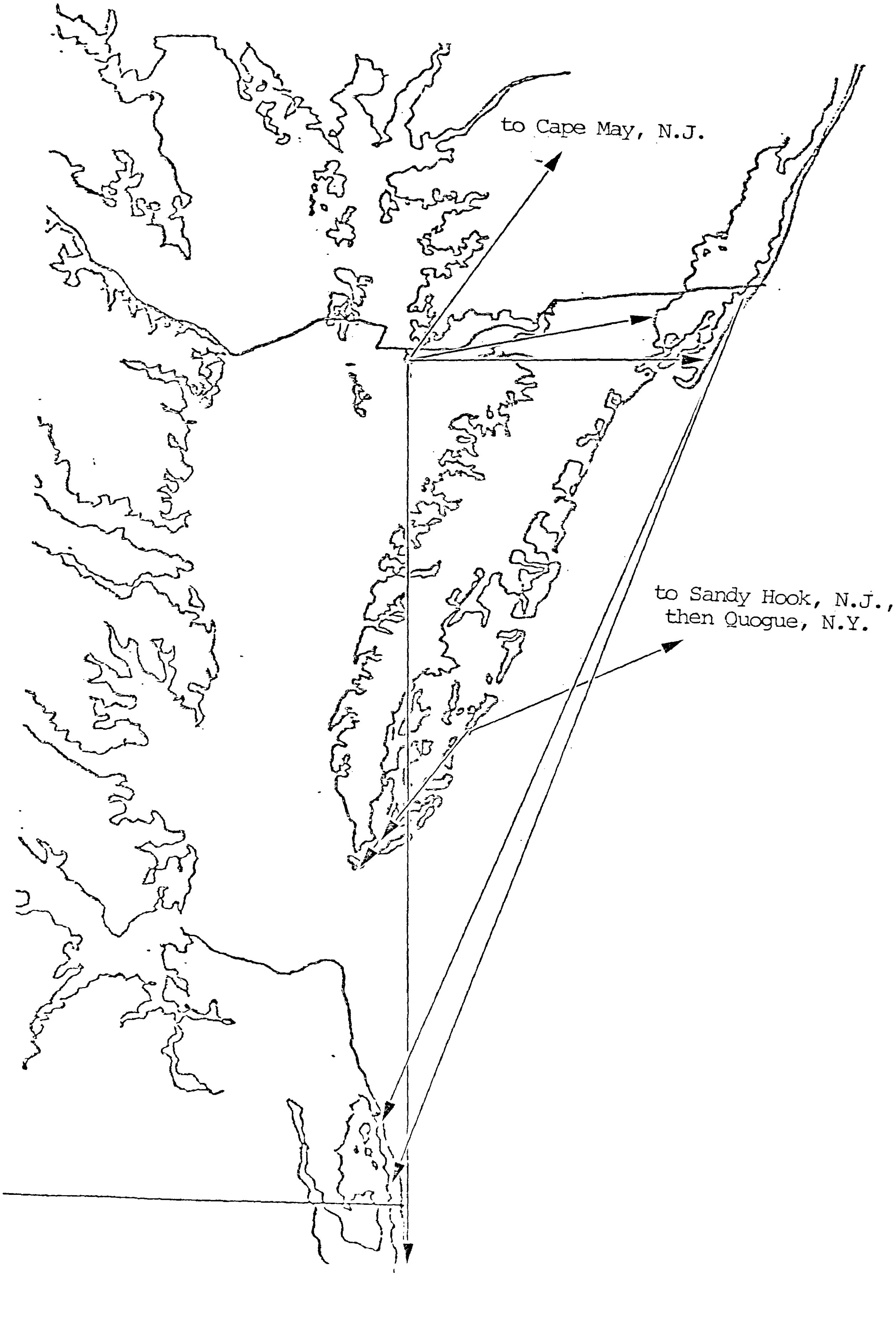
In March or April 1981 the first pair formed and established a territory at the tower erected at Wallops Island earlier that spring. The pair was accidently disturbed, abandoned the Wallops tower and became territorial at the Assateague tower, 12 miles distant. No nesting occured due to the hacking being attempted at Assateague. During October, 1981, a pair was observed to defend a territory at Fisherman Island. The tiercel was captured and identified as a 1980 Cobb release. The following February courtship and copulation were observed in the vicinity of the Fisherman tower. Simultaneously, a pair had established territory at the Cobb tower. Courtship and copulation were also observed. A third pair appeared resident on the Assateague tower beginning the first week in April. The falcon of this pair was observed in late April and through mid-May. On May 20, 1982, the first naturally produced peregrine in Virginia in over 20 years hatched. The Assateague pair produced three female young all of whom fledged successfully. The resident pairs at Fisherman and Cobb were unsuccessful in their nesting attempts. First time breeders are frequently unproductive due to the complex timing of behavior that is required in synchronizing gonadal maturation in both members of the pair (Cornell staff, pers. comm.). All three pairs have remained resident in the area of their respective towers through the early winter of 1982.

Dispersal and movements

Information has been compiled from band recoveries on movement of twelve Virginia released peregrines and four peregrines released out of state which have been recovered in Virginia (Appendix, Table 9). Most of the data are due to trapping efforts of raptor banders cooperating with the U.S. Fish and Wildlife Service. Several reliable sightings and a dead peregrine found near Quogue, New York, complete the recoveries. The movement of Virginia released peregrines (Figure 6) appear to be consistent with the wanderings typical of juvenile peregrines. The longest known peregrination entailed 520 km over 11 months in contrast to several birds that were captured four months after release in the vicinity of their hack tower. Of the nine plotted movements of Virginia peregrines, five are basically south, two movements are north, and two east. The data are biased by the location of raptor banding stations on the coast. Any inland movements remain undetected. Several peregrines have been recovered in Virginia that were hacked in other states (Figure 7). The direction of movement reflects the fact that successful hacking has not occurred south of Virginia. Speculation has been informally proposed (Recovery Plan, 1979) that coastally released peregrines may wander to the mountains, discover, and use historic eyries. No evidence of this exists. It appears improbable that peregrines that have been "imprinted" to coastal hack towers would recognize a cliff ledge as a breeding site. It is possible that increased population pressure may cause inland movement of juvenals in the future. Releases of peregrines near historic eyries in the southern Appalachians are proposed beginning in 1984 (J. Barclay, pers. comm.).

Many of the young peregrines produced by Cornell are progeny of highly migratory tundrius adults. The first released birds in the eastern U.S. to return and breed were hacked from towers on the coastal marshes of New Jersey. The pairs that formed and bred there were noted to remain resident in the vicinity of the towers

Figure 6. Movement of Virginia-released peregrines.


to Cape May, N.J.
to Sandy Hook, N.J.,
then Quogue, N.Y.

throughout the year (Cornell staff, pers. comm.). The same pattern appears in Virginia. Upon reaching adulthood and establishing a territory, released peregrines, at this latitude, do not migrate but remain sedentary, paralleling the behavior of the extirpated Virginia peregrines. Thus, extrinsic elements do appear to determine behavior to an extent.

Population estimate and projection

Determining total population numbers of peregrines resident in Virginia is difficult due to the high mobility of the young birds and our inability to follow widely dispersed individuals throughout the year. The number of adults is more easily determined due to the tendency for these birds to remain territorial at suitable breeding sites, ie. hack towers. At present three established pairs and two unpaired birds (of the opposite sex) are known to exist. Although two single birds comprise a hypothetical fourth pair, the individuals occupy separate territories approximately 124 km apart. Both birds remain sedentary throughout the year making it improbable that they will pair with each other. Each bird does represent a potential pair at their respective sites.

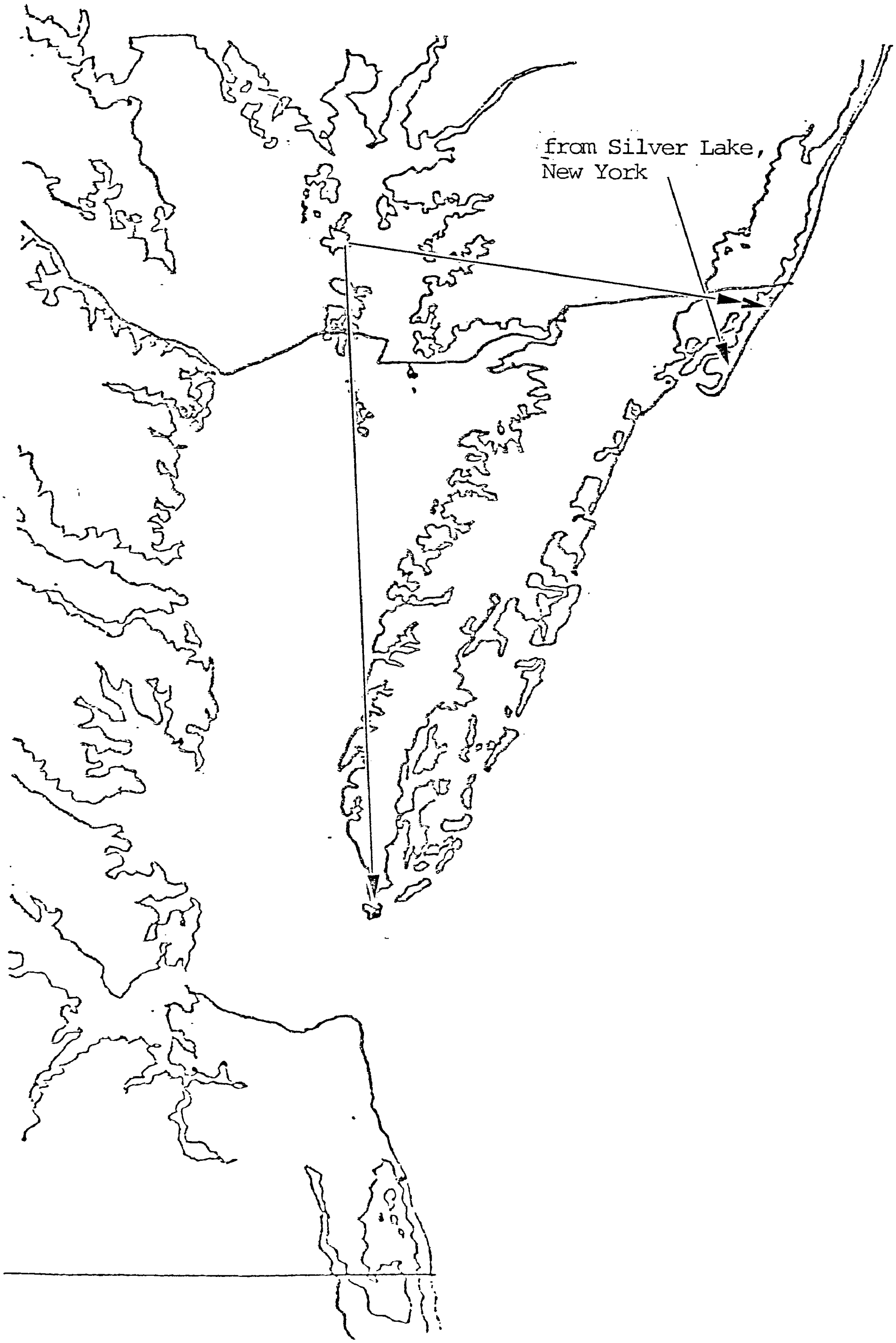
A stochastic model for population growth developed by J. W. Grier (1976), was used to assist in the population estimate and project results of the reintroduction program. The model simulates the growth of an existing or reintroduced population using known parameters. The incorporation of random chance within given probabilities for reproduction, sex of individuals, and mortality realistically approximates the unpredictability of small founding populations. The program parameters include:

1) monogamous or polygamous breeding pattern
2) age that breeding begins
3) maximum number of young per female
4) mean number of young per total breeding attempts
5) mean number of young per successful breeding
6) first year mortality rate
7) mortality rate of older animals
8) limit (if any) on number of breeding pairs per year
9) number (if any) of first year animals released per year
10) number (if any) of older animals released per year

Simulation results include number of animals of given age classes present at the beginning and end of any year. The stochastic nature of the program produces variable results due to random chance. For this reason, five simulations are run for every year and the mean and range of possible outcomes is presented.

Figure 8 displays the simulated growth of the Virginia reintroduced peregrine population. This model is based on the number of peregrines released to date and assumes that nine male an nine female peregrines will be released per year to 1990. Future "releases" may include the supplementation of existing broods. Other parameters include 60% hatch year mortality and 20% post hatch year mortality. These mortality rates are conservative estimates which include pre-dispersal losses and are based on band recovery data from wild populations (Enderson 1969) and returns of

Figure 7. Movement into Virginia of peregrines released out-of-state.


from Silver Lake,
New York

released peregrines (Barclay 1980). Reproduction averages 1.5 young per nesting attempt and 2.5 young per successful nesting attempt. Several studies (Mebs 1960; Herren 1969) indicate that this productivity is conservatively realistic. Forty percent of nesting attempts produce no young which is largely a reflection of the low reproductive success of second year birds which are included as breeders in this model. Beebe (1960) found approximately 60% breeding success of all recorded attempts in the _F. p. peali_ population of Queen Charlotte Islands. The number of breeding pairs in coastal Virginia will probably be limited by the number of towers which are present in a given year. The number of pairs which can attempt breeding is limited to 14 for this series of simulations. That is the maximum number of hack/breeding towers that can be erected in the immediate future. The number of pairs present in any simulation is defined by the number of the sex which is limiting in any given year. The model indicates a current population in Virginia of 15-23 peregrines (mean=18.2) including 3-7 pairs (mean=4.8). Yearly population numbers from 1978 to 1990 are presented in Appendix Table 10.

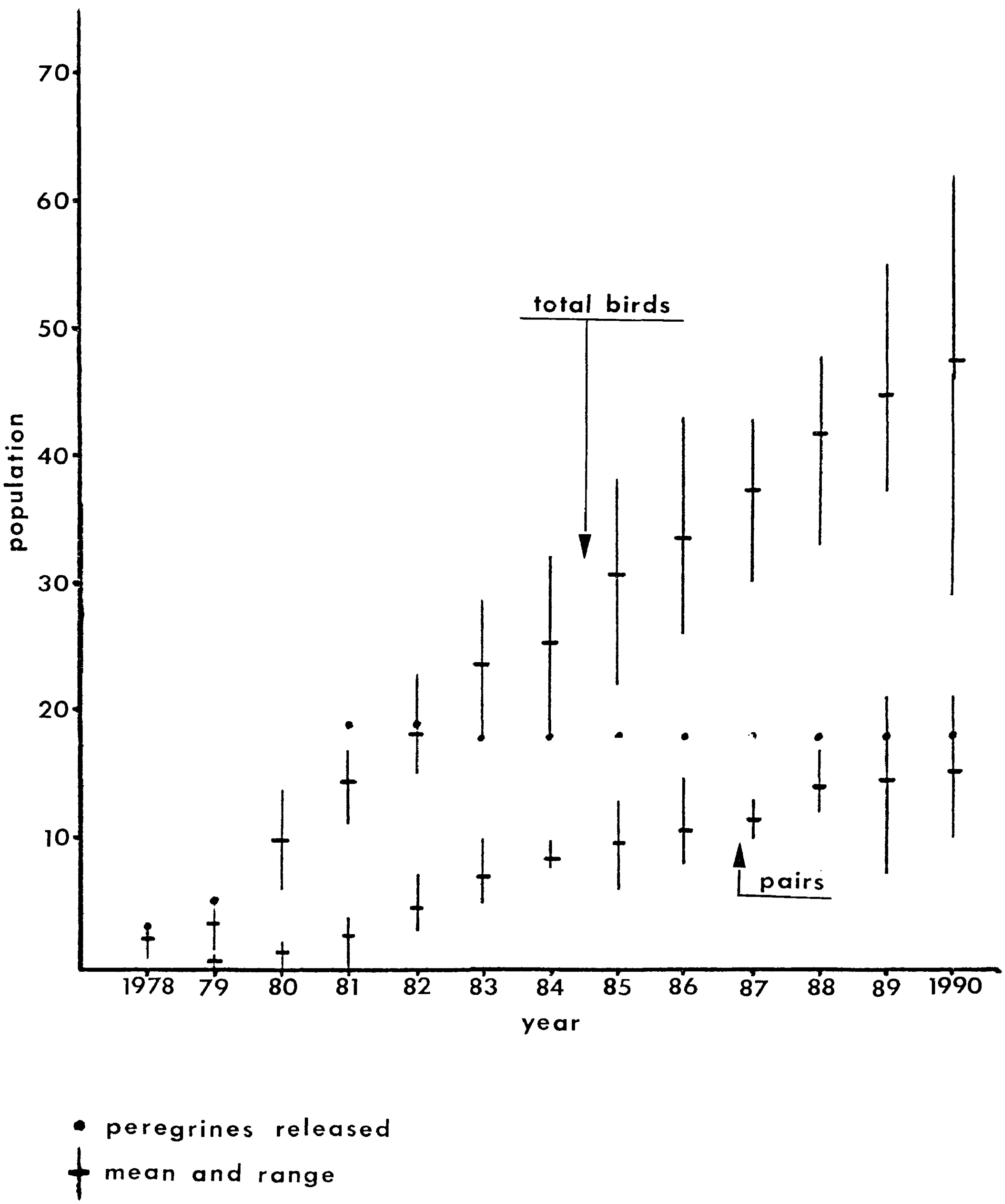
An identical model was run without limiting the number of breeding pairs to determine maximum population numbers. The mean number of breeding pairs present in 1990 under these circumstances is 18. This indicates that 18 nest sites will be needed by 1990 to allow the mean number of potential pairs to attempt breeding.

Analysis of survivorship tables shows that the mortality rate affects population growth to varying degrees partly depending of the age of the maturity of the species. Populations of animals such as the bald eagle (Haliaeetus leucocephalus) which do not breed until their fourth year are extremely affected by slight changes in mortality rates. Species which breed at very young ages, ie. Peromyscus spp. are affected more by reproduction rate changes than mortality rate changes. Peregrines generally do not breed successfully until their third year. The atttempts of sub-adult birds are usually included in reproductive figures. The relatively high percentage of unsuccessful breeding attempts reported (40%) is probably reflective of these sub-adult attempts. Survivorship tables do indicate that relatively small changes in mortality rates have profound effects on peregrine population growth (Young 1969).

Figure 9 shows the simulated growth of a Virginia peregrine population which is subject to 50% hatch year mortality and 15% post hatch year mortality. Other parameters in this model are identical to the growth simulation displayed in Figure 8. The reduction of hatch year mortality by 17% and post hatch year mortality by 25% in the growth simulations produces a significantly higher number of pairs and total birds present in the year 1990. The current population estimate in the simulation is also significantly affected. Table 6 contains the figures and statistical results. As noted earlier, studies of mortality by band recovery methods indicate that some peregrine populations may experience mortality rates as low as 55% (Shor 1970) for hatch year birds.

The growth program allows researchers to determine whether populations, defined by certain parameters, can be

Figure 8. Projected growth of Virginia peregrine population assuming 60% hatch-year and 20% after-hatch-year mortality.



70
60
50
40
30
20
10
population
total birds
pairs
1978
79
80
81
82
83
84
85
86
87
88
89
1990
year
peregrines released
mean and range

self-supportive. When no artificial release of animals occurs, natural reproduction has to be sufficient to compensate mortality or the population declines. Repeated simulations indicate that a peregrine population experiencing 60% hatch year and 20% post hatch year mortality rates cannot be self-supportive at documented reproductive rates. This implies that stable wild populations which display these reproductive rates are subject to lower mortality rates than is calculated by band recovery studies. Apparently more study is needed to accurately determine parameters of wild and re-established peregrine falcon populations.

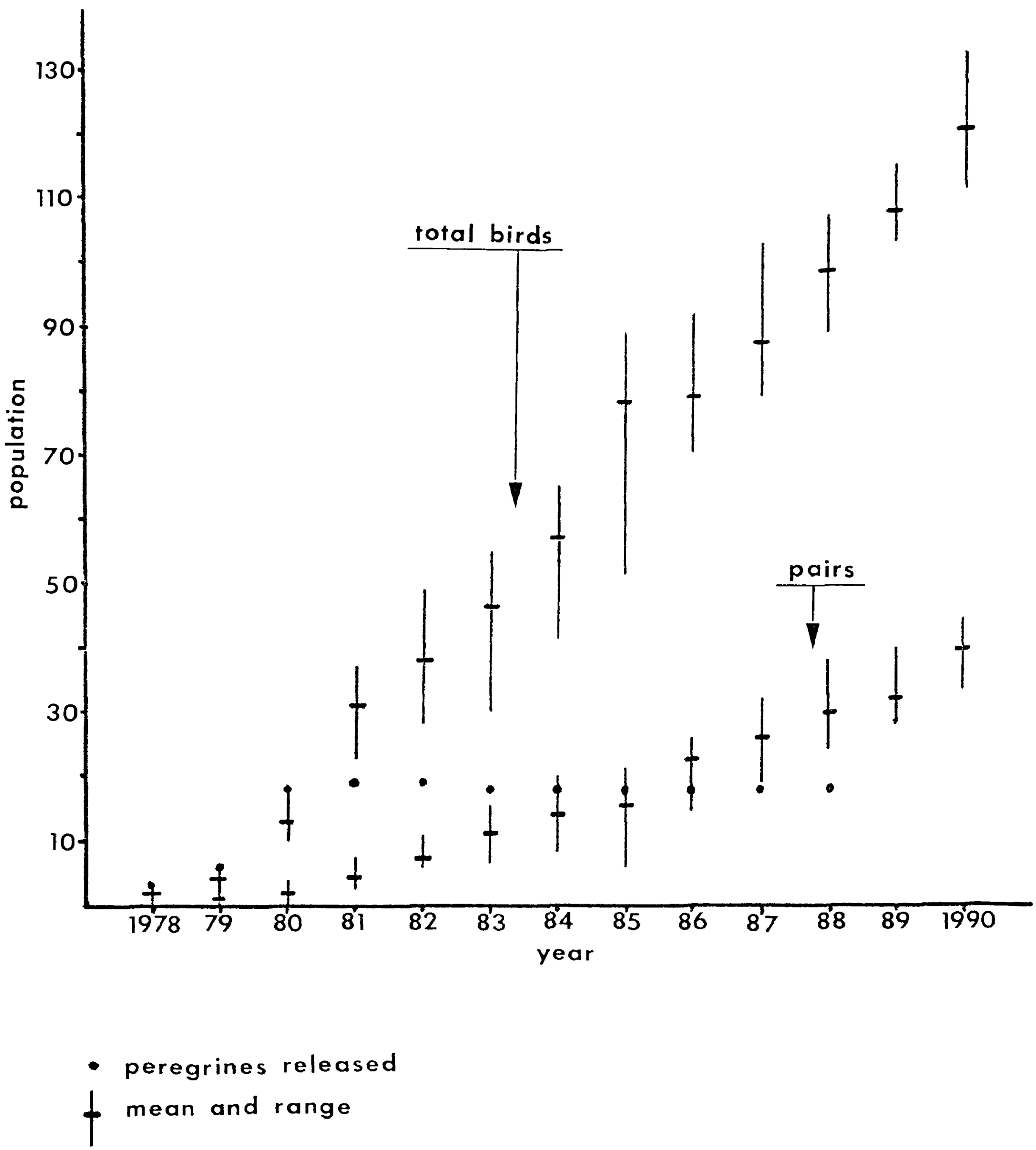
Table 6. Differences of simulated populations using T-test comparison of means. Degrees of freedom equal 8 for all tests.

Simulation A - 60% hatch year mortality; 20% post-hatch year mortality.
Simulation B - 50% hatch year mortality; 15% post-hatch year mortality.

	Simulation A (n=5)	Simulation B (n=5)	t
1982			
pairs present	4.8 ± 1.44	7.6 ± 4.30	2.95
total birds present	18.2 ± 3.27	31.0 ± 5.15	4.69
1990			
pairs present	16.2 ± 4.49	40 ± 4.30	8.56
total birds present	47.2 ± 13.59	108 ± 5.12	9.46

$t_{.05}\ (8) = 2.306$
$t_{.01}\ (8) = 3.355$
$t_{.001}\ (8) = 5.041$

Figure 9. Projected growth of Virginia peregrine population assuming 50% hatch-year and 15% after-hatch-year mortality.



130
110
90
70
50
30
10
population
total birds
pairs
1978
79
80
81
82
83
84
85
86
87
88
89
1990
year
peregrines released
mean and range

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APPENDIX

Table 7. Historic site summary.

EYRIE NAME: Towers

LOCALITY:

County: Dickinson

Geologic Survey Quadrangle: Elkhorn City

PHYSICAL CHARACTERISTICS:

Number of cliff faces: 2

Substrate: Sandstone

Maximum vertical height (m): 73

Maximum horizontal extent (m): 91

Compass aspect (degrees): 100

Altitude at base (m): 479

SURROUNDING HABITAT:

Directly above cliff: Mixed woods

Directly below cliff: Mixed woods

Distance to water (m): 230

Type of water body: River

Distance to nearest road (m): 600

DISTURBANCE FACTOR:

Type of: State Park

Distance to (m): 600

UTILIZATION OF SITE:

Present occupancy: None

Evidence: None seen

Date of visit: Feb. 16-17
Hours spent at site: 5
How cliff was examined: Spotting scope, across gorge.

EYRIE NAME: Great Falls

LOCALITY:

County: Fairfax

Geologic Survey Quadrangle: Falls Church

PHYSICAL CHARACTERISTICS:

Number of cliff faces: 1

Substrate: Mixed metamorphic

Maximum vertical height (m): 18

Maximum horizontal extent (m): 1818

Compass aspect (degrees): 30

Altitude at base (m): 18.2

SURROUNDING HABITAT:

Directly above cliff: Deciduous woods

Directly below cliff: Deciduous woods

Distance to water (m): 1

Type of water body: River

Distance to nearest road (m): 530

DISTURBANCE FACTOR:

Type of: Hiking trail

Distance to (m): 100

UTILIZATION OF SITE:

Present occupancy: None

Evidence:

Date of visit: Feb. 4
Hours spent at site: 2
How cliff was examined: Binoculars, above cliff

EYRIE NAME: Fort Valley

LOCALITY:

County: Warren

Geologic Survey Quadrangle: Strasburg

PHYSICAL CHARACTERISTICS:

Number of cliff faces: 1

Substrate: Sandstone, shale

Maximum vertical height (m): 61

Maximum horizontal extent (m): 333

Compass aspect (degrees): 95

Altitude at base (m): 539

SURROUNDING HABITAT:

Directly above cliff: Deciduous woods

Directly below cliff: Deciduous woods

Distance to water (m): 980

Type of water body: River

Distance to nearest road (m): 1250

DISTURBANCE FACTOR:

Type of: Hiking trail

Distance to (m):20

UTILIZATION OF SITE:

Present occupancy: Ravens

Evidence: Nest, Whitewash

Date of visit: Feb. 2
Hours spent at site: 2.5
How cliff was examined: Binoculars, climbing

EYRIE NAME: New Market

LOCALITY:

County: Page

Geologic Survey Quadrangle: Hamburg

PHYSICAL CHARACTERISTICS:

Number of cliff faces: Sandstone, shale

Substrate:

Maximum vertical height (m): 26

Maximum horizontal extent (m): 76

Compass aspect (degrees): 210

Altitude at base (m): 582

SURROUNDING HABITAT:

Directly above cliff: Coniferous woods

Directly below cliff: Deciduous, rocky woods

Distance to water (m): 100

Type of water body: Small stream

Distance to nearest road (m): 330

DISTURBANCE FACTOR:

Type of: Jeep trail

Distance to (m): 80

UTILIZATION OF SITE:

Present occupancy: Black Vulture roost

Evidence: Birds seen

Date of visit: Feb. 26
Hours spent at site: 2
How cliff was examined: Spotting scope, below cliff

EYRIE NAME: Dixon Ridge

LOCALITY:

County: Rockingham

Geologic Survey Quadrangle: Rawley Springs

PHYSICAL CHARACTERISTICS:

Number of cliff faces: 2

Substrate: Sandstone

Maximum vertical height (m): 11

Maximum horizontal extent (m): 9

Compass aspect (degrees): 250

Altitude at base (m): 715

SURROUNDING HABITAT:

Directly above cliff: Deciduous woods

Directly below cliff: Rocky slope

Distance to water (m): 340

Type of water body: River

Distance to nearest road (m): 300

DISTURBANCE FACTOR:

Type of: Jeep trail

Distance to (m): 180

UTILIZATION OF SITE:

Present occupancy: None

Evidence: None seen

Date of visit: Feb. 23
Hours spent at site: 1
How cliff was examined: Binoculars, climbing

EYRIE NAME: Riven Rock Ridge

LOCALITY:

County: Rockingham

Geologic Survey Quadrangle: Rawley Springs

PHYSICAL CHARACTERISTICS:

Number of cliff faces: 3

Substrate: Sandstone

Maximum vertical height (m): 11

Maximum horizontal extent (m): 8

Compass aspect (degrees): 50

Altitude at base (m): 569

SURROUNDING HABITAT:

Directly above cliff: Mixed woods

Directly below cliff: River, mixed woods

Distance to water (m): 80

Type of water body: River

Distance to nearest road (m): 160

DISTURBANCE FACTOR:

Type of: Residential area

Distance to (m): 150

UTILIZATION OF SITE:

Present occupancy: None

Evidence: None seen

Date of visit: Feb. 23
Hours spent at site: 1.5
How cliff was examined: Spotting scope, below cliff

EYRIE NAME: Old Rag

LOCALITY:

County: Madison

Geologic Survey Quadrangle: Old Rag Mountain

PHYSICAL CHARACTERISTICS:

Number of cliff faces: 2

Substrate: Mixed igneous intrusion

Maximum vertical height (m): 20

Maximum horizontal extent (m): 18

Compass aspect (degrees): 345

Altitude at base (m): 939

SURROUNDING HABITAT:

Directly above cliff: Dwarf deciduous

Directly below cliff: Deciduous, rocky slope

Distance to water (m): 1200

Type of water body: Small stream

Distance to nearest road (m): 1020

DISTURBANCE FACTOR:

Type of: Hiking trails

Distance to (m): 20

UTILIZATION OF SITE:

Present occupancy: Ravens in area

Evidence:

Date of visit: Jan. 30-31
Hours spent at site: 3.5
How cliff was examined: Binoculars, climbing

EYRIE NAME: Stony Man

LOCALITY:

County: Page

Geologic Survey Quadrangle: Old Rag Mountain

PHYSICAL CHARACTERISTICS:

Number of cliff faces: 3

Substrate: Granite

Maximum vertical height (m): 18

Maximum horizontal extent (m): 15

Compass aspect (degrees): 280

Altitude at base (m): 1169

SURROUNDING HABITAT:

Directly above cliff: Deciduous woods

Directly below cliff: Deciduous woods

Distance to water (m): 520

Type of water body: Stream

Distance to nearest road (m): 710

DISTURBANCE FACTOR:

Type of: Hiking trails

Distance to (m): 60

UTILIZATION OF SITE:

Present occupancy: Ravens in area

Evidence:

Date of visit: Jan. 31
Hours spent at site: 2
How cliff was examined: Binoculars, climbing

EYRIE NAME: Rip Rap

LOCALITY:

County: Augusta

Geologic Survey Quadrangle: Crimora

PHYSICAL CHARACTERISTICS:

Number of cliff faces: 2

Substrate: Sandstone, conglamorate

Maximum vertical height (m): 8

Maximum horizontal extent (m): 15

Compass aspect (degrees): 275

Altitude at base (m): 412

SURROUNDING HABITAT:

Directly above cliff: Mixed forest

Directly below cliff: Mixed forest

Distance to water (m): 110

Type of water body: Stream

Distance to nearest road (m): 940

DISTURBANCE FACTOR:

Type of: Hiking trail

Distance to (m): 100

UTILIZATION OF SITE:

Present occupancy: None

Evidence: None seen

Date of visit: Feb. 25
Hours spent at site: 2.5
How cliff was examined: Binoculars, below cliff

EYRIE NAME: Barney's Wall

LOCALITY:

County: Giles

Geologic Survey Quadrangle: Eggleston

PHYSICAL CHARACTERISTICS:

Number of cliff faces: 1

Substrate: Shale, limestone

Maximum vertical height (m): 11

Maximum horizontal extent (m): 424

Compass aspect (degrees): 215

Altitude at base (m): 969

SURROUNDING HABITAT:

Directly above cliff: Mixed forest

Directly below cliff: Mixed forest

Distance to water (m): 700

Type of water body: Stream

Distance to nearest road (m): 1400

DISTURBANCE FACTOR:

Type of: Hiking trail

Distance to (m): 2

UTILIZATION OF SITE:

Present occupancy: Ravens

Evidence: Whitewash

Date of visit: Feb. 17
Hours spent at site: 2.5
How cliff was examined: Binoculars, below cliff

EYRIE NAME: Nichol's Knob

LOCALITY:

County: Alleghany

Geologic Survey Quadrangle: Jordan Mines

PHYSICAL CHARACTERISTICS:

Number of cliff faces: 1

Substrate: Sandstone, shale

Maximum vertical height (m): 14

Maximum horizontal extent (m): 197

Compass aspect (degrees): 90

Altitude at base (m): 1042

SURROUNDING HABITAT:

Directly above cliff: Deciduous slope

Directly below cliff: Deciduous forest

Distance to water (m): 700

Type of water body: Small stream

Distance to nearest road (m): 700

DISTURBANCE FACTOR:

Type of: Local farms

Distance to (m): 800

UTILIZATION OF SITE:

Present occupancy: None

Evidence: None seen

Date of visit: Feb. 18
Hours spent at site: 2
How cliff was examined: Binoculars, below cliff

EYRIE NAME: Harpers Ferry

LOCALITY:

County: Washington, MD

Geologic Survey Quadrangle: Harpers Ferry

PHYSICAL CHARACTERISTICS:

Number of cliff faces: 1

Substrate: Sandstone

Maximum vertical height (m): 39

Maximum horizontal extent (m): 109

Compass aspect (degrees): 250

Altitude at base (m): 85

SURROUNDING HABITAT:

Directly above cliff: Sparse deciduous forest

Directly below cliff: River, train tracks

Distance to water (m): 70

Type of water body: River

Distance to nearest road (m): 50

DISTURBANCE FACTOR:

Type of:

Distance to (m):

UTILIZATION OF SITE:

Present occupancy: Rock Doves

Evidence: Seen roosting

Date of visit: Feb. 4
Hours spent at site: 1.5
How cliff was examined: Spotting scope, below cliff

EYRIE NAME: Jump Mountain

LOCALITY:

County: Rockbridge

Geologic Survey Quadrangle: Goshen

PHYSICAL CHARACTERISTICS:

Number of cliff faces: 1

Substrate: Sandstone, limestone

Maximum vertical height (m): 29

Maximum horizontal extent (m): 106

Compass aspect (degrees): 55

Altitude at base (m): 915

SURROUNDING HABITAT:

Directly above cliff: Deciduous forest

Directly below cliff: Deciduous forest

Distance to water (m): 1360

Type of water body: Stream

Distance to nearest road (m): 1300

DISTURBANCE FACTOR:

Type of: Logging tract

Distance to (m): 1000

UTILIZATION OF SITE:

Present occupancy: Ravens

Evidence: Nest, whitewash

Date of visit: Feb. 20
Hours spent at site: 1
How cliff was examined:

Table 8. Returns and sightings.

Year	Location	Identification (if known)	Comments
1979	Cobb	Subadult tiercel released. from Cobb, 1978.	Seen late May, June 18, July 14-29. Courted released falcons, not aggressive.
1980	Fisherman	Adult pair, probably birds released by Cornell staff on May 14.	Seen on west structures, May 17.
		Adult tiercel, probably of above pair.	Seen at hack tower, June 3.
1981	Wallops	Adult pair.	Resident, but abandoned tower (see next entry).
	Assateague	Adult pair; *falcon identified as 1980 South Marsh, MD release.	Arrival (early May) coincides with Wallops abandonment, not seen after late Sept. Very aggressive toward hacked birds.
	Cobb	Subadult tiercel (age and sex unknown.)	Seen May 5. Seen twice May 16.
		*Subadult tiercel released from Cobb, 1980.	Seen May 24-26. Initially appeared aggresive, but later courted released falcons.
	Great Fox	Subadult tiercel	Seen June 3-July 21. No aggressive or courting behavior noted.

*Known individuals also treated as recoveries (Table 9).

Table 8 (Continued)

Year	Location	Identification (if known)	Comments
1981	Norfolk	Subadult falcon.	Seen May 26, no interactions (young still in hack box).
		Adult falcon.	Seen June 14-15. Possibly made "E-chupp" calls to released young.
	Metompkin Island	Adult falcon.	Seen regularly perched on shack in marsh, May-June.
	Fisherman	Adult pair both banded. *Tiercel identified as Cobb 1980 release, seen at Cobb in May.	Seen Sept. to present, chased migrating peregrines from island routinely, breeding attempted spring 1982.
	Norfolk	Adult (plumage) tiercel.	Resident Nov. to present, courts wintering falcon, seen well Nov. '82 not wearing band.
	Norfolk	Subadult falcon wearing black band.	Seen mid-Dec.-April 6, 1982 frequenting Arts and Letters building, O.D.U. Black band implies 1981 east coast release.
1982	Cobb	Adult pair, both banded, possibly same birds as 1981.	Seen March-present, attempted breeding spring 1982.
	Great Fox	Adult peregrine (sex unknown).	Seen briefly May 8, no interaction with unreleased young.
	Metompkin	Adult pair, falcon probably 1981 resident.	Seen June 23.

*Known individuals also treated as recoveries (Table 9).

Table 9. Recovery of Known Individuals.

Band number	Sex	Hack site/year	Recovery
576-89280	M	Cobb/78	Trapped Fisherman 9/78
576-89270	M	Cobb/78	Returned Cobb (seen) 5/79-7/79
987-01322	F	Cobb/79	Trapped Sandy Hook, NJ 4/15/80 Found dead Quogue, NY 4/24/80
816-40327	M	Cobb/80	Returned Cobb (seen) 5/81-6/81 Trapped Fisherman 10/5/81
816-40322	M	Assateague/80	Trapped Assateague 9/24/80
987-01343	F	Assateague/80	Trapped Assateague 9/24/80 Trapped False Cape 10/1/80 Trapped Assateague 10/8 & 10/13/80
987-49509	F	Great Fox/81	Trapped Assateague 9/18/81
987-49507	F	Great Fox/81	Trapped Corolla, NC 9/30 & 19/1/81
987-49533	F	Great Fox/82	Seen at Horntown, VA 7/18/82
*987-01361	F	South Marsh, MD/80	Resident on Assateague 5/81-10/81 Trapped Assateague 10/81
*987-49559	F	South Marsh, MD/82	Trapped Wise Point, VA 9/25/82
**987-49597	F	Assateague/82	Trapped Back Bay, VA 9/16/82
**987-49598	F	Assateague/82	Trapped Assateague 9/17/82
987-49551	F	Great Fox/82	Trapped Cape May, NJ 9/18/82
*987-49564	F	South Marsh, MD/82	Trapped Assateague 10/3/82
*987-49577	F	Silver Lake, NY/82	Trapped Assateague 10/11/82

*Hacked outside Virginia; recovered in Virginia.
**Young of "natural" nesting in Virginia.

Table 10. Population growth simulation A data. Fifty percent hatch-year and fifteen percent after-hatch-year mortality. Pairs defined by number of limiting sex.

		Total birds present							Pairs present						
		Simulations:							Simulations:						
Year	Birds released	1	2	3	4	5	Mean	Range	1	2	3	4	5	Mean	Range
1978	3	1	1	3	1	2	1.6	1-3	0	0	0	0	0	0.0	0-0
1979	5	2	5	5	1	4	3.4	1-5	0	0	1	0	1	0.8	0-1
1980	18	6	12	14	9	8	9.8	6-14	0	2	2	0	2	1.2	0-2
1981	19	15	17	16	11	14	14.6	11-17	0	4	4	2	3	2.6	0-4
1982	19	17	15	20	16	23	18.2	15-23	3	5	7	4	5	4.8	3-7
1983	18	29	21	22	18	29	23.8	18-29	5	5	8	7	10	7.0	5-10
1984	18	32	23	27	18	26	25.2	18-32	9	8	8	8	10	8.6	8-10
1985	18	38	27	31	22	36	30.8	22-38	13	6	11	7	10	9.4	6-13
1986	18	43	26	32	30	32	32.6	26-43	15	8	9	10	11	10.6	8-15
1987	18	40	30	43	38	35	37.2	30-43	13	10	11	12	12	11.6	10-13
1988	18	42	33	48	43	43	41.8	33-48	14	12	17	12	15	14.0	12-17
1989	18	36	36	55	45	52	44.8	36-55	14	7	21	15	17	14.8	7-21
1990	18	39	28	62	52	55	47.2	28-62	14	10	21	16	20	16.2	10-21

VITA

Johannes Kurt Gabler

Born in Rome, New York August 14, 1957. He attended public schools in Rome and recieved his high school diploma in 1975. Hartwick College, Oneonta, New York awarded Mr. Gabler the degree of Bachelor of Arts in Biology in 1979. Later that year he began work towards the degree of Master of Arts in the graduate program of the Department of Biology at the College of William and Mary. Mr. Gabler has been employed by the college as research assistant and research associate.