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INVESTIGATION OF BREEDING PEREGRINE FALCONS ON BRIDGES

THE CENTER FOR CONSERVATION BIOLOGY

COLLEGE OF WILLIAM AND MARY

VIRGINIA COMMONWEALTH UNIVERSITY

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Project Partners:

Virginia Department of Transportation
Virginia Transportation Research Council
Virginia Department of Game and Inland Fisheries
U.S. Fish and Wildlife Service
Dominion Power
College of William and Mary
Virginia Commonwealth University
The Center for Conservation Biology

Front Cover: Female peregrine falcon with eggs in nest box on the James River Bridge. Photo by Bryan Watts.

The Center for Conservation Biology is an organization dedicated to discovering innovative solutions to environmental problems that are both scientifically sound and practical within today's social context. Our philosophy has been to use a general systems approach to locate critical information needs and to plot a deliberate course of action to reach what we believe are essential information endpoints.

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EXECUTIVE SUMMARY

Following the extirpation of the peregrine falcon (Falco peregrinus) population in Virginia by the early 1960s and an aggressive restoration program during the 1970s and 1980s the population has undergone a slow but steady recovery to more than 30 breeding pairs. Bridges have played a significant role in this recovery, consistently supporting more than 30% of the known population. Due to regulatory restrictions, this role has increased operational costs and caused concerns for bridge management and maintenance. One of the ongoing challenges faced by the Virginia Department of Transportation is the uncertainty and associated financial risk stemming from not knowing the occupancy status of many bridges. The objectives of this project were 1) to determine occupancy for bridges in the Coastal Plain, 2) to test a rapid survey protocol for determining occupancy, 3) to assess bridge characteristics that attract falcons to bridges, and 4) to conduct a retrospective assessment of current peregrine management techniques used on bridges.

We conducted 166 surveys of bridges (n = 83) in coastal Virginia using a call-broadcast protocol. Eleven (13.3%) bridges were occupied by falcons, including ten pairs that produced 11 young. Broadcast calls were extremely effective in eliciting a response from falcons with nearly 60% and 100% of falcons responding within five and 30 seconds of call initiation respectively. Occupied bridges were not a random subset of those surveyed but supported more potential nest sites, were longer and higher and were embedded within landscapes with more foraging habitat compared to unoccupied bridges. Lift and draw bridges were particularly attractive with 60% of those available supporting pairs. The current practice of installing nest boxes or trays has resulted in higher breeding success and reproductive output.

Findings from this study have implications for reducing uncertainty in peregrine falcon management on bridges. Call-broadcast surveys were effective and should be used to expand the set of bridges monitored annually to improve the planning and scheduling of maintenance projects. Current peregrine management techniques improve breeding performance but may also reduce maintenance conflicts and should be continued. The movement of young falcons from bridges for release in the mountains greatly reduces the regulatory burden on bridge managers and should be continued.

BACKGROUND

The historical population of peregrine falcons (Falco peregrinus) in the eastern United States was estimated to contain approximately 350 breeding pairs, relied on open cliff faces and cut-banks for nesting, and was mostly confined to the Appalachian Mountains (Hickey, 1942). The population experienced a precipitous decline throughout the 1950s (Hickey, 1969) due to contaminant-induced reproductive suppression (Anderson and Hickey, 1972) and was believed to have been extirpated by the early 1960s (Berger et al., 1969). The peregrine falcon was listed as endangered on the U.S. Federal List of Endangered and Threatened Wildlife (50 CFR 17.11-17.12) in June 1970. In 1975, the U.S. Fish and Wildlife Service appointed an Eastern Peregrine Falcon Recovery Team to develop and implement a recovery plan (Bollengier et al., 1979). A retrospective assessment of the historic peregrine falcon population in Virginia conducted by J. K. Gabler in 1983 identified 24 historical eyries in the Appalachian Mountains (unpublished data). Two additional nesting sites were documented on old osprey nests along the Virginia portion of the Delmarva Peninsula (Jones, 1946).

As part of a national effort to restore the eastern peregrine population, the Virginia Department of Game and Inland Fisheries (VDGIF), Cornell University, and The Center for Conservation Biology (CCB) at the College of William and Mary initiated a hacking program for Virginia in 1978. The program involved the release of captive-reared peregrines with the hope that these birds would re-colonize the historic breeding range. Between 1978 and 1993, approximately 250 young falcons were released in Virginia. Since the close of this program, captive-reared peregrines have been released on a limited basis within the state. Such releases have involved more targeted projects. Beginning in 2000, Virginia initiated a translocation program that has moved birds from coastal territories to be hacked from mountain release sites. A large portion of the young used in this program has been produced on coastal bridges. Translocating birds from bridges to the mountains serves to release the bridges from restrictions imposed during the breeding season and helps to restore birds to their historic mountain breeding range. More than 250 birds have been moved since the inception of the program (Watts and Watts, 2016).

The first successful nesting of peregrines falcons in Virginia after the DDT era occurred in 1982 on Assateague Island. Since that time, the breeding population has continued a slow but steady increase. The size of the known breeding population within Virginia now exceeds 30 pairs (Watts and Watts, 2016). However, both hatching rate and chick survival remain somewhat erratic in both the coastal and mountain breeding populations. An analysis by the U.S. Fish and Wildlife Service in the early 1990s of addled eggs collected in Virginia, showed levels of DDE, Dieldrin, and egg-shell thinning that have been shown previously to have an adverse impact on reproduction. An additional problem that has been suspected but not fully quantified is that the turnover rate of breeding adults appears to be high. At present, the long-term viability of the Virginia peregrine falcon population remains questionable and the species remains on the state's list of threatened and endangered species (Watts and Watts, 2016).

Bridges have played a significant role in the recovery of the peregrine falcon population in Virginia and the Virginia Department of Transportation (VDOT) has become a valuable conservation partner. Since 1993, bridges have consistently supported more than 30% (ranging up to as high as 50%) of the known breeding population in the state (Figure 1). However, supporting breeding falcons on bridges has increased operational costs and caused concerns for bridge management and maintenance planning. Time-of-year restrictions set by VDGIF restrict activities within 600 feet (185 m) of a falcon nest between 15 February and 15 July in order to protect nesting pairs from disturbance that may reduce productivity. VDGIF provides funds annually to survey bridges known to have had nesting pairs in past years in order to inform VDOT of occupancy status. Knowing the occupancy status of a bridge in advance of bridge maintenance projects is useful in project planning and may reduce costs resulting from project delays if pairs are discovered after a project is initiated. Installing nest boxes to encourage falcons to nest away from areas requiring frequent management (e.g., wire boxes, navigational lights, lift spans) may reduce costs and improve operational efficiency. In addition, understanding bridge characteristics that attract nesting falcons may help to identify bridges that are likely to be colonized in the future and aid in long-range planning.

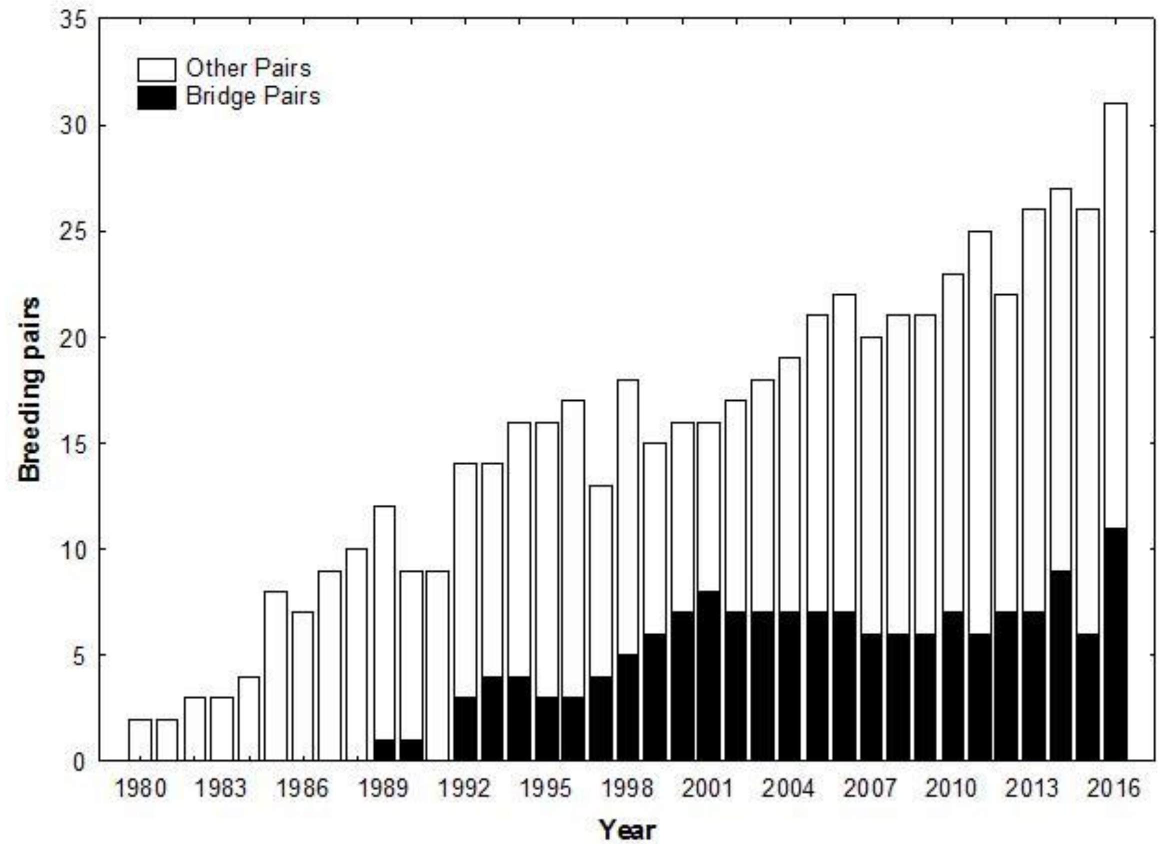

Figure 1 The number of breeding pairs of peregrine falcons in Virginia (1980-2016). Dark bars represent pairs nesting on bridges and open bars represent pairs on all other structures. Data from The Center for Conservation Biology archives.

PURPOSE AND SCOPE

One of the challenges faced by VDOT in both planning and executing bridge maintenance projects is the uncertainty and associated financial risk in peregrine falcon occupation of bridges. The primary purpose of this project is to reduce uncertainty by surveying bridges for falcon pairs and determining occupation during the 2016 breeding season. Additional objectives include the testing of a rapid survey protocol that may be used in future bridge surveys within Virginia and other eastern states, the identification of bridge characteristics that attract falcon pairs that may be used in identifying bridges with high potential for colonization in the future, and a retrospective study of the effectiveness of falcon management techniques that have been and continue to be used on bridges in Virginia. This set of objectives is intended to identify sites currently used by falcons (pairs have high site fidelity and often use territories for many years) and to be forward-looking in developing a practical approach to future surveys and forecasting of use that may be useful in reducing uncertainty.

METHODS

Study Area

This study included the Coastal Plain of Virginia from the Atlantic Ocean to the fall line including the lower Chesapeake Bay and the lower Delmarva Peninsula. The fall line is an erosional scarp where the metamorphic rocks of the Piedmont meet the sedimentary rocks of the Coastal Plain. The geologic formations along this boundary frequently determine the landward extent of tidal influence. Because this boundary required portage of goods from tidal to nontidal waters it became a common site along tributaries for the development of trading settlements and later major cities (e.g., Richmond, Fredericksburg, Washington, D.C, Baltimore). The Coastal Plain supports an extensive network of tidal rivers that penetrate virtually the entire land surface. Both the development of the land and the modern transport of goods have required the construction of hundreds of automobile and railroad bridges. Bridges have become concentrated along the fall line and outer coast, reflecting the distribution of major population centers. Increasingly, suitable bridges have been colonized by breeding peregrine falcons as the population has recovered from the DDT era. Bridge pairs now account for both a significant portion of the state breeding population and young production (Watts and Watts, 2016).

Bridge Selection

Bridges (n = 83) were selected for inclusion in the study from a large pool (>2,500) of structures within the study area. Structures included both automobile (n = 69) and railroad (n = 14) bridges (Figure 2). The survey of railroad bridges was funded separately by The Center for Conservation Biology. Bridges were selected for inclusion based on their prominence within the landscape. All bridges that cross the main channel of primary Chesapeake Bay tributaries (i.e. James River, York River, Rappahannock River) somewhere between their mouth and the fall line were included. Bridges that cross the main channels of minor tributaries of the Chesapeake Bay (e.g., Elizabeth River, Nansemond River, Chickahominy River, Appomattox River, Piankatank River, Great Wicomico River) were also included. Prominent bridges that cross some inlets of the outer coast (e.g., Lynnhaven Inlet, Little Creek, Rudy Inlet, Chincoteague) were included. Finally, selected bridges that cross prominent creeks flowing into the major tributaries (e.g., Cat Point Creek, Occoquan Creek, Neabsco Creek) were included. We believe that the set of bridges selected represents the most likely sites of peregrine colonization from among the large pool of bridges within the study area.

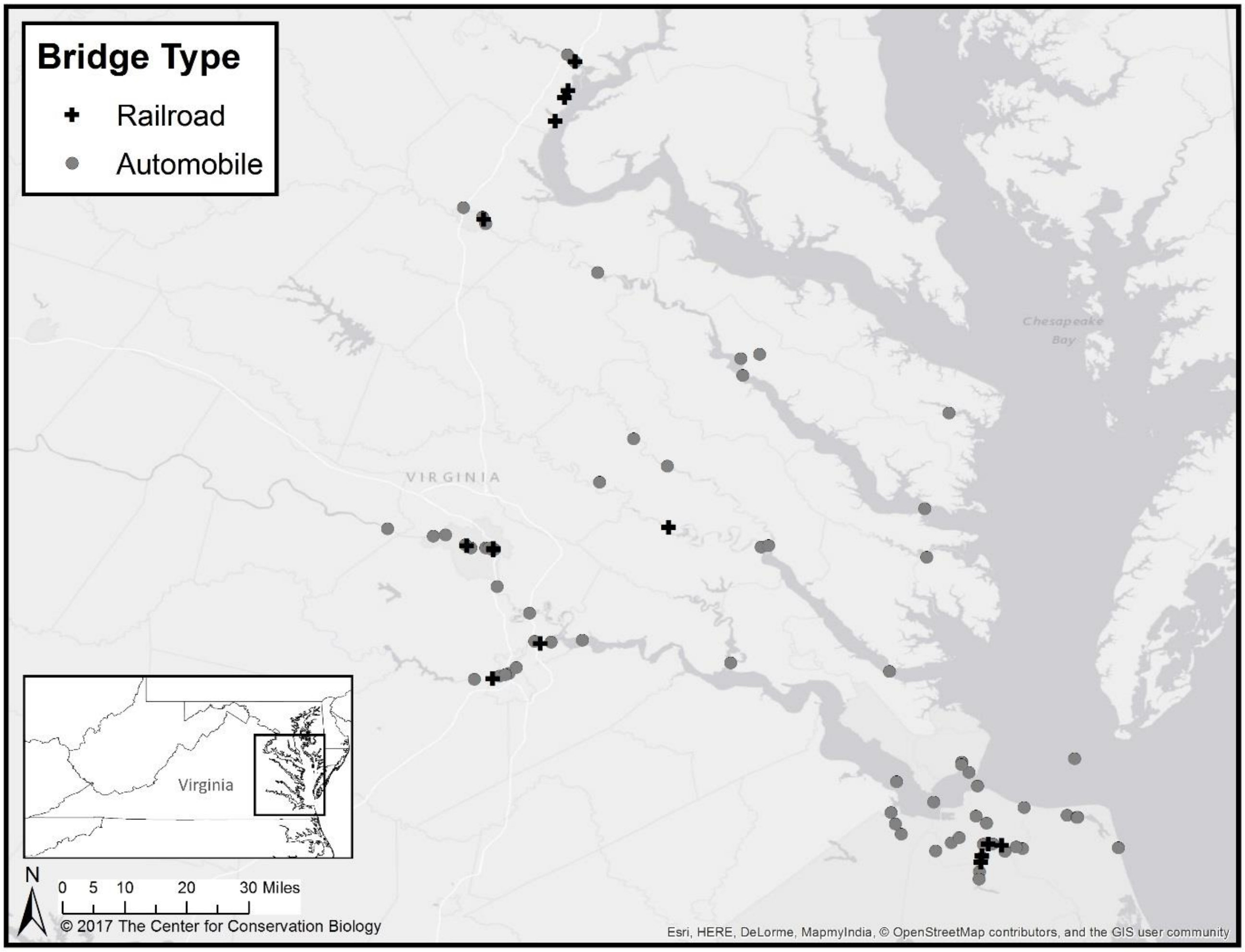

Figure 2. Map of study area indicating the location of bridges included in the 2016 peregrine falcon survey. Circles indicate the location of automobile bridges and hatches indicate the location of railroad bridges.

Bridge Characteristics

We recorded bridge characteristics including basic dimensions and type, potential eyrie sites and landscape setting through the lens of potential breeding falcons. We obtained bridge span length, width and age from the Virginia Department of Transportation bridge database for automobile bridges and the bridge hunter database for railroad bridges. We were unable to locate a source of data for bridge height. We placed bridges in two height categories based on the estimated height of the underside of the road or rail bed. Categories included higher or lower than 6 m. We categorized bridges according to whether or not they were stationary or moveable and if moveable the type of mechanism (i.e. lift bridge, draw bridge, pivot bridge). Peregrine falcons generally require nest sites with some overhead protection and substrate such as gravel or dirt to form a nest cup to hold their clutch (Ratcliffe, 1993, White et al., 2002). A wide range of bridge designs have been constructed within the study area. Bridge designs differ in what they offer to nesting falcons. Most bridges have some type of ledge but many do not provide any overhead protection or enclosed space for nesting. For example, a common design found throughout the study area uses steel or concrete beams set on a series of upright concrete pilings. These bridges may have open joints that provide only exposed ledges or may have additional partitions near the joints that provide protected spaces with ledges. We examined bridges for enclosed spaces that could be used as eyries by nesting falcons and categorized them according to their relative availability. Categories used include none (no sites detected), few (one to five sites) and many (more than five sites). Nesting substrate such as gravel is built up on ledges under bridges as road debris falls through the joints and accumulates. Older bridges have had longer periods of time to accumulate debris that may be used for nesting. We were not generally able to examine the availability of debris on ledges under bridges. Peregrine falcons have evolved to capture live birds on the wing as they fly over open space (Ratcliffe, 1993). They prefer to hunt in open habitats such as over water, along beaches, over grasslands or agricultural fields or over cityscapes. They prefer nest sites that are prominently positioned within open landscapes. We examined the position of each bridge within the surrounding landscape and graded the site as poor (subordinate position within a forest-dominated landscape), fair (subordinate to dominant position within a partially open landscape) or good (dominant position within an open landscape).

Peregrine Surveys

We used a call-broadcast protocol developed by Barnes et al. (2012) in Arizona and Nevada to survey bridges for peregrine occupation. The ten-minute, call-back protocol includes a series of advertisement and courtship calls interspersed with silent listening periods. There are five segments including 1) three minutes of silent listening and observing, 2) 30 seconds of calls with the specific order of five seconds of "cack" call, ten seconds of "eechup" call, five seconds of "cack" call and ten seconds of "eechup" call, 3) one minute of silent listening and observing, 4) repeat of segment two, and 5) five minutes of silent listening and observing. They demonstrated detection rates that were equal to or greater than those achieved using the "passive" survey method recommended in the post-delisting monitoring plan (USFWS, 2003). Response rates measured from detection trials were 83% during the breeding season overall with a peak of 100% during the courtship period. In addition to demonstrating high response rates to play backs, Barnes et al. (2012) found no time-of-day effects suggesting that the protocol is effective throughout the day. We compiled digital audio files, loaded them onto a Foxpro game caller and broadcasted them with a sound pressure of 105 decibels. We conducted bridge surveys between 15 February and 30 April, 2016 to maximize response rates. This date range corresponds to the courtship and incubation periods within the study area (Watts et al., unpublished data) the breeding stages found to have the highest response rates by Barnes et al. (2012).

We surveyed selected bridges twice during the study period. We conducted surveys either from a stationary boat under or adjacent to the bridge or from the shoreline depending on circumstance. Shoreline surveys were conducted primarily for bridges along the fall line where water depth prohibited boat access. We conducted surveys from single shorelines when channel width was less than 500 m and attempted to survey from both shorelines when channel width was greater than 500 m. This distance is well below the 700-m surveyor-to-eyrie distance recommended by Barnes et al. (2012).

Peregrine Response

We recorded the response of peregrine falcons to the call-broadcast protocol. We recorded the gender of the responding falcon, their behavior and the latency of response. We defined a peregrine response to be a vocalization or flight initiated after we began the vocal portion of the call-broadcast protocol (McLeod and Andersen, 1998). We classified the response as vocal, vocal and flight and flight and noted any additional behaviors displayed (e.g., courtship behavior, interaction with other adult). We recorded the latency in response as the time elapsed between the initiation of the vocal portion of the call-broadcast protocol and when we detected the first response.

Breeding Activity

Bridges that were confirmed to have peregrine activity using the call-broadcast protocol were monitored with two to five additional visits to document breeding activity, to band young and to document fledging success. A breeding territory was considered to be "occupied" if a pair of adult peregrines was resident during the breeding season regardless of whether or not eggs or young were confirmed. Nests were considered to be "active" if eggs or young were detected (Postupalsky, 1974). Complete breeding information (e.g. clutch size, hatching rate) could not be obtained for a small portion of active sites due to poor access. However, fledging rate was determined for all active sites when possible. Nest sites were visited approximately 2 weeks after projected fledging date to determine fledging success. This time threshold was developed from satellite tracking data (2001-2002) that indicates a pulse of mortality just prior to fledging and in the 2 weeks following fledging (Watts et al., 2011). Reproductive rates were calculated using number of chicks reaching banding age.

Management Techniques

The Center for Conservation Biology in collaboration with VDGIF and VDOT have used a range of management techniques for nesting peregrine falcons on bridges. Techniques have included adding gravel to bridge structures used for nesting, installing nest trays and installing nest boxes. Pea gravel has been used to mimic the nesting substrate encountered in natural cliff settings. Nest trays are boards with a wooden frame around the edge to hold gravel. Nest boxes are similar to trays except that they also have a closed roof and two sides. The choice of structures used has depended on the circumstance and the potential exposure to weather. Management activities have intended to improve nesting success, improve fledging rates and focus peregrine activities away from bridge operations or maintenance projects.

Historical Bridge Use

We extracted historical information pertaining to bridge use by peregrine falcons in Virginia from records generated through the long-term (1977-2016) peregrine monitoring program. Information from the long-term monitoring program conducted jointly by the Virginia Department of Game & Inland Fisheries and The Center is archived within The Center at the College of William & Mary. We extracted information on years of occupation and breeding performance on all bridges that have been documented with peregrine pairs. This effort focused on years with documented pairs rather than observations of single individuals.

Statistical Analyses

Because the sample size of occupied bridges was low and some of the bridge and reproductive parameters were highly skewed, we used Mann-Whitney U tests to make univariate comparisons. We used goodness-of-fit tests (G-test with Yates correction) to compare frequencies of categorical data.

RESULTS

We included a wide range of bridges (n = 83) within the study area (Appendix A) that varied according to type, span length, height, availability of potential eyries and surrounding landscape (Appendix B). The bridges were not a random sample from those available throughout the Coastal Plain but represent ones that are more likely to be used by nesting peregrines.

Response to Broadcast Calls

We conducted 166 call-broadcast surveys of bridges during the study period. We recorded peregrine responses during 20 (12%) call-broadcasts that included birds associated with 11 bridges (Appendix C). Only two surveys failed to elicit a response for bridges determined to be occupied during the season. This included the second survey of the CBBT South Span bridge (northern section of Chesapeake Bay Bridge Tunnel). We believe that this pair abandoned the site following an early failure. The second instance was the first survey of the Berkley Bridge, a site that ultimately produced young. Based on backdating from the age of the brood at banding, we believe that one of the adults (likely the female) was on eggs during this survey and that the second adult (likely the male) was not on the bridge. Both adults were present during the second survey.

Broadcast calls were extremely effective in eliciting a response from falcons and revealing residency. The first and second surveys were identical in the response rates recorded with each independently discovering 10 of 11 (90.9%) occupied bridges. However the two surveys that produced false negatives (one due to early abandonment and the second due to lack of response), one each during the two survey rounds, involved different bridges suggesting that there is a modest benefit for conducting two surveys if there is no response during the first survey.

Response of falcons to tapes varied by gender was nearly immediate and was dramatic (Appendix C). Response rate for females was higher than for males (90.5% vs 80.9%) though this difference was not statistically significant (G-statistic with Yates Correction = 0.04, df = 1, $p > 0.5$). Latency in response to taped calls was low. When both males and females are combined, 59.5% of responses were within 5 sec, 81.1% were within 10 sec and all responses occurred within 30 sec of call initiation. Latency for females was significantly (G-statistic with Yates Correction = 011.4, df = 3, $p < 0.01$) lower compared to males (Figure 3). Nearly all (97.2%) responses included both calls and flights. Birds typically flew out from the bridge infrastructure toward the caller, circled several times giving the cackle call and then returned to a perch. Males and females often flew out from different perches on the bridge but perched together following responses. On one occasion a female flew directly to a perched male and dislodged him from a hidden location and elicited a response. On three occasions males flew to the nest site and initiated courtship displays (bowing and strutting).

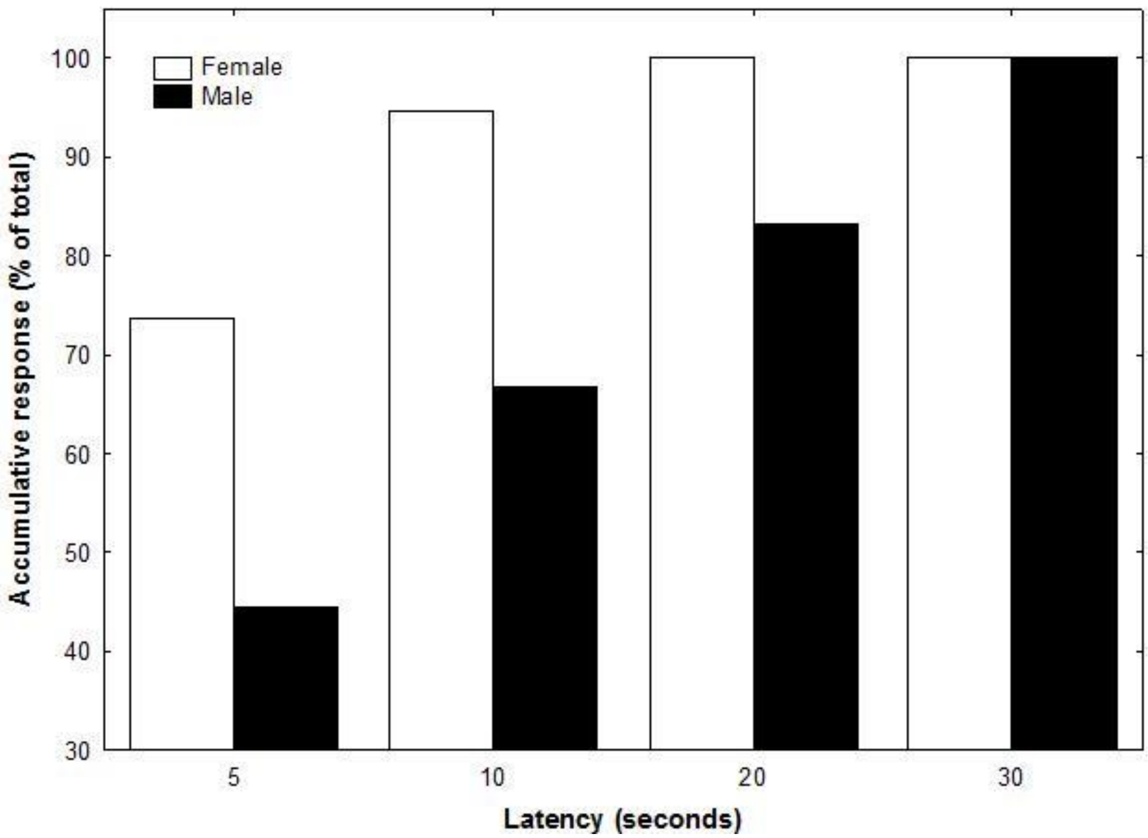

Figure 3. Latency in the response of peregrine falcons to call-broadcasts near bridges. Responses during first and second surveys are combined. Time intervals indicate the number of seconds since the initiation of broadcast calls. Data are presented as accumulated values reflecting the percentage of responses that have occurred before the end of stated time. Females and males showed significantly different responses.

Bridge Use

We documented 11 occupied bridges within the study area that involved 10 resident falcon pairs (Table 1, Figure 4). One of the pairs made breeding attempts on two separate bridges (Mills Godwin Bridge and Hazelwood Bridge). Although resident, we did not document breeding attempts (no eggs laid) for two of the pairs. The pair associated with the Highrise Bridge was late in forming and is not believed to have laid a clutch. The pair associated with the Beltline Bridge appears to be a new pair establishing a new territory. The pair moved back and forth between the Beltline Bridge and the New Jordan Bridge. We did not confirm the presence of eggs on either bridge. Remaining pairs produced a total of 11 young, 8 of which were translocated to Shenandoah National Park and hacked.

Table 1. Summary of breeding activity for peregrine falcon pairs using bridges in Virginia during the 2016 breeding season. Band age for this purpose was considered to be 25 days.

Nest Name	Occupied Territory	Active Nest	Eggs	Young Hatched	Band Age
James River Bridge	Y	Y	4	3	3 [a]
Berkley Bridge	Y	Y	>=3	>=3	3 [b]
Benjamin Harrison Bridge	Y	Y	3	1	1
Mills Godwin Bridge	Y	Y	2	1	1
Norris Bridge	Y	Y	2	0	0 [c]
Highrise Bridge	Y	N	-----	-----	-----
Chesapeake Bay Bridge Tunnel	Y	Y	>=1	U	0
Tappahannock Bridge	Y	Y	4	3	3 [a]
Eltham Bridge	Y	Y	4	0	0
Beltline Bridge[e]	Y	U	-----	-----	-----
Hazelwood Bridge[e]	-----	-----	>=1	0	0 [d]

[a]All young translocated to Shenandoah National Park and hacked.
[b]Two of three young translocated to Shenandoah National Park and hacked.
[c]Adult male lost early in season but later replaced.
[d]Same pair that later nested on Mills Godwin Bridge.
[e]New occupied bridges located during this project.

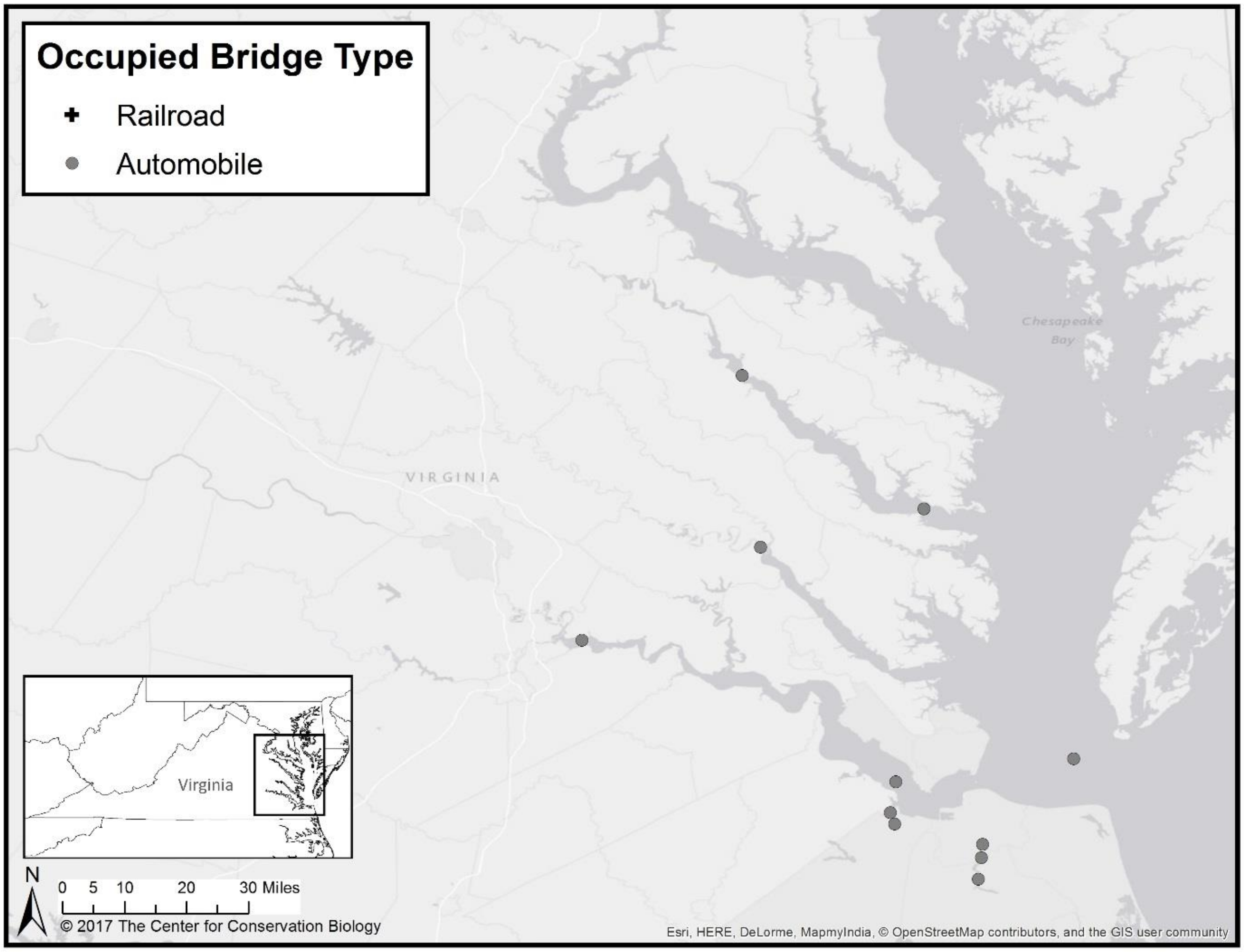

Figure 4. Map of bridges determined to be occupied by pairs of peregrine falcons during the 2016 breeding season.

Since re-establishment of the Virginia peregrine falcon breeding population, we have documented pairs during the breeding season on 15 bridges (Table 2). Five bridges have been used for 18 years or more and continue to be occupied. Three bridges including the Coleman Bridge, West Norfolk Bridge and Norfolk Southern Railroad Bridge were used for a period of time but have not been used in recent years. The Coleman Bridge was used up until the year of replacement but has not been used since. A breeding pair is now resident on the stack of the Yorktown Substation and that pair is often observed roosting on the bridge during the nonbreeding season. The male of the West Norfolk Bridge appears to have been lost. The female remained resident on the bridge for a number of years after but never recruited a replacement male. The Norfolk Southern Bridge was used for a short period of time but then abandoned. In addition to these sites, the Berkley Bridge pair has also used the Jordan Lift Bridge in the past. This bridge was dismantled and is no longer available.

Table 2. Bridges within the Coastal Plain of Virginia that have been documented to support a breeding pair of peregrine falcons (1980-2016). Span of use refers to the range of years when a peregrine pair has been documented. Years occupied refers to the number of years that a resident pair has been documented.

Bridge	Span of Use	Years Occupied
James River Bridge	1993-2016	24
Berkley Bridge	1995-2016	21
Norris Bridge	1993-2016	21
Benjamin Harrison Bridge	1997-2016	20
Mills Godwin Bridge	1998-2016	18
West Norfolk Bridge	1998-2012	14
Chesapeake Bay Bridge Tunnel	2000-2016	12
Tappahannock Bridge	1995-2016	5
Coleman Bridge	1989-1994	5
Highrise Bridge	2012-2016	4
Norfolk Southern RR Bridge	1992-1999	4
Eltham Bridge	2014-2016	3
Jordan Lift Bridge	2008	1
Beltline Bridge	2016	1
Hazelwood Bridge	2016	1

Bridge Characteristics

A combination of bridge type, characteristics and landscape position had an influence on occupancy by falcons. Six of ten (60%) lift or draw bridges within the study area were occupied during the 2016 season and historic occupation of these bridges has been even higher (81.8%). This rate is significantly (G-statistic with Yates Correction = 11.1, df = 1, $p < 0.001$) higher than the 6.8% occupancy rate for stationary and pivot brides. Only two of the lift or draw bridges within the study area have never been used including the Gilmerton Bridge across the Southern Branch of the Elizabeth River and the Norfolk Southern Bridge across the Eastern Branch of the Elizabeth River. The Gilmerton Bridge is relatively new (constructed in 2013) and the Norfolk Southern Bridge is very low to the water. All but one of these bridges was judged to support many potential eyrie sites.

Available eyrie sites had a significant (G-statistic with Yates Correction = 20.4, df = 2, $p < 0.001$) influence on the distribution of falcon pairs among bridges (Figure 5). Forty percent of the bridges classified as having many potential eyrie sites were occupied compared to none of the bridges classified as having no potential eyries. None of the bridges with heights estimated to be below 6 m were occupied. Span length was significantly (Mann-Whitney U statistic = 105.5, Z = -3.9, $p<0.001$) longer for occupied compared to unoccupied bridges (Figure 6). Although there is considerable overlap in span lengths between the two samples, the shortest bridges occupied by falcons was 350 m. It should be noted that the bridges included in the pool for survey were not a random sample of bridges within the study area but were prominent bridges such that the difference in span length reported here is very conservative. Pairs occupied bridges that were embedded within open landscapes. Ten of the 11 occupied bridges were surrounded by landscapes classified and good and the remaining site was classified as fair. No occupied bridges were embedded within landscapes that were considered poor for foraging habitat.

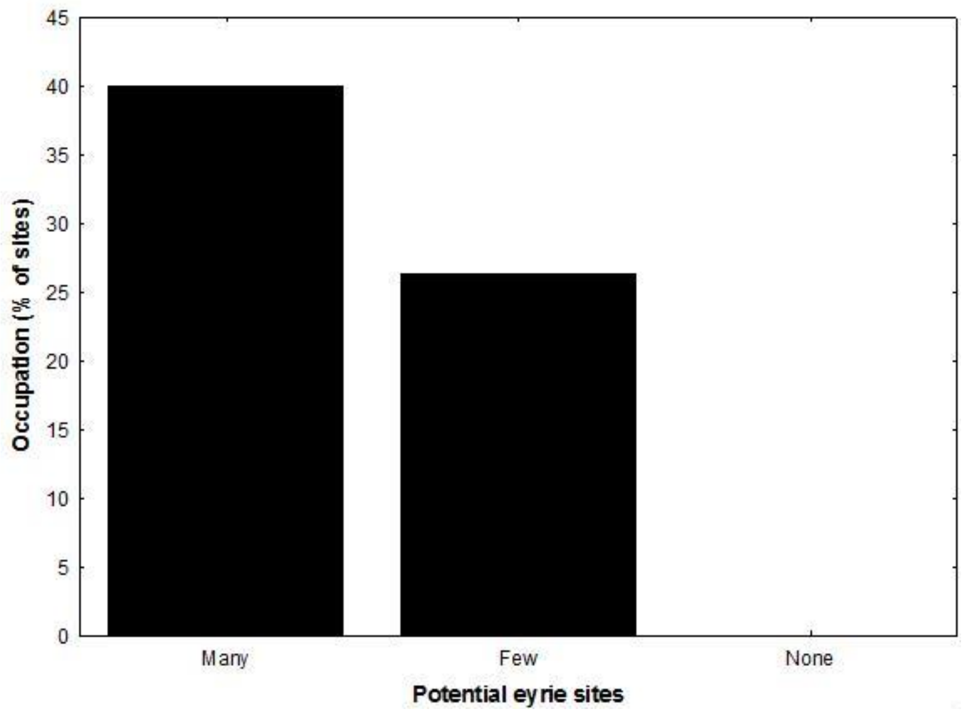

Figure 5. Occupation of bridges by peregrine falcon pairs as a function of available eyrie sites. Frequency of occupation varied significantly across categories of potential eyries.

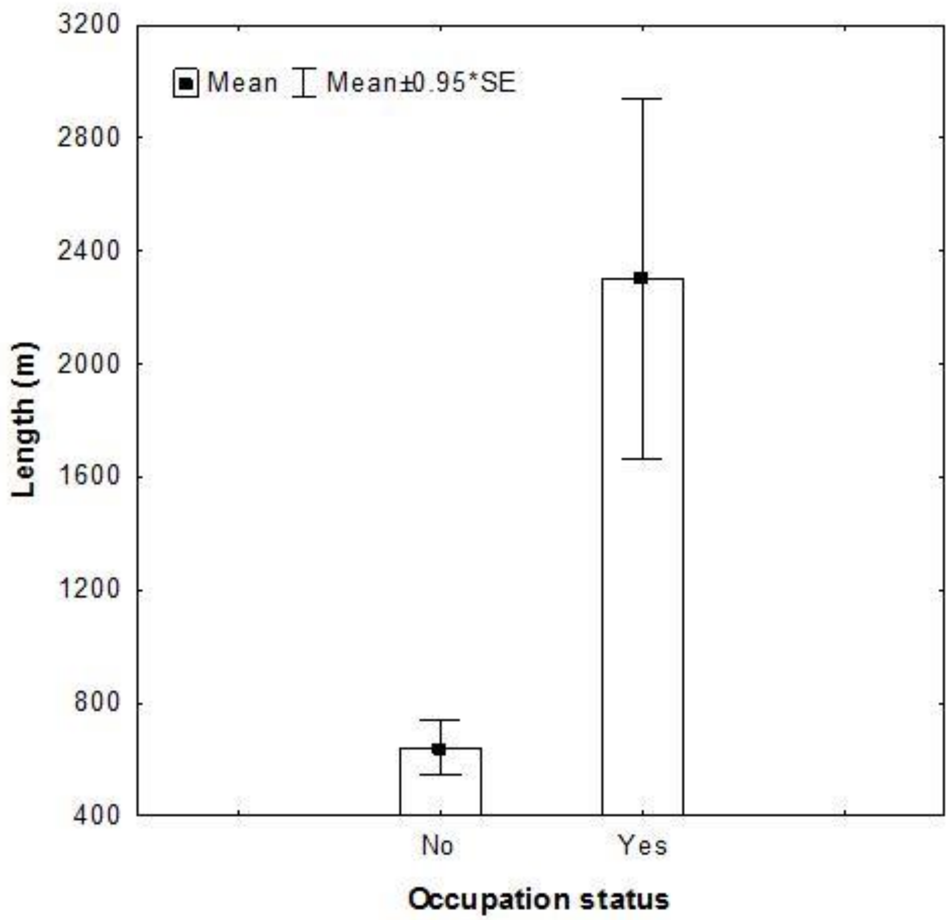

Figure 6. Comparison of mean length between bridges documented to support peregrine falcon pairs during the 2016 breeding season and bridges not known to support pairs.

Management Activities and Breeding Success

The installation of management structures (nest box or nest tray) on bridges for use by nesting falcons has had a positive influence on breeding performance. Breeding success was significantly (G-statistic with Yates Correction = 61.7, df = 1, $p < 0.001$) higher (70.1 vs 34.2%) following the installation of management structures compared to before installation (Figure 7). In addition to an increase in breeding success, pairs nesting on management structures produced significantly (Mann-Whitney U statistic = 1,428.5, Z = -3.4, $p<0.001$) more young compared to pairs nesting without such structures. Pairs nesting within boxes or on trays produced more than twice as many young compared to those that did not (Figure 8).

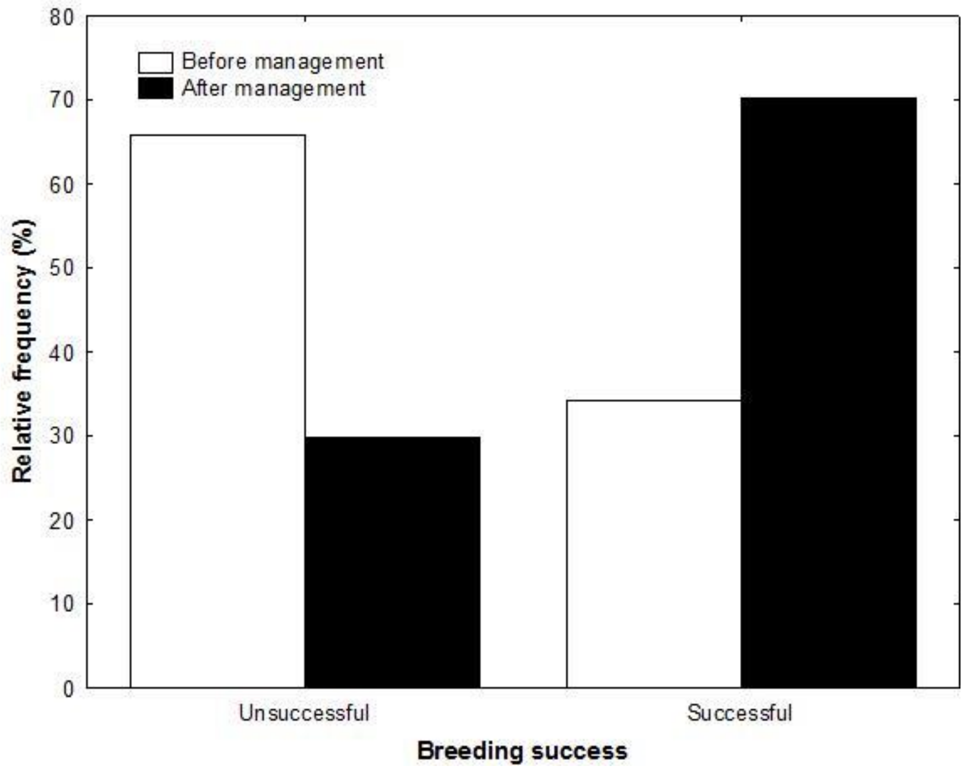

Figure 7. Comparison of peregrine falcon breeding success before (n = 38) and after (n = 117) management activities on bridges in Virginia. Breeding attempts used in the analysis included 12 bridges. Data from The Center for Conservation Biology archives.

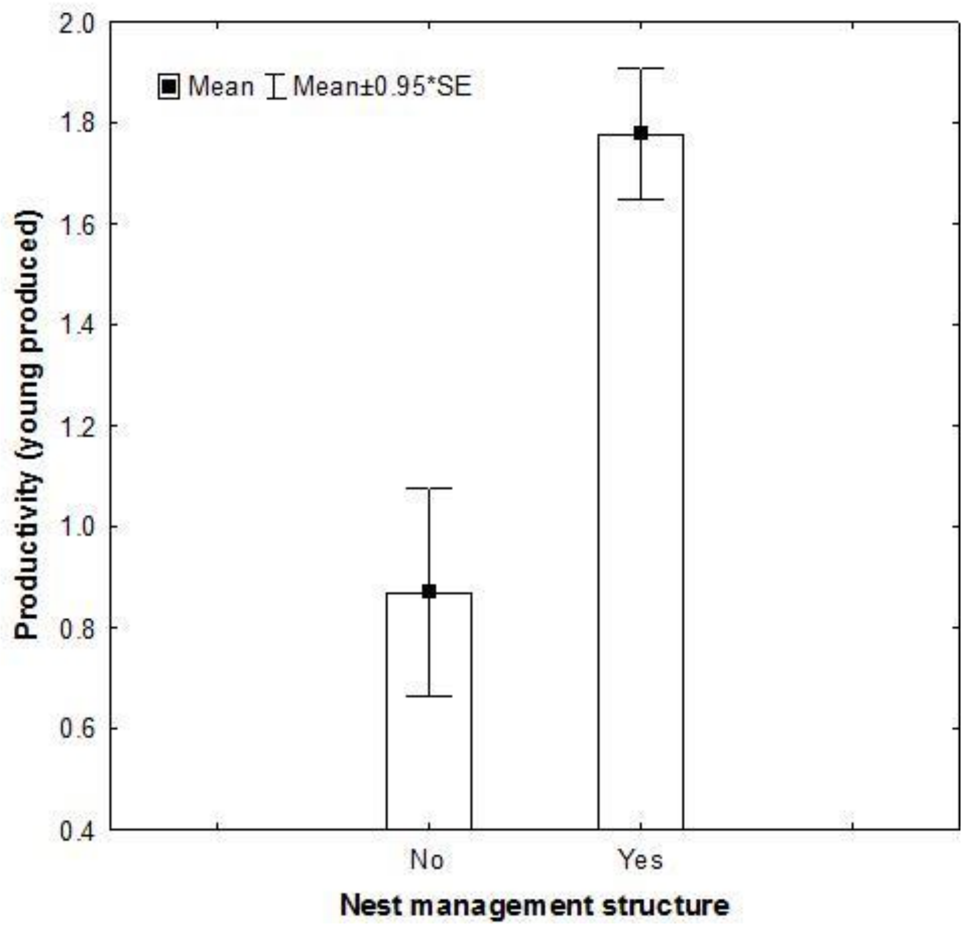

Figure 8. Comparison of mean productivity for peregrine falcons before (n = 38) and after (n = 117) management activities on bridges in Virginia. Breeding attempts used in the analysis included 12 bridges. Data from The Center for Conservation Biology archives.

DISCUSSION

Resident peregrine falcons using bridges responded consistently to the call-broadcast protocol used from late February through April. Responses were swift and dramatic suggesting that the call-broadcasts offer a very efficient field technique to determine occupancy of bridges in Virginia. This result is consistent with broadcast trials conducted in Arizona and Nevada (Barnes et al., 2012). The response rate recorded here was higher (90.9%) than the 83% rate presented from the western study. However their study included nesting stages from courtship through fledging. This study restricted surveys to courtship and incubation only which were the stages with the highest response rates in their study. Response times were considerably faster for the bridge pairs compared to those reported by Barnes et al., (2012). All responses in Virginia were initiated within 30 seconds and nearly 60% were within the first five seconds. By comparison, Barnes et al. (2012) reported 89% of responses were within 180 seconds and 100% were within 300 seconds. Differences in latency between the two studies likely reflect proximity to eyries. Mean distance from broadcast to eyries in the western study was 382 m with a range of 85 to 1,600 m. All broadcasts conducted here were within 100 m of the bridges and most were within 50 m.

Only 11 of 83 bridges surveyed during the 2016 breeding season were occupied. An additional four were occupied historically but not in 2016. Occupied sites were not random samples of bridges within the survey pool but shared characteristics that have been of known importance to breeding peregrines within other study areas. The most definitive characteristic associated with occupation was the availability of potential eyrie sites. These sites were ledges that offered protection from the elements overhead and often on two sides. This result is consistent with recent findings from the Northeast (Gahbauer et al., 2015) that have shown higher productivity for sites with overhead protection from the weather and from the Midwest where some nest failure has been attributed to weather exposure (Redig and Tordoff, 1996). We found potential eyrie sites to be concentrated on movable bridges within the study area. The design of these bridges includes towers that house the mechanical structures required to move the road or rail bed. The towers typically have multiple, recessed ledges that are attractive nest sites. Stationary bridges may also support recessed ledges facing the main navigational channel.

Other bridge characteristics that appear to be important for site selection include height and landscape context. Although not fully quantified, peregrines in the study area selected some of the highest bridges available and did not nest on structures below 6 m. This pattern is consistent with findings elsewhere. Redig and Tordoff (1994) and Tordoff et al. (1999) have suggested that peregrines are attracted to the highest available structures that provide eyrie sites. Cade and Bird (1990) demonstrated that peregrines within cities were selecting the tallest buildings available within their respective cities. Nearly all of the bridges within the study area that were colonized in the early phase of recovery and that have been the most consistently used (Table 2) are above 30 m in height and among the tallest available. Tall nesting sites provide peregrines with a commanding view over the landscape from which to detect and hunt potential prey. Young peregrines often have difficulty maintaining altitude in their first flights. High eyrie sites may provide young with a larger margin for error and more potential perch sites below. Peregrines typically hunt from high perches or soar to altitude where they may search vast open airspaces to detect prey in flight from above (Ratcliffe, 1993, White et al., 2002, Willey, 1986). Selecting nests in open landscapes serves to facilitate preferred hunting techniques.

Bridges represent an important nesting substrate for peregrine falcons in Virginia and have made a significant contribution to recovery of the population. Resident pairs have been documented on 15 bridges historically and ten pairs of falcons were associated with bridges during the 2016 breeding season, representing 32% of the known Virginia population (Watts and Watts, 2016). Two bridges (Hazelwood and Beltline Bridges) supported pairs in 2016 that were not previously known. Beyond the study area, bridges have become important nest sites within the broader region. Of 88 nesting substrates identified within the mid-Atlantic region, 33% were bridges (Watts et al., 2015). This compares to 23% in the Northeast (Gahbauer et al., 2015) and 10% in the mid-West (Redig and Tordoff, 1996).

A retrospective analysis of bridge management demonstrated that actions have significantly improved breeding success and reproductive output within the study area. Average production of young (to banding age) more than doubled in response to the installation of management structures on bridges. This result is consistent with other study areas where installation of nest boxes has become a significant management strategy (Tordoff et al., 2003, Altwegg et al., 2014). One of the primary advantages of nest boxes is that they provide protection for both incubating birds and broods from weather (Tordoff et al., 1996, Gahbauer et al., 2015). A second advantage is that they provide nesting substrate. Peregrines use fine materials such as dirt sand, fine gravel or other materials to form a nest scrape to hold their clutch (White et al., 2002). Within the Northeast, Gahbauer et al., (2015) showed that productivity for birds nesting on dirt or gravel substrates was higher than those nesting on bare concrete or metal ledges. The lack of debris on many bridges limits the opportunity for pairs to create nest scrapes. Nest boxes that provide pea gravel or similar substrate offer a good substitute for the traditional dirt or gravel found within cliff eyries..

CONCLUSIONS

- ***Call-broadcast surveys were effective in determining bridge occupancy*** – The call-broadcast protocol used from late February through April was highly effective within the study area in eliciting a response from resident falcons. Responses were virtually immediate and dramatic suggesting that the approach represents a quick and effective technique for surveying bridges for breeding pairs.

- ***Bridges occupied by peregrine falcons shared a set of characteristics*** – Occupied bridges were not a random subset of the bridges surveyed. Occupied bridges supported recessed ledges with overhead protection that could be used for nest sites, were significantly longer and higher than unoccupied bridges and were embedded within open landscapes preferred for hunting. All of these characteristics are consistent with features known to be important to nesting peregrines from studies throughout their range.

- ***Use of management structures on bridges is beneficial to breeding pairs*** – A retrospective assessment of the use of nest boxes and trays on bridges documented a significant improvement of both breeding success and breeding performance. Enclosed boxes provide the pair and brood with protection from weather events and the gravel substrate supplied with boxes and trays provide the pair with material to form nest scrapes.

- ***Bridges make a significant contribution to the Virginia peregrine falcon population*** – Bridges have made a significant contribution to both the recovery and maintenance of the Virginia peregrine falcon population. Since bridges were first colonized in the early 1990s they have consistently supported more than 30% of the known population and have contributed to overall production. The continued management of pairs on bridges should remain a priority for state agencies.

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APPENDICES

Appendix I. Bridge table.

BRIDGE NAME	LATITUDE	LONGITUDE	TYPE	ROADWAY	WATER BODY	JURISDICTION
Port Royal Bridge	38.174927	-77.188042	Automobile	US Route 301	Rappahannock River	Caroline County
Chickahominy River Bridge	37.26342362	-76.87747273	Automobile	Virginia Route 5	Chickahominy River	Charles City County
Indian River Bridge	36.82337555	-76.23680621	Automobile	Indian River Road	E. Branch of Elizabeth River	Chesapeake
High Rise Bridge	36.75811382	-76.2972867	Automobile	Interstate 64	S. Branch of Elizabeth River	Chesapeake
Gilmerton Bridge	36.77523905	-76.29623325	Automobile	Route 13	S. Branch of Elizabeth River	Chesapeake
Paradise Point	36.79701905	-76.29280286	Railroad	-----	S. Branch of Elizabeth River	Chesapeake
I-295 Bridge Appomattox	37.31372627	-77.33530047	Automobile	Interstate 295	Appamattox River	Chesterfield County
Appamattox Bridge	37.31229859	-77.29705064	Automobile	Virginia Route 10	Appamattox River	Chesterfield County
Tappahannock Bridge	37.93518911	-76.84948274	Automobile	US Route 360	Rappahannock River	Essex County
Blue and Gray Prkwy Bridge	38.28993543	-77.44938022	Automobile	Blue and Gray Parkway	Rappahannock River	Fredericksburg
Rappahannock I-95 Bridge	38.3266981	-77.50149042	Automobile	Interstate 95	Rappahannock River	Fredericksburg
Chatham Bridge	38.304952	-77.456316	Automobile	Williams Street	Rappahannock River	Fredericksburg
Chatham Train Tressle	38.299436	-77.453857	Railroad	-----	Rappahannock River	Fredericksburg
HRBT North	37.007283	-76.321292	Automobile	Interstate 64	James River	Hampton
Hampton River Bridge	37.031259	-76.337214	Automobile	Interstate 64	Hampton River	Hampton
Settlers Landing Bridge	37.025778	-76.338543	Automobile	Settlers Landing Road	Hampton River	Hampton
I-295 Bridge Dutch Gap	37.37936388	-77.3466592	Automobile	Interstate 295	James River	Henricho County
Vietnam Vets Mem. Bridge	37.44195877	-77.42295957	Automobile	Pocohontas Parkway	James River	Henricho County

BRIDGE NAME	LATITUDE	LONGITUDE	TYPE	ROADWAY	WATER BODY	JURISDICTION
CSX Appomattox Bridge	37.307846	-77.32164	Railroad	-----	Appamattox River	Hopewell
Hazelwood Bridge	36.913542	-76.503151	Automobile	US Route 17	Chuckatuck Creek	Isle of Wight
Pamunkey Rt 360 Bridge	37.685722	-77.183261	Automobile	US Route 360	Pamunkey River	King William County
Mattaponi Rt 360 Bridge	37.786816	-77.103822	Automobile	US Route 360	Mattaponi River	King William County
Eltham Bridge	37.533887	-76.806234	Automobile	Virginia Route 30	Pamunkey River	King William County
Mattaponi Bridge	37.53724181	-76.78864001	Automobile	Virginia Route 33	Mattaponi River	King William County
Walkerton Bridge	37.723004	-77.025593	Automobile	Walkerton Landing Road	Mattaponi River	King William County
Piankatank Bridge	37.51034366	-76.41987911	Automobile	Virginia Route 3	Piankatank River	Middlesex County
Norris Bridge	37.62362678	-76.42385262	Automobile	Virginia Route 3	Rappahannock River	Middlesex County
Poplar Grove Bridge	37.579747	-77.021525	Railroad	-----	Pamunkey River	New Kent County
Monitor Merrimac Bridge	36.93831637	-76.40285001	Automobile	Interstate 664	James River	Newport News
James River Bridge	36.98536726	-76.48991002	Automobile	US Route 17	James River	Newport News
Campostella Bridge	36.840303	-76.264976	Automobile	Campostella Road	E. Branch of Elizabeth River	Norfolk
Gramby Street Bridge	36.888507	-76.279804	Automobile	Gramby Street	Lafeyette River	Norfolk
Lafeyette River Bridge	36.90555636	-76.30482271	Automobile	Hampton Boulevard	Lafeyette River	Norfolk
Berkley Bridge	36.83924	-76.28704728	Automobile	Interstate 264	E. Branch of Elizabeth River	Norfolk
HRBT South	36.975239	-76.3005	Automobile	Interstate 64	James River	Norfolk
I-64 E. Elizabeth River	36.8291482	-76.19538727	Automobile	Interstate 64	E. Branch of Elizabeth River	Norfolk
Little Creek Bridge	36.925157	-76.191755	Automobile	Ocean View Avenue	Little Creek	Norfolk
Military Highway	36.83265545	-76.21060834	Automobile	South Military Highway	E. Branch of Elizabeth River	Norfolk
Ford Plant Bridge	36.83672432	-76.24380182	Railroad	-----	E. Branch of Elizabeth River	Norfolk

BRIDGE NAME	LATITUDE	LONGITUDE	TYPE	ROADWAY	WATER BODY	JURISDICTION
Norfolk Southern Bridge	36.83929414	-76.27485379	Railroad	-----	E. Branch of Elizabeth River	Norfolk
CBBT South Span	37.11661728	-75.96915817	Automobile	US Route 13	Chesapeake Bay	Northampton County
Great Wicomico Bridge	37.847139	-76.36752	Automobile	Jesse Dupont Memorial Highway	Great Wicomico River	Northumberland County
Fleet Street Bridge	37.23252002	-77.41741805	Automobile	Fleet Street	Appamattox River	Petersburg
Appomattox I-95 Bridge	37.23901119	-77.39535569	Automobile	Interstate 95	Appamattox River	Petersburg
Pickett Avenue Bridge	37.22500093	-77.47591472	Automobile	Pickett Avenue	Appamattox River	Petersburg
Second Street Bridge	37.23632716	-77.404055	Automobile	Second Street	Appamattox River	Petersburg
Temple Avenue Bridge	37.25286917	-77.37837586	Automobile	Temple Avenue	Appamattox River	Petersburg
CSX Petersburg Bridge	37.22585753	-77.4325895	Railroad	-----	Appamattox River	Petersburg
High Street Bridge	36.84271727	-76.36198364	Automobile	High Street West	W. Branch of Elizabeth River	Portsmouth
New Jordan Bridge	36.80844047	-76.28947161	Automobile	Poindexter Street	S. Branch of Elizabeth River	Portsmouth
Hodges Ferry Bridge	36.82399089	-76.39872363	Automobile	Portsmouth Boulevard	W. Branch of Elizabeth River	Portsmouth
West Norfolk Bridge	36.85477362	-76.34354092	Automobile	Western Freeway	W. Branch of Elizabeth River	Portsmouth
Beltline Bridge	36.81195017	-76.29030442	Railroad	-----	S. Branch of Elizabeth River	Portsmouth
Benjamin Harrison Bridge	37.316877	-77.223629	Automobile	Virginia Route 156	James River	Prince George County
Occoquan Route 123 Bridge	38.68405	-77.258098	Automobile	Gordon Boulevard	Occoquan Creek	Prince William County
I-95 Occoquan Bridge	38.672273	-77.245369	Automobile	I-95	Occoquan Creek	Prince William County
Occoquan Route 1 Bridge	38.6678	-77.240733	Automobile	Route 1	Occoquan Creek	Prince William County
Powells Creek Bridge	38.584196	-77.264526	Railroad	-----	Powells Creek	Prince William County

BRIDGE NAME	LATITUDE	LONGITUDE	TYPE	ROADWAY	WATER BODY	JURISDICTION
Neabsco Creek Bridge	38.600307	-77.25665	Railroad	-----	Neabsco Creek	Prince William County
Occoquan Tressle Bridge	38.667462	-77.24018	Railroad	-----	Occoquan Creek	Prince William County
14th Street North Bridge	37.530818	-77.433499	Automobile	14th Street	James River	Richmond
14th Street South Bridge	37.528188	-77.434471	Automobile	14th Street	James River	Richmond
S. 9th Street Bridge	37.531987	-77.442547	Automobile	9th Street	James River	Richmond
Chippingham Prkwy Bridge	37.55974209	-77.57185434	Automobile	Chippingham Parkway	James River	Richmond
James I-95 Bridge	37.52809526	-77.42920565	Automobile	Interstate 95	James River	Richmond
Robert E. Lee Bridge	37.53243778	-77.44972851	Automobile	US Route 1	James River	Richmond
Huguenot Bridge	37.56182412	-77.54395516	Automobile	Virginia Route 147	James River	Richmond
Nickel Bridge	37.53219983	-77.4837548	Automobile	Virginia Route 161	James River	Richmond
Veterans Mem. Bridge	37.57687421	-77.67904906	Automobile	Virginia Route 288	James River	Richmond
Powhite Prkwy Bridge	37.539046	-77.496521	Automobile	Virginia Route 76	James River	Richmond
CSX Bridge Richmond	37.536723	-77.493384	Railroad	-----	James River	Richmond
Tressle Bridge North	37.530285	-77.431494	Railroad	-----	James River	Richmond
Tressle Bridge South	37.527843	-77.4315	Railroad	-----	James River	Richmond
Mills Godwin Bridge	36.886733	-76.492492	Automobile	US Route 17	Nansemond River	Suffolk
Rudee Inlet Bridge	36.831501	-75.972135	Automobile	General Booth Boulevard	Rudee Inlet	Virginia Beach
North Great Neck Bridge	36.902924	-76.068448	Automobile	North Great Neck Road	Broad Bay	Virginia Beach
Lestner Bridge	36.907528	-76.091856	Automobile	Shore Drive	Lynnhaven Inlet	Virginia Beach

BRIDGE NAME	LATITUDE	LONGITUDE	TYPE	ROADWAY	WATER BODY	JURISDICTION
West Great Neck Bridge	36.902727	-76.067026	Automobile	West Great Neck Road	Broad Bay	Virginia Beach
Coleman Bridge	37.24349909	-76.50621728	Automobile	US Route 17	York River	York County
Newland Road Bridge	37.984119	-76.809818	Automobile	Virginia Route 624	Cat Point Creek	Richmond County
Naylors Beach Bridge	37.974546	-76.853970	Automobile	Virginia Route 634	Cat Point Creek	Richmond County
Bennetts Creek	36.863121	-76.478766	Automobile	US Route 17	Bennetts Creek	Suffolk
Quantico Creek	38.528851	-77.287218	Railroad	-----	Quantico Creek	Prince William County

Appendix II. Bridge characteristics.

BRIDGE NAME	JURISDICTION	ROADWAY	WATER BODY	TYPE	LENGTH (M)	WIDTH (M)	DATE	POTENTIAL EYRIES	LANDSCAPE POSITION	NEST STRUCTURE
Port Royal Bridge	Caroline County	US Route 301	Rappahannock River	Stationary	452.0	22.8	1980	Few	Fair	None
Chickahominy River Bridge	Charles City County	Virginia Route 5	Chickahominy River	Stationary	777.2	17.2	2009	None	Fair	None
Indian River Bridge	Chesapeake	Indian River Road	Indian River	Stationary	177.1	31.3	1974	None	Poor	None
High Rise Bridge	Chesapeake	Interstate 64	S. Branch of Elizabeth River	-----	1470.7	20.4	1991	Many	Good	Nest Box
Gilmerton Bridge	Chesapeake	Route 13	S. Branch Elizabeth River	Draw	581.6	26.0	2013	Many	Good	None
Paradise Point	Chesapeake	-----	S. Branch of Elizabeth River	Lift	306.9	6.1	1930	Many	Good	Nest Box
I-295 Bridge Appomattox	Chesterfield County	Interstate 295	Appamattox River	Stationary	598.6	18.8	1991	None	Fair	None
Appamattox Bridge	Chesterfield County	Virginia Route 10	Appamattox River	Stationary	516.3	10.4	1966	Few	Fair	None
Tappahannock Bridge	Essex County	US Route 360	Rappahannock River	Stationary	1708.1	10.1	1978	Few	Good	Nest Box
Blue and Gray Prkwy Bridge	Fredericksburg	Blue and Gray Parkway	Rappahannock River	Stationary	206.7	23.1	1984	None	Poor	None
Rappahannock I-95 Bridge	Fredericksburg	Interstate 95	Rappahannock River	Stationary	395.6	18.8	1982	Many	Fair	None

BRIDGE NAME	JURISDICTION	ROADWAY	WATER BODY	TYPE	LENGTH (M)	WIDTH (M)	DATE	POTENTIAL EYRIES	LANDSCAPE POSITION	NEST STRUCTURE
Chatham Bridge	Fredericksburg	Williams Street	Rappahannock River	Stationary	306.6	12.8	1941	None	Poor	None
Chatham Train Tressle	Fredericksburg	-----	Rappahannock River	Stationary	131.1	9.1	1925	Many	Poor	None
HRBT North	Hampton	Interstate 64	James River	Stationary	1805.9	16.8	1974	None	Good	None
Hampton River Bridge	Hampton	Interstate 64	Hampton River	Stationary	848.0	17.0	1985	None	Fair	None
Settlers Landing Bridge	Hampton	Settlers Landing Road	Hampton River	Stationary	413.0	21.6	1985	None	Fair	None
I-295 Bridge Dutch Gap	Henricho County	Interstate 295	James River	Stationary	1428.3	38.3	2012	None	Fair	Nest Tray
Vietnam Vets Mem. Bridge	Henricho County	Pocohontas Parkway	James River	Stationary	1453.0	22.6	2002	Few	Fair	None
CSX Appomattox Bridge	Hopewell	-----	Appamattox River	Pivot	335.6	7.6	1930	None	Fair	None
Hazelwood Bridge	Isle of Wight	US Route 17	Chuckatuck Creek	Stationary	773.3	12.8	1988	Few	Fair	None
Pamunkey Rt 360 Bridge	King William County	US Route 360	Pamunkey River	Stationary	151.5	10.1	1971	None	Poor	None
Mattaponi Rt 360 Bridge	King William County	US Route 360	Mattaponi River	Stationary	112.8	12.8	1969	None	Poor	None
Eltham Bridge	King William County	Virginia Route 30	Pamunkey River	draw	1631.9	21.4	2007	Many	Good	None

BRIDGE NAME	JURISDICTION	ROADWAY	WATER BODY	TYPE	LENGTH (M)	WIDTH (M)	DATE	POTENTIAL EYRIES	LANDSCAPE POSITION	NEST STRUCTURE
Mattaponi Bridge	King William County	Virginia Route 33	Mattaponi River	Stationary	1080.5	21.4	2006	None	Good	None
Walkerton Bridge	King William County	Walkerton Landing Road	Mattaponi River	Stationary	366.4	11.6	1996	Few	Fair	None
Piankatank Bridge	Middlesex County	Virginia Route 3	Piankatank River	Stationary	637.6	9.1	2014	None	Good	None
Norris Bridge	Middlesex County	Virginia Route 3	Rappahannock River	Stationary	3044.6	7.9	1996	Few	Good	Nest Tray
Poplar Grove Bridge	New Kent County	-----	Pamunkey River	Pivot	238.0	7.6	<1900	None	Fair	None
Monitor Merrimac Bridge	Newport News	Interstate 664	James River	Stationary	5085.6	13.4	1990	Many	Good	None
James River Bridge	Newport News	US Route 17	James River	Lift	7071.4	20.8	1980	Many	Good	Nest Box
Campostella Bridge	Norfolk	Campostella Road	E. Branch of Elizabeth River	Stationary	756.5	28.7	1996	Few	Good	None
Gramby Street Bridge	Norfolk	Gramby Street	Lafeyette River	Stationary	302.4	28.9	1979	None	Poor	None
Lafeyette River Bridge	Norfolk	Hampton Boulevard	Lafeyette River	Stationary	534.9	17.1	1994	None	Fair	Nest Tray
Berkley Bridge	Norfolk	Interstate 264	E. Branch of Elizabeth River	Draw	648.6	17.5	1991	Many	Good	Nest Tray
HRBT South	Norfolk	Interstate 64	James River	Stationary	1724.6	16.8	1974	None	Good	None
I-64 E. Elizabeth River	Norfolk	Interstate 64	E. Branch of Elizabeth River	Stationary	469.4	23.7	1992	None	Poor	None

BRIDGE NAME	JURISDICTION	ROADWAY	WATER BODY	TYPE	LENGTH (M)	WIDTH (M)	DATE	POTENTIAL EYRIES	LANDSCAPE POSITION	NEST STRUCTURE
Little Creek Bridge	Norfolk	Ocean View Avenue	Little Creek	Stationary	125.0	27.3	2002	None	Fair	None
Military Highway	Norfolk	South Military Highway	E. Branch of Elizabeth River	Stationary	311.5	19.1	1996	None	Poor	None
Ford Plant Bridge	Norfolk	-----	E. Branch of Elizabeth River	pivot	527.6	12.8	-----	None	Good	None
Norfolk Southern Bridge	Norfolk	-----	E. Branch of Elizabeth River	draw	203.0	9.1	1946	Few	Good	None
CBBT South Span	Northampton County	US Route 13	Chesapeake Bay	Stationary	5064.3	13.7	1964	Few	Good	None
Great Wicomico Bridge	Northumberland County	Jesse Dupont Memorial Highway	Great Wicomico River	Stationary	537.4	13.2	1994	Few	Good	None
Fleet Street Bridge	Petersburg	Fleet Street	Appamattox River	Stationary	30.5	11.6	1990	None	Poor	None
Appomattox I-95 Bridge	Petersburg	Interstate 95	Appamattox River	Stationary	249.6	33.2	1984	None	Poor	None
Pickett Avenue Bridge	Petersburg	Pickett Avenue	Appamattox River	Stationary	123.1	9.9	2006	None	Poor	None
Second Street Bridge	Petersburg	Second Street	Appamattox River	Stationary	35.7	24.7	1991	Few	Poor	None
Temple Avenue Bridge	Petersburg	Temple Avenue	Appamattox River	Stationary	36.0	10.4	1958	None	Poor	None

BRIDGE NAME	JURISDICTION	ROADWAY	WATER BODY	TYPE	LENGTH (M)	WIDTH (M)	DATE	POTENTIAL EYRIES	LANDSCAPE POSITION	NEST STRUCTURE
CSX Petersburg Bridge	Petersburg	-----	Appamattox River	Stationary	350.5	10.4	1930	None	Poor	None
High Street Bridge	Portsmouth	High Street West	W. Branch of Elizabeth River	Stationary	620.3	20.4	1975	None	Poor	None
New Jordan Bridge	Portsmouth	Poindexter Street	S. Branch of Elizabeth River	Stationary	1638.3	8.5	2012	Many	Good	None
Hodges Ferry Bridge	Portsmouth	Portsmouth Boulevard	W. Branch of Elizabeth River	Stationary	249.0	22.3	1983	None	Poor	None
West Norfolk Bridge	Portsmouth	Western Freeway	W. Branch of Elizabeth River	Stationary	666.6	27.6	1978	Few	Fair	Nest Tray
Beltline Bridge	Portsmouth	-----	S. Branch of Elizabeth River	Lift	350.5	9.1	<1900	Many	Good	None
Benjamin Harrison Bridge	Prince George County	Virginia Route 156	James River	Lift	1360.3	9.4	1988	Many	Good	Nest Box
Occoquan Route 123 Bridge	Prince William County	Gordon Boulevard	Occoquan Creek	Stationary	96.3	41.5	1995	None	Poor	None
I-95 Occoquan Bridge	Prince William County	I-95	Occoquan Creek	Stationary	264.2	18.5	1962	None	Poor	None
Occoquan Route 1 Bridge	Prince William County	Route 1	Occoquan Creek	Stationary	280.4	12.2	-----	None	Poor	None
Powells Creek Bridge	Prince William County	-----	Powells Creek	Stationary	335.3	9.1	1928	None	Fair	None
Neabsco Creek Bridge	Prince William County	-----	Neabsco Creek	Stationary	225.6	9.1	<1900	Few	Fair	None

BRIDGE NAME	JURISDICTION	ROADWAY	WATER BODY	TYPE	LENGTH (M)	WIDTH (M)	DATE	POTENTIAL EYRIES	LANDSCAPE POSITION	NEST STRUCTURE
Occoquan Tressle Bridge	Prince William County	-----	Occoquan Creek	Stationary	281.3	9.1	1915	Few	Poor	None
Quantico Creek	Prince William County	-----	Quantico Creek	Stationary	539.8	6.1	2007	None	Fair	None
14th Street North Bridge	Richmond	14th Street	James River	Stationary	162.5	13.4	1913	None	Good	None
14th Street South Bridge	Richmond	14th Street	James River	Stationary	162.5	13.4	1913	None	Good	None
S. 9th Street Bridge	Richmond	9th Street	James River	Stationary	885.7	31.1	1973	None	Good	None
Chippingham Prkwy Bridge	Richmond	Chippingham Parkway	James River	Stationary	1286.0	12.7	1990	-----	-----	None
James I-95 Bridge	Richmond	Interstate 95	James River	Stationary	1275.6	27.0	2011	None	Fair	None
Robert E. Lee Bridge	Richmond	US Route 1	James River	Stationary	1146.0	33.7	1989	Many	Good	None
Huguenot Bridge	Richmond	Virginia Route 147	James River	Stationary	909.8	17.3	2013	None	Good	None
Nickel Bridge	Richmond	Virginia Route 161	James River	Stationary	619.4	8.5	1993	-----	-----	None
Veterans Mem. Bridge	Richmond	Virginia Route 288	James River	Stationary	449.6	33.5	1995	Few	Fair	None
Powhite Prkwy Bridge	Richmond	Virginia Route 76	James River	Stationary	600.8	21.9	1972	-----	-----	None
CSX Bridge Richmond	Richmond	-----	James River	Stationary	670.6	5.5	1919	Many	Good	None
Tressle Bridge North	Richmond	-----	James River	Stationary	160.9	9.1	1901	None	Fair	None
Tressle Bridge South	Richmond	-----	James River	Stationary	179.8	9.1	1901	None	Fair	None

BRIDGE NAME	JURISDICTION	ROADWAY	WATER BODY	TYPE	LENGTH (M)	WIDTH (M)	DATE	POTENTIAL EYRIES	LANDSCAPE POSITION	NEST STRUCTURE
Newland Road Bridge	Richmond County	Virginia Route 624	Cat Point Creek	Stationary	248.4	12.9	2008	None	Fair	None
Naylors Beach Bridge	Richmond County	Virginia Route 634	Cat Point Creek	Stationary	202.4	7.6	1984	None	Good	None
Mills Godwin Bridge	Suffolk	US Route 17	Nansemond River	Stationary	1250.3	12.8	1981	Few	Good	Nest Box
Bennetts Creek	Suffolk	US Route 17	Bennetts Creek	Stationary	308.8	11.0	1969	None	Fair	None
Rudee Inlet Bridge	Virginia Beach	General Booth Boulevard	Rudee Inlet	Stationary	208.2	11.3	1968	None	Fair	None
North Great Neck Bridge	Virginia Beach	North Great Neck Road	Broad Bay	Stationary	342.0	11.2	1988	None	Poor	None
Lestner Bridge	Virginia Beach	Shore Drive	Lynnhaven Inlet	Stationary	465.7	10.5	1967	Few	Good	None
West Great Neck Bridge	Virginia Beach	West Great Neck Road	Broad Bay	Stationary	488.3	31.9	2014	None	Poor	None
Coleman Bridge	York County	US Route 17	York River	draw	1145.1	23.6	1996	Many	Good	Nest Box

Appendix III. Peregrine survey.

BRIDGE NAME	FEMALE 1ST	LATENCY	MALE 1ST	LATENCY	FEMALE 2ND	LATENCY	MALE 2ND	LATENCY
Port Royal Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
Chickahominy River Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
Indian River Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
High Rise Bridge	Vocal and Flight	<5 sec	Vocal and Flight	<5 sec	Vocal and Flight	<5 sec	Vocal and Flight	<5 sec
Gilmerton Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
Paradise Point	No Response	-----	No Response	-----	No Response	-----	No Response	-----
I-295 Bridge Appomattox	No Response	-----	No Response	-----	No Response	-----	No Response	-----
Appamattox Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
Tappahannock Bridge	Vocal and Flight	<10 sec	Vocal and Flight	<30 sec	Vocal and Flight	<10 sec	Vocal	<10 sec
Blue and Gray Prkwy Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
Rappahannock I-95 Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
Chatham Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
Chatham Train Tressle	No Response	-----	No Response	-----	No Response	-----	No Response	-----
HRBT North	No Response	-----	No Response	-----	No Response	-----	No Response	-----
Hampton River Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
Settlers Landing Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
I-295 Bridge Dutch Gap	No Response	-----	No Response	-----	No Response	-----	No Response	-----
Vietnam Vets Mem. Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
CSX Appomattox Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
Hazelwood Bridge	Vocal and Flight	<5 sec	Not Present	-----	Incubating	-----	Vocal and Flight	<5 sec
Pamunkey Rt 360 Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
Mattaponi Rt 360 Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----

BRIDGE NAME	FEMALE 1ST	LATENCY	MALE 1ST	LATENCY	FEMALE 2ND	LATENCY	MALE 2ND	LATENCY
Eltham Bridge	Vocal and Flight	<5 sec	Vocal and Flight	10 sec	Vocal and Flight	<5 sec	No Response	-----
Mattaponi Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
Walkerton Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
Piankatank Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
Norris Bridge	Vocal and Flight	<5 sec	Not Present	-----	Vocal and Flight	<5 sec	Vocal and Flight	<30 sec
Poplar Grove Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
Monitor Merrimac Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
James River Bridge	Vocal and Flight	<5 sec	Vocal and Flight	<5 sec	Vocal and Flight	<5 sec	Vocal and Flight	<5 sec
Campostella Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
Gramby Street Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
Lafeyette River Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
Berkley Bridge	No Response	-----	No Response	-----	Vocal and Flight	<10 sec	Vocal and Flight	<30 sec
HRBT South	No Response	-----	No Response	-----	No Response	-----	No Response	-----
I-64 E. Elizabeth River	No Response	-----	No Response	-----	No Response	-----	No Response	-----
Little Creek Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
Military Highway	No Response	-----	No Response	-----	No Response	-----	No Response	-----
Ford Plant Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
Norfolk Southern Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
CBBT South Span	Vocal and Flight	<20 sec	Vocal and Flight	<20 sec	Not Present	-----	Not Present	-----
Great Wicomico Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
Fleet Street Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
Appomattox I-95 Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
Pickett Avenue Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----

BRIDGE NAME	FEMALE 1ST	LATENCY	MALE 1ST	LATENCY	FEMALE 2ND	LATENCY	MALE 2ND	LATENCY
Second Street Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
Temple Avenue Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
CSX Petersburg Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
High Street Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
New Jordan Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
Hodges Ferry Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
West Norfolk Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
Beltline Bridge	Vocal and Flight	<10 sec	Vocal and Flight	<15 sec	Vocal and Flight	<5 sec	Vocal and Flight	<10 sec
Benjamin Harrison Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
Occoquan Route 123 Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
I-95 Occoquan Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
Occoquan Route 1 Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
Powells Creek Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
Neabsco Creek Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
Occoquan Tressle Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
14th Street North Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
14th Street South Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
S. 9th Street Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
Chippingham Prkwy Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
James I-95 Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
Robert E. Lee Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
Huguenot Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
Nickel Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----

BRIDGE NAME	FEMALE 1ST	LATENCY	MALE 1ST	LATENCY	FEMALE 2ND	LATENCY	MALE 2ND	LATENCY
Veterans Mem. Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
Powhite Prkwy Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
CSX Bridge Richmond	No Response	-----	No Response	-----	No Response	-----	No Response	-----
Tressle Bridge North	No Response	-----	No Response	-----	No Response	-----	No Response	-----
Tressle Bridge South	No Response	-----	No Response	-----	No Response	-----	No Response	-----
Mills Godwin Bridge	Vocal and Flight	<5 sec	Vocal and Flight	<10 sec	Vocal and Flight	<5 sec	Vocal and Flight	<5 sec
Rudee Inlet Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
North Great Neck Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
Lestner Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
West Great Neck Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
Coleman Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
Newland Road Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
Naylors Beach Bridge	No Response	-----	No Response	-----	No Response	-----	No Response	-----
Bennetts Creek	No Response	-----	No Response	-----	No Response	-----	No Response	-----
Quantico Creek	No Response	-----	No Response	-----	No Response	-----	No Response	-----