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Status and Management of Bats Roosting in Bridges in Florida

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INTRODUCTION

At least five species of bats use highway bridges in Florida as colonial roosting sites (J. A. Gore, unpublished data), but the abundance and distribution of bat bridges across the state are not well known. Broader knowledge of bat roosts in bridges would be useful to biologists working to conserve bat populations in Florida and to the Florida Department of Transportation (FDOT), the agency responsible for managing most bridges in the state. As manager of Florida's highway bridges, FDOT is concerned with potential problems roosting bats might present, such as structural damage to bridges, interference with maintenance or inspection procedures, and hazards to traffic. As a public agency, FDOT also has an interest in conserving bat roosts where they are important to local bat populations. Additionally, FDOT may find information on bat bridges useful in responding to inquiries from the public about wildlife viewing opportunities. For all of these reasons, FDOT supported a study by the Florida Fish and Wildlife Conservation Commission (FWC) to assess the current distribution and abundance of colonial bat roosts in highway bridges in Florida.

Although not all species of bats roost in colonies, many species do and roosting colonies across the United States range in size from several individuals to many thousands or even millions of bats (Kunz 1982). The largest bat colonies in Florida contain about 90,000 adults (Gore and Hovis 1998), but the majority of colonies in the state support less than 1,000 bats. The roosting sites used by colonial bats provide important advantages, including energy conservation, optimal social interactions and mating opportunities, shelter from weather, and protection from predators and human disturbance (Kunz 1982). Because few sites can optimally meet these needs, the availability of suitable roosting sites may be a factor that limits the size of bat populations (Humphrey 1975).

Because conserving energy is critically important to survival and reproductive success of bats (Speakman and Thomas 2003), they are often highly selective in choosing roosts that help them maintain optimal body temperatures (Kunz 1982). For example, wintering bats typically select a roost site that is cool but not freezing, which allows them to conserve energy by lowering their body temperature (McNab 1982). Cool winter roosts that provide stable temperatures relative to outside ambient conditions are optimal, but even in Florida bats in poor roosts can freeze in cold weather (J.A. Gore, personal observation). Optimal summer roosts also have stable temperatures, especially those used as maternity (nursery) roosts. Because young bats are born naked and stay in the roost when the mother is out foraging, they are dependent upon warm temperatures within the roost for proper growth and development (Tuttle 1976, Tuttle and Stevenson 2003).

In addition to these critical thermal benefits, roosts also provide protection from predators and inclement weather. This protection is particularly important for colonial bats because a single predator or storm event could destroy many bats at roosts that do not provide adequate protection. Colonial roosts may also provide social benefits to bats. For example, some bats congregate seasonally at particular roost sites to mate, and successful reproduction may depend upon bats being present at the site where most other local bats are roosting. Nevertheless, the reasons why specific roosts are used are often unclear.

Colonial bats roost most often in sheltered natural sites, such as caves and hollow trees, or in crevices within manmade structures, such as buildings and bridges (Barbour and Davis 1969, Jennings 1958, Kunz 1982, Kunz and Reynolds 2003). Colonial bats in Florida use some roosts only seasonally, as wintering sites or summer nursery sites, but other roosts are used year round (Jennings 1958, Gore and Hovis 1998). Roosting colonies often include more than one species, particularly colonies in caves, bridges, and other large roost sites where space is not limiting. Most multiple species roosts probably result simply from different species being drawn to the same type of roosts, but some species may prefer or be obligated to roosting with other species (Kunz 1982).

Highway and railroad bridges have long been known as roosting sites for colonial bats (Barbour and Davis 1969, Davis and Cockrum 1963, Jennings 1958). Bats roost most frequently in bridges made of concrete, probably because concrete bridges are relatively permanent structures on the landscape and because they provide numerous crevices with optimal temperature ranges for roosting bats (Keeley and Tuttle 1999, Adam and Hayes 2000). In contrast, bridges made primarily of wood are seldom used as roosting sites (Adam and Hayes 2000; J. A. Gore, unpublished data; Keeley and Tuttle 1999; Lance et al. 2001; McDonnell 2001). Bats may choose concrete bridges over natural roosting sites because they provide better roosting conditions. Conversely, concrete bridges may now simply be more abundant and available than the caves and large old cavity trees in which colonial bats formerly roosted. If suitable natural roosting sites are limited in Florida (Gore and Hovis 1998) or if some bat species have become highly adapted to roosting in manmade structures (Kunz and Reynolds 2003), then highway bridges may provide the most common or optimal roosting sites for colonial bats.

Our study was designed to provide FDOT with information on the extent of bat roosts in highway bridges in Florida and guidelines for conducting bridge maintenance and inspection activities at bridges with bat roosts. We had 4 primary objectives. The first was to survey a sample of FDOT-maintained highway bridges in Florida and provide an estimate of the number of bridges occupied by roosting bats in 2003 and to map and identify all surveyed bridges used by roosting bats. The second objective was to summarize the characteristics and design features of roost bridges and correlate bridge features with presence, number, and species of roosting bats. The third objective was to prepare guidelines for minimizing contact between FDOT employees and bats at bridge roosts and to suggest methods for FDOT employees to record presence of bats in bridges. Our final objective was to identify bridges that are planned for replacement or repair in the FDOT 2025 plan and describe ways that bat roosts in those bridges could be conserved. This information should allow FDOT to fully maintain the transportation function of bat roost bridges while conserving local bat populations.

STUDY AREA AND METHODS

Although relatively small in land area, Florida extends more than 700 km both north-south and east-west and covers a range of climatic and ecological variation from subtropical to temperate (Fernald and Purdum 1992). Despite this extensive range, no part of the state is greater than125 m above sea level or more than100 km from the coast. As of 2000, Florida had a population of nearly 16 million people (U. S. Census Bureau 2002) and nearly 120,000 miles of public roads, including some 12,000 miles in the state highway system (U. S. Census Bureau 2001). We visited bridges throughout Florida (Figure 1) and in or near every major terrestrial and freshwater habitat type in the state (see Myers and Ewel 1990).

For this study we defined highway bridges as any bridge maintained by FDOT. We selected bridges to survey from a 2003 FDOT database containing geographic, structural, and use information for Florida's 11,373 highway bridges (FDOT, Tallahassee, unpublished data). These bridges included all those maintained by FDOT as part of their state highway responsibilities, regardless of whether the bridge carried roads, railroads, or pedestrian walkways. Thus our definition of highway bridges is broad and covers bridges that cross or carry highways. The FDOT list did not include privately owned or maintained bridges or those maintained solely by another government agency. Examples of federally maintained bridges include those within Everglades National Park. We surveyed 8 "non-FDOT" bridges to ensure they offered no distinct features from other bridges, but we did not combine those observations with data from the FDOT bridges.

We designed our survey to include a random and a non-random sample of bridges. We first identified all bridges known to support roosting bats prior to 2003 by compiling information from the literature, from previous bat surveys, and from observations submitted by wildlife biologists, FDOT staff, and the public. We labeled these previously reported roost sites as known bat bridges and visited each once from February - October 2003 to confirm the presence of bats. During the course of surveying the known bat bridges, we also opportunistically visited some nearby bridges that appeared suitable for bats or easy to examine. These incidental bridges and the known bat bridges totaled 180 sites and together were classed as non-random bridges.

In the same months of 2003, we also surveyed a set of randomly selected bridges. Based on our study of highway bridges in north Florida in 1995 and 2000 (J.A. Gore, unpublished data), we knew that bats most often used 1 of 5 bridge structure (material and design) types: (1) prestressed concrete multibeam, (2) prestressed concrete continuous multibeam, (3) prestressed concrete slab, (4) concrete T beam, and (5) steel multibeam (Fig. 2; see Appendix 1 for definitions). Therefore, we filtered the FDOT statewide list to select all 5,840 bridges of these 5 structure types. We stratified the selected bridges across the 8 administrative districts of FDOT to insure coverage across the state and then randomly selected a 5% sample of bridges from each district for a total of 299 randomly selected bridges. We visited these randomly selected bridges in 2003 concurrently with the non-random bridges noted above.

At each bridge visited we looked for evidence of use by roosting bats, such as guano (feces), staining, odors, carcasses, or the roosting bats themselves (Fig. 3). If we could not see or hear bats, we still recorded a bridge as a bat roost if, based on our expertise, the presence of guano, stains, odors, or dead bats indicated regular use by bats. We labeled bridges being used by roosting bats as occupied bridges. Because the bats often roosted within inaccessible crevices in the bridges, we were not always able to see them well enough to confirm species or numbers of individuals. The crevices bats used were not structural defects, rather the roost crevices were the narrow spaces created by the expansion joints that are built between bridge sections to accommodate the expansion of the material with increasing temperature. Rarely, bats also roosted in small drainage holes built into the concrete deck of the highway. We noted when species identification was confirmed versus suspected. Exact counts were often not possible; therefore, we estimated the minimum size of colonies and grouped estimates into 3 size classes: small (<25 bats), medium (25-500 bats), and large (>500 bats).

We used the randomly selected bridges primarily to estimate the percentage of all bridges used by bats. We compared occupied bat bridges (random and non-random) with a same-size set of the randomly selected bridges to determine characteristics associated with bat roosts. The primary bridge characteristics that we evaluated were bridge structure type, age, length, height, and mean daily vehicle traffic. Measures for all these bridge variables were retrieved from the FDOT bridge database in 2003. We used Statistix 8.0 (Analytical Software, Tallahassee, Florida) to run statistical tests of comparisons. We used standard parametric tests (Pearson's correlation, Chi-square, 2 sample t tests) and a probability of less than 0.05 to indicate results that were significant.

RESULTS

We found bats in 16 (5.4%) of the 299 randomly selected bridges and in 6 of the 8 FDOT districts (Table 1). Occupied random bridges were found across the state (Fig. 1), but districts 1, 2, and 3 contained 13 of the 16 occupied bridges. The number of occupied random bridges within an FDOT district was not correlated with the total number of random bridges surveyed (Pearson correlation –0.04, P=0.920). We found an additional 135 bridges occupied by bats when we visited the known bat bridges and during surveys incidental to the random searches (Table 1). Combining the random and non-random surveys, we visited 151 bridges in Florida occupied by roosting bats. We found occupied bridges throughout the state, except in District 6, which covers far south Florida and the Keys (figures 4 - 6). However, 83 of 151 (55.0%) occupied bridges occurred in north Florida, i.e., in FDOT districts 2 and 3. We visited 14 bridges (2.9%) in February or October, 75 (15.7%) in March or September, and 390 (81.4%) in the typical breeding months from April – August.

We found 4 species of bats roosting in bridges (Table 2). Free-tailed bats (*Tadarida brasiliensis*) were by far the most common species both in number of bridges occupied (Table 2) and estimated number of individuals (Table 3). They occurred in bridges in all FDOT districts, except District 6 in extreme south Florida (Fig. 7). We found southeastern myotis (*Myotis austroriparius*) roosting in bridges only in FDOT District 3, northwest

Florida (Fig. 8). Big brown bats (*Eptesicus fuscus*) roosted only in north Florida, Districts 2 and 3 (Fig. 9), and evening bats (*Nyteceius humeralis*) occurred in north Florida as well as in southwest Florida, Districts 1-3 (Fig. 10). We observed only 1 bat species in most bridge roosts, and these single species bridges supported either Brazilian free-tailed bats or, less often, big brown bats (Table 4). Multiple species roosted at 35 bridges, and evening bats and southeastern myotis only roosted in bridges with other species (Table 4). We found no bridges with Rafinesque's big-eared bats (*Corynorhinus rafinesquii*) in 2003, although *Corynorhinus* is previously known to use bridges in Florida (J. A. Gore, unpublished data) and is a fifth species to consider at bridge roosts. At 38 of the 151 bridges where we found bats roosting, we could not see the bats well enough to confirm the species. Still, we found no evidence (such as relative size, coloration, facial features) indicating that any species other than 1 of the 4 noted above roosted in Florida bridges in 2003.

Because we often could not see all the bats roosting in bridge crevices, our estimates of the number of roosting bats are conservative. Where we could reasonably estimate the number of bats, we found most species roosted in clusters of less than 25 individuals (Table 3). In some cases, a species had multiple small clusters of bats roosting in separate crevices in the bridge. Only the Brazilian free-tailed bat occurred most often in groups of 25 – 500 individuals (Table 3).

Among the 299 randomly sampled bridges, we found no significant association between bridge structure and the number of bridges occupied by bats ($\chi^2 = 1.78$, df = 2, P = 0.410). However, the number of occupied bridges in the random sample was small (n = 16). When we compared all (random and nonrandom) occupied bridges of the 5 main structure types (n = 142) with the randomly sampled unoccupied bridges (n = 283), we found a significant association between structure type and presence of bats ($\chi^2 = 31.86$, df = 3, P < 0.001). Bats roosted more often than expected by chance in prestressed concrete bridges with multiple I-design beams (Table 5, Appendix 1). In addition to the 5 main structure types, we surveyed bridges of 8 other structure types and found 9 occupied by bats (Table 5).

Bridges with bats were significantly older than bridges without bats (t test, *P*< 0.001). Occupied bridges were built between 1926 and 1993 with 1969 being the mean construction year. In a matching random sample of unoccupied bridges (n = 148), those without bats were built between 1938-2001 and 1977 was the mean year of construction. Average daily vehicle traffic was significantly greater (t test, P< 0.001) across unoccupied bridges than across bridges with bats. Unoccupied bridges averaged 32,953 vehicles daily while bridges with bats averaged 16,152 vehicles. Neither total length (*P* = 0.079) nor bridge height (vertical underclearance; *P* = 0.870) differed significantly between bridges with or without bats.

DISCUSSION

Bridge Types and Numbers

Our random sampling of the 5 most commonly occupied bridge types (Table 5), suggests that bats use about 5.4% of bridges in those types. As of 2003, Florida had approximately 5,480 bridges of those types and, therefore, we estimate roosting bats occupy 296 bridges. Because our random and nonrandom surveys together found only 142 occupied bat bridges among the 5 commonly used bridge types (Table 5), we estimate 154 additional bat bridges exist among the bridges we did not survey.

Keeley and Tuttle (1999) estimated that bats roost in about 3,600 highway structures (bridges and culverts) in the southern half of the United States. The basis for that estimate was not clearly stated and the estimate may be low considering McDonnell (2001) found bats using 135 culverts and bridges in just 25 counties in North Carolina, Trousdale and Beckett (2004) found 36 bridges in DeSoto National Forest in Mississippi, and we estimate nearly 300 bridges are used in Florida. In any case, bats are using a large number of bridges as roosts in the southern United States. Unfortunately, we do not know how important bridge roosts are to local bat populations relative to other available roosting structures nor do we know how important any individual bridge roost is.

Bats did not select bridges of particular structural types based upon the relative abundance of those types; instead they selected bridges that provided suitable roosting crevices. Prestressed concrete multibeam bridges were the most common structural type among occupied bridges and they typically provide suitable roosting crevices in the expansion joints created above the support column (pier) and perpendicular to the road bed, where the beams of each span are connected by a flat section (diaphragm) of concrete (Fig. 2). Prestressed concrete *continuous* multibeam bridges look superficially like the simple concrete multibeam bridges but, as the term continuous implies, they do not typically have open crevices between spans (Hartle et al. 2002). Concrete T beam bridges can also provide suitable roosting crevices between spans, but these bridges are of an older design and not common (N = 224). Often concrete T beam bridges are small bridges with only 1 span (Hartle et al. 2002) and, therefore, they do not have between-span crevices in which bats could roost.

Like the concrete multibeam and T beam bridges, prestressed concrete slab bridges (Fig. 2) sometimes provided roosting crevices in the joints where spans met. Some slab bridges were constructed with multiple slabs in each span. These bridges sometimes offered suitable crevices in joints running between the parallel slabs (Fig. 2). The only concrete slab bridges that we randomly surveyed were made of prestressed concrete, but regular concrete slab bridges (N = 1,079) can also offer crevices for bats as we found in 1 bridge (Table 5). These bridges tend to be older and have only 1 span composed of a single slab; therefore, like most T beam bridges, they do not have between-span crevices suitable for bats. Concrete slab bridges also come in a continuous slab design, but these are not common (N = 536) and generally do not have joints between slabs.

We found 6 steel bridges with bats, but the bats did not roost on steel components of any bridge. Rather, they roosted in expansion joints between concrete sections between steel spans, in joints in the concrete deck, or even in expansion joints in approach spans made of concrete. Steel bridges come in a variety of designs (Hartle et al. 2002) and together there are about 1,200 steel bridges in Florida. Although bats almost strictly use concrete bridges for roosting, steel bridges should not be discounted as bat roosts if they have some concrete components with crevices.

Because bats are often found roosting in tree cavities and in wooden frame buildings (Kunz and Reynolds 2003), they might be assumed to also use wooden (timber) bridges as roosts. We found no record of bats roosting in wooden bridges in Florida and researchers in other states have also found bats rarely roost in wooden bridges (Adam and Hayes 2000, Keeley and Tuttle 1999, Lance et al. 2001, and McDonnell 2001). Wooden beams would seem to be suitable roosting surfaces because bats can easily cling to them and because they are thermally stable. However, bats may have reason to avoid wooden bridges. For instance, the preservatives used in most bridge timbers may repel bats and the crevices of wooden bridges may be readily accessible to predators, particularly snakes. In addition, the thermal stability of crevices in wooden bridges probably does not match that provided by the mass of concrete structures. Florida has more than1,600 wooden bridges, but all are small (< 30 m in length) and only about 75 exceed 8 m. Timber bridges are not significant roosting sites for bats in Florida and, therefore, not a bat management concern for FDOT.

Our estimate of 296 occupied bat bridges in Florida did not take into account the 8 minor types of bridges we surveyed, but we found bats in only 9 bridges among all these types (Table 5). Although we found few bat bridges among these minor types, we directly surveyed only 21 bridges in this group and additional surveys would help ascertain the importance these minor bridge types as bat roosts. However, we do not expect many new bat roosts to be found among these bridge types because only 9 bat roosts were known or reported to us from the 2,381 bridges of these minor types. The most common of these minor types of bat bridges is the simple poured-in-place concrete slab type, which includes 1,079 bridges in Florida. As noted above, these slab bridges typically do not have the suitable crevices that prestressed concrete slabs often provide. In addition to the single concrete slab bridge that we knew about prior to this study, we incidentally visited 8 other poured-in-place concrete slabs and found no new bat roosts. Therefore, although any bridge with concrete crevices is potentially suitable for bats, we believe few roosts will be found in any but the 5 types in which we randomly surveyed (Table 5).

Bats typically roost in bridges during the day within crevices formed by joints between concrete sections of the bridge. These dark, tight spaces provide the bats protection from predators and weather, but they also importantly provide thermal conditions needed by the bats to conserve energy when roosting (Keeley and Tuttle 1999). In our 1995 study, we found bats most often use crevices in bridge joints that are closed at the top (J. A. Gore, unpublished data). In 2003, we found bats in at least 2 bridges where the expansion joint used was open at the top, either by design or loss of a seal, and the bats could be readily observed from above through the bridge deck. We also found several bridges where big brown bats were roosting in joints between concrete guardrail posts above the deck of the bridge. Expansion joints come in a variety of designs (Hartle et al. 2002), but we found bats used various configurations as long as the joint provided a concrete surface and suitable space. Some joints are armored with metal, but we found no bats on the metal portions of armored joints. Metal would be difficult for bats to grasp and would transmit heat too readily to be a good roosting surface. Bats used both the long shallow joints that paralleled sections of concrete slab spans and the shorter, deeper joints that ran transverse to the roadway and connected spans as they met above support pillars or piers (Fig. 3).

We did not routinely measure the width or depth of joint crevices used by roosting bats in bridges because of the time required and because we could not reach many of the joints. Although we did not measure most joint crevices, we found no occupied crevices that appeared wider than 5 cm (2 inches) or shallower than 8 cm (3 inches). Most were narrower and deeper. Keeley and Tuttle (1999) reported bats typically roosted in crevices 0.25 – 3.0 cm (0.5 – 1.25 inches) wide and 30 cm (12 inches) deep. We suggest that in Florida bridges, crevice joints suitable for roosting bats are 1.25 – 5 cm (about 0.5 – 2 inches) wide and greater than 8 cm (about 3 inches) deep and covered at the top. Of course larger joints can potentially hold more bats than smaller joints, but available roost space does not often seem to be limited within a single bridge.

In slab design bridges, bats roosted primarily in joints that ran lengthwise between the concrete slabs and therefore parallel to the bridge span. These crevices were highly variable in size, even at the same bridge, and seemed to be more related to construction variation rather than design specifications. They were typically shallow, but they extended many meters and they allowed bats the freedom to drop out of the roost and take flight. At bridges with either concrete or steel multibeam spans, bats roosted primarily in the expansion joints above the support piers and abutments. Depending upon bridge design and joint seals, bats could enter these joint crevices from below, from the side, or both. Where bats roosted in transverse crevices above the support piers, the opening into the expansion joint was generally less than 50 cm above the top of the pier. This made a flying entry and exit into the joint difficult for the bats. In some cases, guano from bats roosting in the joint accumulated up so high on the top of the pier that it nearly reached the bottom of the expansion joint and blocked the bats' access to their own roost. Bats often exited from the side of joints and off the outer edge of the bridge deck and pier, and this may have been more common where the flight path below the joint was obstructed. Periodic removal of guano might alleviate some of this problem.

Bat Species

The 4 species of bats we found in 2003 were all species that we had found in bridges in previous years and that had been reported in bridges by others (Adams and Hayes 2000, Davis and Cockrum 1963, Keeley and Tuttle 1999, McDonnell 2001). Interestingly, we did not find any Rafinesque's big-eared bats even though they occur in Florida in the same forested wetland areas used by southeastern myotis. We recorded a small colony of Rafinesque's big-eared bats at a bridge in Union County in 1995, but this bridge has since been replaced. Unlike other Florida species, the big-eared bat prefers to roost in open areas, such as the sides of bridge beams, rather than in crevices (McDonnell 2001). That makes them hard to miss on a survey, but also leaves them susceptible to disturbance. Elsewhere in the southeastern United States, Rafinesque's big-eared bat frequently has been found roosting under concrete multi-beam bridges (Lance et al. 2001, McDonnell 2001, Trousdale and Beckett 2004).

Roosts of the southeastern myotis are most commonly known from caves where they can contain tens of thousands of individuals (Gore and Hovis 1998). We recorded 8 bridges with southeastern myotis and confirmed 1 was a large maternity roost (Table 3). The southeastern myotis ranges across north Florida and into central Florida (Humphrey and Gore 1992), but we found it in bridges only in northwest Florida and mainly along the Choctawhatchee River (Fig. 8). That distribution may reflect our extensive field searches in northwest Florida in past years more than a restriction of the species to bridges in that area. Nevertheless, bridges are used by this species and may be important roosts for local populations, especially where caves are not available. This species frequently uses hollow trees with low entrances for roosts in some areas of the south (Humphrey and Gore 1992), but bridges may be better roosts because they are more thermally stable, less susceptible to flooding, and possibly safer from predators such as raccoons (*Procyon lotor*) and rat snakes (*Elaphe obsoleta*).

Big brown bats and evening bats are common species in the southeast and both are most often found in colonies in buildings (Barbour and Davis 1969, Jennings 1958, Whitaker and Hamilton 1998). Both species have often been found using concrete bridges (Davis and Cockrum 1963, Keeley and Tuttle 1999, McDonnell 2001), but not necessarily in the same bridge together. We frequently found both species roosting with each other or with other species (Table 4). Jennings (1958) noted that evening bats and big brown bats were frequently roosted with Brazilian free-tailed bats; we also found free-tailed bats at the majority of bridges where either of these species roosted (Table 4). We never found evening bats roosting alone, but we had 7 bridges with only big brown bats. The big brown bat ranges south only to central Florida (Gore 1992) but the evening bat is found throughout most of the state (Whitaker and Hamilton 1998). We did not find these species in bridges throughout their range in Florida (figures 9-10). The evening bat was the only species besides the Brazilian free-tailed bat that we found south of Gainesville (Fig.10) and we confirmed them at only 1 southern bridge (Highway 17 over Shell Creek in Charlotte County).

Brazilian free-tailed bats are likely the most abundant bridge-roosting bats in North America (Keeley and Tuttle 1999) and they were by far the most abundant species in our survey (Table 2). This species occurs in exceptionally large colonies in the western United States (Barbour and Davis 1969) and some colonies in buildings in Florida contain tens of thousands of individuals (Belwood 1992; Jennings 1958; J.A. Gore, unpublished data). Although we often could only estimate colony size based on evidence such as guano piles, we found no bridges where the estimated colony size was greater than10,000 bats and most roosts supported less than1,000 bats (Appendix 2). The Brazilian free-tailed bat has long been associated with buildings in Florida and it was apparently the first species recorded to roost in bridges in the state (Jennings 1958). Because they typically roost in larger numbers than most other species (Table 3), Brazilian free-tailed bats are the bats most likely to be considered a nuisance by bridge inspection and maintenance crews. These bats occurred in more bridges than any other species and their relatively large colonies can produce a substantial volume of guano, which can build up on bridge components or below bridges. Urine and body oils from the bats can stain bridge components, especially those made of concrete. Stains are also created when rain or drainage water percolates through large piles of guano. In addition, Brazilian free-tailed bats have a strong and distinct odor that is much stronger than any of Florida's other species and smells unpleasant to many people. Despite its common appearance in bridge roosts in Florida (Fig. 7), we do not have an accurate assessment of the status of this species in the state (Belwood 1992). The large colonies of this species suggest that this species is abundant and not likely to be impacted by disturbance. On the contrary, large roosts can be a liability to bat populations because a single disturbance has the potential to adversely impact many bats compared to disturbance at a much smaller colony.

We recorded a bridge as occupied when we saw a bat, heard vocalizations, or found guano beneath a roost. We identified the species of bats at a roost by observing them directly in the roost crevices or by capturing individuals with a hand net. We often were unable to identify all the bats roosting at a bridge (Appendix 2, Fig. 11) because we could not see or readily capture all the bats within the roost crevices. Because our primary goal was to estimate the number of bridges used by bats rather than the types of species present in each bridge, we concentrated on visiting many bridges instead of identifying species at a few bridges. We did not set mist nets or harp traps at the bridges to capture bats for species identification because this would have required 1 or more nights of effort at each bridge. Neither did we have time to record the species-specific echolocation calls of bats flying out from bridge roosts at night, but that is a method that might be more efficient than mist nets for ascertaining which species are using a particular bridge. Learning more about species differences in use of bridges would be helpful to bridge and wildlife managers, but results may be of limited value because bats may shift among roosts (Lewis 1995) and species composition in a bridge colony may change between years or seasons.

MANAGEMENT IMPLICATIONS

Benefits of Bats in Bridges

All species of bats found in Florida bridges eat strictly insects, but each species consumes a different array of insects (see Whitaker and Hamilton 1998). Bats provide a benefit to humans because the insects that bats consume include mosquitoes and agricultural pest species. Although bats can consume an enormous number and mass of insects each night, the relative impact of their feeding on local insect populations remains largely unknown. Therefore, although the potential exists for Florida's bridge-roosting bats to be helpful controls on harmful insects in the state, the extent of this benefit remains undetermined.

A more direct benefit provided by bats in bridges is the opportunity for the public to observe some species of wildlife that they seldom see. Wildlife viewing is a popular activity and active management of bat roosts by FDOT could provide positive public relations for the agency and viewing opportunities for the citizens of Florida. We conducted a trial public bat-viewing event, held in Orlando in May of 2004 and additional viewing opportunities could be provided with little effort. Ideally, bat-viewing opportunities would be facilitated at bridges where the public could watch the bats on any night without the need for FDOT or FWC personnel to be present. However, setting up these kinds of viewing opportunities requires finding bridges with large colonies of bats as well as sufficient areas for people to easily and safely watch the bats. Because of these concerns, designation of viewing areas at bridges will be possible only if public safety issues and bat disturbance issues can be fully addressed. This will require coordination between FDOT, FWC, and local communities to identify and designate viewing bridges, and it may be that no Florida bridges will meet the safety and security restrictions.

A final benefit of bat roosts in bridges is the benefit they provide to the bat populations. Although we cannot determine the importance of bridge roosts to local populations, the roosts may be significant when other roosts are not available. Providing roosts in bridges might even be considered as mitigation for loss of roosts elsewhere. Although the benefits to local bat populations are uncertain, they probably exceed the costs of providing bridge roosts. Creation of roosts in bridges is typically very inexpensive and in new bridges requires little if any special design needs.

Potential Nuisance Issues

Impacts to Bridge Structure. Roosting bats use available crevices and hang freely on existing surfaces. Unlike rodents, they do not chew or claw at materials and, therefore, they cause no direct damage to bridge structures, including pipes or wiring. Bats do deposit urine and guano at the roost and over time the deposits can be substantial. However, we found no evidence from our study or others that indicated the presence of bat urine or guano harmed the structure or integrity of a bridge. In Texas, Keeley and Tuttle (1996) found no reports of damage to bridges caused by roosting bats, although they noted that "materials that retain moisture, such as bat droppings, could facilitate oxidation on unprotected metal parts. Thus, bat roosts above exposed metal components should be discouraged." Based on this information, we believe that any potential minor damage to bridges can be avoided by adhering to general maintenance and cleaning schedules.

Human Health and Safety. Bats roosting in bridges pose little threat to humans, as long as the bats are not directly contacted. If bats are disturbed in bridge roosts they may exit or fly out of bridge crevices very quickly, but normal, healthy bats will not attack people. Furthermore, all Florida bats are quite small and the largest bats found in bridges have a wingspan of about 300 cm (12 inches) and weigh about 20 g (<1 ounce), hardly big enough to be a direct threat to humans. Nevertheless, caution should be taken to disturb roosting bats as little as possible, this includes during maintenance, construction and inspection activities. Small but serious threats are posed by 2 diseases associated with bats: rabies and histoplasmosis.

Rabies is an infectious viral disease that affects the nervous system of humans and other mammals (Brass 1994). People typically contract the virus from the bite of an animal with rabies. Any warm-blooded, wild mammal can have and transmit rabies to people, but bats are notoriously common vectors (Brass 1994). It is possible, but quite rare, that people may contract rabies if infectious material from a rabid animal, such as saliva, gets directly into eyes, nose, or open wounds.

The ecology of rabies in bat populations is complex and not fully understood, but only about 1% or fewer of the bats in a local population are typically infected with rabies and those infected with rabies soon die (Brass 1994, Messenger et al.2003). Under normal circumstances, bats are quite timid and avoid humans. The best precaution for anyone working near bat bridges is to avoid any bat observed outside in the day and particularly those found on the ground or behaving in an unusual manner. Untrained persons should never handle any bat, especially one found under unusual circumstances. Although the threat is small, rabies is a fatal disease and anyone that is bitten or suspects they have been bitten should seek immediate, professional medical attention. More information on bats and rabies can be found at the Centers for Disease Control website at: http://www.cdc.gov/ncidod/dvrd/rabies/bats_&_rabies/bats&.htm. Appendix 3 provides suggested safety practices for individuals that work near bat roosts in bridges.

Histoplasmosis is a disease caused by inhaling spores of the fungus *Histoplasma capsulatum*. The disease is contracted by breathing fungal spores stirred up from areas where bat or bird droppings accumulate, but it is not contagious and cannot be transmitted among people or from an infected animal. Histoplasmosis primarily affects the lungs, and its symptoms vary greatly. The vast majority of infected people show no symptoms or they experience symptoms so mild they do not seek medical attention. However, the symptoms of histoplasmosis can become severe, and if left untreated can lead to death.

The large accumulation of bat guano and pigeon droppings found under some bridges can be a threat to people working beneath bridges, particularly those that clean away or disturb the droppings. Sorley et al. (1979) documented histoplasmosis in Maryland bridge workers and Jones et al. (1999) provided additional documentation on histoplasmosis in bridge workers. General precautions, such as wearing a facemask, or using a respirator when working around bat feces, or simply not disturbing or standing directly in guano for extended periods, can greatly reduce any risk of contracting histoplasmosis. More information on histoplasmosis and bats can be found on website of the Centers for Disease Control at: http://www.cdc.gov/niosh/97146eng.html.

Regulations and removal of bats. None of the species of bats that roost in Florida bridges are currently listed as protected species, i.e., endangered, threatened, or of special concern, by FWC or the U. S. Fish and Wildlife Service. Thus, none of the regulations addressing protected species apply in regards to disturbance or removal of bat roosts in bridges. However, flagrant destruction of roosting bats is illegal according to FWC rules as listed in Chapter 68A-4.001, Section 1, Florida Administrative Code (F.A.C.) which states "no wildlife or freshwater fish or their nests, eggs, young, homes or dens shall be taken, transported, stored, served, bought, sold, or possessed in any manner or quantity at any time except as specifically permitted by these rules nor shall anyone take, poison, store, buy, sell, possess or wantonly or willfully waste the same except as specifically permitted by these rules." Use of toxic chemicals to destroy bats is prohibited under Section 2 which states "The use of gasoline or any other chemical or gaseous substances to drive wildlife from their retreats is prohibited" and by Chapter 68A12.009, Section 1, F.A.C. Conversely, destructive wildlife may be killed by property owners per Chapter 68A12.009, F.A.C., but only at the location where damage has occurred. Additionally, the executive director of FWC has authority to permit take of wildlife otherwise prohibited by these rules. In practice, FWC requires property owners with complaints about bats to demonstrate that the bats are causing damage or are a threat to human safety. Secondly, FWC asks property owners to use non-lethal control measures before requesting a permit to move or destroy roosting bats.

Excluding bats from their roosts is a much safer and preferable method for eliminating a bat colony than destroying the bats directly. From an ecological perspective, destruction of a roosting colony can have a significant effect on local bat populations because, unlike nuisance rodents, the bats that roost in Florida bridges are long-lived species that produce only 1 young per year. Their populations cannot quickly recover from loss of many individuals, particularly when many of the bats from a wide area may be at a single bridge. Destroying bats is also not recommended for safety reasons. Attempts to trap the bats, poison them, or seal them in place invariably leave some bats alive but injured or stressed. These animals often become grounded and are a potential threat to human safety, and questions of legal liability exist if a bat injured during a pest removal activity bites someone. Finally, the public generally does not approve of destruction of native wildlife when other solutions are available. For all these reasons, destruction of bat colonies in Florida bridges is not recommended.

Fortunately, an effective alternative exists in a process commonly known as "exclusion." This preferred method of removal of bats that are considered a nuisance involves placing netting over the roost crevices so that bats can escape but not re-enter the roost. More information on excluding bats from roosts is provided in Appendix 4, and additional information may be available from Bat Conservation International (www.batcon.org). Some wildlife control companies provide bat exclusion services and the Florida Bat Center (www.floridabats.org) is a good contact for information on excluding bats in Florida.

Some roosts are used by maternity colonies and may contain young bats that are unable to fly and would be trapped at the roost if adults were excluded. For that reason, bats should not be excluded during the maternity season, which in Florida typically runs from April 15 to August 15. Exceptions could be made for summer exclusions if experienced biologists confirm no non-flying juvenile bats or pregnant or lactating females are present. This usually requires capturing an adequate sample of bats from the roost and determining their age and reproductive status.

Maintenance and inspection activities that require work at an expansion joint used by bats should be scheduled for fall or winter when bats are less likely to be using the bridge. As noted above, roosts should not be disturbed between April 15 and August 15. Disrupting a roost for emergency or essential activities during this period will require special attention and coordination with FWC (see Appendix 3). Invasive activities, such as replacing expansion joint seals, risk the most harm to roosting bats and should be conducted after consultation with a qualified biologist. During any bridge maintenance, caution should be taken to disturb roosting bats as little as possible. High-pressure washers should not be used to clean out expansion crevices when bats are present and bridge workers should never handle bats. Harassing bats in an attempt to get them to leave a roost may result in bats biting people in a defensive response.

Evaluating Bridges for Use by Bats

The most obvious evidence that bats are using a bridge is seeing the animals. As noted above, bats are most likely to be seen in crevices formed by expansion joints and therefore lights are usually necessary to check for bats. Because bats can shift roosts, results from any inspection of a bridge cannot guarantee whether bats will be present in the future, unless the bridge has no suitable crevices.

If bats are observed at a bridge, their presence can also be confirmed from hearing vocalizations, seeing stains or guano, or smelling the bats. Confirming bats via their echolocation calls requires specialized equipment and training. However, the audible social call of bats can often be used to find bats hidden in bridge crevices. Bat calls are high-pitched squeaks or chattering that might be confused with birdcalls. However, if the sound comes from inside an expansion joint and is rather constant, it is most likely from bats. Vocalizations are particularly helpful at new roosts where other evidence of bat use has not accumulated.

Bridge components located below bat roosts or near guano deposits may show stains created by urine from roosting bats or by water draining across guano piles. However, a variety of other stains (e.g., from bird feces, oil, gas, rust and highway runoff) are also present on bridges, and distinguishing between bat stains and other types of stains can be difficult.

Guano deposits are an easy way to determine if bats are roosting in a bridge. Small guano pellets (3-5 mm in length) may be present anywhere below bat roost crevices and large piles of guano are hard to miss. Individual pellets may be scattered across nearly any portion of a bridge, including vertical surfaces when bats defecate while flying out of a bridge. Bird droppings, which are largely formless masses, are easily distinguished from the pellet-shaped feces of bats. Even in large piles of bat guano, individual pellets are discernable.

Odors from bats or guano may also be present throughout a bat roost bridge. Bat odors are typically very musk-like or may have an ammonia smell, but inexperienced persons may have difficulty distinguishing between bat odors and other bridge odors. Therefore, odor alone should seldom be accepted as conclusive evidence of bat roosts in bridges.

Data on bat roosts in bridges can be provided to regional nongame wildlife biologists at Regional Offices of FWC or to the Terrestrial Mammal Research Program within FWC. A more appropriate and accessible repository for bat roost data might be the bridge inspection database maintained by FDOT. Some FDOT districts currently keep notes on bats in bridges and it may be most efficient to incorporate a field for recording bat evidence into inspection databases statewide. Further discussion is needed to determine the easiest and most reliable method of recording and archiving data on bat roosts in bridges. A database that is readily accessible to FDOT staff would be valuable in determining, for example, which bridges may pose concerns for inspectors due to bats, which bridges should be undisturbed during maternity season, which bridges may have concerns to address during repair, and which bridges should have new roost structures incorporated when they are replaced.

Replacing and Adding Bat Roosts

New or renovated bridges can be constructed with suitable bat roosting crevices in the expansion joints at little cost (Keeley and Tuttle 1999). We recommend that FDOT consider incorporating bat roosts in future bridge design, particularly for bridges over streams. Precast concrete arch bridges offer tremendous opportunities for designing small roosting spaces for bats directly into the edges of the cast concrete spans. Because these bridges usually have a large mass of fill between the arch and the bridge deck, designed roosts would be thermally stable and there would be no problems with drainage into the roost or with expansion joint seals. These bridges are popular because of their low maintenance and aesthetic features, and we recommend that FDOT specify that bat roost crevices be cast into some concrete arch bridges over streams. Regardless of the bridge type, bridges with existing bat roosts should be strongly considered as candidates for having roosts provided when the bridges are replaced or renovated. Appendix 5 provides a list of occupied bat bridges that may be replaced or improved under the FDOT 2025 plan for highway improvements in Florida.

If roosting crevices are not possible in a bridge design, bat roosts or houses can be attached or retrofitted to bridge beams. Bat Conservation International, Austin, Texas, provides a variety of options and designs for constructing new or alternate bat roosts on bridges. The most common of these add-on roosts are simply wooden or composite sheets designed to fit between 2 concrete I-beams (Keeley and Tuttle 1996, 1999). These attached bat roosts could be added to existing bridges to increase the number of roost sites in a local area. Creation of additional roosts on new or existing bridges presents a valuable conservation option, but more information on costs, suitable materials, available bridge sites, and bat use of new roosts is needed before these are routinely installed. We recommend that FDOT identify some suitable bridges and test some add-on roost designs to see if they attract bats in Florida.

Bridges along the Choctawhatchee river drainage basin provide a good example of the importance of considering bat roosts when planning bridge replacements. We found 5 bridges in this area with roosts of southeastern myotis, but 2 of these bridges that cross the Choctawhatchee River (State Road 2 and U.S. Highway 90) have since been demolished and the replacement bridges do not provide suitable crevices for roosting bats. A roost in another Highway 90 bridge over the Choctawhatchee relief was lost a few years earlier to bridge replacement. The impact of the loss of these roost bridges on local populations of the southeastern myotis is unknown, but it may be significant because we know of no other roosts of this species in this area. Providing replacement roosts in the new bridges likely would have provided important conservation benefits to local bat populations without affecting construction costs. We strongly recommend incorporating roosts for southeastern myotis in any new bridges in north Florida and also recommend that some bridges along streams in northwest Florida be retrofitted with roost boxes for southeastern myotis.

Adding roost structures offers advantages beyond just replacing roosts lost to bridges. Designed roost structures (whether integral or add-on) can be placed between bridge beams at any location along the bridge spans, therefore roosts and bats can be located where they least interfere with humans. Bats excluded from other roosts in a bridge would likely occupy newly placed structures instead of returning to expansion joints in the bridge, especially if all joints are filled or screened. In this way, bats could be directed away from expansion joints and other bridge components that require regular maintenance or inspection. Alternative or add-on roosts could also be used to move roosting bats away from areas of the bridge where they might cause conflicts with vehicle traffic or pedestrians.

CONCLUSION

Colonial bats roost in about 5% of 5 common types of highway bridges in Florida. In the 2003 survey, prestressed concrete multibeam (I beam) bridges most often supported bats, but bats also roosted in several other structure types including concrete T beam, concrete slab, and steel multibeam. Regardless of the type of bridge, bats always roosted in the expansion joints between concrete components of the bridge. We found no bats roosting on the metal components of bridges or in bridges made primarily of metal or timber. Bats do not cause damage to the bridge structure, but they can sometimes be a nuisance and, rarely, a health hazard for people working on bridges. Bat roosts should not be disturbed if possible, particularly in the summer months. Consultation with an experienced biologist may be necessary to resolve conflicts between bats and essential FDOT activities. Bridges provide important roost sites for bats and bridges can be designed or retrofitted with roost structures. With sufficient planning, bat roosts can be placed on sections of bridges where they will cause minimal interference with human activities.

Highway bridges will likely continue to be used by roosting bats and some bridges will be important roost sites for local bat populations. We recommend that FDOT routinely monitor bat use of bridges, provide inspection and maintenance staff with protocols for working near bat roosts without disturbing them, and work to design and retrofit bridges with roosting spaces that offer the least conflict between bats and people. With relatively little effort and cost, bridges can provide numerous roosting sites for Florida's native bats while maintaining their vital transportation function.

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Table 1. Number (%) of highway bridges occupied by roosting bats in Florida, 2003.[a]

FDOT District	Random		Nonrandom		Total	
	Surveyed	Occupied	Surveyed	Occupied	Surveyed	Occupied
1	39	5 (12.8)	13	8 (61.5)	52	13
2	40	4 (10.0)	30	25 (83.3)	70	29
3	30	4 (13.3)	75	50 (75.0)	105	54
4	45	0	14	9 (64.3)	59	9
5	46	2 (4.3)	25	24 (96.0)	71	26
6	34	0	4	0	38	0
7	34	0	6	6 (100.0)	40	6
8	31	1 (3.2)	13	13 (100.0)	44	14
Totals	299	16 (5.4)	180	135 (75.0)	479	151

[a]Bridges sorted by randomly and non-randomly selected survey groups.

Table 2. Bat species roosting in highway bridges in Florida, 2003.

		Bridges Occupied[a]		
Common Name	Scientific Name	Random	Nonrandom	Total (%)[b]
Southeastern myotis	*Myotis austroriparius*	0	8	8 (5.3)
Big brown bat	*Eptesicus fuscus*	2	33	35 (23.2)
Evening bat	*Nycticeius humeralis*	2	8	10 (6.6)
Free-tailed bat	*Tadarida brasiliensis*	13	91	104 (68.9)
Undetermined sp.[c]		2	14	16 (10.6)

[a]Number of bridges in randomly and non-randomly selected survey groups.
[b]Percentage of 151 occupied bat bridges where each species roosted. Percentages do not sum to 100 because some bridges supported multiple species.
[c]Bats were not observed closely and species identification was not confirmed. All animals in this category are assumed to belong to 1 of the 4 species listed here. We found no evidence of Rafinesque's big-eared bat in this study, although that species has been found roosting in Florida bridges in the past.

Table 3. Number of highway bridges occupied by roosting bats by species and colony size, in Florida, 2003[a].

	Bat colony size			
Common Name	<25	25-500	>500	Unknown
Southeastern bat	5	2	1	
Big Brown bat	27	5		3
Evening bat	5	3		2
Free-tailed bat	33	51	1	19
Undetermined[b]	20	16	1	
All species	90	77	3	24

[a] Colony size is reported independently for each species at a bridge, regardless of the number of species present.
[b]Bats were not observed closely and species identification was not confirmed. All animals in this category are assumed to belong to 1 of the 4 species listed here. We found no evidence of Rafinesque's big-eared bat in this study, although that species has been found roosting in Florida bridges in the past.

Table 4. Species composition of bat roosts in highway bridges in Florida, 2003.[a]

Roost Composition	Number of Bridges
Single Species	
Big brown bat	7
Free-tailed bat	71
Multiple Species	
Southeastern myotis, big brown bat	2
Big brown bat, free-tailed bat	11
Evening bat, free-tailed bat	6
Free-tailed bat, unidentified sp.	6
Southeastern bat, big brown bat, free-tailed bat	6
Big brown bat, evening bat, free-tailed bat	4
Only unidentified species	38

[a]Species could not be identified at all bridges.

Table 5. Summary of highway bridge structure types occupied by roosting bats in Florida, 2003.[a]

Main Material	Main Design	Random		Nonrandom		Total	
		Surveyed	Occupied	Surveyed	Occupied	Surveyed	Occupied
Prestressed Concrete	Stringer	180	12	121	108	301	120
Prestressed Concrete	Slab	72	3	16	9	88	11
Steel and Stringer	Multi-beam	22	1	4	4	26	5
Concrete	Tee Beam	15	0	5	3	20	3
Prestressed Concrete Continuous	Stringer	10	0	13	2	23	2
Steel Continuous	Girder			3	2	3	2
Steel Continuous	Stringer			2	2	2	2
Concrete	Slab			9	1	9	1
Concrete Continuous	Slab			3	1	3	1
Prestressed Concrete	Box Beam			1	1	1	1
Steel	Movable Bascule			1	1	1	1
Prestressed Concrete	Channel Beam			1	1	1	1
Steel	Truss			1	0	1	0
Totals		299	16	180	135	479	151

[a]Bridges sorted by randomly and non-randomly selected survey groups.

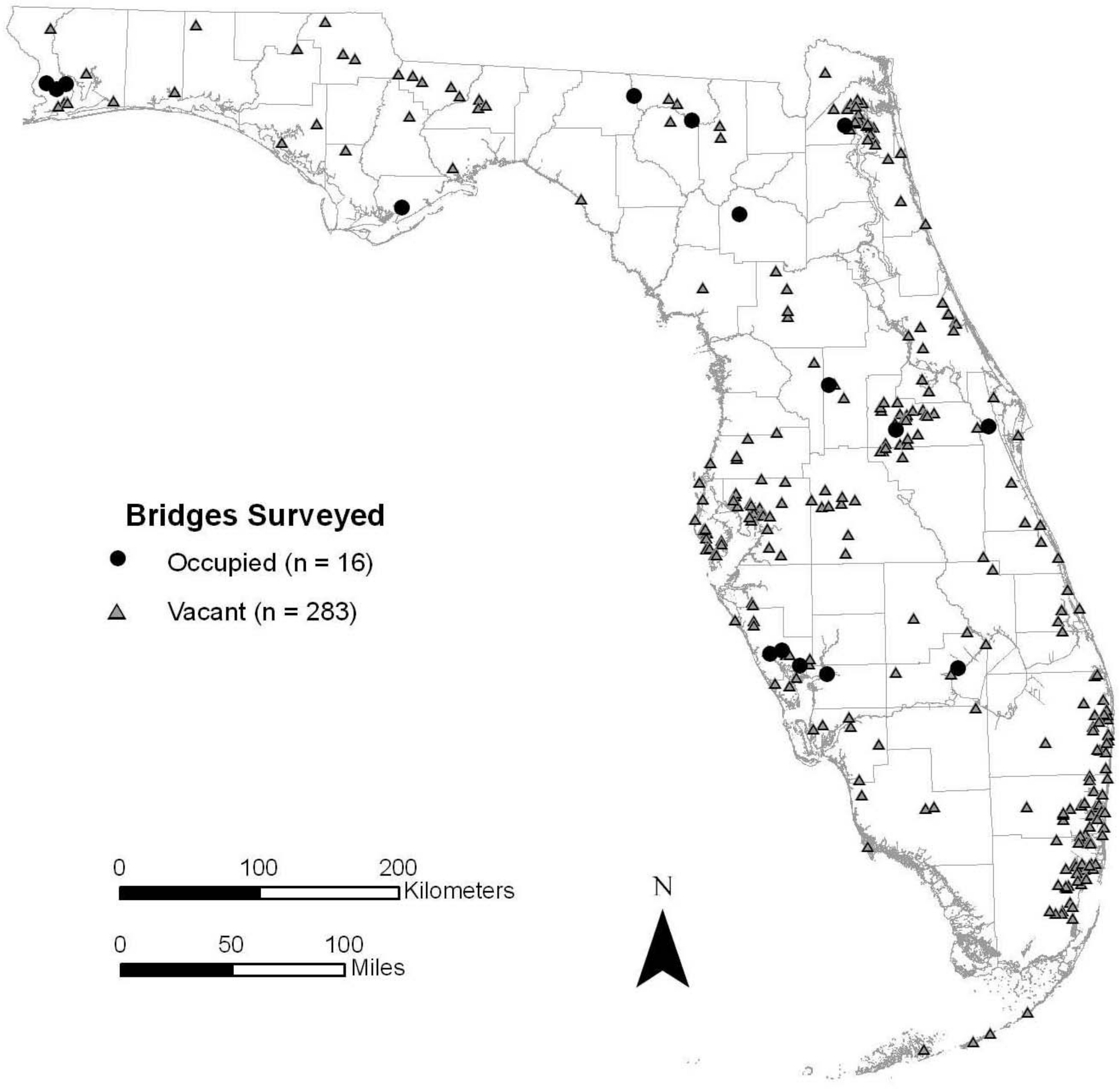

Figure 1. Randomly selected highway bridges surveyed for roosting bats in Florida, 2003.

Figure 2. (A) Prestressed concrete multibeam bridge. (B) Prestressed concrete slab bridge. (C) Steel multibeam bridge. (D) Concrete tee beam bridge. (E) Continuous concrete multibeam bridge.

Figure 3. (A) Bats roosting in crevice formed by joint between 2 concrete slabs in a bridge span. (B) Guano below a bat roost and stains along roost in a concrete slab bridge. (C) Bats flying from expansion joint. (D) Guano and stains on support pier below an expansion joint in a concrete multibeam bridge.

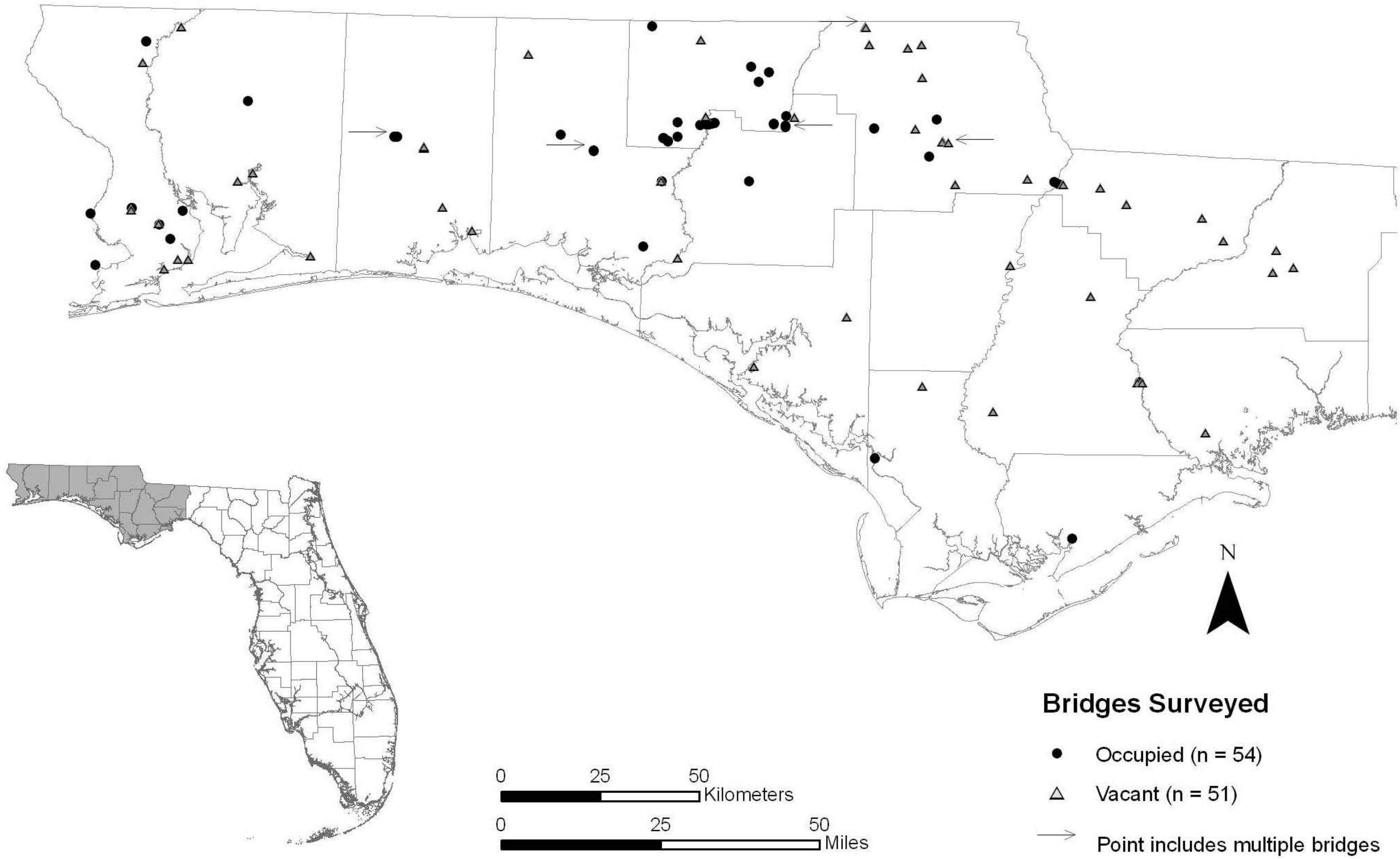

Figure 4. Location of highway bridges in northwest Florida surveyed for roosting bats, 2003.

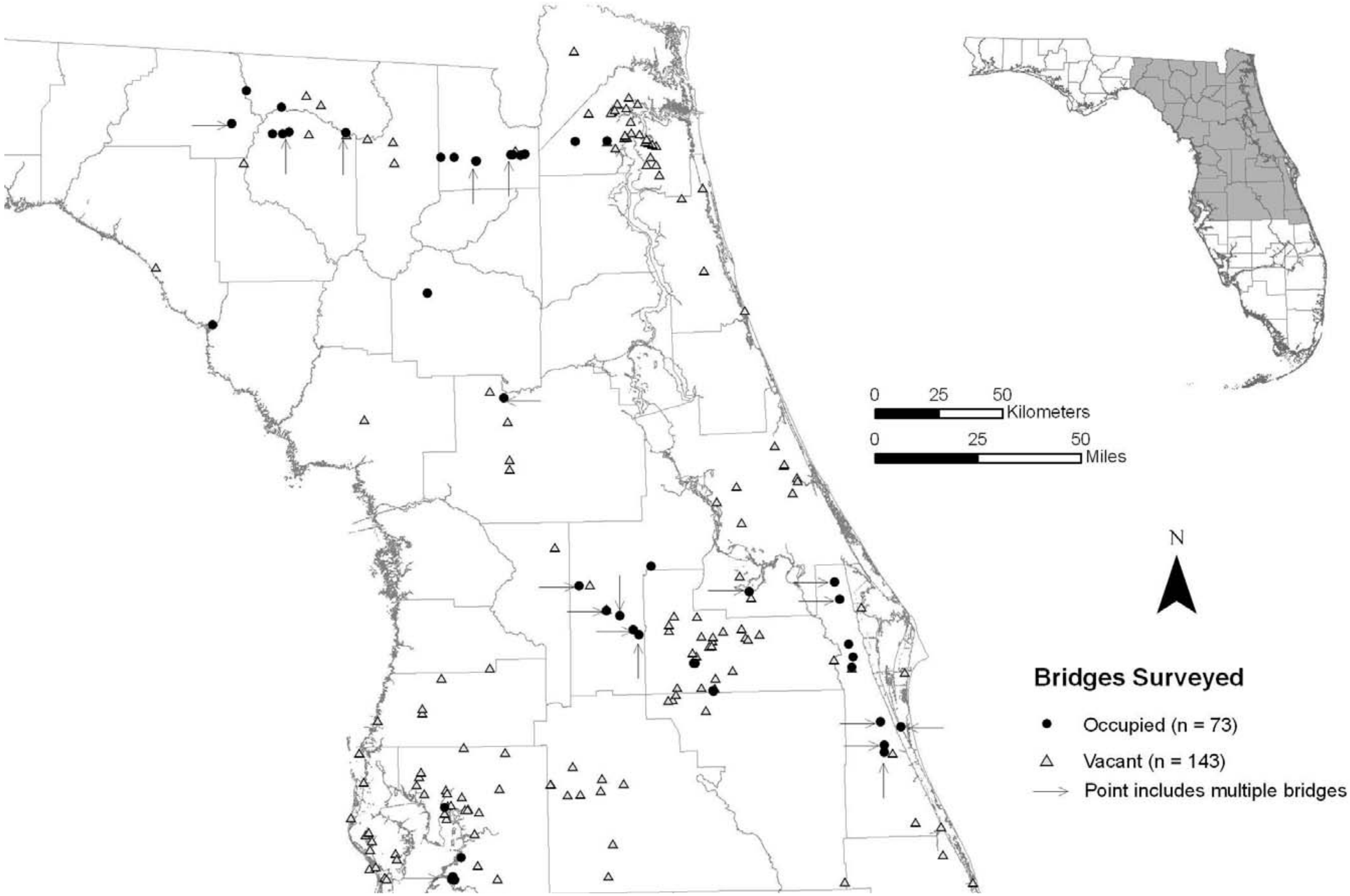

Figure 5. Location of highway bridges in north Florida peninsula surveyed for roosting bats, 2003.

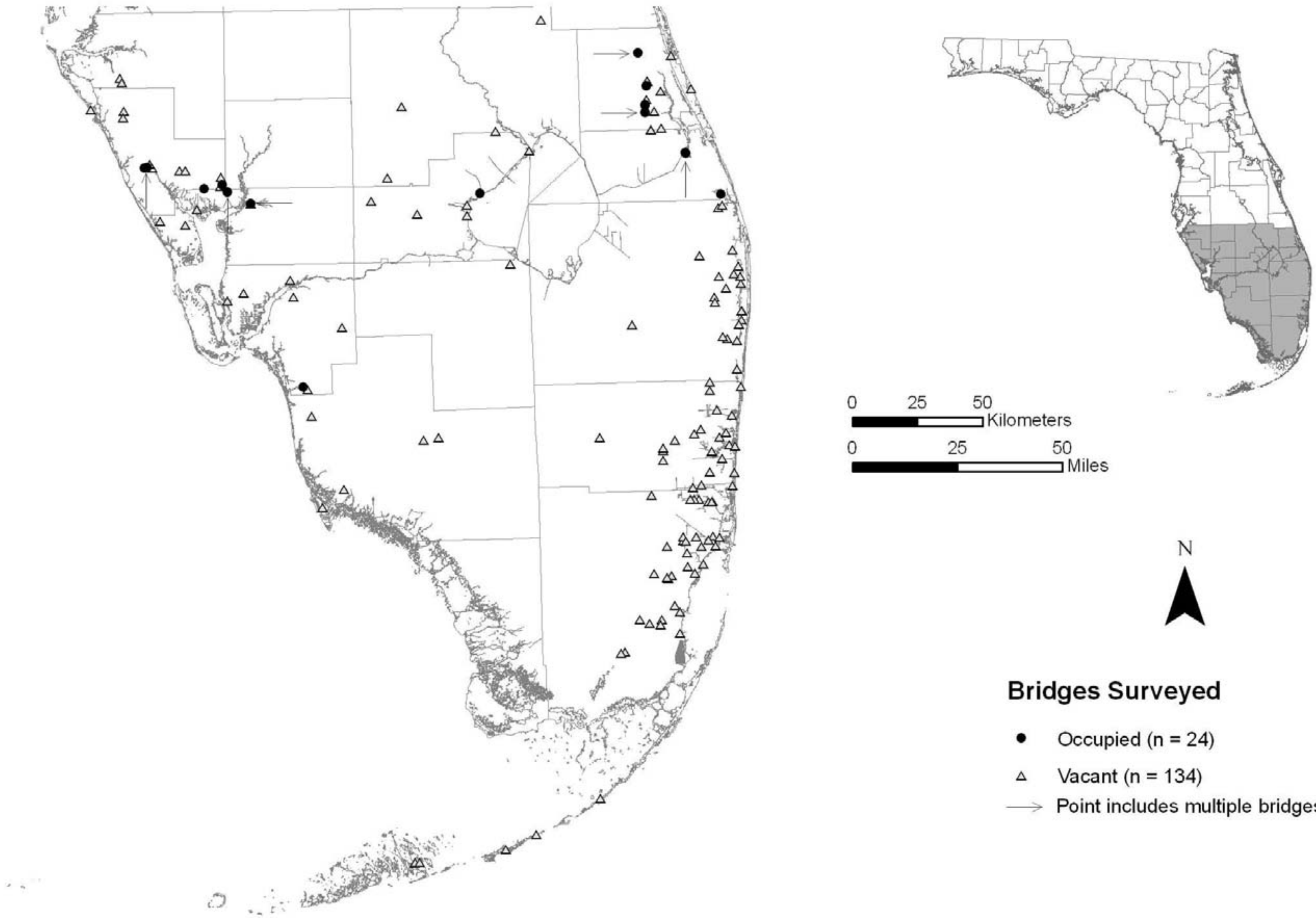

Figure 6. Location of highway bridges in south Florida surveyed for roosting bats, 2003.

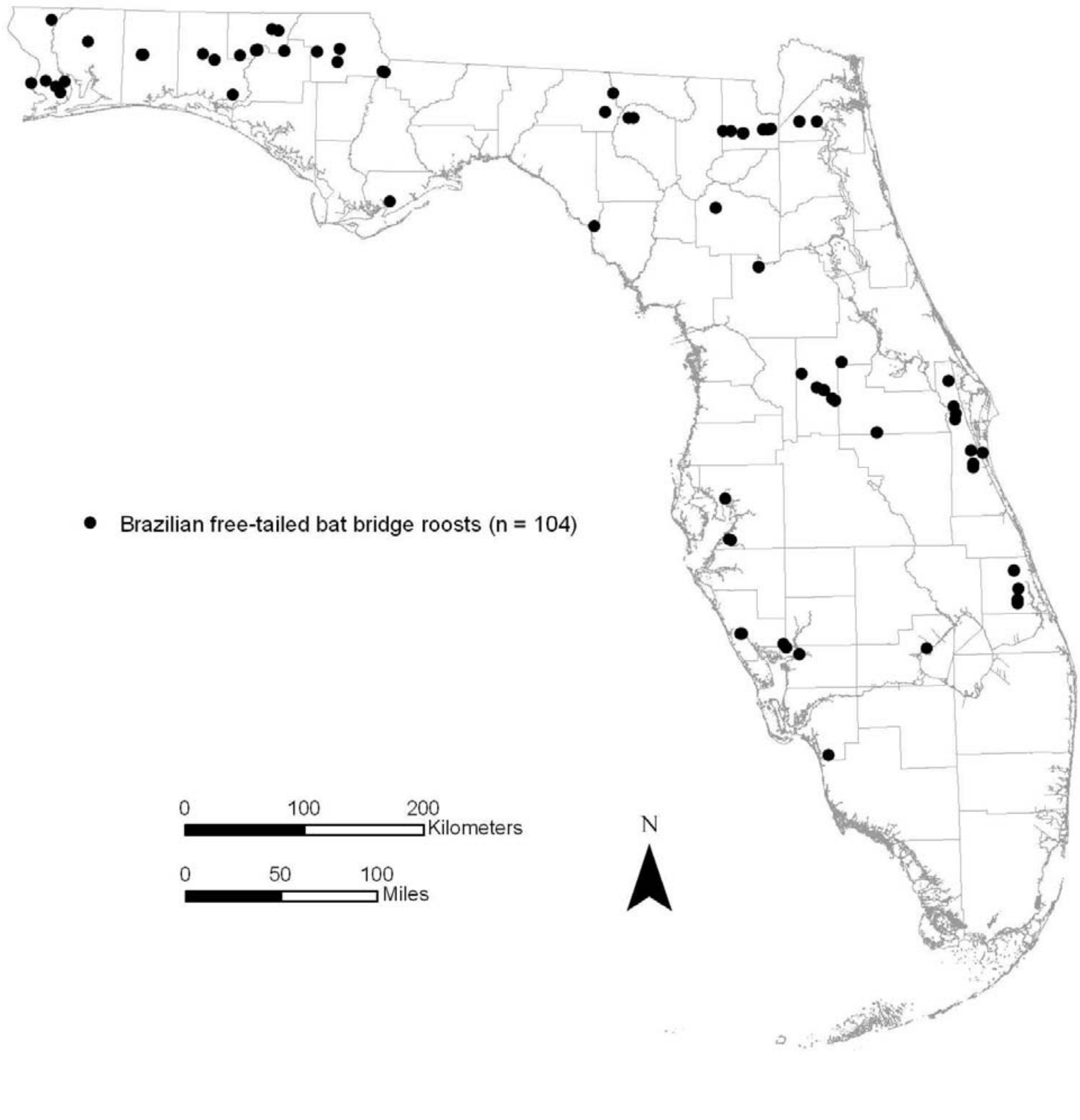

Figure 7. Location (●) of highway bridges (n = 104) used by roosting Brazilian free-tailed bats in Florida, 2003.

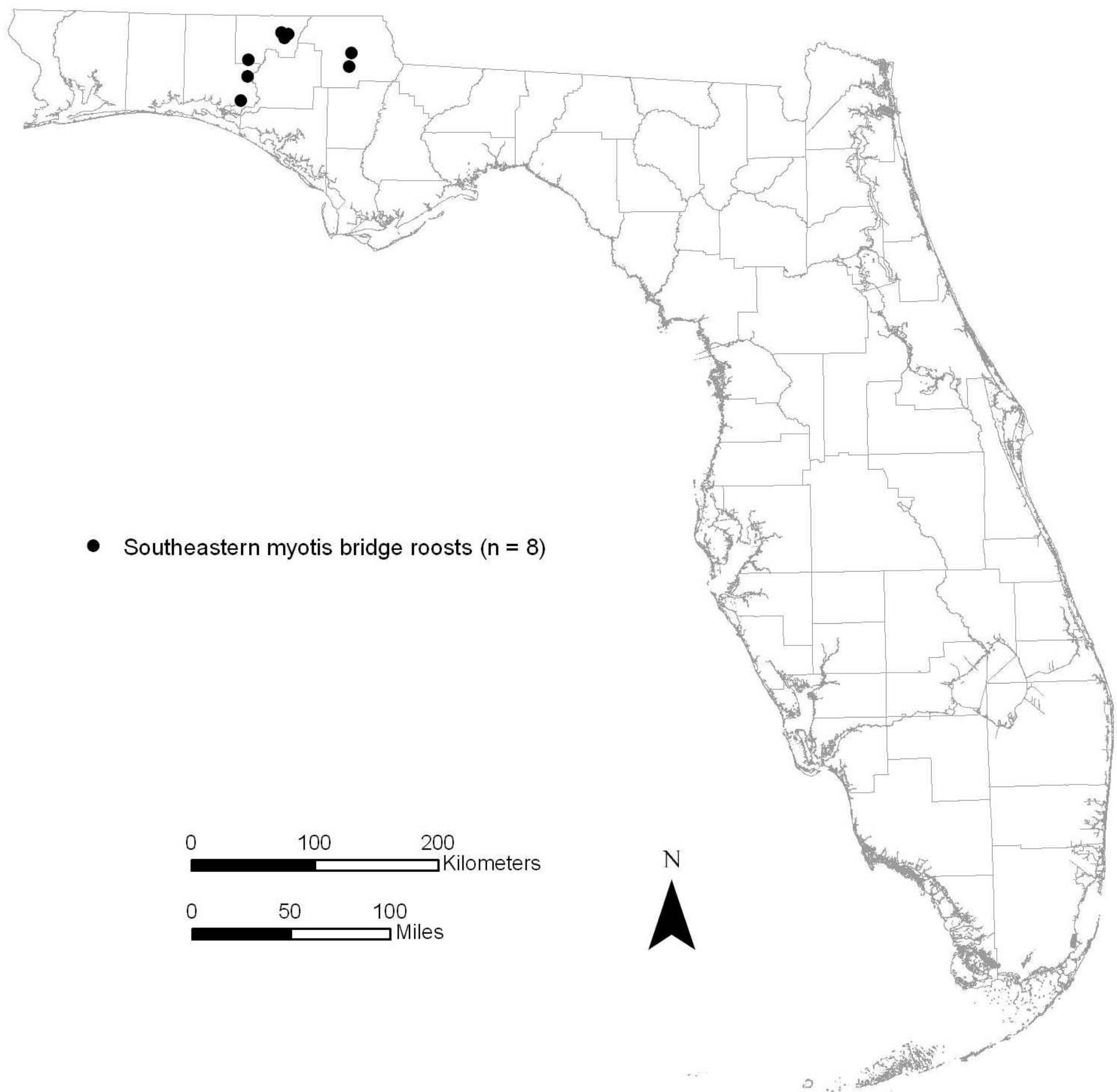

Figure 8. Location (●) of highway bridges (n = 8) used by roosting southeastern myotis in Florida, 2003.

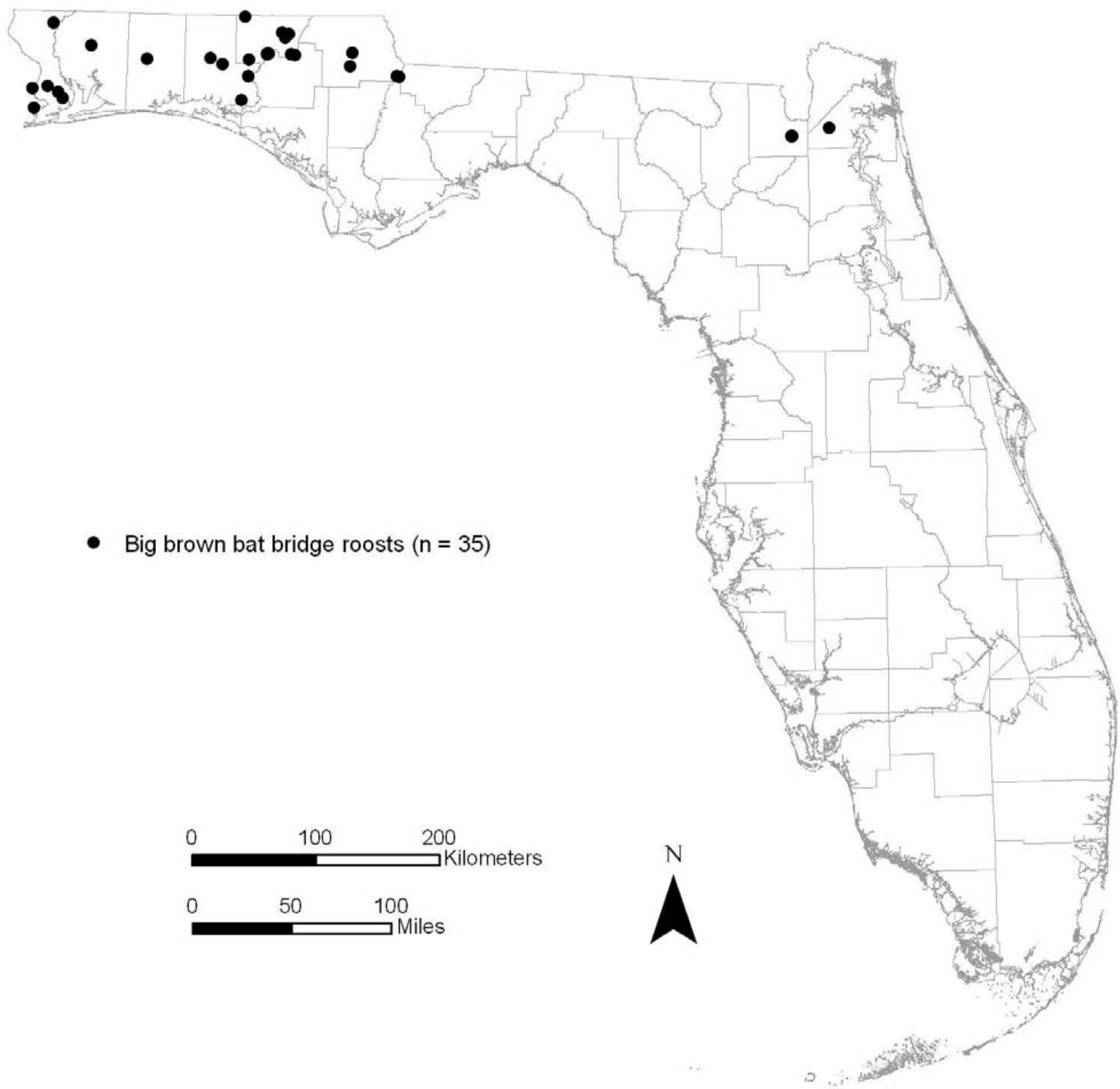

Figure 9. Location (●) of highway bridges (n = 35) used by roosting Big brown bats in Florida, 2003.

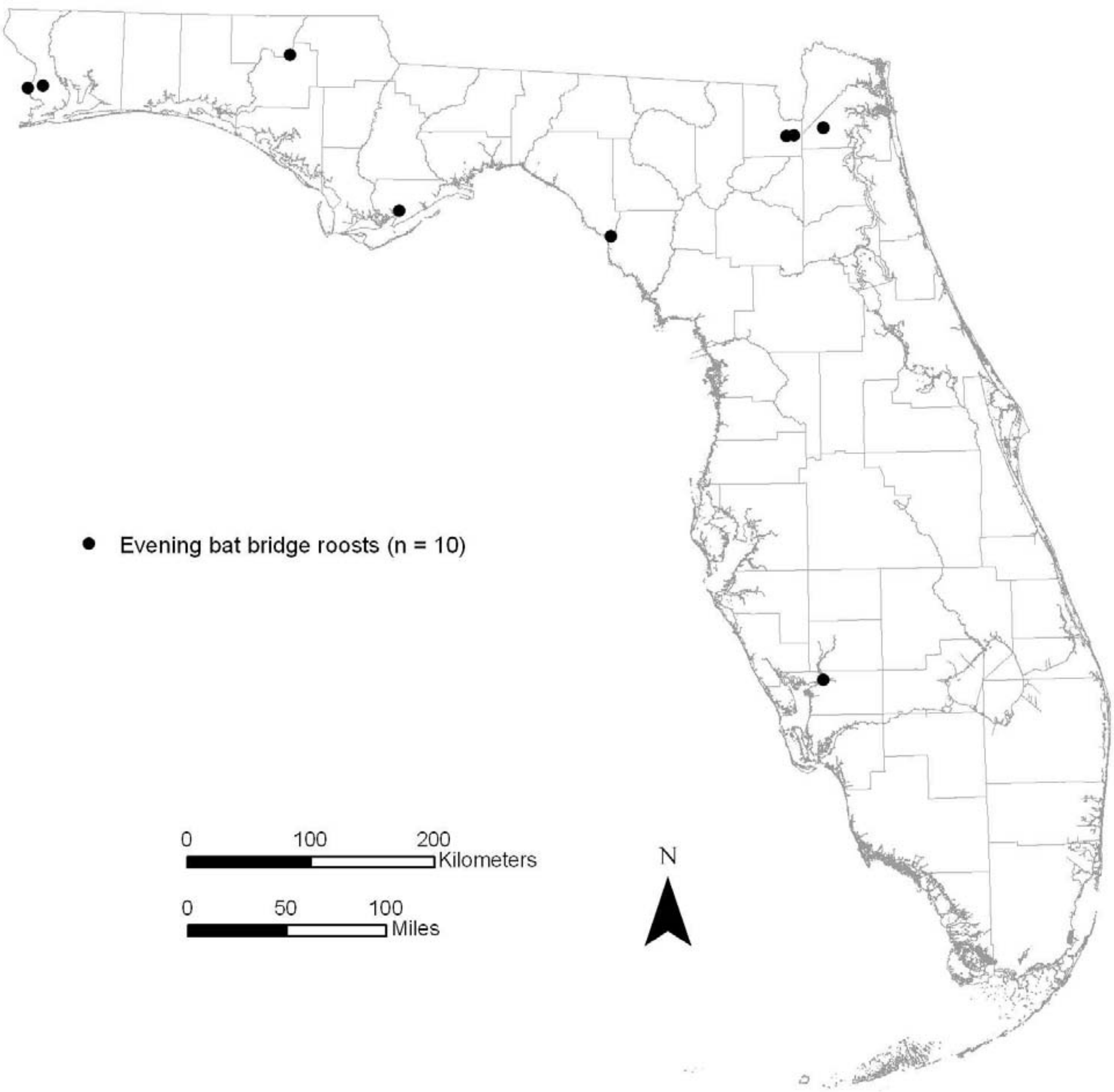

Figure 10. Location (●) of highway bridges (n = 10) used by roosting evening bats in Florida, 2003.

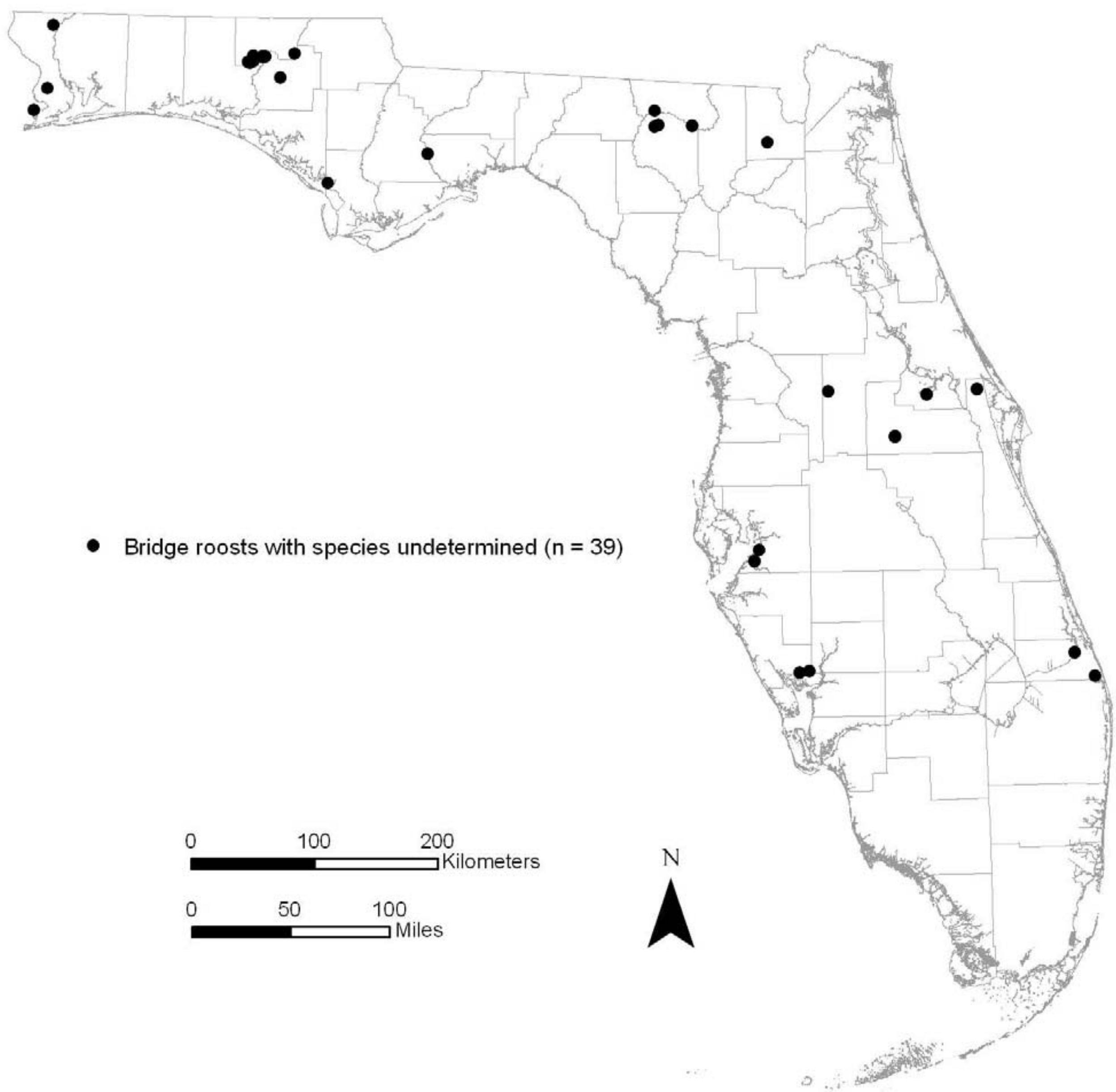

Figure 11. Location (●) of highway bridges (n = 39) where bats were present but species was not determined in Florida, 2003.

Appendix 1. Bridge types and terminology[a].

Major Bridge Components

Most bridges can be divided into three basic parts or components:

Deck
Superstructure
Substructure

Deck: The deck is that component of a bridge to which the live load is directly applied. The purpose of the deck is to provide a smooth and safe riding surface for the traffic utilizing the bridge.

Superstructure: The basic purpose of the superstructure is to carry loads from the deck across the span and to the bridge supports. The superstructure is that component of the bridge which supports the deck or riding surface of the bridge, as well as the loads applied to the deck. The function of the superstructure is to transmit loads. Bridges are named for their type of superstructure.

Substructure: The substructure is that component of a bridge which includes all the elements which support the superstructure. The purpose of the substructure is to transfer the loads from the superstructure to the foundation soil or rock. Substructures are divided into two basic categories:

Abutments
Pier and bents

Abutments provide support for the ends of the superstructure and retain the approach embankment. Piers and bents provide support for the superstructure at intermediate points along the bridge spans with a minimum obstruction to the flow of traffic or water.

Span Classifications

Beams and bridges are classified into three span classifications that are based on the nature of the supports and the interrelationship between spans. These span classifications are:

Simple
Continuous
Cantilever

Simple: A simple span is a span with only two supports, each of which is at or near the end of the span. A simple span bridge can have a single span supported at the ends by two abutments or multiple spans with each span behaving independently of the others.

Continuous: A continuous span is a configuration in which a beam has one or more intermediate supports and the behavior of each individual span is dependent on its adjacent spans. A continuous span bridge is one which is supported at the ends by two abutments and which spans uninterrupted over one or more piers. A continuous span bridge allows longer spans than a bridge consisting of many simple spans.

(continued on next page)

Cantilever: A cantilever span is one with one end restrained against rotation and deflection and the other end completely free. The restrained end is also known as a fixed support. While a cantilever generally does not form an entire bridge, portions of a bridge can behave as a cantilever (e.g., cantilever bridges and bascule bridges).

Concrete Shapes

Cast-in-place Flexural Shapes:
Slabs
Tee Beams
Channel Beams

Slabs: Concrete slabs are used for concrete decks and slab bridges. On concrete decks, the concrete spans the distance between superstructure members. On slab bridges, the slab spans the distance between piers or abutments, forming an integral deck and superstructure.

Tee Beams: Bridge use for tee beams is generally limited to superstructure elements. Distinguished by a "T" shape, tee beams combine the functions of a rectangular beam and slab to form an integral deck and superstructure.

Channel Beams: Channel beams are formed in the shape of a "C" and placed legs down when erected. They function as both superstructure and deck and are typically used for shorter span bridges.

Precast Flexural Shapes:
I-Beams (Multi-beams)
Box Beams
Box Girders

I-Beams: I-beams, distinguished by their "I" shape, function as superstructure members and support the deck. This type of beam can be used for spans as long as 46 m (150 feet).

Box Beams: Box beams are distinguished by a square or rectangular shape. Box beams can be adjacent or spread, and they are typically used for short and medium span bridges.

Box Girders: Box girders, distinguished by their trapezoidal box shapes, function as both deck and superstructure. Box girders are used for long span or curved bridges.

Other Terms:

Bascule: A type of movable bridge.

Prestressed Concrete: Uses high tensile strength steel strands as reinforcement and can be precast at a fabricator's plant using high strength concrete.

(continued on next page)

Stringer: Support components used in steel rigid frame bridges. Stringers are typically rolled sections and are connected to the web of the floor beams.

Truss: A type of beam bridge using steel or timber as superstructure components.

[a]Information in this appendix is from: Bridge Inspectors Reference Manual. Report No. FHWA NHI 03-001. October 2002. Federal Highway Administration. National Highway Institute (HNHI-10). Arlington, Virginia. http://www.nhi.fhwa.dot.gov/crsmaterial.asp?courseno=130055

Appendix 2. Number and species of bats observed roosting at 151 highway bridges in Florida, 2003.

		Initial Record		Species[a]				
FDOT District County	Bridge Number	Source	Year	Southeastern myotis	Big brown bat	Evening bat	Free-tailed bat	Unknown
District 1								
Charlotte	010071	Other	2003				>50	
Charlotte	010072	Other	2003				>25	
Charlotte	010093	FWC-I	2003			P	6	
Charlotte	010094	FWC-R	2003				2	
Glades	050011	FWC-R	2003				1	
Lee	124005	Other	2003				>100	
Sarasota	170091	FWC-I	2003				>30	
Sarasota	170092	FWC-I	2003				>25	
Sarasota	170093	FWC-R	2003				>25	
Sarasota	170094	FWC-R	2003				>25	
Sarasota	170133	FWC-I	2003					U
Sarasota	170134	FWC-I	2003				>25	
Sarasota	175036	FWC-R	2003					U
District 2								
Alachua	260068	FWC-I	2003				>300	
Alachua	260071	FWC-R	2003				>135	
Baker	270016	FWC-I	2003			S	>150	
Baker	270044	FWC-I	2003		2	S	>115	
Baker	270045	FWC-I	2003		1			
Baker	270047	Other	2003		S	S	>200	
Baker	270050	FWC-1995	1993				>96	
Baker	270052	FWC-1995	1995				>36	
Baker	270054	FWC-1995	1995				4	
Baker	270055	FWC-I	2003		>10	S	>100	
Baker	270056	FWC-I	2003			3	P	
Baker	270057	Other	2003		S	>15	>150	
Baker	270059	FWC-1995	1995					U
Baker	270066	FWC-1995	1995				>50	U
Baker	270951	FWC-1995	1995				>25	
Duval	720203	FDOT	2003		>25	>50	>10	
Duval	720260	FWC-R	2003				>100	
Duval	720324	FDOT	2003		>25	>50	>50	
Hamilton	320017	FWC-R	2003				P	U
Hamilton	320052	FDOT	2003					U
Madison	350033	FWC-1995	1995				>50	
Madison	350050	FWC-1995	1995				>51	
Suwannee	370016	FWC-I	2003				>130	
Suwannee	370023	FWC-I	2003					U
Suwannee	370024	FDOT	2003				>200	
Suwannee	370025	FDOT	2003					U
Suwannee	370030	FWC-R	2003					U

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Appendix 2. continued.

FDOT District County	Bridge Number	Initial Record Source	Initial Record Year	Species[a] Southeastern myotis	Big brown bat	Evening bat	Free-tailed bat	Unknown
Suwannee	370031	FDOT	2003					U
Taylor	380087	Other	2003			P	P	
District 3								
Escambia	480001	FWC-1995	1995		2	10	2	
Escambia	480013	FDOT	2003		1		P	
Escambia	480024	FDOT	2003		>167		>3	
Escambia	480065	FWC-R	2003		>10	S	>50	
Escambia	480069	FWC-R	2003		10	>25	P	
Escambia	480070	FWC-I	2003					U
Escambia	480140	FDOT	2003		P			
Escambia	480178	FDOT	2003					U
Escambia	480920	FWC-R	2003				>100	
Franklin	490033	FWC-R	2003			>32	>5	
Gadsden	500086	FWC-I	2003		>13		P	
Gadsden	500087	FWC-I	2003		P		P	
Gulf	510048	FDOT	2003					U
Holmes	520009	FWC-2000	2000					U
Holmes	520047	FWC-2000	2000					U
Holmes	520048	FWC-2000	2000					U
Holmes	520050	FWC-2000	2000					U
Holmes	520055	FWC-2000	2000					U
Holmes	520057	FWC-2000	2000					U
Holmes	520070	FWC-2000	2000					U
Holmes	520072	FWC-1995	1995	>364	40		>481	
Holmes	520073	FWC-2000	2000	50	12		>215	
Holmes	520077	FWC-2000	2000		P			
Holmes	520078	FWC-2000	2000		5			
Holmes	520080	FWC-2000	2000			S	>9	
Holmes	520081	FWC-2000	2000		>5	>6	P	
Holmes	520082	FWC-2000	2000	1	3			
Holmes	520084	FWC-1995	1995		4			
Holmes	520093	FWC-2000	2000	6	8		17	
Jackson	530005	FWC-2000	2000	1	5		2	
Jackson	530068	FWC-I	2003				>10	
Jackson	530069	FWC-I	2003				>75	>5
Jackson	530089	FWC-I	2003	5	2		2	
Liberty	560013	FWC-1995	1995					U
Okaloosa	570049	FDOT	2003		>55		>5	
Okaloosa	570050	FDOT	2003		>12		>25	
Okaloosa	570067	FDOT	2003	S			P	
Okaloosa	570951	FWC-I	2003	S			P	

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Appendix 2. continued.

		Initial Record		Species[a]				
FDOT District County	Bridge Number	Source	Year	Southeastern myotis	Big brown bat	Evening bat	Free-tailed bat	Unknown
Santa Rosa	580086	FDOT	2003		>5		P	
Walton	600005	FWC-1995	1995		>20		>20	
Walton	600057	FWC-1995	1995		>20		>25	
Walton	600073	FWC-I	2003		>5		>50	
Walton	600098	FWC-2000	2000	585	18		>1115	
Walton	600102	FWC-2000	2000	1	4			
Washington	610001	FWC-2000	2000					U
Washington	610008	FWC-2000	2000					4
Washington	610042	FWC-2000	2000		3			
Washington	610045	FWC-2000	2000		7		>35	
Washington	610047	FWC-2000	2000				2	
Washington	610049	FWC-2000	2000					U
Washington	610050	FWC-2000	2000		3		>25	
Washington	610062	FWC-2000	2000				>56	
Washington	610063	FWC-2000	2000				>5	
Washington	610951	FWC-2000	2000		1			
District 4								
Martin	890132	FDOT	2003					U
Martin	890133	FDOT	2003					U
Martin	894019	FWC-1995	1995					U
St. Lucie	940057	FDOT	2003				28	
St. Lucie	940073	FWC-I	2003				P	
St. Lucie	940108	FWC-1995	1995				>400	
St. Lucie	940109	FWC-1995	1995				>300	
St. Lucie	940113	FWC-1995	1995				P	
St. Lucie	940114	FWC-1995	1995				P	
St. Lucie	940115	FWC-1995	1995				>3	
St. Lucie	940116	FWC-1995	1995				P	
District 5								
Brevard	700043	FDOT	2003				>6	
Brevard	700047	FDOT	2003				>3	
Brevard	700060	FDOT	2003				>10	
Brevard	700066	FDOT	2003					U
Brevard	700079	FDOT	2003				P	
Brevard	700091	FDOT	2003				>15	
Brevard	700122	FDOT	2003				P	
Brevard	700123	FDOT	2003				>15	
Brevard	700124	FDOT	2003				>5	
Brevard	700136	FWC-I	2003				>3	
Brevard	700138	FDOT	2003					U
Brevard	700145	FDOT	2003				P	
Brevard	700151	FWC-I	2003				>10	2

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Appendix 2. continued.

FDOT District	Bridge	Initial Record		Species[a]				
County	Number	Source	Year	Southeastern myotis	Big brown bat	Evening bat	Free-tailed bat	Unknown
Brevard	700941	FDOT	2003				P	
Brevard	704161	FWC-R	2003				>10	
Lake	110016	FWC-I	2003					U
Lake	110017	FDOT	2003				>10	
Lake	110029	FWC-R	2003				>10	
Lake	110030	FDOT	2003				>75	
Lake	110032	FWC-1995	1995				>126	
Lake	110033	FDOT	2003				>200	
Lake	110037	FWC-1995	1995				>50	
Lake	110038	FDOT	2003				>175	
Lake	110064	FDOT	2003				3	2
Lake	110066	FWC-1995	1995				>125	
Lake	110070	FWC-I	2003				>30	
Lake	110920	FWC-I	2003				>151	
Marion	360910	FDOT	2003				>26	
Marion	360941	FDOT	2003				>50	
Orange	750043	FWC-1995	1995					U
Orange	750044	FWC-1995	1995					U
Orange	750045	FWC-I	2003					U
Orange	750060	FDOT	2003				4	
Orange	750143	FWC-R	2003					U
Orange	750144	FWC-1995	1995					U
Orange	750262	FDOT	2003				2	
Seminole	770054	FDOT	2003					U
Seminole	770055	FDOT	2003					U
District 7								
Hillsborough	100039	FWC-1995	1995				>100	
Hillsborough	100104	FWC-1995	1995				1	
Hillsborough	100105	FWC-1995	1995					U
Hillsborough	100940	FWC-1995	1995					U
Hillsborough	104322	FWC-1995	1995					U
Hillsborough	105503	FWC-1995	1995				>26	

P = species present, but no estimate made of number of individuals. S = species strongly suspected, but bats not seen U = bats present, but species and number of individuals could not be determined.

Appendix 3. Guidelines for FDOT field staff working near bat roosts in highway bridges.

- Like all mammals, bats are susceptible to rabies, and rabies is the primary health and safety concern for humans working near bat roosts. Not all bats have rabies; in fact, only a very small percentage does. Although the risk of contracting rabies from a bat is small, rabies is a fatal disease and deserves serious attention.

- Never handle an injured or downed bat. If bitten, or even possibly bitten, by a bat, thoroughly wash the affected area and promptly seek professional medical help. A bat bite does not require the same immediate and urgent response as, for example, the bite from a venomous snake. However, it is critical that any bat bite be reported to a physician and evaluated as soon as practical.

- Downed and severely injured bats found at a bridge can be humanely killed if they are likely to come into contact with humans. Dead bats should be removed (do not handle with bare hands) and buried away from human activity.

- Do not prod, hit, capture or otherwise disturb roosting or flying bats. The chances of being bitten by a roosting or flying bat are very slim. On the other hand, the chances are fairly good of being bitten when disturbing or handling a bat. As with any wild animal, leave them alone and they are likely to leave you alone.

- Histoplasmosis is an infection of the respiratory tract caused by a fungus that sometimes grows in bat or bird feces. Piles of bat droppings (guano) should be left undisturbed whenever possible so that spores of the fungus are not transmitted into the air. If guano must be removed, workers should wear masks capable of filtering fungal spores. Workers should be especially cautious when disturbing guano piles situated at head level, such as on ledges, or in enclosed spaces, such as box culverts.

- Additional information on rabies and histoplasmosis is available from the federal Centers for Disease Control (www.cdc.gov) or the nearest county health department. Both sources can provide information on these two health issues, and on concerns and protocols regarding rabies vaccinations. Pre-exposure vaccinations are available for humans, but the associated costs and risks are usually not warranted except for persons who regularly handle wild animals.

DISCLAIMER: These guidelines represent practical advice for avoiding health threats posed by bats at highway bridges. They are not medical instructions and are always secondary to any instructions or guidance provided by a physician or other medical professional.

Appendix 4. Guidelines for managing bat roosts in highway bridges in Florida.

Detecting bats

Bats typically roost in the crevices formed by the expansion joints in bridge decks and superstructure components. Bats are obvious when visible, but they are often out of sight within the roost crevice. Even when no bats are seen, other evidence can be used to determine whether bats have been roosting at a bridge. For example, urine and body oils from roosting bats will, over time, leave dark colored stains on the concrete near the roost. Stains indicate use at some time, but they do not confirm current use by bats. Water draining from the bridge deck can also cause dark stains that may be difficult to distinguish from bat stains. Presence of bat guano (or feces) also confirms use of a site by roosting bats. Guano pellets are about the size of grains of rice and are typically deposited in piles below the roost. Bats also defecate as they fly into and out of the roost and pellets are often lightly scattered on the vertical walls of beams near the roost. Recently deposited pellets are soft, dark, and moist, while older pellets are hard, light, and dry. Some bats, particularly Brazilian free-tailed bats, have a strong musky odor that is noticeable at bridge roosts. However, if the bats can be smelled, other evidence of their presence is also usually obvious. Finally, although bats navigate with ultrasonic calls, they make social calls that are audible to humans. These high-pitched chirps may be made in the roost throughout the day and they often can be used to confirm the presence of bats. When bats are detected at a bridge, that information should be recorded in a formal location such as the files maintained by FDOT bridge inspectors.

Avoiding bats and minimizing disturbance

Whenever possible workers should avoid working near roosting bats. This minimizes disturbance to the bats and prevents anyone from being accidentally bitten by defensive animals. No one should touch or capture bats or prod them in the roost or on the ground. Workers should not shine lights directly at roosting bats unless trying to temporarily move the bats from a precise location. For example, if roosting bats are covering a critical spot that needs inspection or maintenance and the bats have room to move, shining a bright light at the bats may temporarily force them further into the roost. Lights should not be used to routinely harass bats or unnecessarily force them from their roost. Bats roosting in bridges are often subject to high noise and vibration and are not likely to be as disturbed by those conditions as are, for example, bats that roost in caves or hollow trees.

Maintenance and construction activities

In some instances construction or maintenance activities cannot be avoided at a bat roost. In these instance bats need to be excluded from the roost. Exclusion involves closing off portions of the expansion joint (crevice) where the bats are roosting in order to funnel them out one exit path. That exit is then draped with loose screen or plastic sheeting which is open at the bottom. The bats are able to exit from the roost but they are not able to return because the draped sheet blocks the entrance and they can't find the bottom opening. More information on excluding bats from a roost is available from the website of Bat Conservation International (www.batcon.org) and from regional offices of FWC in Panama City, Lake City, Ocala, Lakeland, and West Palm Beach. The regional offices may also be able to provide names of companies that have conducted successful bat exclusions in the region. Another valuable resource for guidance on bat exclusions is the non-profit Florida Bat Center (www.floridabats.org). Because of the many open expansion joints in some bridges, excluding bats from the entire bridge may require extensive effort.

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If bats only need to be moved from a small section of bridge, an exclusion may be simple and effective. However, exclusions should be avoided from April 15 through August 15 when young flightless bats may be in the roosts. These pups do not leave the roost at night and would not be excluded as described above. Furthermore, the adults would be more persistent in returning to a roost where they had left young. For these reasons it is important that FDOT identify bridges occupied by bats and schedule work or exclusions accordingly whenever possible. If a roosting colony has no young or pregnant females, a summer exclusion could be successfully accomplished without significant harm to the bats. However, confirming that a bridge is not occupied by young bats or pregnant females usually requires an experienced bat biologist to capture a number of bats and verify their age and reproductive status.

As noted above, if the work area occupied by bats is very small and the work will be quick, shining a light toward the bats may make them retreat far enough to complete the necessary work. Mesh screen, such as silt fencing, or compression seals, as used for covering expansion joints, may be placed to keep bats from returning to the part of the bridge from which they are excluded. It is important that bats moved in this manner have an alternate exit and not be trapped in the roost. Sometimes, particularly in urban or high traffic areas, work on highways is scheduled for night. This is convenient because all the bats leave before work commences and bats are not likely to return to the same roosting spot if it is brightly lighted. When cleaning bridge surfaces by pressure washing, it is important not to spray directly into the roost or on any bats. Ideally, intensive cleaning would be scheduled outside the April 15 to August 15 maternity season. Even outside that period, the interior surfaces of expansion joints should never be pressure-washed when bats are present.

Flagrant destruction of roosting bats and poisoning bats may be considered illegal according to FWC rules as listed in Chapter 68A-4.001, Section 1, Florida Administrative Code. Legal and conservation considerations aside, trying to destroy bats is not advised because of the negative public relations that can result and, more important, because it poses a safety hazard. Attempts to destroy a colony invariably leave some animals injured and these downed animals may well bite someone who tries to pick them up. This creates a health hazard as well as a potential legal liability. Another reason for not destroying bats is that many animals will likely die within the roost and create extremely unpleasant and unsanitary conditions as they decay.

Replacement Bat Roosts

New or replacement bridges can be constructed with suitable bat roosting crevices designed in the expansion joints at little cost. If roosting crevices are not possible in a bridge design, bat roosts or houses attached to bridge beams should be considered. Bat Conservation International (www.batcon.org) provides a variety of options and designs for constructing new or alternate bat roosts on bridges. Bat roost structures could also be added to existing bridges to increase the number of roost sites in a local area. Creation of additional roosts on new or existing bridges presents a valuable conservation option, but they have not been tried in Florida. Designs are simple and could be tested on individual bridges at little cost.

Appendix 5. Highway bridges in Florida that are occupied by roosting bats and may be affected by highway improvements according to the FDOT 2025 Cost Feasible Plan.

FDOT District County	Bridge Number	Facility	Feature	Proposed Years of Improvement
District 1				
Charlotte	010071	I-75 SB (SR 93)	Kings Highway	2016-2020
Charlotte	010072	I-75 NB (SR 93)	Kings Highway	2016-2020
Sarasota	170093	I-75 SB (SR 93)	North Havana Rd.	2008-2013
Sarasota	170094	I-75 NB (SR 93)	North Havana Rd.	2008-2013
Sarasota	170091	I-75 SB (SR 93)	North Jackson Rd.	2008-2013
Sarasota	170092	I-75 NB (SR 93)	North Jackson Rd.	2008-2013
Sarasota	170133	I-75 SB	Yorkshire St.	2016-2020
Sarasota	170134	I-75 NB	Yorkshire St.	2016-2020
District 2				
Baker	270044	I-10 WB (SR 8)	CR-125	2021-2025
Baker	270055	I-10 EB (SR 8)	CR-125	2021-2025
Baker	270016	SR-121	I-10 (SR 8)	2021-2025
Baker	270045	I-10 WB (SR 8)	Little St. Mary River	2021-2025
Baker	270056	I-10 EB (SR 8)	Little St. Mary River	2021-2025
Baker	270047	I-10 WB (SR 8)	SR-228	2021-2025
Baker	270057	I-10 EB (SR 8)	SR-228	2021-2025
Duval	720203	I-10 WB (SR 8)	CSXRR (abandoned)	2016-2020
Duval	720324	I-10 EB (SR 8)	CSXRR (abandoned)	2016-2020
District 3				
Escambia	480065	I-10 (SR 8)	I-10 SR8/US29 SR95	2021-2025
Escambia	480920	US 90A SR 10	US90A SR10/SR291 Davis	2016-2020
District 4				
Martin	890132	I-95 SB (SR 9)	St. Lucie Canal	2021-2025
Martin	890133	I-95 NB (SR 9)	St. Lucie Canal	2021-2025
St. Lucie	940115	I-95 SB (SR 9)	CR 709 & FECRR	2021-2025
St. Lucie	940116	I-95 NB (SR 9)	CR 709 & FECRR	2021-2025
District 5				
Brevard	700066	I-95	Aurantia Rd.	2014-2015
Brevard	700138	I-95	Aurantia Rd.	2014-2015
Brevard	700091	SR 407	I-95	2003-2008
Brevard	704161	Fay Blvd	I-95	2003-2008
Brevard	700123	I-95	Lake Washington Rd.	2003-2008
Brevard	700043	I-95	Lake Washington Rd.	2003-2008
Brevard	700060	I-95	SR 46	2014-2015
Brevard	700136	I-95	SR 46	2014-2015
Brevard	700122	I-95	SR 518	2003-2008
Brevard	700941	I-95	SR 518	2003-2008
Brevard	700047	I-95	Wickham Rd.	2003-2008
Brevard	700124	I-95	Wickham Rd.	2003-2008
Lake	110017	US 27	SR 19	2021-2025
Lake	110064	US 27	SR 19	2021-2025
Orange	750043	SR 482	SR 435	2016-2020

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Appendix 5. continued.

FDOT District County	Bridge Number	Facility	Feature	Proposed Years of Improvement
Orange	750044	SR 482	SR 435	2016-2020
Orange	750045	Ramp from SR 482	SR 435	2016-2020
Orange	750143	SR 482	SR 435	2016-2020
Orange	750144	SR 482	SR 435	2016-2020