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A REVIEW OF PIPE AND BAMBOO ARTIFICIAL REFUGIA AS SAMPLING TOOLS IN ANURAN STUDIES

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***Abstract*.—Artificial pipe-like refugia have been used for more than 40 years in anuran studies, and have captured 28 species, primarily (82%) hylid treefrogs. Early pipe-like refugia were made using cut pieces of bamboo in the tropical forests of Puerto Rico, but most recent studies have used synthetic pipes and have occurred primarily in the southeastern United States. Characteristics of artificial refugia (e.g., color, length, and diameter), and their placement in the environment have varied greatly among studies, making comparisons difficult. Here, we summarize and evaluate different pipe designs and placement, address potential concerns when using artificial pipe-like refugia, and suggest studies necessary to better interpret the data gained from this technique in anuran studies.**

Key Words.—bamboo trap; Hylidae; methodology; PVC pipe trap; sampling technique; treefrog

INTRODUCTION

The need to capture a sufficient and representative sample of a target population has long been a primary consideration in organismal field studies. The diverse behaviors and life histories of anurans have given rise to a diverse array of capture techniques for sampling frogs and toads, including visual encounter surveys, acoustic detection of calling males, coverboards, pitfall traps, funnel traps, and dipnet or minnow traps for tadpoles (Dodd 2010). Some of these techniques are efficient at detecting or capturing certain species by capitalizing on specific life history traits, such as vocalizations to attract mates (acoustic detection), migratory behavior to breeding ponds (pitfall traps), or fossorial lifestyles (coverboards). Another anuran sampling method, the bamboo or pipe trap, takes advantage of the need of arboreal frogs to find refuge from weather extremes and predators.

Artificial refugia created by pipe traps capture treefrogs and other agile climbers often underrepresented in samples using other methods. For example, treefrogs readily climb out of pitfall traps and over drift fences, and they escape detection in visual encounter surveys because of their habitats and cryptic coloration (Dodd 1991; Moulton 1996). Pipe traps may attract frogs by augmenting a limited number of natural refuge sites (Stewart and Pough 1983) or by providing a favorable thermal and hydric environment (Donnelly et al. 2001).

Although artificial refugia are known to attract frogs and render them easy to capture, there are many unresolved questions pertaining to the methodology. For the capture data to be useful for frog population monitoring, the sampling biases of pipe traps need to be understood. Several studies have shown that materials used and trap placement can affect frog use (e.g., Boughton et al. 2000; Bartareau 2004), and that the success of pipe traps can vary seasonally (e.g., Donnelly et al. 2001, Zacharow et al. 2003). Other factors, such as inter- and intraspecific interactions may also affect trap success (e.g., Hoffman et al. 2009; Campbell et al. 2010). In all cases, inferences from a refugia study rely upon assumptions about the degree to which the frogs captured are representative of the total population of interest.

Recent treatment of pipe sampling in technique-oriented publications has been informative but brief (Willson and Gibbons 2010; Tuberville 2013). Here, we review the literature on the use of pipes as a capture technique in anuran studies, focusing on the history of the technique, the various methodologies employed, the types of studies for which it has been used, the limitations and concerns of its use, and future research needs. We conducted a literature review of the subject, focusing largely on primary peer-reviewed literature, two important early references (Goin 1955; Drewry 1970), and several unpublished master's theses and doctoral dissertations. Although there is a fair amount of gray literature on the subject, these sources were not included in this review paper.

HISTORY OF THE USE OF ARTIFICIAL REFUGIA

Goin (1955) was the first to describe artificial refugia as a means to study anurans in the wild. She used inverted, empty tin cans on top of a row of six stakes about four feet high in a backyard in Gainesville, Florida, USA, to study *Hyla squirella* and *H. cinerea*

(Goin and Goin 1957; Goin 1958). In addition to using tin cans, both species also used the cavity of a 2.54 cm (1 in) diameter iron pipe lying on the ground "with one end angled upward to a height of about 15 inches (38.1 cm)" as a retreat site. More than a decade later, Drewry (1970) used bamboo nodes, cut to be closed at both ends with a notched doorway at the bottom end, attached to scaffold tower legs in a Puerto Rican rain forest to capture *Eleutherodactylus coqui* and *E. hedricki*. Another decade passed before McComb and Noble (1981) used wooden nest boxes hung six m high in trees to specifically target amphibians and reptiles in Louisiana and Mississippi. The success of the technique for anurans was low, as only 3.4% of inspections yielded captures, but three treefrog species were captured (*H. cinerea*, *H. squirella*, and *H. chrysoscelis*). In the 1980s and early 1990s many studies used bamboo nodes similar to those of Drewry (1970) to study *Eleutherodactylus* in Puerto Rican rain forests (Stewart and Pough 1983; Stewart 1985; Townsend 1989; Woolbright 1989; Stewart and Rand 1991). Buchanan (1988) tied small pieces of PVC pipes to the petioles of palmettos in a Louisiana forest and, to our knowledge, was the first to use polyvinyl chloride (PVC) pipes as artificial refugia for anurans. Based on the literature, PVC pipes became a more common sampling technique in the southeastern United States during the late 1990s and early 2000s, following work in the southeastern United States leading to three M.S. theses (Phelps 1993; O'Neill 1995; Boughton 1997), one Ph.D. dissertation and associated techniques paper (Moulton 1996; Moulton et al. 1996), and a detailed study of the technique (Boughton et al. 2000).

CHARACTERISTICS OF ARTIFICIAL REFUGIA

Material.—Besides the inverted tin cans used by Goin (1955), Goin and Goin (1957), and Goin (1958), and the wooden nest boxes used by McComb and Noble (1981), early work on artificial refugia used bamboo to supplement natural retreats in Puerto Rican forests (Table 1). More recently, synthetic pipe, including PVC and acrylonitrile butadiene styrene (ABS), has been used extensively, particularly in the United States (Table 1).

Color.—Early studies, the inverted tin cans of Goin (1955), Goin and Goin (1957), and Goin (1958) excepted, used natural materials, such as bamboo or wood, to provide inconspicuous artificial refugia (e.g., Drewry 1970; McComb and Noble 1981; Stewart and Pough 1983). Polyvinyl chloride pipes used in artificial refugia studies were often standard white in color (but see Hirai [2006] and Leach [2011] who used gray PVC pipes). Lohoefner and Wolfe (1984) used both black and white short 20-cm sections of 1.9-cm inner diameter (ID) PVC pipes laid flush with the ground. These pipes punctured a drift fence, so that animals, particularly lizards and snakes, traveling along the fence would enter the pipe and fall into a screen mesh trap. Though not directly comparable to vertical PVC pipes in the ground or those hung in a tree, Lohoefner and Wolfe (1984) found the black pipe to be superior to white pipe at capturing animals, and hypothesized that black pipe more closely simulated an 'earthen hole.' Likewise, Johnson (2005a) stated that the black ABS pipe he used provided more realistic dark refugia and other possible advantages, including warmer internal temperatures and greater camouflage from predators. However, Ferreira et al. (2012) tested three colors of pipe (white, gray, and black) and found that pipe color did not significantly affect occupancy rates of treefrogs in the Amazonia/Cerrado ecotone of Brazil.

Diameter.—Several investigations have examined the effect pipe diameter has on treefrog capture (e.g., Phelps and Lancia 1995; Boughton et al. 2000; Zacharow et al. 2003; Bartareau 2004; Hirai 2006; Piacenza 2008; Leach 2011). Phelps and Lancia (1995) used 2.5-cm and 5-cm ID, 1.5-m sections of PVC pipe driven into the ground in South Carolina and found that *H. cinerea* was caught significantly more often in 2.5-cm pipes in their control (uncut) forest than in their clearcut area, whereas *H. cinerea* was caught significantly more often in 5-cm pipes in the clearcut, indicating a variability in preference dependent on habitat. There was no significant preference by *H. chrysoscelis* for pipe ID, though captures were few.

Boughton et al. (2000), in Florida, hung four 60-cm sections of PVC pipe (three of 3.81-cm ID, one of 1.75-cm ID) vertically on each of 24 trees. Due to pipe modifications on two of the 3.81-cm ID pipes (one pipe was capped on top, and another was capped on the bottom and retained water), only two pipes on the trees were directly comparable with respect to ID. Both pipes were open at both ends, and the 3.81-cm ID pipe accounted for 6.9% of treefrog captures whereas the 1.75-cm ID pipes accounted for 5.0% of treefrog captures.

In Florida, Zacharow et al. (2003) used 91.4-cm sections of three different ID (1.9 cm, 5.1 cm, and 7.7 cm) PVC pipes driven into the ground, with 61 cm of pipe above the ground. A set of three pipes (one of each ID) was placed at 30 stations, with half of the stations on a low shrubby berm at an ecotone near the forest edge and the other half further up the berm away from the forest edge. With nearly 2,000 total captures of *H. cinerea* and *H. squirella*, there was a significant difference between the numbers of individuals of each species among pipe ID. The smaller species, *H. squirella*, exhibited an especially strong preference for the smallest ID pipes (81.2% of all *H. squirella* captures were in 1.9 cm ID pipes). The larger species, *H.*

TABLE 1. List of materials used in artificial refugia studies on anurans. PVC = polyvinyl chloride, ABS = acrylonitrile butadiene styrene.

Material	# of Studies	Source
Tin Can	3	Goin 1955; Goin and Goin 1957; Goin 1958
Bamboo	12	Drewry 1970; Stewart and Pough 1983; Stewart 1985; Townsend 1989; Woolbright 1989; Stewart and Rand 1991; Fogarty and Vilella 2001, 2002, 2003; Waldram 2008; Beard et al. 2009; von May et al. 2009
Wood Nest Box	1	McComb and Noble 1981
PVC Pipe	67	Buchanan 1988; Phelps 1993; O'Neill 1995; Phelps and Lancia 1995; Meshaka 1996; Moulton 1996; Moulton et al. 1996; Lamb et al. 1998; Fleet and Autry 1999; Brandt et al. 2003; Moseley et al. 2003; Schurbon and Fauth 2003; Zacharow et al. 2003; Bartareau 2004; Borg et al. 2004; Matthews and Cook 2004; Wyatt and Forys 2004; Tomasek et al. 2005; Hall 2006; Hirai 2006; Muenz et al. 2006; Pittman and Dorcas 2006; Rice et al. 2006; Smith et al. 2006a; Smith et al. 2006b; Waddle 2006; da Silva and Rossa-Feres 2007; Dawson and Hostetler 2007; Hoffman 2007; LaBram et al. 2007; Langford et al. 2007; Myers et al. 2007; Pham et al. 2007; Gordon 2008; Liner et al. 2008; Piacenza 2008; Pittman et al. 2008; Tomasek and Matthews 2008; Waddle et al. 2008; Beard et al. 2009; Campbell et al. 2009; Farmer et al. 2009; Hoffman et al. 2009; Hutchens and DePerno 2009; Laurencio and Malone 2009; McGarrity and Johnson 2009; Miranda and Wilczynski 2009; von May et al. 2009; Campbell et al. 2010; Haggerty 2010; Johnson et al. 2010; McGarrity and Johnson 2010; Windes 2010; Granatosky and Krysko 2011; Layman 2011; Leach 2011; Rice et al. 2011; Ferreira et al. 2012; Glorioso et al. 2012; Kirkman et al. 2012; Elston et al. 2013
ABS Pipe	5	Johnson 2005a; Johnson 2005b; Johnson et al. 2007; Mahan and Johnson 2007; Johnson et al. 2008

cinerea, was more likely than *H. squirella* to be captured in the two larger ID pipes, but preferred the smallest ID pipes (57.5% of all *H. cinerea* captures were in 1.9 cm ID pipes).

In south Florida, in a coastal oak scrub community, Bartareau (2004) used 1-m sections of four different ID PVC pipes (1.3 cm, 2.5 cm, 3.8 cm, and 5.1 cm) driven into the ground 10 cm. A pipe of each ID was placed directly alongside each other in three widely spaced areas for a total of 12 pipes. The pipes captured three species, *H. cinerea*, *H. squirella*, and *Osteopilus septentrionalis*, but no captures were made in the 5.1-cm pipes. Only juvenile *H. cinerea* and juvenile and small adult *H. squirella* used the smallest ID pipes, and only adult *H. squirella* and *O. septentrionalis* used the 3.8-cm pipes. Both juveniles and adults of *H. cinerea* and *H. squirella* used the 2.5-cm pipes. Evidence from Bartareau (2004) suggests that native species selected pipes to avoid *O. septentrionalis*, but this is clearly confounded with body size of the frogs and the limited ability of larger frogs, such as *O. septentrionalis* to use smaller ID pipes.

Hirai (2006) used 2.5-cm and 4.0-cm ID PVC pipes, and found no effect of ID size on *Hyla japonica* captures in Japan. In Florida, Piacenza (2008) used 76-cm sections of both 1.9-cm and 4.45-cm ID PVC pipes hung 2 m high in the same trees. She found that all four hylid species (*H. cinerea*, *H. femoralis*, *H. squirella*, and *O. septentrionalis*) were captured more often in the 4.45-cm ID PVC, with *H. femoralis* and *O. septentrionalis* found significantly more often in 4.45-cm ID PVC than 1.9-cm ID PVC. In Missouri, Leach (2011) hung 60-cm sections of both 1.8-cm and 4.0-cm ID gray PVC pipes side by side on 96 trees at 2 m height across four treatments to determine if smaller diameter pipes would enhance capture rates of metamorph *H. versicolor* compared to larger pipes. He captured 83% of his total metamorph *H. versicolor* (n = 55) in the large pipes, but did find individual metamorphs on several occasions using adjacent refugia of both sizes.

Length.—Buchanan (1988) used 50 each of 8-cm and 4.5-cm lengths of 1.8-cm ID PVC pipes, corking one end on half of the pipes, and attached them to the petioles of palmettos in Louisiana to capture *H. squirella*. Frogs showed a general lack of preference of retreat types, except during the dry season when frogs overwhelmingly preferred long retreats over short ones, leading Buchanan (1988) to believe frogs were capable of assessing retreat quality based on local conditions. He postulated that desiccation potential, especially during the dry season, was the likely driver of retreat site choice. Boughton et al. (2000) found that *H. cinerea* was captured significantly more often in long retreats than in t-shaped or short retreats, and *H. squirella* was captured significantly more often in long retreats and t-shaped retreats than in short retreats. This information was used to further study pipe designs at a different site, and because no demonstrable advantages were seen in t-shaped pipes as opposed to straight pipes, the t-shaped pipe design was not used in the follow-up study (Boughton et al. 2000).

Configuration.—Comparing both long and short capped and uncapped pipes, Buchanan (1988) found that *H. squirella* generally preferred capped pipes over open pipes. Boughton et al. (2000) showed that treefrogs showed a strong preference for pipes that were capped on the bottom (78% of all captures), as opposed to capped on the top (9.5%), allowing for retention of up to 15 cm of water in the pipe. Windes (2010), in a limited non-replicated study, showed that capture rates of *H. squirella* were not significantly different in bottom-capped pipes that retained water versus bottom-capped pipes that did not contain water (a hole was drilled in bottom cap to let water pass through). However, in a reduced model that excluded a seldom-used tree morphotype, she found pipes that retained water had significantly more captures of *H. squirella* than those that allowed water to pass through.

Prior use by frogs.—Myers et al. (2007) compared frog capture rates of new and used (previously by frogs) PVC pipes placed in trees and on the ground. They found that *Pseudacris regilla* was more likely to be found in used PVC pipes on trees than the other three refugia categories. Used ground-placed pipes (i.e. pipes resting flush with ground on top of stakes driven partially into the ground) and new tree-placed pipes (i.e. pipes hung vertically on trunks) had similar probabilities of use, and new ground-placed pipes had the lowest probability of use. However, prior use of PVC refugia by frogs did not have an effect on capture rates or latency to initial detection. In a laboratory study, Hoffman (2007) found that native treefrog (*H. cinerea* and *H. femoralis*) use of PVC pipe refugia was not altered by the former presence of similar-sized *O. septentrionalis*.

During spring when re-hanging PVC pipes used from the previous fall, Windes (2010) added 50% more new pipes and found that old pipes had nine times the recapture percentage of the previous year's marked animals than new pipes. Frogs potentially use olfactory cues to select refugia. Myers et al. (2007) speculated that frogs may avoid new PVC pipes due to off-gassing of volatile chemicals, such as phthalates, at normal atmospheric pressure. Alternatively, perhaps frogs are attracted to chemicals from other frogs lingering in the pipes.

Myers et al. (2007) measured latency to detection, defined as the amount of time lapsed from when pipes were placed in the environment to their initial use by frogs. In their study of *P. regilla*, latency to detection was 16 and 13 days for ground-based and tree-based refugia, respectively. Boughton et al. (2000) stated that frogs were found in pipes within one week of installation. Zacharow et al. (2003) stated that *H. cinerea* and *H. squirella* quickly established presence in the pipes. In Brandt et al. (2003), treefrogs were observed in pipes in four of five tree islands in Florida within the first month.

Location.—Though there has been ample use of both tree placement and ground placement of PVC pipes, few studies have examined them concurrently. Boughton et al. (2000) captured significantly more hylid treefrogs in tree-placed pipes (vertically hung on trunks) than ground-placed pipes (driven vertically into ground). Also, frogs were found on tree-placed pipes significantly more at 2 m and 4 m than at the base (0 m) of the tree. This suggests that even when pipes are on trees, treefrogs prefer pipes higher than ground level; there was no difference between pipes placed at 2 m and 4 m. Windes (2010) found no significant difference in captures with pipes placed at 2, 3 and 4 m high on trees. Myers et al. (2007) found that tree-placed pipes captured 81% more *P. regilla* than ground-placed pipes in California. Windes (2010) hung pipes on each of the four cardinal directions of trees, and found no significant effect on *H. squirella* captures based on pipe orientation.

Boughton et al. (2000) found that *H. cinerea* captures decreased with distance of PVC pipes from a lake. In Florida, Piacenza (2008) found a significant positive correlation between captures and distance to water in *H. squirella* and *O. septentrionalis*, but no significant difference was observed for *H. cinerea* and *H. femoralis*. In Japan, Hirai (2006) found no effect of distance to water on *H. japonica* captures.

Boughton et al. (2000) found that treefrogs were captured significantly more often on hardwood trees than on pine trees, but the significant positive relationship between total captures and increasing tree diameter likely influenced this pattern (Boughton et al. 2000). Piacenza (2008) found that *H. squirella* and *O. septentrionalis* were found significantly more often on PVC pipes hung on oak trees than on cabbage palm and pine trees; no significant difference in captures among tree types was observed in *H. cinerea* and *H. femoralis*. Windes (2010) found that PVC pipes attached to cabbage palms with boots were used significantly less by treefrogs than those attached to either smooth-trunked cabbage palms or oak trees.

Moulton et al. (1996) saw no significant differences in capture rates in PVC pipes among three categories of cover (vegetative cover, partial cover, no cover). Phelps and Lancia (1995) showed that *H. cinerea* preferred PVC pipes in the clearcut area as opposed to the intact forest, whereas *H. chrysoscelis*, though captures were few, preferred the intact forest to the clearcut area, which aligns with their known natural history. Fogarty and Vilella (2003), using bamboo retreats, found *E. coqui* densities to be correlated with vegetation structure variables, but similar densities were found between native forest and eucalyptus plantations. Zacharow et al. (2003) found a significant difference in PVC pipe

TABLE 2. Locations where artificial refugia have been used to sample anuran, particularly treefrog, populations.

Place Used	# of Studies	Source
Brazil	2	da Silva and Rossa-Feres 2007*; Ferreira et al. 2012
Costa Rica	1	Laurencio and Malone 2009
Equatorial Guinea	1	Layman 2011*
Japan	1	Hirai 2006
Peru	2	Waldram 2008; von May et al. 2009
Puerto Rico	9	Drewry 1970; Stewart and Pough 1983; Stewart 1985; Townsend 1989; Woolbright 1989; Stewart and Rand 1991; Fogarty and Vilella 2001, 2002, 2003
United States	69	
North Carolina	10	Moulton 1996; Moulton et al. 1996; Lamb et al. 1998; Matthews and Cook 2004; Tomasek et al. 2005; Hall 2006; Pittman and Dorcas 2006; Pittman et al. 2008; Tomasek and Matthews 2008; Hutchens and DePerno 2009
South Carolina	6	Phelps 1993; Phelps and Lancia 1995; Perison et al. 1997; Schurbon 2000; Schurbon and Fauth 2003; LaBram et al. 2007
Georgia	8	Moseley et al. 2003; Borg et al. 2004; Muenz et al. 2006; Smith et al. 2006a; Smith et al. 2006b; Liner et al. 2008; Farmer et al. 2009; Kirkman et al. 2012
Florida	31	Goin 1955; Goin and Goin 1957; Goin 1958; O'Neill 1995; Meshaka 1996; Boughton 1997; Boughton et al. 2000; Donnelly et al. 2001; Meshaka 2001; Brandt et al. 2003; Zacharow et al. 2003; Bartareau 2004; Wyatt and Forys 2004; Rice et al. 2006; Waddle 2006; Dawson and Hostetler 2007; Hoffman 2007; Piacenza 2008; Waddle et al. 2008; Campbell et al. 2009; Hoffman et al. 2009; McGarrity and Johnson 2009; Campbell et al. 2010; Haggerty 2010; Johnson et al. 2010; McGarrity and Johnson 2010; Windes 2010; Granatosky and Krysko 2011; Rice et al. 2011; Glorioso et al. 2012; Elston et al. 2013
Mississippi	2	McComb and Noble 1981; Langford et al. 2007
Louisiana	2	McComb and Noble 1981; Buchanan 1988; Pham et al. 2007
Texas	2	Fleet and Autry 1999; Miranda and Wilczynski 2009
Missouri	7	Johnson 2005a; Johnson 2005b; Johnson et al. 2007; Mahan and Johnson 2007; Gordon 2008; Johnson et al. 2008; Leach 2011
California	1	Myers et al. 2007
Hawaii	1	Beard et al. 2009

*no captures were made in these studies

occupancy between species on the lower berm versus the upper berm; *H. cinerea* occupancy was not significantly different between the upper and lower berms, but *H. squirella* was found significantly more often on the lower berm (95% of all *H. squirella* captures) than the upper berm.

USE OF ARTIFICIAL REFUGIA IN SCIENTIFIC STUDIES

Where is the technique being used?—Artificial refugia have been used to study frogs predominantly in the Americas, particularly in the United States, but also in Brazil, Costa Rica, Peru, and Puerto Rico (Table 2). Only two studies using artificial refugia have come from outside the Americas, one from Japan (Hirai 2006) and another from Equatorial Guinea (Layman 2011). In the United States, most studies were performed in the southeastern states, particularly Florida (Table 2).

What species and how many are being captured?—At least 28 anuran species, representing four families (Hylidae, 23 species; Eleutherodactylidae, 3 species; Microhylidae, 1 species; and Dendrobatidae; 1 species; Table 3) have been captured using this technique. Though some studies have reported no success or relatively small numbers of anurans captured using pipe or pipe-like refugia, other studies report thousands of individuals captured (Appendix A). Many studies have reported nontarget species using artificial pipe refugia.

TABLE 3. List of anuran species captured within PVC, bamboo, and ABS pipe traps, as well as wood nest boxes and inverted tin cans.

Species	Source
Family Dendrobatidae	
Ranitomeya biolat	Waldram 2008; von May et al. 2009
Family Eleutherodactylidae	
Eleutherodactylus altamazonicus	Waldram 2008
Eleutherodactylus coqui	Drewry 1970; Stewart and Pough 1983; Stewart 1985; Townsend 1989; Woolbright 1989; Stewart and Rand 1991; Fogarty and Vilella 2001, 2002, 2003; Beard et al. 2009
Eleutherodactylus hedricki	Drewry 1970; Stewart 1985; Stewart and Rand 1991
Family Hylidae	
Dendropsophus minutus	Ferreira et al. 2012
Dendropsophus nanus	Ferreira et al. 2012
Dendropsophus rubicundulus	Ferreira et al. 2012
Hyla chrysoscelis	Phelps 1993; Phelps and Lancia 1995; Perison et al. 1997; Lamb et al. 1998; Borg et al. 2004; Hall 2006; Muenz et al. 2006; Pittman and Dorcas 2006; Liner et al. 2008; Pittman et al. 2008; Kirkman et al. 2012
Hyla chrysoscelis/versicolor complex	McComb and Noble 1981; Fleet and Autry 1999
Hyla cinerea	Goin 1955; Goin 1958; McComb and Noble 1981; Phelps 1993; Phelps and Lancia 1995; Moulton 1996; Moulton et al. 1996; Boughton 1997; Perison et al. 1997; Lamb et al. 1998; Fleet and Autry 1999; Boughton et al. 2000; Schurbon 2000; Donnelly et al. 2001; Brandt et al. 2003; Schurbon and Fauth 2003; Zacharow et al. 2003; Bartareau 2004; Borg et al. 2004; Wyatt and Forys 2004; Hall 2006; Muenz et al. 2006; Rice et al. 2006; Smith et al. 2006a; Smith et al. 2006b; Waddle 2006; Dawson and Hostetler 2007; Hoffman 2007; LaBram et al. 2007; Langford et al. 2007; Pham et al. 2007; Liner et al. 2008; Piacenza 2008; Waddle et al. 2008; Campbell et al. 2009; Farmer et al. 2009; Hoffman et al. 2009; Hutchens and DePerno 2009; Miranda and Wilczynski 2009; Campbell et al. 2010; Haggerty 2010; Windes 2010; Granatosky and Krysko 2011; Rice et al. 2011; Kirkman et al. 2012; Elston et al. 2013
Hyla femoralis	O'Neill 1995; Moulton 1996; Moulton et al. 1996; Boughton 1997; Boughton et al. 2000; Schurbon 2000; Schurbon and Fauth 2003; Hall 2006; Smith et al. 2006a; Smith et al. 2006b; Hoffman 2007; Langford et al. 2007; Liner et al. 2008; Piacenza 2008; Campbell et al. 2009; Farmer et al. 2009; Hoffman et al. 2009; Campbell et al. 2010; Haggerty 2010; Windes 2010; Granatosky and Krysko 2011; Kirkman et al. 2012
Hyla gratiosa	Boughton 1997; Boughton et al. 2000; Borg et al. 2004; Muenz et al. 2006; Smith et al. 2006b; Liner et al. 2008; Farmer et al. 2009; Windes 2010; Kirkman et al. 2012
Hyla japonica	Hirai 2006
Hyla squirella	Goin 1955; Goin and Goin 1957; Goin 1958; McComb and Noble 1981; Buchanan 1988; Moulton 1996; Moulton et al. 1996; Boughton 1997; Lamb et al. 1998; Boughton et al. 2000; Schurbon 2000; Schurbon and Fauth 2003; Zacharow et al. 2003; Bartareau 2004; Borg et al. 2004; Hall 2006; Muenz et al. 2006; Rice et al. 2006; Smith et al. 2006a; Smith et al. 2006b; Waddle 2006; Dawson and Hostetler 2007; Hoffman 2007; LaBram et al. 2007; Langford et al. 2007; Liner et al. 2008; Piacenza 2008; Waddle et al. 2008; Campbell et al. 2009; Farmer et al. 2009; Hoffman et al. 2009; Campbell et al. 2010; Haggerty 2010; Windes 2010; Granatosky and Krysko 2011; Rice et al. 2011; Kirkman et al. 2012; Elston et al. 2013

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Whereas invertebrates account for most of the nontarget species, captured vertebrates include lizards: *Anolis carolinensis* (e.g., O'Neill 1995; Lamb et al. 1998; Donnelly et al. 2001; Rice et al. 2006; Piacenza 2008), *Anolis gundlachi* (Stewart and Rand 1991), *Anolis sagrei* (Dawson and Hostetler 2007; Piacenza 2008), *Hemidactylus garnotii* (Piacenza 2008), *Mabuya frenata* (Ferreira et al. 2012), *Plestiodon fasciatus* (Johnson 2005a), *Plestiodon inexpectatus* (Piacenza 2008), and *Stenocercus roseiventris* (Waldram 2008), and snakes: *Diadophis punctatus* (Piacenza 2008), *Lampropeltis triangulum* (Piacenza 2008), *Pantherophis obsoletus* (Leach 2011), and *Thamnophis sauritus* (Piacenza 2008).

TABLE 3. *Continued*

Hyla versicolor	Johnson 2005a; Johnson 2005b; Johnson et al. 2007; Mahan and Johnson 2007; Gordon 2008; Johnson et al. 2008; Leach 2011
Hypsiboas raniceps	Ferreira et al. 2012
Osteocephalus taurinus	Ferreira et al. 2012
Osteopilus septentrionalis	Meshaka 1996; Bartareau 2004; Wyatt and Forys 2004; Rice et al. 2006; Hoffman 2007; Piacenza 2008; Campbell et al. 2009; Hoffman et al. 2009; McGarrity and Johnson 2009; Campbell et al. 2010; Haggerty 2010; Johnson et al. 2010; McGarrity and Johnson 2010; Granatosky and Krysko 2011; Rice et al. 2011; Glorioso et al. 2012; Elston et al. 2013
Pseudacris crucifer	Johnson 2005a; Johnson 2005b; Hall 2006; Granatosky and Krysko 2011; Leach 2011
Pseudacris nigrita	Langford et al. 2007
Pseudacris ocularis	Moulton 1996; Moulton et al. 1996; Haggerty 2010
Pseudacris regilla	Myers et al. 2007
Scinax cruentommus	Waldram 2008
Scinax elaeochroa	Laurencio and Malone 2009
Scinax fuscomarginatus	Ferreira et al. 2012
Scinax gr. ruber	Ferreira et al. 2012
Smilisca phaeota	Laurencio and Malone 2009
Trachycephalus venulosus	Laurencio and Malone 2009; Ferreira et al. 2012
Family Microhylidae	
Chiasmocleus ventrimaculata	Waldram 2008
Other	
Unstated	Moseley et al. 2003
No species captured	da Silva and Rossa-Feres 2007; Layman 2011

In addition to reptiles, small mammals have also been captured (Borg et al. 2004; Johnson 2005a). In Missouri, 12 of 15 mammals (comprised of mice [*Peromyscus* sp.] and Southern Flying Squirrels [*Glaucomys volans*]) captured in ABS pipes were dead (Johnson 2005a). Borg et al. (2004) found 22 dead *G. volans* in their PVC pipes at pre-treatment study sites in Georgia. They determined that dead *G. volans* had a significant negative effect on overall treefrog occupancy. After adding an escape rope to half of the pipes, Borg et al. (2004) observed no mortality in pipes with ropes compared to 10 dead *G. volans* in pipes without ropes during 18 months of post-treatment observations. Also, pipes with ropes did not affect treefrog occupancy, as 238 treefrogs were captured in pipes with ropes compared to 223 treefrogs in pipes without ropes.

Types of studies.—Since the technique was first used, many studies have addressed various technique-related questions (Table 4). As the methodology has become more widely known, there has been considerable research that has employed the use of artificial refugia in both herpetological inventories and to address various ecological questions. Many studies that use PVC and bamboo pipes as a capture technique are designed to gather information on species distribution and richness and demographic information, such as estimates of population size, occupancy, abundance, and survival (Table 4). In other studies PVC pipes are used to measure the response of anurans to habitat changes associated with events such as fire, habitat fragmentation, clearcutting, hydrologic restoration, off-road vehicle use, and pesticide application. There has been a considerable amount of research in Florida that used PVC pipes to examine the effect *O. septentrionalis*, a non-native invasive treefrog species, has on native treefrogs. Other types of anuran studies include investigations into spatial and temporal distribution, breeding, diet, movement, and territoriality (Table 4).

Outreach and citizen science applications.—One aspect of the technique that should not be overlooked is the ease with which it can be used to teach children and non-scientists about sampling or other ecological questions. Alternatively, the technique could be used simply to raise awareness and interest about frogs, and thus amphibian conservation, through directed programs to highlight the plight of amphibians worldwide. For example, after a visit by Margaret Stewart to learn about frogs, particularly *E. coqui*, which she studied extensively in Puerto Rico, a group of third-graders added PVC pipes for treefrog habitats along their nature trail to further their amphibian studies (Matthews and Cook 2004).

Tomasek et al. (2005) discussed extensively how to use PVC pipes among other sampling methods to study

TABLE 4. Focal topics of studies using artificial pipe-like refugia.

Focal Topic	# of Studies	Source
breeding	3	Townsend 1989; Waldram 2008; von May et al. 2009
changes in population size due to supplemented retreat sites	4	Drewry 1970; Stewart and Pough 1983; Buchanan 1988; Hirai 2006
diet	3	Johnson 2005b; Mahan and Johnson 2007; Glorioso et al. 2012
indicator species	2	Muenz et al. 2006; Waddle 2006
inventory	8	O'Neill 1995; Lamb et al. 1998; Brandt et al. 2003; Hall 2006; Rice et al. 2006; Smith et al. 2006a; LaBram et al. 2007; Laurencio and Malone 2009
inventory with differences across habitats	6	Fleet and Autry 1999; Dawson and Hostetler 2007; Liner et al. 2008; Piacenza 2008; Haggerty 2010; Windes 2010
laboratory	2	Miranda and Wilczynski 2009; Johnson et al. 2010
movement	3	Stewart 1985; Fogarty and Vilella 2003; McGarrity and Johnson 2010
O. septentrionalis effects on native treefrogs	7	Bartareau 2004; Wyatt and Forys 2004; Hoffman 2007; Piacenza 2008; Campbell et al. 2010; Rice et al. 2011; Elston et al. 2013
ontogenetic habitat shifts	1	Granatosky and Krysko 2011
outreach and citizen science	4	Matthews and Cook 2004; Tomasek et al. 2005; Tomasek and Matthews 2008; Pittman and Dorcas 2006
physiology	1	Gordon 2008
response to event (fire, fragmentation, clearcut, off-road vehicle use, pesticide use, hydrologic restoration)	10	Phelps 1993; Phelps and Lancia 1995; Moulton 1996; Perison et al. 1997; Schurbon 2000; Moseley et al. 2003; Schurbon and Fauth 2003; Waddle 2006; da Silva and Rossa-Feres 2007; Langford et al. 2007
retreat use	2	McComb and Noble 1981; Meshaka 1996
sexual size dimorphism	2	Woolbright 1989; McGarrity and Johnson 2009
spatial and temporal distribution	7	Goin and Goin 1957; Goin 1958; Zacharow et al. 2003; Johnson 2005b; Johnson et al. 2007; Johnson et al. 2008; Campbell et al. 2010
species distribution; species richness; population demographics (size, density, occupancy, abundance, survival)	14	Donnelly et al. 2001; Fogarty and Vilella 2001, 2002, 2003; Smith et al. 2006b; Waddle 2006; Pham et al. 2007; Piacenza 2008; Waddle et al. 2008; Waldram 2008; Windes 2010; Layman 2011; Rice et al. 2011; Kirkman et al. 2012
technique-related	14	Moulton et al. 1996; Boughton 1997; Boughton et al. 2000; Borg et al. 2004; Johnson 2005a; Rice et al. 2006; Myers et al. 2007; Beard et al. 2009; Campbell et al. 2009; Farmer et al. 2009; Ferreira et al. 2012; Hoffman et al. 2009; Hutchens and DePerno 2009; Leach 2011
territoriality and site fidelity	4	Buchanan 1988; Stewart and Rand 1991; Pittman et al. 2008; Windes 2010

reptiles and amphibians on school property, and even proposed possible questions to be asked based on grade level from kindergarteners through high-school students. Tomasek and Matthews (2008), working with elementary school teachers, described their accomplishments (using PVC pipes and other methods in amphibian studies) in changing the negative images and unfounded fears for second through fifth graders.

Pittman and Dorcas (2006) described a multi-state citizen science effort to inventory amphibians and reptiles within the Catwaba River Corridor in the Carolinas involving people from academia, government, and private industry. Their primary capture technique was coverboards as they are easy to deploy and check, but many of the participants chose to add PVC pipes. Besides creating awareness for land managers of the sites sampled, hundreds of school-aged children also participated in the sampling, gaining insight into the ecology of amphibians and reptiles and how to catch them. Increased knowledge and appreciation of amphibians and reptiles from persons of all ages is the first step towards better implementing conservation strategies (Pittman and Dorcas 2006).

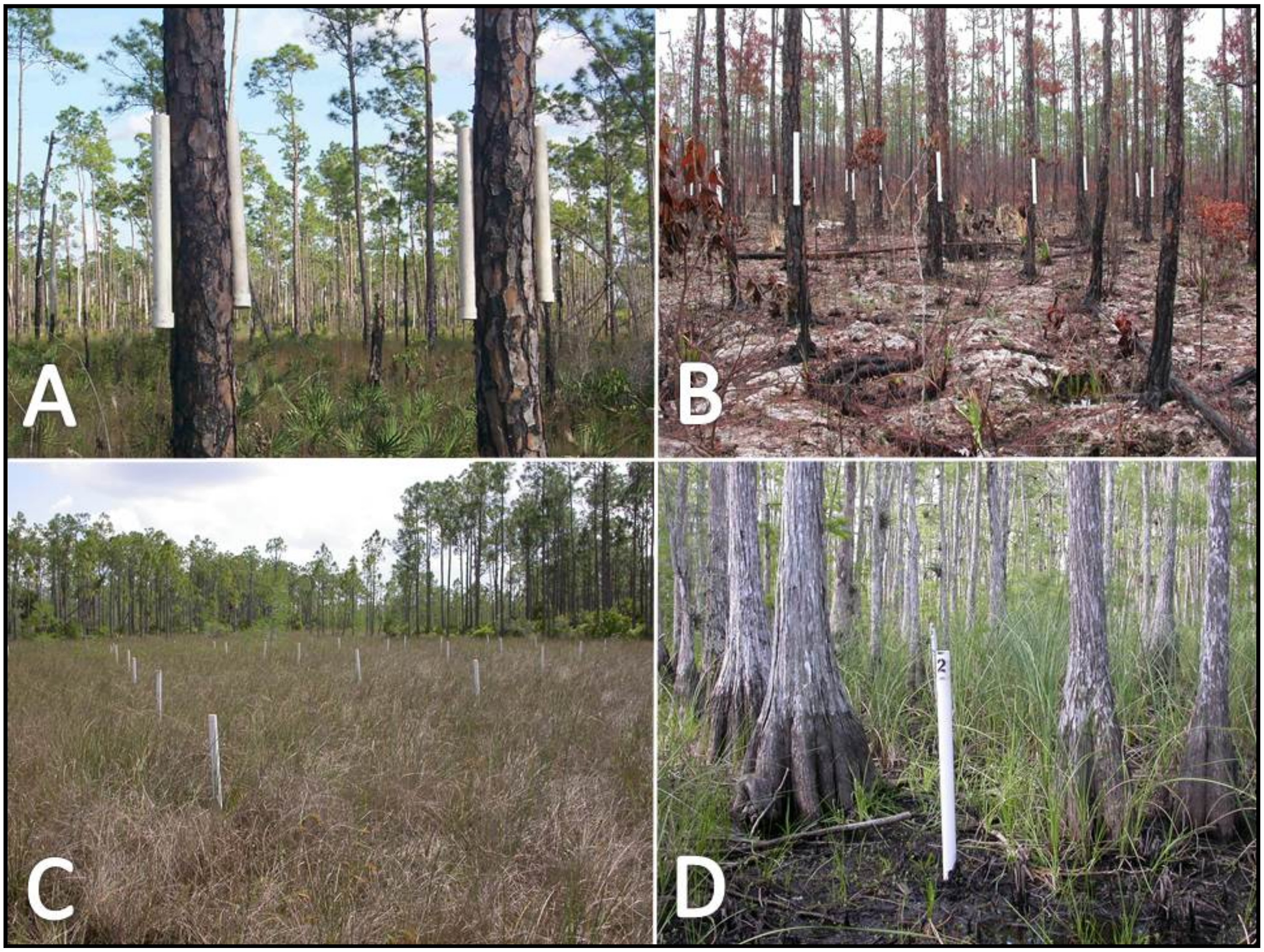

FIGURE 1. Various pipe placement in Everglades National Park habitats: (A) Close up of paired tree-placed pipes on pine trees; (B) Single tree-placed pipes on adjacent pine trees in a recently burned forest; (C) Ground-placed pipes in an array in a prairie habitat; (D) Ground-placed pipes in a cypress swamp. (Photographed by J. Hardin Waddle).

CONSIDERATIONS FOR ARTIFICIAL REFUGIA STUDIES

As with any animal capture technique there are concerns associated with using refugia to sample anurans that should be evaluated before beginning a project. One of the biggest considerations about this technique is whether there is equal capture probability among individuals of the population of interest, particularly in studies examining demographic variables such as abundance or survival. There are several potential sources of bias in samples taken from refugia. As described above, the size, color, configuration, and location of the refuge array can impact the effectiveness of refugia as a capture technique for a species at a location. There may be size, sex, or ontogenetic differences in preference for pipes. There may also be inter- or intraspecific interactions making it more or less likely for individuals to co-occur in an occupied refuge. Preference for refugia may follow a seasonal pattern. With a myriad of biases, it may be difficult to determine to what degree the population captured in pipe traps represents the demographic makeup of the entire population (Piacenza 2008).

The effect of season on capture rates could have serious implications in studies that do not encompass a full year of data. In multiple studies, especially in the southeastern United States, treefrog captures increase with drier conditions and/or cooler temperatures (e.g., Donnelly et al. 2001; Zacharow et al. 2003; Waddle 2006). However, in areas that experience below freezing temperatures for extended periods of time, treefrog captures in pipes may become limited or cease completely in winter months, as treefrogs presumably take up more permanent shelter in insulated natural refugia during these times (Pittman et al. 2008).

If the presence of one species affects the occupancy of another, this could have serious implications for some study designs. Several pipe refugia studies have found negative correlations between *H. squirella* and *O. septentrionalis*, suggesting *H. squirella* presence in the pipes is affected by the presence of *O. septentrionalis*, perhaps because of possible predation by or competition with *O. septentrionalis* on the smaller *H. squirella* (Meshaka 2001; Bartareau 2004; Campbell et al. 2010). However, Hoffman (2007) found no evidence that *H. squirella* avoided pipes that had been used by *O. septentrionalis* in a laboratory study, and Elston et al. (2013) found no evidence of native treefrog avoidance of pipes with *O. septentrionalis* in the field. Interspecific interactions in artificial refugia have not been reported for other species, but should be an important consideration in areas with dominant or aggressive species.

Although often difficult to locate and quantify, the number of natural refugia at a site could affect the proportion of frogs using pipe traps (Piacenza 2008). This bias in use of pipe traps is of special concern when comparing sites that differ in the number of natural refugia, and thus the proportion of the population that uses artificial refugia.

Knowing the proportion of frogs in a population that are using pipe traps at a given time would greatly increase the utility of this sampling technique. Understanding how this proportion might vary with seasons, environmental conditions, habitat factors, or among species would help to elucidate the degree to which samples from populations using artificial refugia are biased. We believe it may be possible to do so by using mark-recapture techniques on individuals captured from within and outside the refuge array at the same location, similar to the methods Corn et al. (2011) used to study the relationship between chorus index and population abundance of *Pseudacris maculata*. Further research into this potential bias would be very valuable for determining the utility of artificial refugia for population modeling.

Cost is another important consideration in artificial refugia studies. Pipe refugia are a relatively inexpensive and easy to implement method to detect treefrogs that may otherwise not be sampled efficiently or at all with techniques such as drift fences and coverboards (e.g., Dodd 1991; Moulton 1996). However, Hutchens and DePerno (2009) found that PVC pipes had the highest total cost per species observed of 11 capture techniques, with no unique species in a North Carolina study. The cost of purchasing PVC or ABS pipe can vary greatly depending on the diameter, thickness, and length of pipes, as well as the quantity, as some sources may offer discounts if pipe is purchased in large quantities. Cutting large pieces down to size and transporting them to the study site are additional costs. Availability of PVC pipes in some parts of the world may also be a factor limiting the use of pipe refugia as a survey method.

PVC Pipe Technique Best Practices

Pipes used to capture frogs are typically Schedule 40 PVC and white in color. Thinner walled pipe may also be available and will decrease weight and simplify cutting, but may not provide the same thermal properties of thicker pipes. Other colors of synthetic pipe should also work, and may be favored by researchers in studies where the conspicuousness of white pipes may be a concern due to vandalism and theft. The inner diameter of pipes should be between 2.5 cm and 5.0 cm depending on the species of interest, with the understanding that smaller diameter pipes may exclude larger species and size classes, and may not necessarily be favored by smaller species and size classes over larger diameter pipes. Furthermore, frogs may be more difficult to remove from smaller diameter pipes.

Pipes may be erected vertically into the ground or hung on trees in appropriate habitats (Fig. 1). Ground pipes are typically 1-m sections, with one end of the pipe beveled to help insert it into the ground to a depth of about 40 cm (60 cm exposed). Alternatively, ground pipes can be placed over wooden stakes inserted into ground. This method makes it easier to check pipes and remove frogs from the pipes, but care should be exercised to ensure that the pipes fit snug with the stake and flush to the ground to provide a more stable thermal microclimate in the pipes and to prevent potential predators from accessing the frogs from below. Ground pipes should be placed in vegetated areas near water, and are especially good for sampling treefrogs during the breeding season.

Tree pipes typically are 60-cm long, capped on the bottom end, and with holes drilled ~15 cm above the cap to drain excess water. The pipes are hung a minimum of 2 m high on large trees. Hardwood trees are preferable, unless the frog species of interest is known to prefer pine trees. Tree pipes are good for sampling treefrogs during the non-breeding season.

Specific information on appropriate pipe spacing is currently lacking, but pipes should be spaced far enough apart as deemed appropriate for the study area and species being sampled. Pipes may be installed in grids, along transects or drift fences, around the perimeter of breeding areas, or in other arrangements conforming to the study question. Frogs are removed by (1) shaking them out of the pipes into a plastic bag, or (2) by using a handmade plunger and gently pushing them out of the pipe into a plastic bag. Because trap mortality of anurans is negligible (frogs are free to move into and out of pipes), there is a great degree of flexibility in checking pipe traps, and this technique could be an effective sampling method in remote areas that are visited infrequently.

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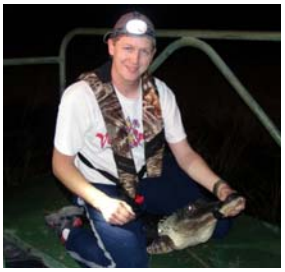

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Appendix A. The number of captures made within artificial pipe or pipe-like refugia. In most instances, the number presented represents all captures (including recaptures) of the given species in the study. This list includes only literature sources where the number of anuran captures is explicitly stated or could be accurately gleaned from the text.

Species	Study Site	Captures	Source
Family Dendrobatidae			
Ranitomeya biolat	Explorers Inn, Tambopata region, department of Madre de Dios, Peru	271	Waldram 2008
Family Eleutherodactylidae			
Eleutherodactylus altamazonicus	Explorers Inn, Tambopata region, department of Madre de Dios, Peru	1	Waldram 2008
Eleutherodactylus coqui	Cordillera Forest Reserves, Puerto Rico	1354	Fogarty and Vilella 2002, 2003
Eleutherodactylus coqui	Luquillo Experimental Division, Caribbean National Forest, Puerto Rico	91	Stewart 1985
Eleutherodactylus coqui	Luquillo Experimental Division, Caribbean National Forest, Puerto Rico	74	Stewart and Rand 1991
Eleutherodactylus coqui	Luquillo Experimental Division, Caribbean National Forest, Puerto Rico	135	Woolbright 1989
Eleutherodactylus hedricki	Luquillo Experimental Division, Caribbean National Forest, Puerto Rico	2	Stewart 1985
Family Hylidae			
Hyla chrysoscelis	Joseph W. Jones Ecological Research Center, Baker County, Georgia	7	Borg et al. 2004
Hyla chrysoscelis	Cool Springs Environmental Education Center, Craven County, North Carolina	110	Hall 2006
Hyla chrysoscelis	Lower Roanoke River Floodplain, Martin and Bertie County, North Carolina	12	Lamb et al. 1998
Hyla chrysoscelis	Edisto River Swamp, Orangeburg County, South Carolina	33	Perison et al. 1997
Hyla chrysoscelis	Edisto River Swamp, Orangeburg County, South Carolina	33	Phelps 1993; Phelps and Lancia 1995
Hyla chrysoscelis	Cowan's Ford Wildlife Refuge, Mecklenburg County, North Carolina	141	Pittman et al. 2008
Hyla cinerea	Rookery Bay National Estuarine Research Reserve, Collier County, Florida	36	Bartareau 2004
Hyla cinerea	Joseph W. Jones Ecological Research Center, Baker County, Georgia	1	Borg et al. 2004
Hyla cinerea	Katharine Ordway Preserve-Carl Swisher Memorial Sanctuary, Putnam County, Florida	691	Boughton 1997; Boughton et al. 2000

Hyla cinerea	Morris Bridge Wellfield, Hillsborough County, Florida	171	Campbell et al. 2009
Hyla cinerea	Southwest Florida Water Management District lands, Hillsborough County, Florida	673	Campbell et al. 2010
Hyla cinerea	Everglades National Park, Florida	589	Elston et al. 2013
Hyla cinerea	Alachua County, Florida	42	Goin 1958
Hyla cinerea	University of Florida Natural Areas Teaching Lab, Alachua County, Florida	189	Granatosky and Krysko 2011
Hyla cinerea	Hillsborough and Pasco County, Florida	179	Haggerty 2010
Hyla cinerea	Cool Springs Environmental Education Center, Craven County, North Carolina	269	Hall 2006
Hyla cinerea	Orange and Hillsborough County, Florida	1	Hoffman 2007
Hyla cinerea	Bull Neck Swamp, Washington County, North Carolina	5	Hutchens and DePerno 2009
Hyla cinerea	Lower Roanoke River Floodplain, Martin and Bertie County, North Carolina	15	Lamb et al. 1998
Hyla cinerea	Pocosin Lakes National Wildlife Refuge, North Carolina	9	Moulton 1996
Hyla cinerea	Edisto River Swamp, Orangeburg County, South Carolina	768	Perison et al. 1997
Hyla cinerea	Edisto River Swamp, Orangeburg County, South Carolina	768	Phelps 1993, Phelps and Lancia 1995
Hyla cinerea	Hillsborough County, Florida	162	Piacenza 2008
Hyla cinerea	Everglades National Park, Florida	943	Rice et al. 2006
Hyla cinerea	Everglades National Park, Florida	127	Rice et al. 2011
Hyla cinerea	Okefenokee National Wildlife Refuge, Georgia	45	Smith et al. 2006a
Hyla cinerea	Big Cypress National Preserve, Collier County, Florida	2008	Waddle 2006; Waddle et al. 2008
Hyla cinerea	MacArthur Agro-Ecology Research Center, Highlands County, Florida	13	Windes 2010
Hyla cinerea	Eckerd College, Pinellas County, Florida	274	Wyatt and Forys 2004
Hyla cinerea	Florida Integrated Science Center (FISC), Alachua County, Florida	699	Zacharow et al. 2003
Hyla femoralis	Katharine Ordway Preserve-Carl Swisher Memorial Sanctuary, Putnam County, Florida	42	Boughton 1997; Boughton et al. 2000
Hyla femoralis	Morris Bridge Wellfield, Hillsborough County, Florida	719	Campbell et al. 2009
Hyla femoralis	Southwest Florida Water Management District lands, Hillsborough County, Florida	945	Campbell et al. 2010
Hyla femoralis	University of Florida Natural Areas Teaching Lab, Alachua County, Florida	8	Granatosky and Krysko 2011
Hyla femoralis	Hillsborough and Pasco County, Florida	14	Haggerty 2010
Hyla femoralis	Cool Springs Environmental Education Center, Craven County, North Carolina	208	Hall 2006
Hyla femoralis	Orange and Hillsborough County, Florida	1517	Hoffman 2007
Hyla femoralis	Pocosin Lakes National Wildlife Refuge, North Carolina	76	Moulton 1996
Hyla femoralis	Hawthorne Forest, Alachua County, Florida	1663	O'Neill 1995
Hyla femoralis	Hillsborough County, Florida	54	Piacenza 2008
Hyla femoralis	Okefenokee National Wildlife Refuge, Georgia	391	Smith et al. 2006a
Hyla femoralis	MacArthur Agro-Ecology Research Center, Highlands County, Florida	7	Windes 2010
Hyla gratiosa	Joseph W. Jones Ecological Research Center, Baker County, Georgia	20	Borg et al. 2004
Hyla gratiosa	Katharine Ordway Preserve-Carl Swisher Memorial Sanctuary, Putnam County, Florida	48	Boughton 1997; Boughton et al. 2000
Hyla gratiosa	MacArthur Agro-Ecology Research Center, Highlands County, Florida	1	Windes 2010
Hyla japonica	Agricultural Experiment Station Furukawa, Miyagi Prefecture, Japan	145	Hirai 2006
Hyla squirella	Rookery Bay National Estuarine Research Reserve, Collier County, Florida	96	Bartareau 2004
Hyla squirella	Joseph W. Jones Ecological Research Center, Baker County, Georgia	497	Borg et al. 2004

Hyla squirella	Katharine Ordway Preserve-Carl Swisher Memorial Sanctuary, Putnam County, Florida	2660	Boughton 1997; Boughton et al. 2000
Hyla squirella	Morris Bridge Wellfield, Hillsborough County, Florida	688	Campbell et al. 2009
Hyla squirella	Southwest Florida Water Management District lands, Hillsborough County, Florida	1530	Campbell et al. 2010
Hyla squirella	Everglades National Park, Florida	76	Elston et al. 2013
Hyla squirella	Alachua County, Florida	434	Goin and Goin 1957
Hyla squirella	University of Florida Natural Areas Teaching Lab, Alachua County, Florida	307	Granatosky and Krysko 2011
Hyla squirella	Hillsborough and Pasco County, Florida	39	Haggerty 2010
Hyla squirella	Cool Springs Environmental Education Center, Craven County, North Carolina	592	Hall 2006
Hyla squirella	Orange and Hillsborough County, Florida	14	Hoffman 2007
Hyla squirella	Lower Roanoke River Floodplain, Martin and Bertie County, North Carolina	51	Lamb et al. 1998
Hyla squirella	Pocosin Lakes National Wildlife Refuge, North Carolina	48	Moulton 1996
Hyla squirella	Hillsborough County, Florida	450	Piacenza 2008
Hyla squirella	Everglades National Park, Florida	1041	Rice et al. 2006
Hyla squirella	Everglades National Park, Florida	996	Rice et al. 2011
Hyla squirella	Okefenokee National Wildlife Refuge, Georgia	2	Smith et al. 2006a
Hyla squirella	Big Cypress National Preserve, Collier County, Florida	1066	Waddle 2006; Waddle et al. 2008
Hyla squirella	MacArthur Agro-Ecology Research Center, Highlands County, Florida	1854	Windes 2010
Hyla squirella	Florida Integrated Science Center (FISC), Alachua County, Florida	1247	Zacharow et al. 2003
Hyla versicolor	Thomas Baskett Wildlife Research Area, Boone County, Missouri	565	Johnson 2005a
Hyla versicolor	Thomas Baskett Wildlife Research Area, Boone County, Missouri	772	Johnson 2005b
Hyla versicolor	Thomas Baskett Wildlife Research Area, Boone County, Missouri	704	Johnson et al. 2007
Hyla versicolor	Thomas Baskett Wildlife Research Area, Boone County, Missouri	131	Gordon 2008
Hyla versicolor	Thomas Baskett Wildlife Research Area, Boone County, Missouri	737	Johnson et al. 2008
Hyla versicolor	Daniel Boone Conservation Area, Warren County, Missouri	55	Leach 2011
Osteocephalus taurinus	Parque Estadual do Cantão, Fazenda Santa Fé, Fazenda Lago Verde, Brazil	5	Ferreira et al. 2012
Osteopilus septentrionalis	Rookery Bay National Estuarine Research Reserve, Collier County, Florida	28	Bartareau 2004
Osteopilus septentrionalis	Morris Bridge Wellfield, Hillsborough County, Florida	1293	Campbell et al. 2009
Osteopilus septentrionalis	Southwest Florida Water Management District lands, Hillsborough County, Florida	4089	Campbell et al. 2010
Osteopilus septentrionalis	Everglades National Park, Florida	1371	Elston et al. 2013
Osteopilus septentrionalis	Everglades National Park, Florida	767	Glorioso et al. 2012
Osteopilus septentrionalis	University of Florida Natural Areas Teaching Lab, Alachua County, Florida	44	Granatosky and Krysko 2011
Osteopilus septentrionalis	Hillsborough and Pasco County, Florida	656	Haggerty 2010
Osteopilus septentrionalis	Orange and Hillsborough County, Florida	532	Hoffman 2007
Osteopilus septentrionalis	Central Florida	195	Johnson et al. 2010
Osteopilus septentrionalis	Hillsborough, Polk, and Orange County, Florida	312	McGarrity and Johnson 2009
Osteopilus septentrionalis	English Creek Environmental Education Center, Hillsborough County, Florida	18	McGarrity and Johnson 2010
Osteopilus septentrionalis	Hillsborough County, Florida	1468	Piacenza 2008
Osteopilus septentrionalis	Everglades National Park, Florida	3	Rice et al. 2006
Osteopilus septentrionalis	Everglades National Park, Florida	1005	Rice et al. 2011
Osteopilus septentrionalis	Eckerd College, Pinellas County, Florida	387	Wyatt and Forys 2004
Pseudacris crucifer	University of Florida Natural Areas Teaching Lab, Alachua County, Florida	1	Granatosky and Krysko 2011
Pseudacris crucifer	Cool Springs Environmental Education	20	Hall 2006

	Center, Craven County, North Carolina		
Pseudacris crucifer	Thomas Baskett Wildlife Research Area, Boone County, Missouri	1	Johnson 2005a
Pseudacris ocularis	Pocosin Lakes National Wildlife Refuge, North Carolina	12	Moulton 1996
Pseudacris ocularis	Hillsborough and Pasco County, Florida	1	Haggerty 2010
Pseudacris regilla	Humboldt Bay National Wildlife Refuge, Humboldt County, California	494	Myers et al. 2007
Scinax cruentommus	Explorers Inn, Tambopata region, department of Madre de Dios, Peru	17	Waldram 2008
Scinax elaeochroa	Parque Nacional Carara, Costa Rica	1	Laurencio and Malone 2009
Scinax fuscomarginatus	Parque Estadual do Cantão, Fazenda Santa Fé, Fazenda Lago Verde, Brazil	39	Ferreira et al. 2012
Scinax gr. ruber	Parque Estadual do Cantão, Fazenda Santa Fé, Fazenda Lago Verde, Brazil	39	Ferreira et al. 2012
Smilisca phaeota	Parque Nacional Carara, Costa Rica	4	Laurencio and Malone 2009
Trachycephalus venulosus	Parque Estadual do Cantão, Fazenda Santa Fé, Fazenda Lago Verde, Brazil	31	Ferreira et al. 2012
Trachycephalus venulosus	Parque Nacional Carara, Costa Rica	1	Laurencio and Malone 2009
Family Microhylidae			
Chiasmocleus ventrimaculata	Explorers Inn, Tambopata region, department of Madre de Dios, Peru	6	Waldram 2008