AN ABSTRACT FOR THE THESIS OF

Kennith B. Chance for the Master of Science Degree

in Biological Sciences presented on 5 November 2002

Title: A telemetric study of winter habitat selection by the American Bullfrog, *Rana catesbeiana*, in east-central Kansas.

Abstract Approved: Lynnette Sievert

The overwintering behavior and ecology of American Bullfrogs are poorly understood. A Jolly-Seber capture/recapture population estimation was conducted during fall 2001 and summer 2002 to estimate winter mortality of American Bullfrogs at a pond located on the property of Wolf Creek Nuclear Operating Corporation in Coffey County, KS. American Bullfrogs (12 adults $\geq$ 69g) were collected and a radio transmitter was implanted into each frog. Frogs were located once a week and ten habitat variables were recorded at each frog's location (frog points), at one point, < 1 m, 1-4 m, and > 4 m from the frog's location (non-frog points), and in areas where frogs were not located (pond points). Locations were recorded on aerial photos and Spearman rank correlation was conducted to determine if movements were correlated among frogs. Principal Components Analysis was conducted on the habitat variables. ANOVA revealed that the only significant differences between frog, non-frog, and pond points were on PC-1 and PC-2, with a Tukey's studentized range test

grouping frog and non-frog points as a significantly different group than the pond points on PC-1 and PC-2. The high, positive loading score for temperature and the high, negative loading score for dissolved oxygen on PC-1 show that as temperature increased at sample sites dissolved oxygen decreased. The high, positive loading scores for depth and % gravel substrate show a positive correlation between these variables. American bullfrogs were selecting shallow areas of the pond with lower temperatures and higher dissolved oxygen. The estimate of winter mortality could not be estimated due to an absence of ranids at the pond during summer sampling. Movements were uncorrelated among frogs during the winter sampling and the purpose for long-range movements is unclear.

A TELEMETRIC STUDY OF WINTER HABITAT SELECTION BY THE AMERICAN BULLFROG, *RANA CATESBEIANA*, IN EAST-CENTRAL KANSAS

A Thesis

Presented to

The Department of Biological Sciences

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In Partial Fulfillment

of the Requirements for the Degree

Master of Science

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by

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PREFACE

My thesis will be submitted for publication to the Journal of Herpetology, and is formatted for that journal.

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INTRODUCTION

Investigation of the problem of amphibian decline is hampered by the general lack of knowledge concerning amphibian winter ecology (Hecnar 1997). Ectothermic organisms might be active at winter temperatures (Friet, 1993; Stinner *et al.*, 1994; Matthews and Pope, 1999; Lamoureux and Madison, 1999; Holenweg and Reyer, 2000). Making an understanding of the winter habitat and behavior of amphibians vital to the development of an understanding of their entire life history.

The American Bullfrog, *Rana catesbeiana*, is the largest amphibian in Kansas, having an adult snout-vent length of 90 to 152 mm (Collins, 1993). Historically, research concerning the winter habitat of ranids is anecdotal, stemming from chance encounters (Emery *et al.*, 1972; Cunjak, 1986) or descriptions of the disappearance and reappearance of frogs in late fall and spring, respectively (Willis *et al.*, 1956). American Bullfrogs are visibly active (*i.e.*, seen in and around ponds) from February (earliest accounts) to late October or early November in Missouri and Kansas (Willis *et al.*, 1956; Collins, 1993), little is known about American Bullfrog behavior and habitat selection during winter when visual encounters are rare. Although, Bohnsack (1952) found an American Bullfrog overwintering in a soil pocket under several cm of leaf litter in an oak-hickory forest of Michigan, Pinder *et al.* (1992) contended that American Bullfrogs must stay in permanent bodies of water to avoid freezing because they cannot burrow. Paradoxically, when prairie ponds freeze over during winter, the bottom can become anoxic (Barica and Mathias, 1979), forceing an American Bullfrog to rely solely on anaerobic metabolism, and leading to a potentially toxic buildup of lactic acid (Donohoe *et al.*, 1998).

In order to respond to anoxic conditions at the bottom of a pond, frogs must retain the potential for activity, albeit at a greatly reduced level. Studies of overwintering American Bullfrogs (Freit, 1993; Stinner *et al.*, 1994) and Common Frogs, *Rana temporaria,* (Tattersall and Boutilier, 1997) demonstrate a selection for microhabitats with lower temperatures and higher dissolved oxygen when subjected to a gradient in the laboratory, to maximize energy savings during winter, a behavior commonly referred to as behavioral hypothermia. The Northern Leopard Frog, *Rana pipiens*, remains active at winter temperatures (Emery *et al.*, 1972; Cunjak, 1986), and has been observed situated in shallow pits doing "pushups," presumably to increase cutaneous oxygen uptake during winter by increasing water flow over the skin and removing silt from their back (Emery *et al.*, 1972). Northern Leopard Frogs overwinter on the bottom of ice covered ponds at a maximum depth of 3 m (Emery *et al.*, 1972), and under rubble or rock ledges in streams (Cunjak, 1986). The Green Frog, *Rana clamitans,* migrates to overwintering sites in seeps and springs that differ from its summer territory (Lamoureux and Madison, 1999), and the Pool Frog, *Rana lessonae,* and Edible Frog, *Rana esculenta*, move to terrestrial habitats in winter(Holenweg and Reyer, 2000). In all these investigations, frogs were able to swim or hop away when disturbed.

Water bodies are vital to American Bullfrog winter survival, but pose the risk of oxygen deprivation. Therefore, American Bullfrogs must retain the ability to move during winter to areas with high dissolved oxygen. Areas of high dissolved oxygen are going to be shallow (<1/2 m deep) and will therefore contain colder water. In addition, these areas will allow for mixing of water and air to increase dissolved oxygen concentrations when the pond surface is not frozen. I implanted 12 adult American Bullfrogs with radio transmitters in order to located and measure habitat parameters at the frogs' location and areas

(<1 m, 2-4 m, and >4m) from the frogs'. I also conducted stratified sampling of the pond to allow for comparison of frog locations to areas of the pond containing that did not contain frogs. A Jolly-Seber mark/recapture population estimation was conducted in fall 2001 and summer 2002 to allow estimation of winter mortality. I also recorded each frogs' location on an aerial photo each week to allow for correlations of frog movements to be conducted.

I predicted that American Bullfrogs would select shallow areas of the ponds (<1 m deep) to avoid anoxic conditions at the bottom of the pond. I also predicted that American Bullfrogs movements would be correlated to one another throughout the winter, and that selection of habitats with lower temperatures and higher dissolved oxygen concentrations would occur. The American bullfrog population estimates for fall 2001 at this pond were predicted to be higher than the summer 2002 estimates due to winter mortality.

MATERIALS AND METHODS

The procedures of this experiment were conducted under the approval of the Emporia State University Animal Care and Use Committee and a scientific collecting permit issued by Kansas Department of Wildlife and Parks.

Surgical Procedure:

Beginning 4 October 2001, I collected 14 adult American Bullfrogs ($\geq$ 69g) from a pond (~1.5 hectares) located on the property of Wolf Creek Nuclear Operating Corporation in Coffey County, KS, (38°14′22.9″ N by 95°40′05.1″ W), recorded capture locations on an aerial photograph, and toe-clipped each frog for identifiction. Captured frogs were housed individually at Emporia State University in 38 L aquaria with ventilated lids, and fasted for 7 d at ca. 7°C, a temperature approximating the pond temperature at the time of capture. After 7 d, the 12 frogs that appeared the most vigorous were implanted with a G3 transmitter (AVM Instrument Company, Ltd.; Livermore, CA), drawing a 0.040 mA current, powered by a 2032 lithium cell, with a perimeter loop antenna, into the peritoneal cavity of each frog. Each transmitter had a range of *ca.* 50 m, a life span of *ca.* five months, and weighed approximately 5 g, which was approximately 7% of the body mass of the smallest frog I used for this investigation (69 g). Transmitters were wiped with 70% ethanol, rinsed with sterile, distilled water, coated with a layer of sterile paraffin wax, and subsequently tested to ensure that they were functioning.

I anesthetized each frog by placing it in 0.05 (Werner, 1991) to 0.075% MS-222 (tricaine methanesulfonate) by mass for 10 to 60 minutes. After anesthetization, I washed the lateral abdominal area of the frog with Betadine® (Werner, 1991) and placed moist gauze over the frog's body to prevent desiccation during surgery. I made a 15 to 20 mm long incision through the skin, underlying muscle, and peritoneal membrane, 1-2 cm from the midventral line with the anterior end of the incision approximately midway down the vertebral column (Werner, 1991). I then inserted the transmitter into the peritoneal cavity, oriented the antenna dorsally, checked to make sure the lungs and gastrointestinal tract were not inhibited by the transmitter, and closed the incision using 2 mm mattress sutures of 4-O polyglactin 910 (Colberg *et al.*, 1997). I wiped the incision area with Betadine®, and placed the frog in a clean bucket of cool, aerated spring water to facilitate recovery (Colberg *et al.*, 1997). After each frog recovered from anesthesia, it was returned a holding containers with water, a dry area to exit the water, and a basking lamp for warmth. Spring water in the holding containers was changed daily. I monitored the frogs' recovery for 19 d, to insure the incision was completely healed, and released the frogs on 6 December 2001 at their sites of capture.

Tracking and Microhabitat Measurements:

Frogs were located using an AVM LA12-Q receiver and a three element collapsible antenna (AVM Instrument Company, Ltd., Livermore, CA) the day of and 2 d after release to ensure the frogs were healthy and transmitters were functioning properly. After the initial 2 d of tracking, frogs were located *ca*. once a week, weather permitting (except for the last 2 weeks in February and the second week in March) until the transmitters were no longer signaling (a duration of 17 weeks). I triangulated the frog's position using three vectors, to estimate the location within an approximately 2 m^2 area. I recorded the water temperature, dissolved oxygen, turbidity, conductivity, salinity, total dissolved solids, depth, and pH at the center of the approximated area of each frog (frog point) 4-6 cm above the substrate, using a Hydrolab Surveyor 4 attached to a 2 m boom with a Data Sonde 4a (Hydrolab Corporation, Austin, TX).

I repeated the habitat measurements taken at each frog location at 3 points (< 1 m, 1-4 m, and > 4 m) extending from the outside edge of the 2 m^2 approximation of the frog's location (non-frog points). I described the substrate composition as a percentage of gravel substrate (gravel > 0.8 mm) (adapted from Platts *et al.*, 1983), by wading out to an area near the frog, but not close enough to disturb the frog, and analyzing one handful after water chemistry parameters were measured at each point. Aquatic vegetation density was visually estimated from the shoreline and ranked as 1, 2, or 3, with 1 being no vegetation and 3 being dense vegetation (covering more than 1/2 of an observed square meter). In addition, habitat measurements were taken at points throughout the pond, where the frogs were not located (pond points). These points were sampled every 0.5 m of depth from the bottom to the surface of the pond at points spaced 5 m apart along 3 transects spaced 10 m apart running north to south in the pond (the length of the pond). This grid was sampled to allow for comparison between these areas and the areas where the frogs were found.

A Jolly-Seber capture/recapture population estimation (Krebs, 1999) was calculated from data collected 5 October 2001 until 6 December 2001 (during collection of frogs for radio telemetry) and 18 June 2002 until 23 July 2002, during which time the frogs were marked by toe-clipping for identification, and had snout-vent lengths taken to calculate a size distribution of the population. Population estimation was used to estimate winter mortality and quantify population dynamics.

Statistical Analysis:

All habitat data were analyzed using SAS (SAS Version 8, SAS Institute Inc., Cary, North Carolina). Principal components analysis (PCA) was performed on the ten habitat variables. Analysis of variance (ANOVA) was performed on the first six principal components to determine if there were significant differences among the frog, non-frog, and pond points on each principal component. A Tukey's studentized range test (alpha=0.05) was performed on the principal components that were revealed to have significant differences by the ANOVA to compare among frog sites, random frog sites, and random pond sites to determine at what level frogs were selecting winter habitat in the pond.

Straight-line distances were measured between frog locations on each of the sampling dates was measured to assign a magnitude to the movements. A Spearman rank correlation was done to determine if the magnitude of frog movements were correlated to one another.

RESULTS

PCA was conducted on habitat data collected during telemetry and the data are presented in Appendix A. PCA revealed that 87.8% of the variation in the habitat data was explained by the first six principal components. ANOVA performed on PC 1 through PC 6 revealed a significant difference among frog, non-frog, and pond points on PC 1 ($p=0.0002$, $df=2$) and PC 2 ($p=0.0004$, $df=2$), but no significant differences were found on PC 3 through PC 6. A Tukey's studentized range test was performed on PC 1 and PC 2 to determine among which group or groups the differences occurred. The Tukey's studentized range test grouped frog and non-frog points together as being significantly different from pond points. Eigenvectors of PC 1 were positively correlated with temperature, salinity, and total dissolved solids, and negatively correlated with dissolved oxygen and vegetation density (Table 1). PC 2 was positively correlated with % gravel substrate, depth, and pH and negatively correlated with vegetation density (Table 1). Graphing PC 1 vs. PC 2 the groupings of frog, non-frog and pond points along the gradients indicated by the eigenvectors can be seen (Figure 1).

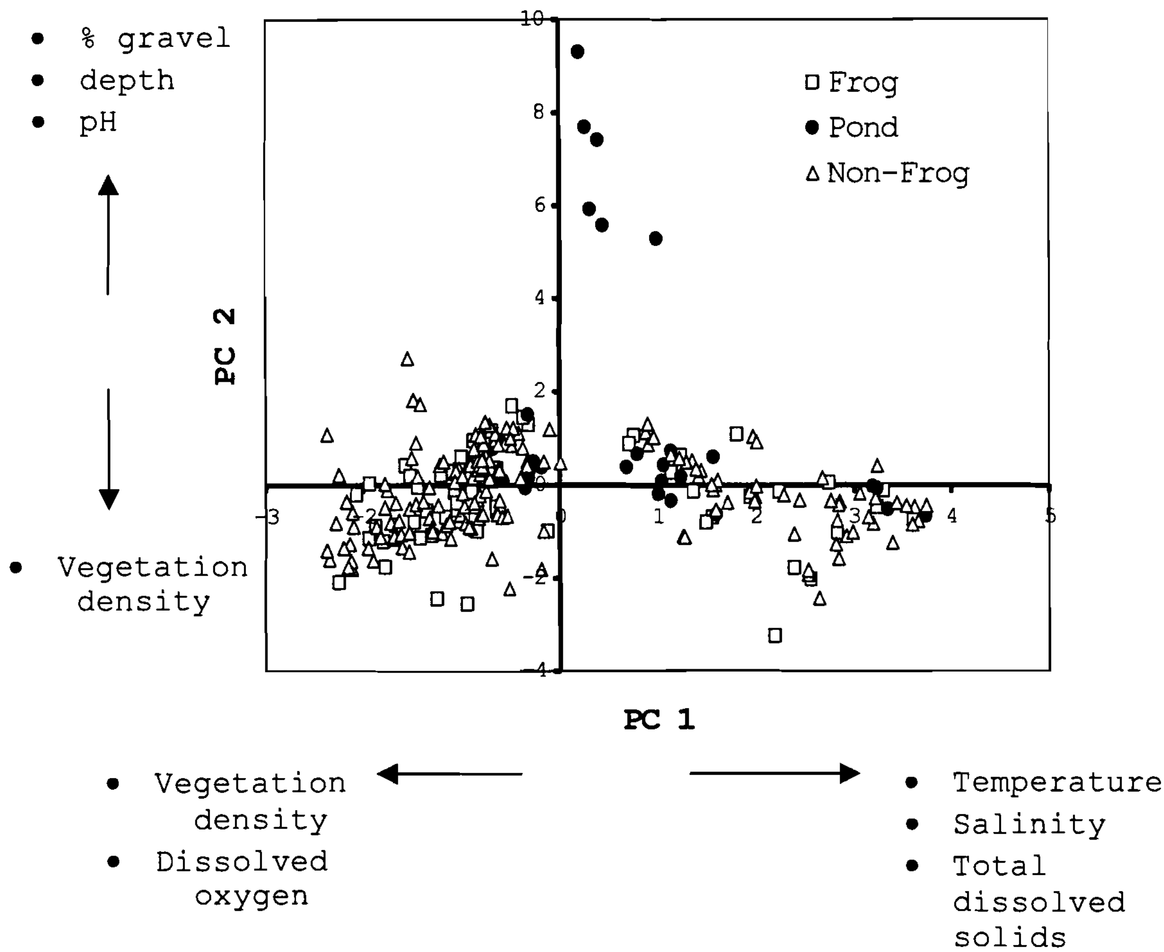
Table 1. Eigenvector values on each principal component for habitat variables collected during telemetry location for American Bullfrogs in Coffey County, KS.

	Principal Components	
	1	2
Gravel	0.04309	0.56584
Vegetation Density	-0.28270	-0.37077
Depth	-0.03713	0.55804
Temperature	0.46882	0.07437
Dissolved Oxygen	-0.54626	-0.04165
Conductivity	0.00051	0.00863
Salinity	0.46589	-0.19035
pH	0.03757	0.36493
Total Dissolved Solids	0.41541	-0.19164
Turbidity	-0.08721	0.13209

Results of the Jolly-Seber mark/recapture population estimation show the population ranged from an estimate of four individuals (95% confidence limits: upper +4.780 and lower -1.108) on 24 October 2001 (the first estimate) to a high of 49 individuals (confidence limits: upper +7.019 and lower -1.700) on 7 November 2001 (the third estimate) (Figure 2). Snout-vent lengths were measured for all frogs toe-clipped and implanted with radio transmitters, and a length-frequency histogram (Figure 3) shows a lack of large frogs in the distribution.

All frogs implanted with radio transmitters were in different locations each time they were found. Movements of each frog implanted with a radio transmitter were monitored by recording location of the frog on aerial photos each time it was located. Each sample date was assigned a number (Table 2) that correlates to the frog locations recorded during telemetry. The frog locations were transferred to figures 4-15 to show the movements of each frog from sample to sample. Each frog displayed movements between sample periods, but figure 9 shows that frog #6 made only short movements, while figure 11 shows that frog #8 made long movements. In figures where there numbers are non-sequential the missing dates are weeks when I was unable to locate the frog.

Figure 1. Graph of principal components one and two with frog, random frog, and pond points labeled for habitat variables for American Bullfrog in Coffey County, KS, from fall 2001 to summer 2002.



% gravel
depth
pH
Vegetation density
PC 2
10
8
6
4
2
0
-2
-4
-3
-2
-1
0
1
2
3
4
5
Frog
Pond
Non-Frog
PC 1
Vegetation density
Dissolved oxygen
Temperature
Salinity
Total dissolved solids

Figure 2. Jolly-Seber population estimates (± 95% confidence intervals) for the American Bullfrog (*Rana catesbeiana*) fall 2001 in Coffey County, KS.

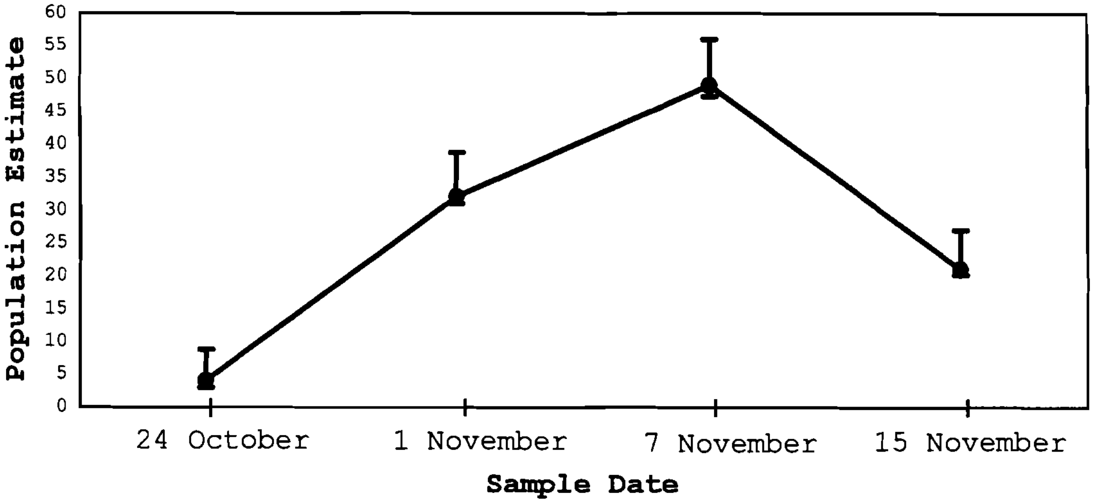

Population Estimate
60
55
50
45
40
35
30
25
20
15
10
5
0
24 October
1 November
7 November
15 November
Sample Date

Figure 3. Length-frequency histogram for American Bullfrogs toe-clipped during population estimation and telemetry at a pond in, Coffey County, KS, during fall of 2001 (n=32).

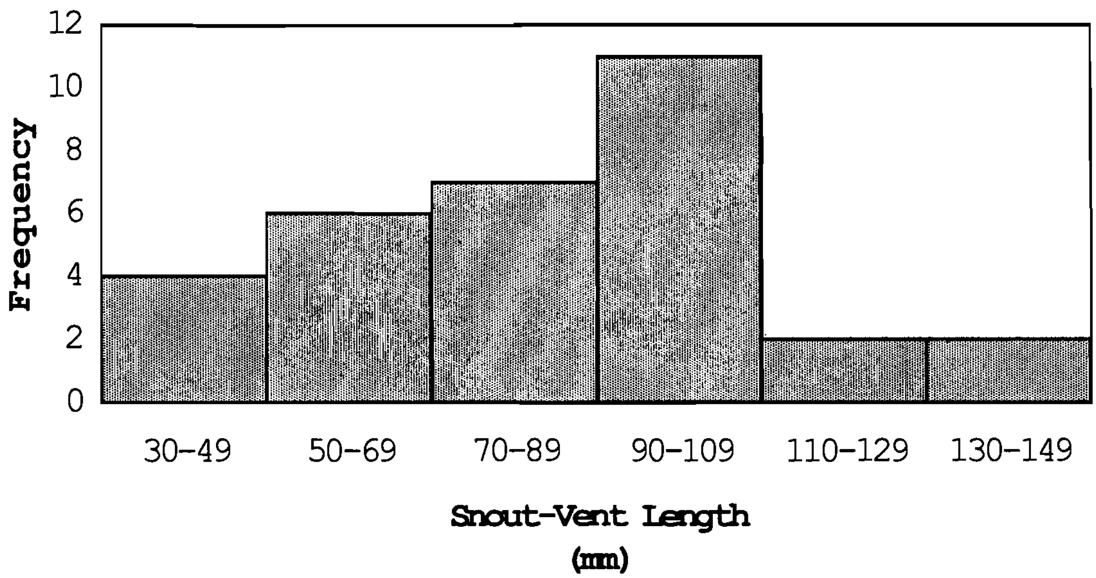

12
10
8
6
4
2
0
Frequency
30-49
50-69
70-89
90-109
110-129
130-149
Snout-Vent Length
(mm)

Table 2. Dates on which radio telemetry was used to locate American Bullfrogs at the study pond Coffey County, KS, during the winter of 2001-2002 and spring 2002, and the corresponding numbers used on the movement maps (figures 4-15) to mark location of each frog.

Sample Date	Frog Position on Map
6 December 2001	1
8 December 2001	2
18 December 2001	3
5 January 2002	4
12 January 2002	5
19 January 2002	6
26 January 2002	7
9 February 2002	8
16 February 2002	9
11 March 2002	10
18 March 2002	11
23 March 2002	12
1 April 2002	13
14 April 2002	14

Figure 4. Movements of frog #1 at a pond in Coffey County, KS, during the winter of 2001-2002 and spring 2002. 1 stands for the release/capture site and #10 corresponds to the final position and date where this frog was observed.

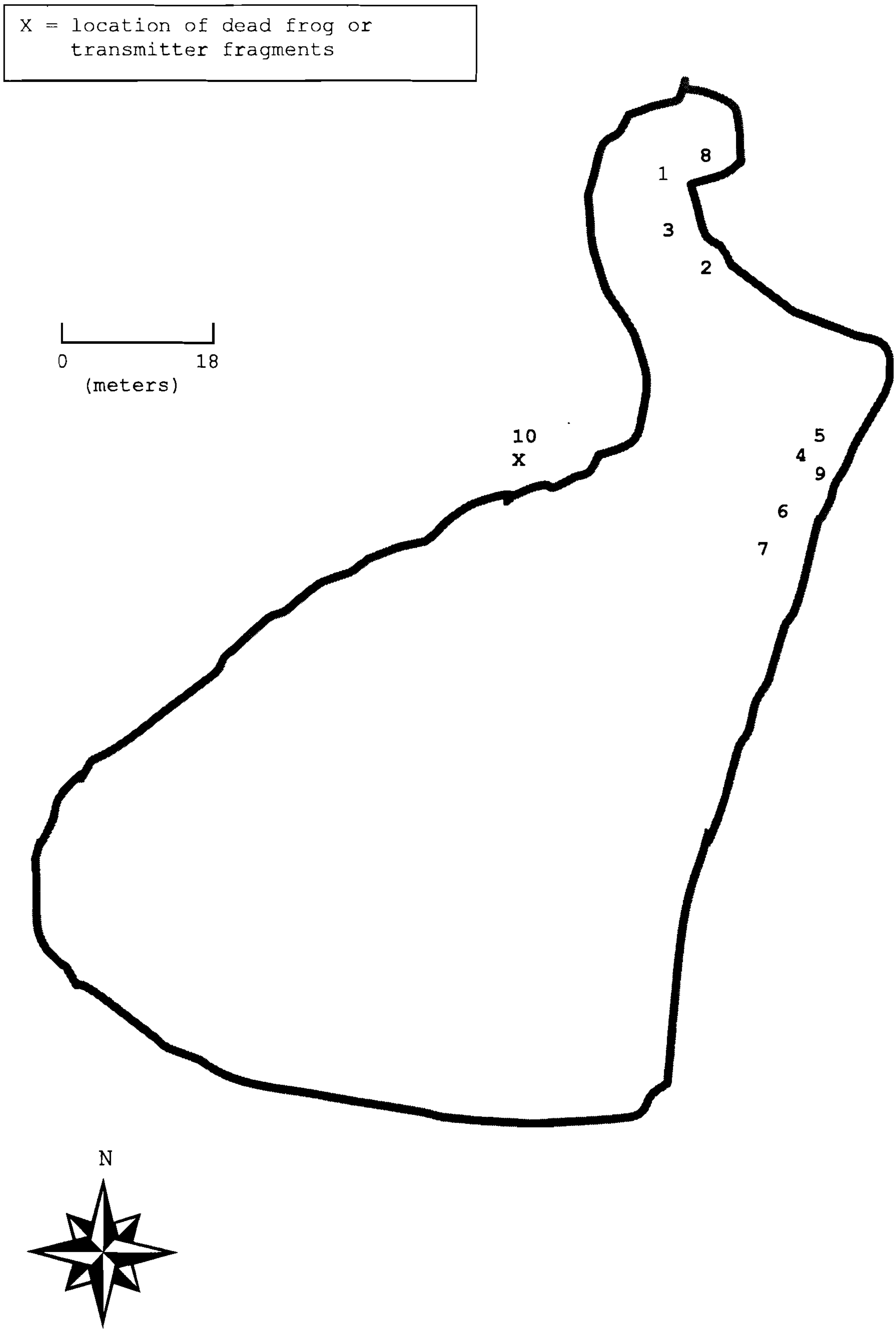

X = location of dead frog or
transmitter fragments
0
18
(meters)
1
8
3
2
10
X
5
4
9
6
7
N

Figure 5. Movements of frog #2 at a pond in Coffey County, KS, during the winter of 2001-2002 and spring 2002. 1 stands for the release/capture site and #7 corresponds to the final position and date where this frog was observed.

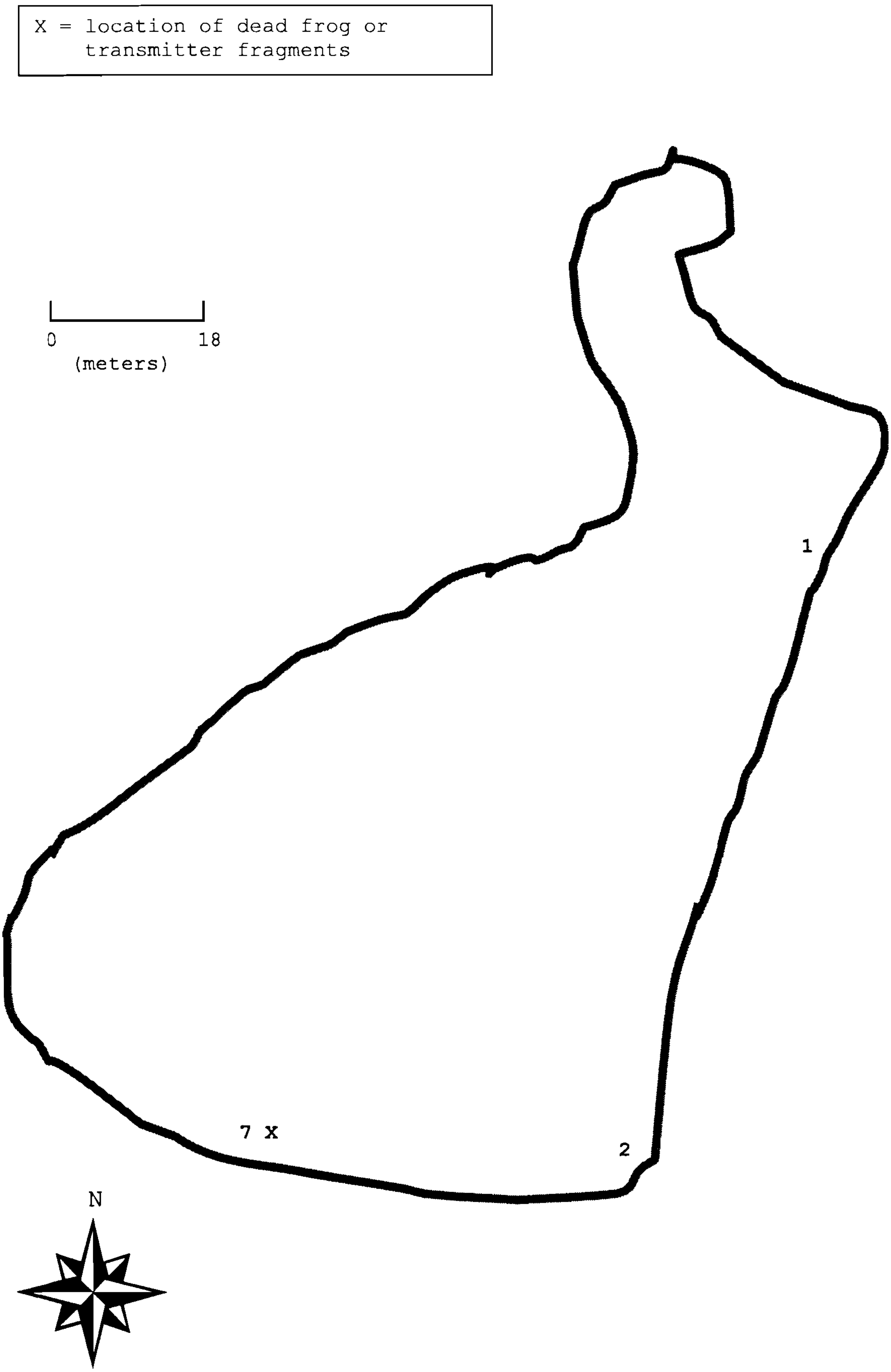

X = location of dead frog or
transmitter fragments
0
18
(meters)
1
7 X
2
N

Figure 6. Movements of frog #3 at a pond in Coffey County, KS, during the winter of 2001-2002 and spring 2002. 1 stands for the release/capture site and #14 corresponds to the final position and date where this frog was observed.

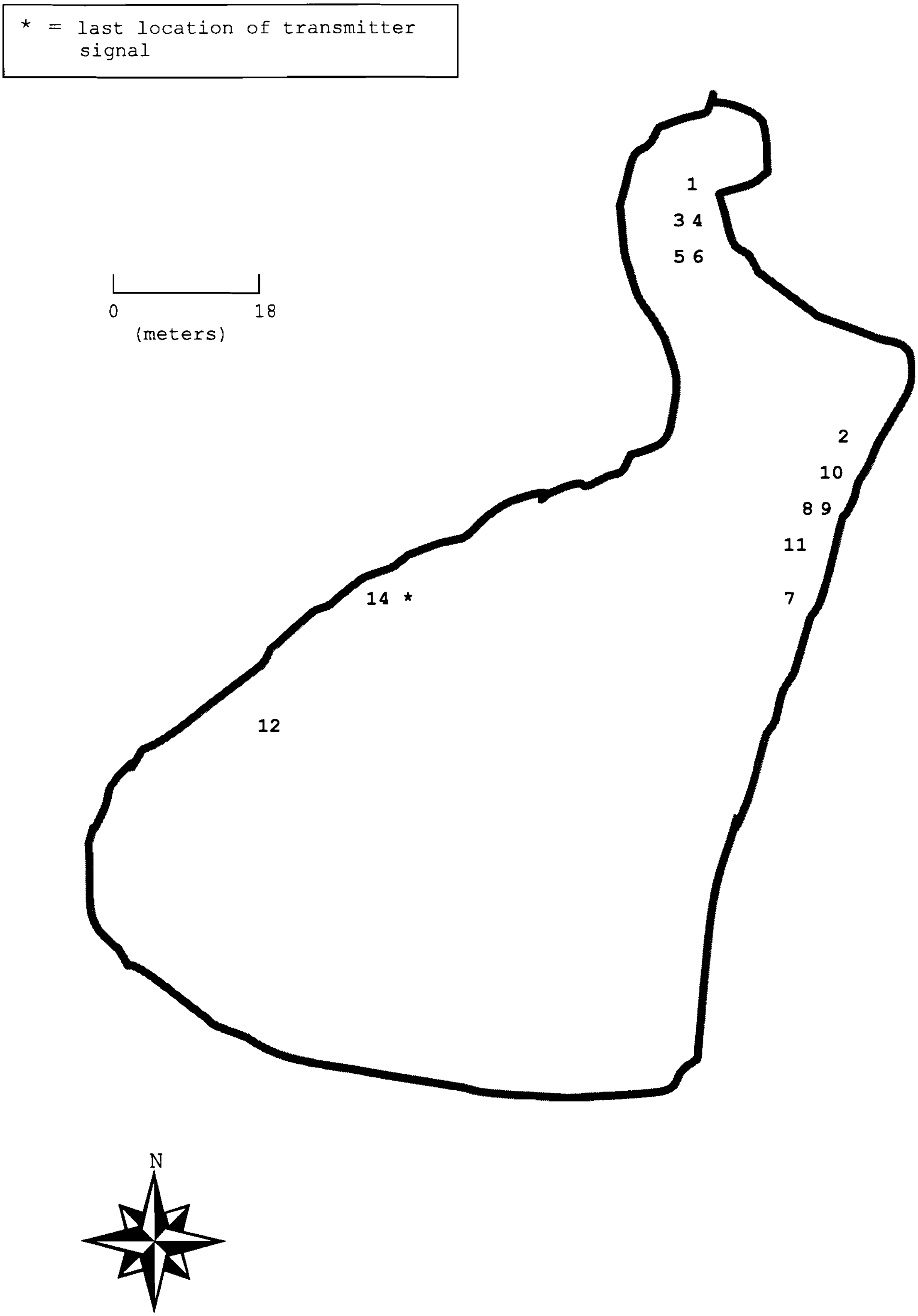

* = last location of transmitter signal
0
18
(meters)
1
3 4
5 6
2
10
8 9
11
7
14 *
12
N

Figure 7. Movements of frog #4 at a pond in Coffey County, KS, during the winter of 2001-2002 and spring 2002. 1 stands for the release/capture site and #6 corresponds to the final position and date where this frog was observed.

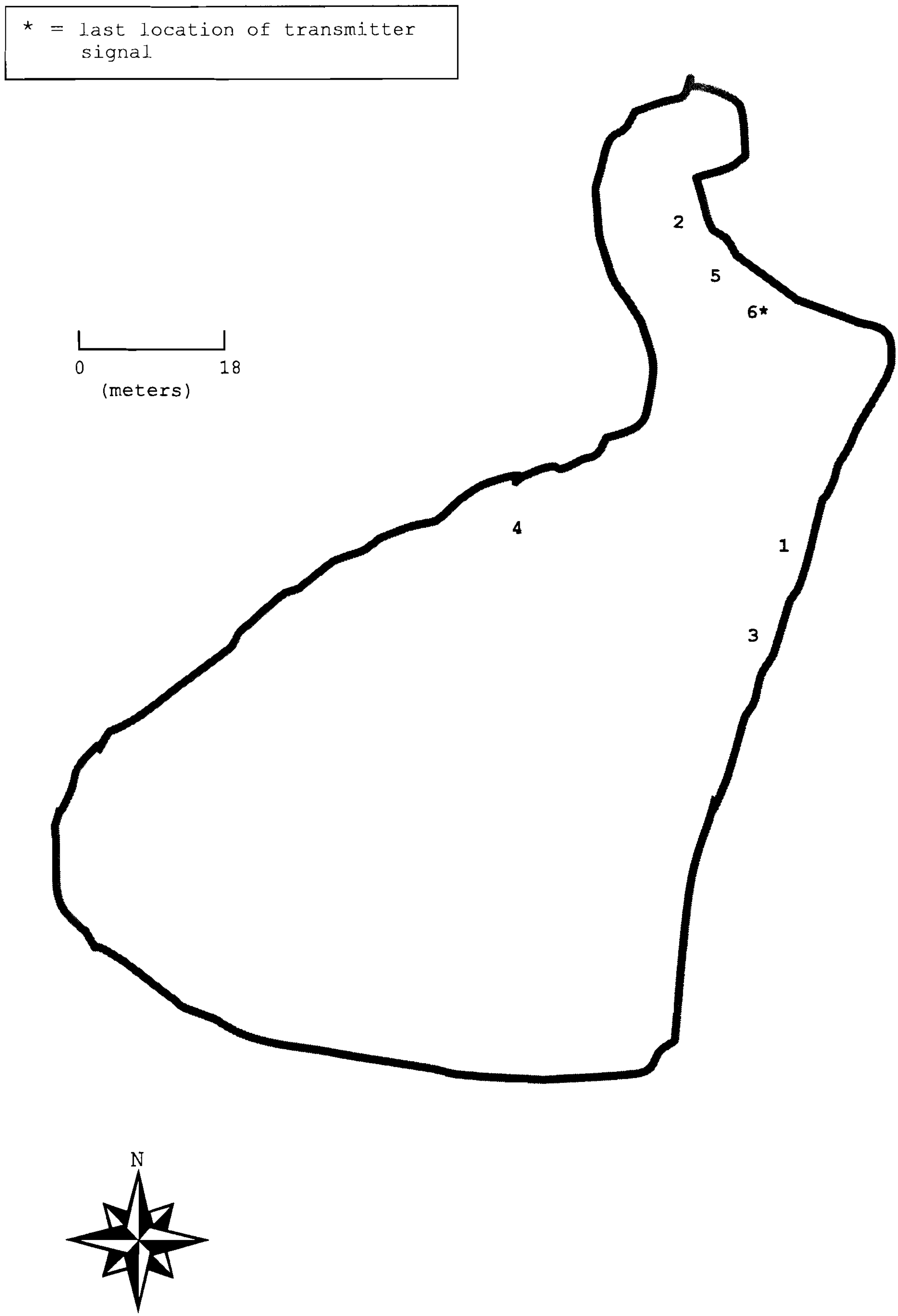

* = last location of transmitter signal
0
18
(meters)
2
5
6*
4
1
3
N

Figure 8. Movements of frog #5 at a pond in Coffey County, KS, during the winter of 2001-2002 and spring 2002. 1 stands for the release/capture site and #13 corresponds to the final position and date where this frog was observed.

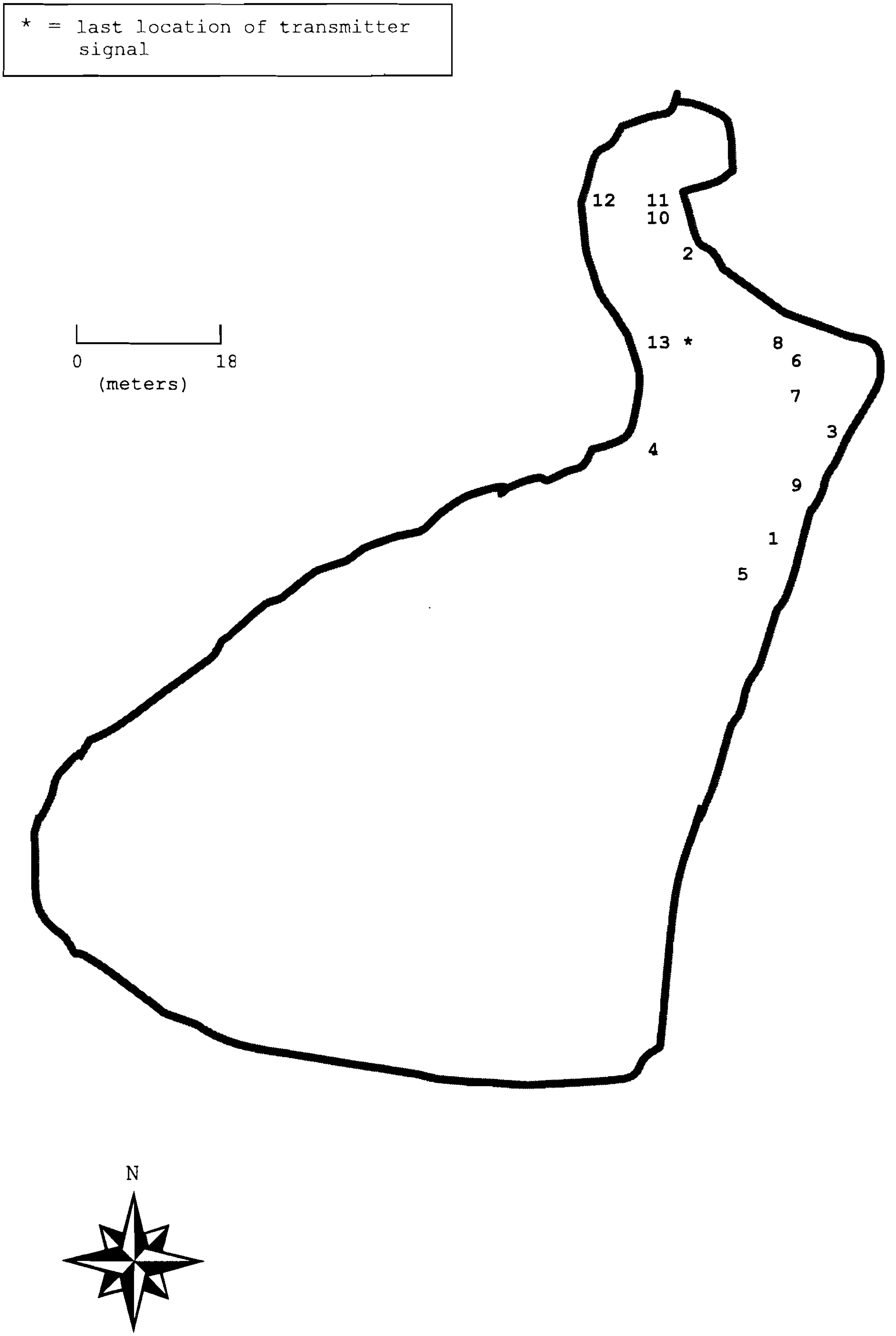

* = last location of transmitter signal
0
18
(meters)
12
11
10
2
13
*
8
6
7
3
4
9
1
5
N

Figure 9. Movements of frog #6 at a pond in Coffey County, KS, during the winter of 2001-2002 and spring 2002. 1 stands for the release/capture site and #14 corresponds to the final position and date where this frog was observed.

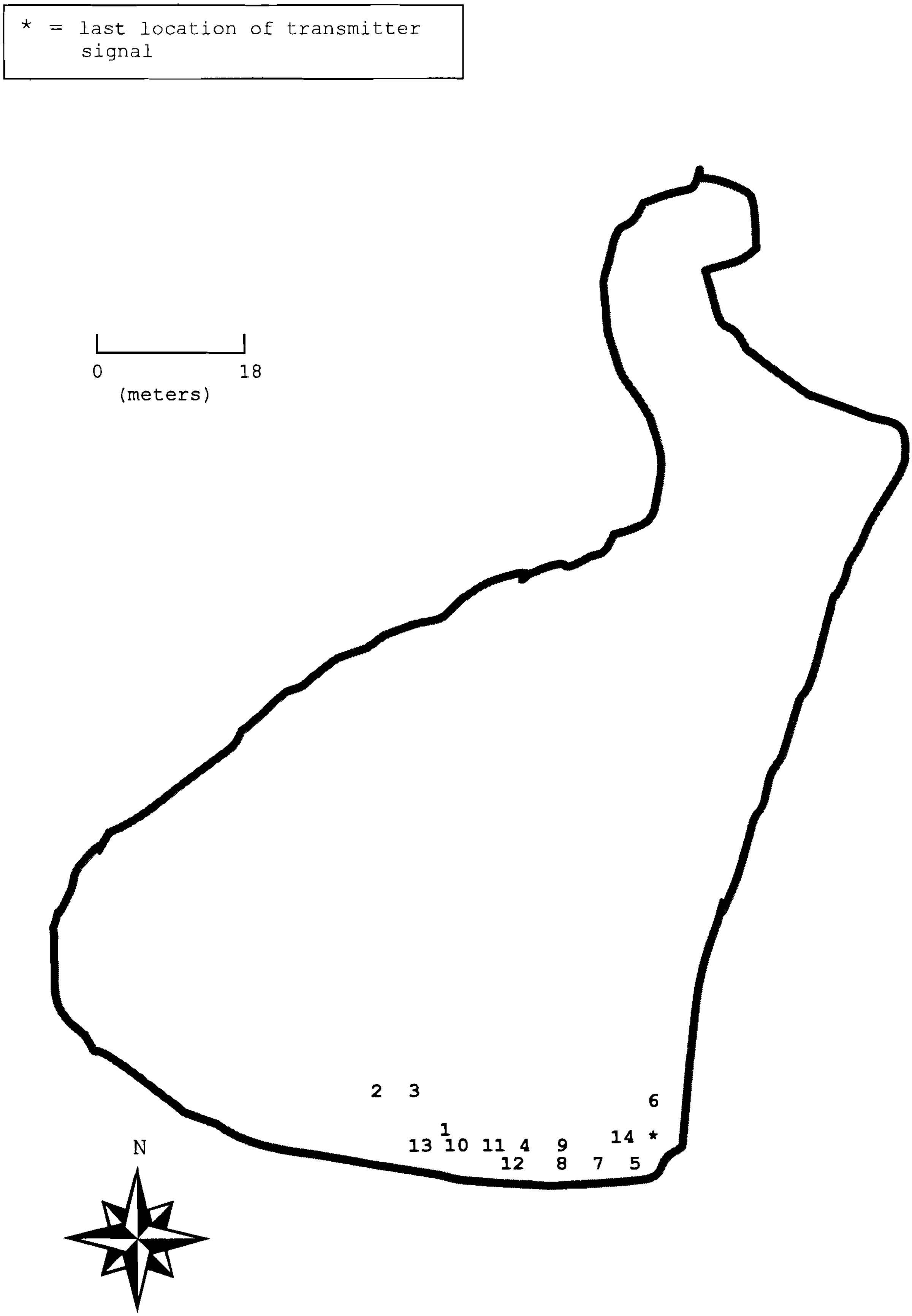

* = last location of transmitter signal
0
18
(meters)
N
2 3
6
1
13 10 11 4 9
14 *
12 8 7 5

Figure 10. Movements of frog #7 at a pond in Coffey County, KS, during the winter of 2001-2002 and spring 2002. 1 stands for the release/capture site and #9 corresponds to the final position and date where this frog was observed.

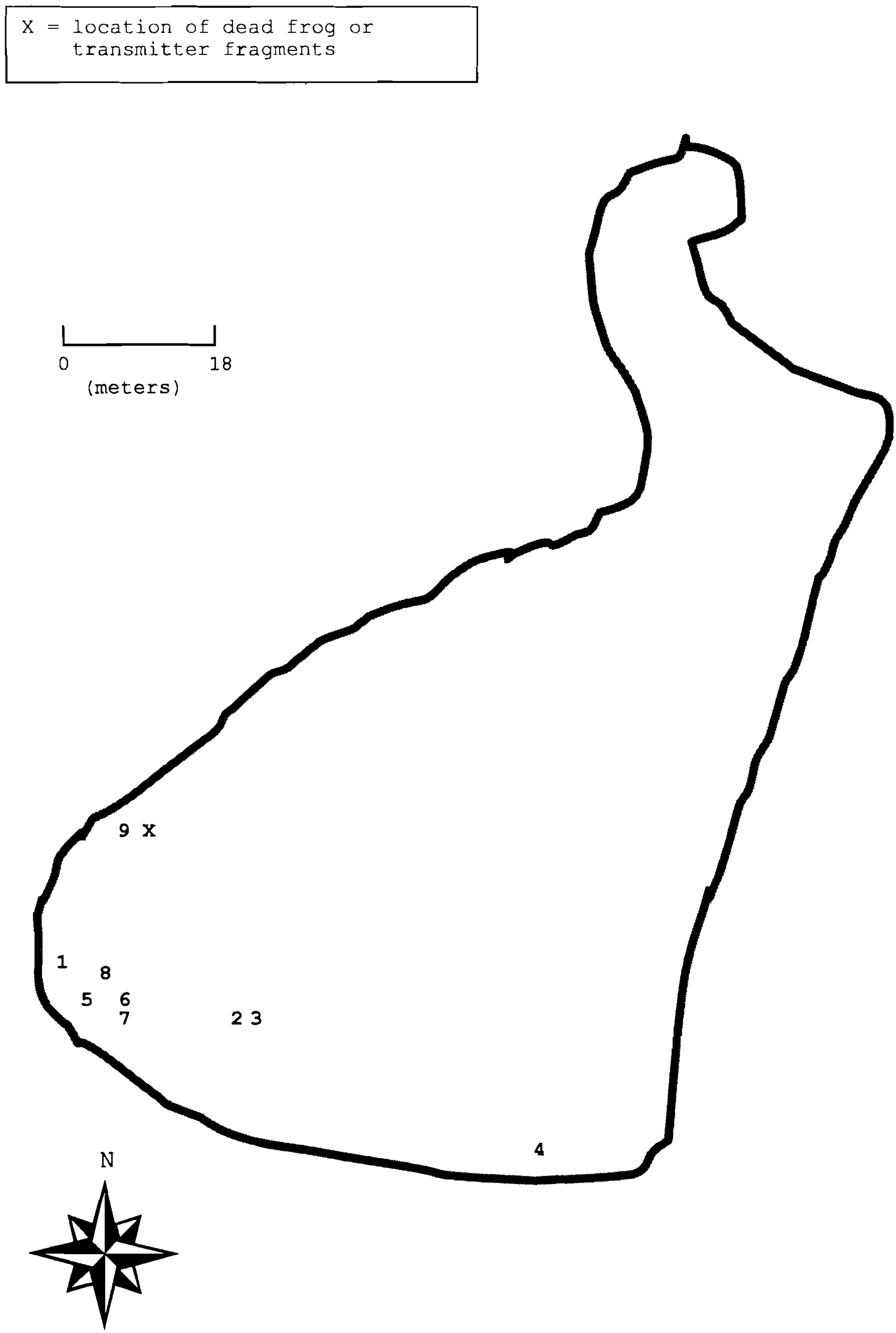

X = location of dead frog or transmitter fragments
0
18
(meters)
9 X
1
8
5
6
7
2 3
4
N

Figure 11. Movements of frog #8 at a pond in Coffey County, KS, during the winter of 2001-2002 and spring 2002. 1 stands for the release/capture site and #14 corresponds to the final position and date where this frog was observed.

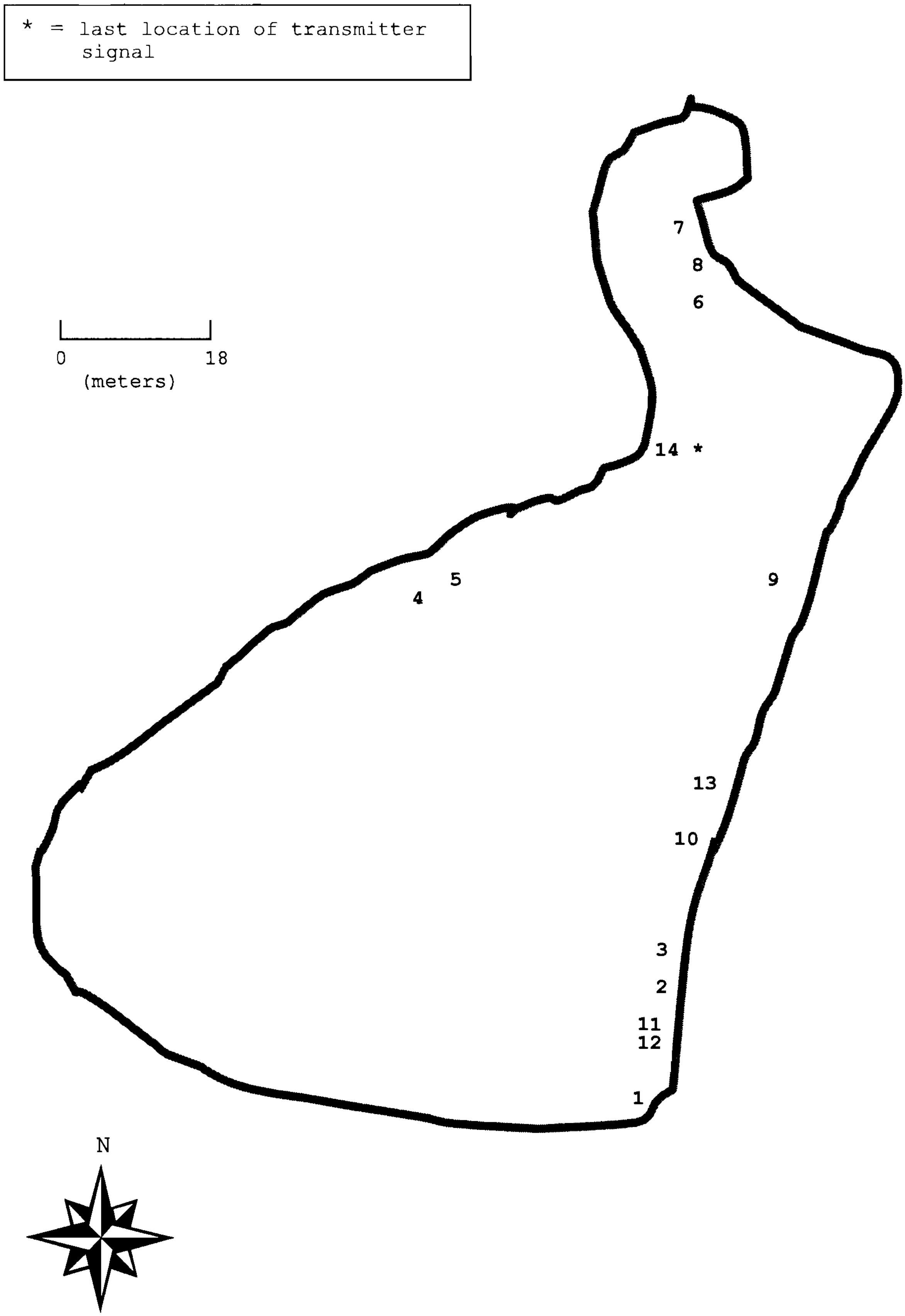

* = last location of transmitter signal
0
18
(meters)
N
7
8
6
14 *
5
4
9
13
10
3
2
11
12
1

Figure 12. Movements of frog #9 at a pond in Coffey County, KS, during the winter of 2001-2002 and spring 2002. 1 stands for the release/capture site and #10 corresponds to the final position and date where this frog was observed.

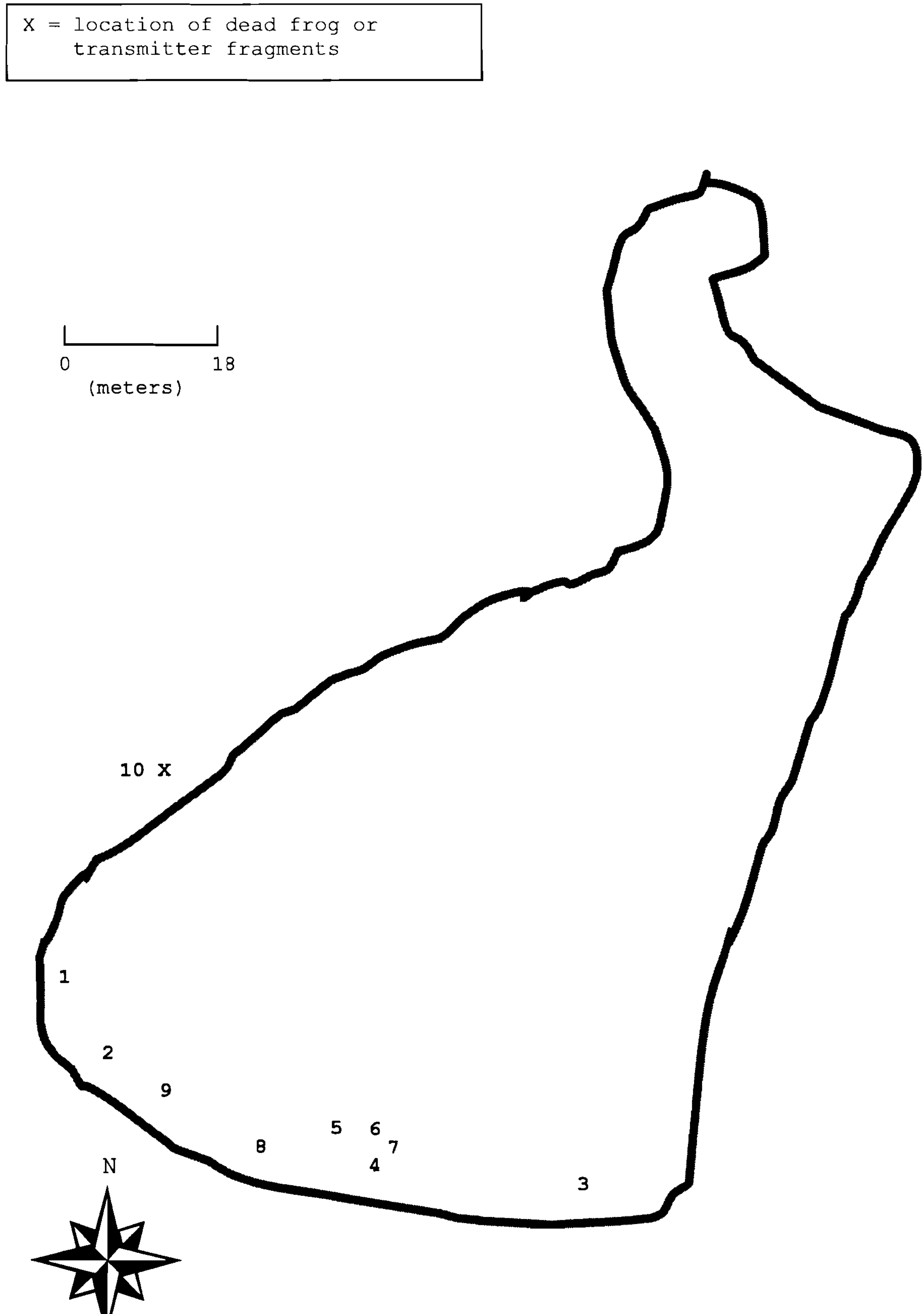
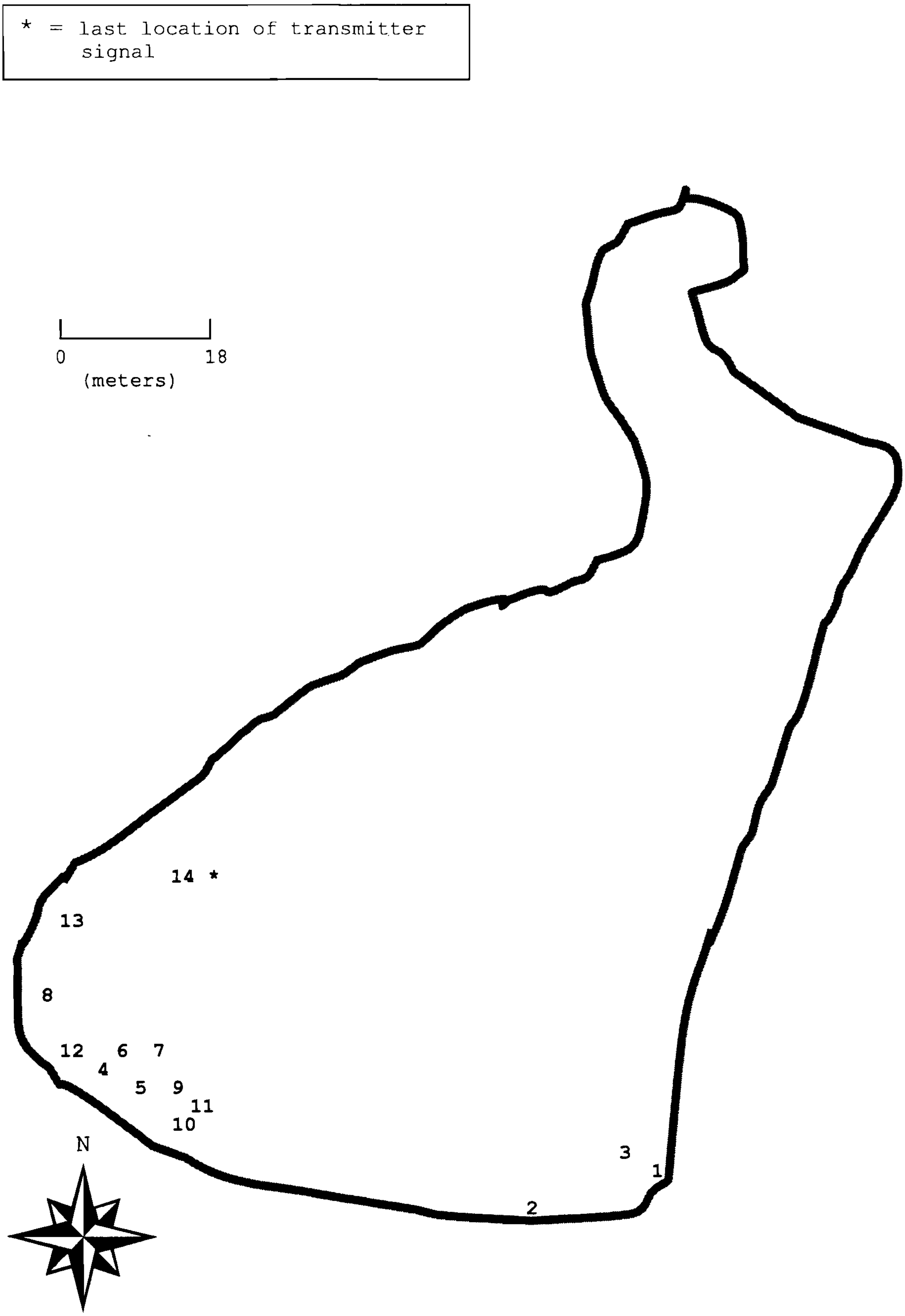

X = location of dead frog or transmitter fragments
0
18
(meters)
10 X
1
2
9
8
5
6
7
4
3
N

Figure 13. Movements of frog #10 at a pond in Coffey County, KS, during the winter of 2001-2002 and spring 2002. 1 stands for the release/capture site and #14 corresponds to the final position and date where this frog was observed.



* = last location of transmitter signal
0
18
(meters)
14 *
13
8
12
6
7
4
5
9
11
10
3
1
2
N

Figure 14. Movements of frog #25 at a pond in Coffey County, KS, during the winter of 2001-2002 and spring 2002. 1 stands for the release/capture site and #13 corresponds to the final position and date where this frog was observed.

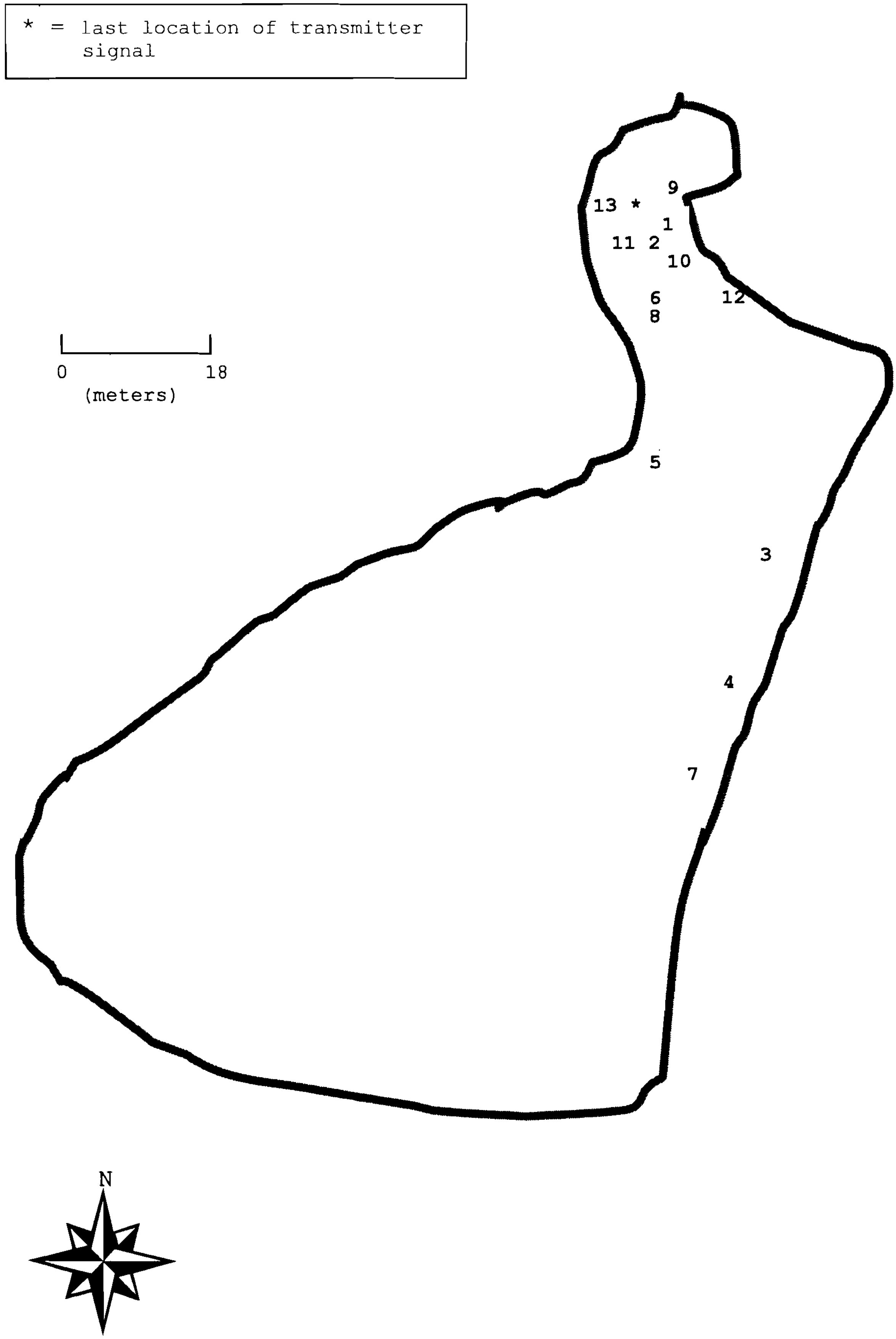
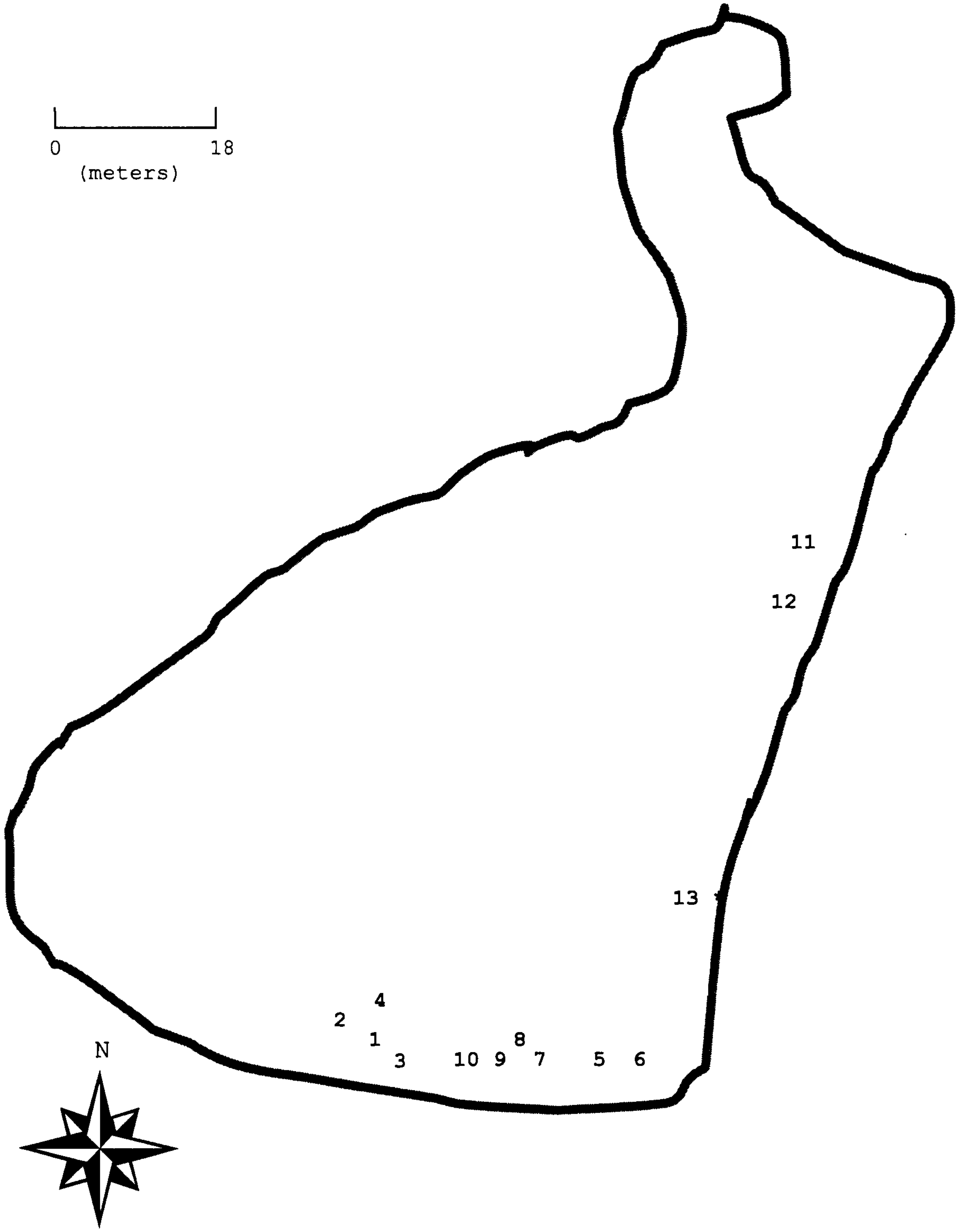

* = last location of transmitter signal
0
18
(meters)
9
13 *
1
11 2
10
6
8
12
5
3
4
7
N

Figure 15. Movements of frog #26 at a pond in Coffey County, KS, during the winter of 2001-2002 and spring 2002. 1 stands for the release/capture site and #13 corresponds to the final position and date where this frog was observed.

* = last location of transmitter signal



DISCUSSION

American Bullfrogs face many challenges during winter months. American Bullfrogs have to avoid freezing by overwintering in aquatic environments, but these environments pose a threat of low dissolved oxygen concentrations due to ice-cover (Barcica and Mathias, 1979). A solution to these problems appears, based on literature, to be stay in areas of the aquatic habitat that have high dissolved oxygen concentrations. To do this, frogs must move throughout the winter to find these favorable areas.

The surface of the pond used in this study was never frozen for more than one day at a time, and, when combined with abnormally warm temperatures from November to January and winds throughout the winter, thermal stratification never occurred.

ANOVA revealed a significant difference between frog, random frog, and pond points. Tukey's test grouped the frog and non-frog points as being significantly different from pond points. This suggests that frogs were not selecting microhabitats, *i.e.*, habitat parameters within their immediate vicinity, ~4m in any direction, but were selecting macrohabitats, *i.e.*, littoral zone vs. profundal zone.

Temperature had a high positive loading score and dissolved oxygen had a high negative loading score on principal component one. The wind associated with prairie habitats, lack of ice-cover, and the shallow water facilitated mixing of the water and air in the shallow areas of the pond. This mixing might have accounted for the high dissolved oxygen concentrations. The shallow water along the pond edge warms and cools more quickly than deeper areas of the pond, and the thermal changes can create convection currents (Stefan *et al.*, 1989), thus reducing the freezing risk to overwintering ranids. Based on results from PCA, the deep sections of the pond had dissolved oxygen concentrations of 6.16 to 7.14 mg/L at depths >1 m (Appendix 1), which placed these scores in the center of the distribution of frog and non-frog points on PC 1 in figure 1. This demonstrates that frogs were not basing selection of shallower habitats on hypoxic conditions in deeper areas of the pond, but on some other habitat characteristic or combination of factors. Salinity and total dissolved solids loaded heavy on principal component one and were positively correlated with temperature. This suggests warmer water temperatures, that have lower dissolved oxygen, have higher salinity and total dissolved solids that could play a part in water balance through osmotic regulation and freeze-tolerance during hibernation, as freeze-tolerance is associated with a pre-existing mechanism for dealing with osmotic stress (Lee et al., 1992; Costanzo et al., 1993; Churchill and Storey, 1995). Selection of cooler temperatures (behavioral hypothermia) in the shallower areas reduces metabolic energy needs thus conserving fat reserves.

Gravel substrate, depth, and pH loaded high on principal component two. The percent gravel substrate was positively correlated to the depth, with higher percent gravel at increasing depths. However, gravel was only found in a small fraction of the sample sites, which means that most frogs were found in areas of 100% mud substrate. This suggests that frogs were not selecting for substrate, because most of the pond was mud. However, a mud substrate would allow frogs to sit partially covered by the substrate and still allow for cutaneous respiration, while helping camouflage them from predators (Freit 1993). Although, this is a possible scenario several, tagged and untagged frogs were found depredated by raccoons during the study, suggesting that the frogs were not very well concealed. Cunjak (1986) found that even in a state of torpor, Northern Leopard Frogs were able to swim away and locate a refuge when disturbed. This would suggesting that predators had to see the frogs prior to capturing them. Groping of the substrate would disturb the frog and stir the substrate reducing visibility, allowing the frog to swim away.

The length-frequency histogram reveals the distribution of the sampled population of frogs in the pond consisted of few large (>110 mm) individuals. This could be due to the possibility that few frogs live to an age comparable to these large sizes. The lack of large frogs could also be due to territoriality in the larger frogs, which would displace large frogs that could rival them for home ranges and breeding rights, a behavior common in a close relative of the American Bullfrog, the Green Frog (*Rana clamitans*) (Martof, 1953). The selection of overwintering sites could also be attributed to territoriality in American Bullfrogs with individuals selecting overwintering sites based on their respective home ranges. However, study found that several frogs of various sizes were found repeatedly in the same areas throughout the study period. This territoriality of bullfrogs during winter warrants more study as a factor influencing overwintering sites. The low abundance of smaller frogs (30 to 69 mm) is most likely due to the fact that this doesn't seem to be a breeding pond. Summer sampling for the Jolly-Seber revealed that no adult American Bullfrogs were present during the breeding season, and none were heard calling. In addition, no tadpoles were seen at any time during the sampling. This means that the frogs would have to travel *ca.* 200 m to Coffey County Lake through thick, prairie grass to get to the nearest permanent body of water to the study pond. However, Coffey County Lake is managed for a high density of predatory fish, which would decrease survival of tadpoles and eggs, but may be why the adult frogs migrate to the study pond to overwinter.

The Jolly-Seber population estimation revealed population estimates from four frogs on 24 October 2001 (second week of fall sampling) to a high of 49 on 7 November 2002 (third week of fall sampling). The highest estimate is mostly likely closer to the actual population size based on personal observation and the fact that some individuals evaded capture during every collecting trip which could have decreased the estimated population size. However, the increase in population size would support the idea that the frogs are migrating to this pond as an overwintering site, and the decrease in population at the last estimate could be due to frogs starting to spend more time submerged in the pond. No definite conclusions as to winter survival rates can be drawn based on this study. No ranid frogs were observed during late spring and early summer sampling trips. Only Northern Cricket Frogs, *Acris crepitans*, were found in and around the pond from May-July 2002. The disappearance of the ranids in this pond warrants further study into their population dynamics.

American Bullfrogs used in this study remained active for the entire study period, with movements that apparently were confined to the littoral zone of the pond. Previous investigations have documented winter movements of ranids (Cunjak, 1986; Freit, 1993; Stinnner *et al.*, 1994; Holenweg and Reyer, 2000), and the frogs in my study were in different locations each week they were sampled. Measurements of linear movements for each frog were estimated from figures 4 through 15. Spearman rank correlation conducted on these measurements revealed that there were no positive correlations for distances moved among frogs for the weeks sampled. This demonstrates that movements were based on individual habitat preferences, responses to disturbance, or physical needs, *i.e.,* removing silt from the back or moving to prevent muscle atrophy.

ANOVA showed that the only significant differences between frog, non-frog, and pond points were on PC-1 and PC-2, with a Tukey's studentized range test grouping frog and non-frog points as being a significantly different group than the pond points on PC-1 and PC-2. This demonstrates that American Bullfrogs were selecting overwintering sites on a macrohabitat (regional) scale as opposed to a microhabitat (local) scale within the pond. The high, positive loading score for temperature and the high, negative loading score for dissolved oxygen on PC-1 show that as temperature increased at sample sites dissolved oxygen decreased. The high, positive loading scores for depth and % gravel substrate show a positive correlation between these variable. American bullfrogs were selecting shallow areas of the pond with lower temperatures and higher dissolved oxygen. The estimate of winter mortality could not be estimated due to an absence of ranids at the pond during summer sampling. This could be due to the fact that this pond is not a breeding pond, and is supported by the absence of tadpoles seen during sampling and the low abundance of smaller individuals in the fall sampling. Movements were uncorrelated among frogs during the winter sampling and the purpose for long range movements is unclear.

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APPENDIX

Appendix A. Habitat data for American Bullfrogs in Coffey County, KS, from fall 2001, winter 2001-2002, and spring 2002.

F = frog point, NF = non frog point,
P = pond point

Points	Date		Gravel	Veg	(m) Depth	(°C) Temp	(mg/L) DO	(µS/cm) Cond	(ppt) Sal.	pH	(mg/L) TDS
Frog 1	1/19/02	F	0	3	0.3	2.22	8.58	0.1821	0.08	7.71	0.1166
Frog 1 <1	1/19/02	NF	0	3	0.37	2.14	8.07	0.1825	0.08	7.76	0.1161
Frog 1 1-4	1/19/02	NF	0	3	0.3	1.96	8.3	0.1814	0.08	7.88	0.116
Frog 1 >4	1/19/02	NF	0	3	0.4	1.87	8.58	0.1858	0.08	7.93	0.1178
Frog 4	1/19/02	F	0	3	0.2	2.93	8.13	0.1879	0.08	7.74	0.1206
Frog 4 <1	1/19/02	NF	0	3	0.15	1.96	8.41	0.1838	0.08	8.04	0.1168
Frog 4 1-4	1/19/02	NF	0	3	0.2	1.54	8.01	0.1857	0.08	8.04	0.1187
Frog 4 >4	1/19/02	NF	0	3	0.4	2.37	8.2	0.186	0.08	8.11	0.1197
Frog 5 1-4	1/19/02	NF	0	3	0.1	2.12	8.33	0.1808	0.08	8.17	0.1151
Frog 5 >4	1/19/02	NF	0	3	0.4	2.23	8.24	0.1829	0.08	8.21	0.1168
Frog 5 <1	1/19/02	NF	0	3	0.2	2.15	8.08	0.1819	0.08	8.18	0.1158
Frog 5	1/19/02	F	0	3	0.35	2.28	8.05	0.1823	0.08	8.19	0.1164
Frog 3 >4	1/19/02	NF	0	3	0.2	2.34	8.4	0.1817	0.08	8.17	0.1159
Frog 3 1-4	1/19/02	NF	0	3	0.21	2.4	8.19	0.1829	0.08	8.2	0.1167
Frog 3	1/19/02	F	0	3	0.5	2.83	8.08	0.1832	0.08	8.24	0.1175
Frog 3 <1	1/19/02	NF	0	3	0.4	2.24	8.13	0.1821	0.08	8.24	0.1185
Frog 25 >4	1/19/02	NF	0	3	0.25	3.15	7.82	0.1847	0.09	8.23	0.1177
Frog 25 1-4	1/19/02	NF	0	3	0.35	2.88	7.82	0.1825	0.08	8.24	0.1169
Frog 25	1/19/02	F	0	3	0.45	2.34	8.07	0.1824	0.08	8.26	0.1168
Frog 25 <1	1/19/02	NF	0	3	0.45	2.43	8.09	0.1826	0.08	8.25	0.1168
Frog 6	1/19/02	F	5	2	0.35	2.24	8.69	0.1805	0.08	8.26	0.1155
Frog 6 <1	1/19/02	NF	0	3	0.35	2.26	8.3	0.1807	0.08	8.27	0.1156
Frog 6 1-4	1/19/02	NF	0	3	0.5	2.51	8.4	0.1817	0.08	8.34	0.1161
Frog 6 >4	1/19/02	NF	0	3	0.65	2.37	8.42	0.182	0.08	8.3	0.1165
Frog 26	1/19/02	F	5	2	0.4	2.19	8.84	0.182	0.08	8.43	0.1165
Frog 26 <1	1/19/02	NF	5	2	0.35	2.15	8.39	0.1819	0.08	8.37	0.1165
Frog 26 1-4	1/19/02	NF	0	3	0.9	2.08	8.38	0.1822	0.08	8.37	0.1165
Frog 26 >4	1/19/02	NF	0	3	1.3	2.18	8.31	0.1821	0.08	8.36	0.1164
Frog 9	1/19/02	F	5	1	0.4	2.22	8.81	0.1814	0.08	8.38	0.1162
Frog 9 <1	1/19/02	NF	0	1	0.5	2.13	8.38	0.1816	0.08	8.39	0.1161
Frog 9 1-4	1/19/02	NF	0	1	1.25	2.04	8.24	0.182	0.08	8.38	0.1164
Frog 9 >4	1/19/02	NF	0	1	1.8	2.03	8.2	0.1816	0.08	8.35	0.1163
Frog 10	1/19/02	F	10	1	0.2	2.29	8.88	0.182	0.08	8.35	0.1164
Frog 10 <1	1/19/02	NF	10	2	0.3	2.51	8.2	0.1803	0.08	8.31	0.1153
Frog 10 1-4	1/19/02	NF	10	1	0.45	2.13	8.26	0.1817	0.08	8.36	0.1163
Frog 10 >4	1/19/02	NF	10	1	1	2.05	8.27	0.182	0.08	8.37	0.1166

					(m)	(°C)	(mg/L)	(µS/cm)	(ppt)		(mg/L)
Points	Date		Gravel	Veg	Depth	Temp	DO	Cond	Sal.	pH	TDS
Frog 7	1/19/02	F	0	1	0.2	2.37	8.48	0.1816	0.08	8.36	0.116
Frog 7 <1	1/19/02	NF	0	1	0.2	2.34	8.31	0.1813	0.08	8.38	0.1161
Frog 7 1-4	1/19/02	NF	0	2	0.3	2.31	8.15	0.1814	0.08	8.35	0.1161
Frog 7 >4	1/19/02	NF	0	1	0.25	2.26	8.36	0.1819	0.08	8.39	0.1163
Frog 8	1/19/02	F	0	2	0.2	3.21	8.82	0.1816	0.08	7.98	0.1163
Frog 8 <1	1/19/02	NF	0	2	0.2	3.03	8.21	0.1819	0.08	8.06	0.1165
Frog 8 1-4	1/19/02	NF	0	2	0.25	2.56	8.26	0.1817	0.08	8.12	0.1162
Frog 8 >4	1/19/02	NF	0	2	0.4	2.41	8.27	0.1815	0.08	8.16	0.1161
Frog 5	1/26/02	F	0	2	0.2	3.26	9.14	0.1838	0.08	7.73	0.1175
Frog 5 <1	1/26/02	NF	0	2	0.25	3.12	8.74	0.1825	0.08	7.91	0.1168
Frog 5 1-4	1/26/02	NF	0	2	0.2	3.26	8.61	0.1829	0.08	7.9	0.1172
Frog 5 >4	1/26/02	NF	0	2	0.2	3.64	8.51	0.1828	0.08	8.07	0.117
Frog 1	1/26/02	F	0	2	0.15	4.91	8.01	0.1813	0.08	8.15	0.1172
Frog 1 <1	1/26/02	NF	0	2	0.15	4.66	8	0.1836	0.08	8.18	0.1173
Frog 1 1-4	1/26/02	NF	0	2	0.2	4.44	8.02	0.1832	0.08	8.18	0.1172
Frog 1 >4	1/26/02	NF	0	2	0.2	4.5	8.09	0.1829	0.08	8.25	0.1175
Frog 3	1/26/02	F	0	2	0.25	5.8	8.17	0.1839	0.08	8.3	0.1177
Frog 3 <1	1/26/02	NF	0	2	0.25	5.82	7.9	0.1838	0.08	8.28	0.1177
Frog 3 1-4	1/26/02	NF	0	2	0.3	5.7	7.82	0.1836	0.08	8.29	0.1176
Frog 3 >4	1/26/02	NF	0	3	0.25	5.87	7.85	0.1831	0.08	8.33	0.1176
Frog 25	1/26/02	F	0	2	0.27	6.47	8.1	0.1833	0.08	6.9	0.1173
Frog 25 <1	1/26/02	NF	0	2	0.27	6.43	7.81	0.1837	0.08	7.47	0.1175
Frog 25 1-4	1/26/02	NF	0	2	0.27	6.57	7.88	0.184	0.08	7.9	0.1177
Frog 25 >4	1/26/02	NF	0	3	0.27	6.3	7.76	0.1842	0.08	8.05	0.1179
Frog 8	1/26/02	F	0	3	0.15	7.1	7.83	0.184	0.08	8.21	0.1171
Frog 8 <1	1/26/02	NF	0	3	0.15	8.85	7.46	0.1846	0.08	8.17	0.1182
Frog 8 1-4	1/26/02	NF	0	3	0.15	6.33	7.97	0.1828	0.08	8.15	0.1167
Frog 8 >4	1/26/02	NF	0	3	0.2	5.8	8.8	0.1825	0.08	8.07	0.1167
Frog 7	1/26/02	F	0	2	0.2	8.15	8.4	0.1854	0.08	8.1	0.1185
Frog 7 <1	1/26/02	NF	0	2	0.15	7.68	7.94	0.1846	0.08	7.21	0.1172
Frog 7 1-4	1/26/02	NF	0	2	0.15	6.34	8.12	0.184	0.08	8.2	0.118
Frog 7 >4	1/26/02	NF	0	2	0.25	5.5	8.3	0.1838	0.08	8.35	0.1175
Frog 10	1/26/02	F	0	2	0.2	6.16	8.17	0.1833	0.08	8.35	0.1172
Frog 10 <1	1/26/02	NF	0	2	0.15	6.61	8.35	0.1831	0.08	8.31	0.1172

Points	Date		Gravel	Veg	(m) Depth	(°C) Temp	(mg/L) DO	(µS/cm) Cond	(ppt) Sal.	pH	(mg/L) TDS
Frog 10 1-4	1/26/02	NF	0	2	0.15	5.54	8.14	0.1838	0.08	8.43	0.1173
Frog 10 >4	1/26/02	NF	0	2	0.25	5.75	8.15	0.1832	0.08	8.39	0.1171
Frog 9	1/26/02	F	0	3	0.15	5.43	9.03	0.1836	0.08	8.42	0.1178
Frog 9 <1	1/26/02	NF	0	3	0.2	5.41	8.1	0.1835	0.08	8.41	0.1173
Frog 9 1-4	1/26/02	NF	0	3	0.15	5.53	8.18	0.1833	0.08	8.34	0.1173
Frog 9 >4	1/26/02	NF	0	3	0.25	5.13	8.19	0.1835	0.08	8.41	0.1172
Frog 26	1/26/02	F	0	2	0.15	5.4	8.97	0.1828	0.08	8.36	0.117
Frog 26 <1	1/26/02	NF	0	2	0.15	5.29	8.31	0.1831	0.08	8.34	0.1174
Frog 26 1-4	1/26/02	NF	0	2	0.15	5.33	8.21	0.1839	0.08	8.35	0.1176
Frog 26 >4	1/26/02	NF	0	2	0.7	5.11	8.15	0.1832	0.08	8.39	0.1173
Frog 6	1/26/02	F	0	2	0.25	5.39	8.45	0.1828	0.08	8.43	0.1169
Frog 6 <1	1/26/02	NF	0	2	0.25	5.43	8.35	0.1833	0.08	8.4	0.1172
Frog 6 1-4	1/26/02	NF	0	1	0.25	5.55	8.18	0.1833	0.08	8.39	0.1174
Frog 6 >4	1/26/02	NF	0	1	0.9	5.15	8.2	0.1838	0.08	8.39	0.1175
Frog 3	2/9/02	F	0	2	0.4	6.83	7.05	0.1727	0.08	8.14	0.1107
Frog 3 <1	2/9/02	NF	0	2	0.4	6.86	6.99	0.1756	0.08	8.14	0.1122
Frog 3 1-4	2/9/02	NF	0	2	0.4	6.65	7.09	0.1756	0.08	8.2	0.1123
Frog 3 >4	2/9/02	NF	0	2	0.4	6.33	7.15	0.1759	0.08	8.23	0.1124
Frog 5	2/9/02	F	0	2	0.3	6.5	7.4	0.176	0.08	8.24	0.1127
Frog 5 <1	2/9/02	NF	0	2	0.3	6.56	7.1	0.176	0.08	8.25	0.1126
Frog 5 1-4	2/9/02	NF	0	2	0.4	6.47	7	0.1761	0.08	8.28	0.1126
Frog 5 >4	2/9/02	NF	0	2	0.45	6.34	7.06	0.1759	0.08	8.32	0.1127
Frog 1	2/9/02	F	0	2	0.3	6.4	7.02	0.1754	0.08	8.48	0.112
Frog 1 <1	2/9/02	NF	0	2	0.3	6.45	6.95	0.1756	0.08	8.37	0.1125
Frog 1 1-4	2/9/02	NF	0	2	0.3	6.8	7.05	0.1757	0.08	8.42	0.1126
Frog 1 >4	2/9/02	NF	0	2	0.475	6.2	7.02	0.1758	0.08	8.4	0.1126
Frog 8	2/9/02	F	0	2	0.4	6.51	7.18	0.1751	0.08	8.41	0.1123
Frog 8 <1	2/9/02	NF	0	2	0.4	6.57	7.22	0.1753	0.08	8.4	0.1123
Frog 8 1-4	2/9/02	NF	0	2	0.4	6.47	7.04	0.1753	0.08	8.46	0.1122
Frog 8 >4	2/9/02	NF	0	2	0.4	6.57	7.07	0.1759	0.08	8.43	0.1125
Frog 25	2/9/02	F	0	2	0.25	6.7	7.64	0.1752	0.08	8.52	0.1112
Frog 25 <1	2/9/02	NF	0	2	0.25	6.68	7.11	0.1757	0.08	8.45	0.1124
Frog 25 1-4	2/9/02	NF	0	2	0.3	6.67	7.15	0.1757	0.08	8.49	0.1125
Frog 25 >4	2/9/02	NF	0	2	0.375	6.65	7.04	0.1758	0.08	8.44	0.1126
Frog 7	2/9/02	F	0	1	0.2	5.98	7.54	0.175	0.08	8.45	0.112

					(m)	(°C)	(mg/L)	(µS/cm)	(ppt)		(mg/L)
Points	Date		Gravel	Veg	Depth	Temp	DO	Cond	Sal.	pH	TDS
Frog 7 <1	2/9/02	NF	0	1	0.2	6	7.31	0.1755	0.08	8.34	0.1121
Frog 7 1-4	2/9/02	NF	0	1	0.2	5.83	7.45	0.1755	0.08	8.33	0.1124
Frog 7 >4	2/9/02	NF	0	1	0.2	5.75	7.4	1.756	0.08	8.32	0.1124
Frog 10	2/9/02	F	0	2	0.25	6.6	7.85	0.1757	0.08	8.41	0.1124
Frog 10 <1	2/9/02	NF	0	2	0.25	6.29	7.58	0.176	0.08	8.39	0.1125
Frog 10 1-4	2/9/02	NF	0	2	0.45	5.78	7.52	0.1754	0.08	8.38	0.1124
Frog 10 >4	2/9/02	NF	0	2	0.5	5.86	7.48	0.176	0.08	8.35	0.1127
Frog 9	2/9/02	F	0	1	0.2	6	8.2	0.1753	0.08	8.38	0.1122
Frog 9 <1	2/9/02	NF	0	1	0.25	5.97	7.82	0.1759	0.08	8.37	0.1127
Frog 9 1-4	2/9/02	NF	0	1	0.425	5.75	7.69	0.1756	0.08	8.37	0.1125
Frog 9 >4	2/9/02	NF	0	1	0.475	5.96	7.6	0.1757	0.08	8.36	0.1128
Frog 26	2/9/02	F	10	1	0.3	5.94	7.61	0.1756	0.08	8.42	0.1125
Frog 26 <1	2/9/02	NF	10	1	0.325	6.2	8.04	0.1754	0.08	8.48	0.1122
Frog 26 1-4	2/9/02	NF	10	1	0.3	5.85	7.45	0.1758	0.08	8.4	0.1126
Frog 26 >4	2/9/02	NF	10	1	0.375	5.82	7.41	0.176	0.08	8.39	0.1127
Frog 6	2/9/02	F	10	1	0.31	5.71	8	0.1765	0.08	8.43	0.1129
Frog 6 <1	2/9/02	NF	10	1	0.4	5.7	7.78	0.1761	0.08	8.39	0.1126
Frog 6 1-4	2/9/02	NF	10	1	0.5	5.7	7.44	0.1763	0.08	8.39	0.1126
Frog 6 >4	2/9/02	NF	0	1	0.575	5.71	7.55	0.1762	0.08	8.37	0.1128
Frog 3	2/16/02	F	0	2	0.2	4.3	7.6	0.177	0.08	8.02	0.113
Frog 3 <1	2/16/02	NF	0	2	0.2	4.3	7.5	0.1777	0.08	8	0.1136
Frog 3 1-4	2/16/02	NF	0	2	0.3	4.34	7.8	0.1774	0.08	8.07	0.1136
Frog 3 >4	2/16/02	NF	0	2	0.4	4.14	7.67	0.1775	0.08	8.06	0.1138
Frog 5	2/16/02	F	0	3	0.2	5.95	7.65	0.1783	0.08	8.18	0.1139
Frog 5 <1	2/16/02	NF	0	3	0.3	5.64	7.53	0.1788	0.08	8.13	0.1142
Frog 5 1-4	2/16/02	NF	0	2	0.35	5.24	7.42	0.1751	0.08	8	0.1123
Frog 5 >4	2/16/02	NF	0	2	0.3	5.11	7.54	0.1784	0.08	8	0.1146
Frog 1	2/16/02	F	0	3	0.175	7.37	7.26	0.1786	0.08	8.4	0.113
Frog 1 <1	2/16/02	NF	0	3	0.175	6.7	7.22	0.178	0.08	8.24	0.1143
Frog 1 1-4	2/16/02	NF	0	2	0.2	6.13	7.2	0.1788	0.08	8.2	0.1144
Frog 1 >4	2/16/02	NF	0	2	0.2	5.62	7.44	0.178	0.08	8.18	0.1141
Frog 8	2/16/02	F	0	3	0.2	5.93	7.82	0.1769	0.08	8.39	0.115
Frog 8 <1	2/16/02	NF	0	3	0.2	5.93	7.39	0.1789	0.08	8.32	0.1146
Frog 8 1-4	2/16/02	NF	0	1	0.3	5.42	7.49	0.1784	0.08	8.3	0.1142
Frog 8 >4	2/16/02	NF	0	1	0.3	5.25	8.25	0.1785	0.08	8.25	0.1143

Points	Date		Gravel	Veg	Depth (m)	Temp (°C)	DO (mg/L)	Cond (µS/cm)	Sal. (ppt)	pH	TDS (mg/L)
Frog 25	2/16/02	F	0	1	0.25	5.5	7.77	0.178	0.08	8.43	0.114
Frog 25 <1	2/16/02	NF	0	1	0.3	5.16	7.58	0.1783	0.08	8.35	0.1144
Frog 25 1-4	2/16/02	NF	0	1	0.4	5	7.59	0.1786	0.08	8.34	0.1143
Frog 25 >4	2/16/02	NF	0	1	0.4	5.03	7.66	0.1783	0.08	8.33	0.1141
Frog 10	2/16/02	F	0	1	0.25	7.52	7.37	0.178	0.08	8.66	0.1136
Frog 10 <1	2/16/02	NF	0	1	0.25	6.44	7.29	0.1784	0.08	8.51	0.1138
Frog 10 1-4	2/16/02	NF	0	1	0.3	6.19	7.43	0.178	0.08	8.48	0.1137
Frog 10 >4	2/16/02	NF	0	1	0.3	6.08	7.6	0.1785	0.08	8.47	0.1142
Frog 9	2/16/02	F	0	1	0.25	6.47	7.61	0.177	0.08	8.61	0.1133
Frog 9 <1	2/16/02	NF	0	1	0.25	6.3	7.35	0.178	0.08	8.44	0.1139
Frog 9 1-4	2/16/02	NF	0	1	0.3	7.53	7.56	0.1786	0.08	8.34	0.1143
Frog 9 >4	2/16/02	NF	0	1	0.4	6.4	7.57	0.1778	0.08	8.44	0.1139
Frog 26	2/16/02	F	10	1	0.7	6.27	7.49	0.1782	0.08	8.36	0.1142
Frog 26 <1	2/16/02	NF	0	1	0.3	6.32	7.33	0.1775	0.08	8.37	0.1136
Frog 26 1-4	2/16/02	NF	0	1	0.3	7.4	7.27	0.1787	0.08	8.37	0.1144
Frog 26 >4	2/16/02	NF	0	1	0.7	5.47	7.71	0.1771	0.08	8.45	0.1143
Frog 6	2/16/02	F	10	1	0.5	6.6	7.55	0.1777	0.08	8.55	0.1138
Frog 6 <1	2/16/02	NF	10	1	0.4	7.12	7.36	0.1791	0.08	8.43	0.1146
Frog 6 1-4	2/16/02	NF	10	1	0.4	6.37	7.56	0.1782	0.08	8.41	0.1141
Frog 6 >4	2/16/02	NF	10	1	0.5	6.21	7.72	0.1786	0.08	8.41	0.1144
Frog 3	3/11/02	F	0	1	0.21	8.69	5.4	0.184	0.08	7.79	0.1177
Frog 3 <1	3/11/02	NF	0	1	0.23	8.58	5.28	0.184	0.08	8.04	0.1177
Frog 3 1-4	3/11/02	NF	0	1	0.3	8.37	5.32	0.184	0.08	8.13	0.1177
Frog 3 >4	3/11/02	NF	0	1	0.29	8.46	5.34	0.1838	0.08	8.2	0.1176
Frog 5	3/11/02	F	0	1	0.25	8.3	5.63	0.1832	0.08	8.09	0.1173
Frog 5 <1	3/11/02	NF	0	1	0.25	8.41	5.51	0.1839	0.08	8.18	0.1175
Frog 5 1-4	3/11/02	NF	0	1	0.25	8.27	5.6	0.1839	0.08	8.27	0.1177
Frog 5 >4	3/11/02	NF	0	1	0.25	8.12	5.67	0.1838	0.08	8.32	0.1176
Frog 25	3/11/02	F	0	1	0.41	8.1	5.92	0.1835	0.08	8.4	0.1174
Frog 25 <1	3/11/02	NF	0	1	0.4	8.19	5.83	0.1835	0.08	8.39	0.1174
Frog 25 1-4	3/11/02	NF	0	1	0.3	8.18	5.72	0.1839	0.08	8.37	0.1177
Frog 25 >4	3/11/02	NF	0	1	0.39	7.93	5.95	0.1832	0.08	8.41	0.1172
Frog 10	3/11/02	F	10	1	0.3	7.43	5.96	0.183	0.08	8.29	0.1172
Frog 10 <1	3/11/02	NF	10	1	0.3	6.72	8.32	0.1829	0.08	8.35	0.1171
Frog 10 1-4	3/11/02	NF	10	1	0.4	7.3	5.87	0.1837	0.08	8.39	0.1169

Points	Date		Gravel	Veg	(m) Depth	(°C) Temp	(mg/L) DO	(µS/cm) Cond	(ppt) Sal.	pH	(mg/L) TDS
Frog 10 >4	3/11/02	NF	10	1	0.51	6.79	6.04	0.1828	0.08	8.43	0.1169
Frog 26	3/11/02	F	10	1	0.35	6.51	6.43	0.1829	0.08	8.5	0.117
Frog 26 <1	3/11/02	NF	10	1	0.35	6.99	6.2	0.1826	0.08	8.47	0.1169
Frog 26 1-4	3/11/02	NF	10	1	0.4	7.03	6.04	0.1824	0.08	8.48	0.1169
Frog 26 >4	3/11/02	NF	10	1	0.52	7	6.09	0.183	0.08	8.5	0.117
Frog 8	3/11/02	F	0	1	0.3	8.47	6.45	0.1835	0.08	8.36	0.1175
Frog 8 <1	3/11/02	NF	0	1	0.3	8.51	5.83	0.183	0.08	8.39	0.1169
Frog 8 1-4	3/11/02	NF	0	1	0.4	8.03	5.95	0.1837	0.08	8.4	0.1175
Frog 8 >4	3/11/02	NF	0	1	0.4	8.16	6.06	0.1834	0.08	8.42	0.1173
Frog 8	3/18/02	F	0	3	0.2	8.35	5.35	0.1881	0.09	8.11	0.1204
Frog 8 <1	3/18/02	NF	0	3	0.2	8.35	5.41	0.1877	0.09	8.16	0.1204
Frog 8 1-4	3/18/02	NF	0	1	0.2	8.36	5.4	0.1875	0.09	8.18	0.1201
Frog 8 >4	3/18/02	NF	0	1	0.25	8.27	5.44	0.1878	0.09	8.2	0.1202
Frog 26	3/18/02	F	0	3	0.2	8.45	5.58	0.1876	0.09	8.2	0.1201
Frog 26 <1	3/18/02	NF	0	3	0.2	8.45	5.46	0.1881	0.09	8.21	0.1204
Frog 26 1-4	3/18/02	NF	0	1	0.18	8.48	5.41	0.1874	0.08	8.25	0.1199
Frog 26 >4	3/18/02	NF	0	1	0.25	8.31	5.47	0.1875	0.08	8.25	0.12
Frog 3	3/18/02	F	0	1	0.2	8.69	5.56	0.1874	0.08	8.2	0.12
Frog 3 <1	3/18/02	NF	0	1	0.2	8.64	5.37	0.1871	0.08	8.14	0.1198
Frog 3 1-4	3/18/02	NF	0	2	0.3	8.64	5.42	0.1875	0.08	8.2	0.12
Frog 3 >4	3/18/02	NF	0	1	0.3	8.81	5.47	0.1875	0.08	8.23	0.12
Frog 25	3/18/02	F	0	2	0.2	8.77	5.86	0.1883	0.09	8.38	0.1208
Frog 25 <1	3/18/02	NF	0	2	0.2	8.87	5.62	0.1876	0.09	8.35	0.1202
Frog 25 1-4	3/18/02	NF	0	2	0.25	8.88	5.57	0.1884	0.09	8.34	0.1207
Frog 25 >4	3/18/02	NF	0	2	0.4	8.7	5.66	0.1881	0.09	8.33	0.1203
Frog 5	3/18/02	F	0	1	0.25	9.46	5.43	0.1894	0.09	8.21	0.1212
Frog 5 <1	3/18/02	NF	0	1	0.25	9.47	5.24	0.1894	0.09	8.16	0.1212
Frog 5 1-4	3/18/02	NF	0	2	0.3	9.51	5.19	0.1906	0.09	8.13	0.1219
Frog 5 >4	3/18/02	NF	0	1	0.2	9.41	5.3	0.1895	0.09	8.15	0.1212
Frog 10	3/18/02	F	0	1	0.2	9.44	5.91	0.1882	0.09	8.37	0.1203
Frog 10 <1	3/18/02	NF	0	1	0.2	9.48	5.32	0.188	0.09	8.35	0.1201
Frog 10 1-4	3/18/02	NF	0	1	0.2	9.51	5.2	0.1889	0.09	8.34	0.1207
Frog 10 >4	3/18/02	NF	0	1	0.2	9.31	5.24	0.1879	0.09	8.36	0.1205
Frog 6	3/18/02	F	20	1	0.3	7.98	5.55	0.1873	0.08	8.43	0.1198
Frog 6 <1	3/18/02	NF	20	1	0.3	7.98	5.38	0.1876	0.09	8.41	0.1201

Points	Date		Gravel	Veg	(m) Depth	(°C) Temp	(mg/L) DO	(µS/cm) Cond	(ppt) Sal.	pH	(mg/L) TDS
Frog 6 1-4	3/18/02	NF	20	1	0.4	7.98	5.38	0.1873	0.08	8.38	0.1199
Frog 6 >4	3/18/02	NF	20	1	0.35	7.98	5.38	0.1876	0.08	8.38	0.12
Frog 26	3/23/02	F	0	3	0.22	6.92	5.23	0.1888	0.09	7.39	0.1206
Frog 26 <1	3/23/02	NF	0	2	0.22	6.91	5.19	0.1886	0.09	7.58	0.1209
Frog 26 1-4	3/23/02	NF	0	1	0.32	6.43	5.22	0.1887	0.09	7.67	0.1208
Frog 26 >4	3/23/02	NF	0	1	0.4	6.16	5.28	0.1897	0.09	7.77	0.1213
Frog 6	3/23/02	F	20	2	0.45	5.6	5.72	0.1886	0.09	8.32	0.1206
Frog 6 <1	3/23/02	NF	20	2	0.45	5.5	5.52	0.1889	0.09	8.26	0.1206
Frog 6 1-4	3/23/02	NF	20	1	0.39	5.41	5.45	0.1886	0.09	8.24	0.1207
Frog 6 >4	3/23/02	NF	0	1	0.49	5.21	5.44	0.1885	0.09	8.23	0.1203
Frog 10	3/23/02	F	0	2	0.25	6.9	7.7	0.1884	0.09	8.5	0.1207
Frog 10 <1	3/23/02	NF	0	2	0.3	6.12	7.92	0.1891	0.09	8.34	0.121
Frog 10 1-4	3/23/02	NF	0	2	0.3	6.26	7.95	0.189	0.09	8.32	0.121
Frog 10 >4	3/23/02	NF	0	2	0.25	6.19	5.42	0.1886	0.09	8.31	0.1208
Frog 3	3/23/02	F	0	1	0.25	6.42	5.32	0.1893	0.09	8.57	0.1202
Frog 3 <1	3/23/02	NF	0	1	0.25	6.25	5.34	0.1888	0.09	8.44	0.1208
Frog 3 1-4	3/23/02	NF	0	1	0.25	6.1	5.43	0.1897	0.09	8.44	0.121
Frog 3 >4	3/23/02	NF	0	1	0.25	6.12	5.36	0.1884	0.09	8.45	0.1203
Frog 5	3/23/02	F	0	1	0.32	7.86	5.42	0.1897	0.09	8.51	0.1217
Frog 5 <1	3/23/02	NF	0	1	0.32	7.42	5.21	0.1896	0.09	8.4	0.1212
Frog 5 1-4	3/23/02	NF	0	1	0.26	9.03	5.11	0.1898	0.09	8.36	0.1219
Frog 5 >4	3/23/02	NF	0	1	0.32	7.22	5.28	0.1895	0.09	8.39	0.1212

(continue to next page)

**Points run from East to West (ie. N1 is the farthest East Point on the North shore and N4 is the farthest West Point on the North shore)

Points	Date		Gravel	Veg	(m) Depth	(°C) Temp	(mg/L) DO	(µS/cm) Cond	(ppt) Sal.	pH	(mg/L) TDS
N1	2/16/02	P	0	1	0.2	7.32	7.32	0.1782	0.08	8.36	0.1134
N2	2/16/02	P	0	1	0.2	6.33	7.43	0.1774	0.08	8.42	0.1132
N3	2/16/02	P	0	1	0.2	6.43	7.82	0.1769	0.08	8.28	0.1133
N4	2/16/02	P	0	1	0.2	6.07	7.42	0.177	0.08	8.59	0.1135
S1	2/16/02	P	0	2	0.25	8.74	7.85	0.1796	0.08	8.46	0.1149
S2	2/16/02	P	0	1	0.35	7.54	8.05	0.179	0.08	8.05	0.1144
S3	2/16/02	P	0	1	0.2	7.48	7.71	0.1796	0.08	8.37	0.1148
S4	2/16/02	P	0	1	0.2	7.28	8.09	0.1793	0.08	8.46	0.1146
NE	2/16/02	P	0	1	0.45	7.12	7.57	0.1784	0.08	8.71	0.1142
NE	3/11/02	P	0	1	0.42	9.77	5.7	0.1841	0.08	8.19	0.1179
N1	3/11/02	P	0	1	0.2	8.02	6.4	0.1832	0.08	8.35	0.1173
N2	3/11/02	P	0	1	0.2	7.75	5.87	0.1833	0.08	8.06	0.1172
N3	3/11/02	P	0	1	0.2	7.4	5.9	0.1839	0.08	8.45	0.1176
N4	3/11/02	P	0	1	0.25	6.98	6.21	0.1826	0.08	8.32	0.1172
S1	3/11/02	P	0	1	0.3	7.94	5.95	0.1837	0.08	8.49	0.1176
S2	3/11/02	P	0	1	0.3	7.83	6.26	0.1826	0.08	8.47	0.117
S3	3/11/02	P	0	1	0.3	7.74	6.31	0.1835	0.08	8.12	0.1173
S4	3/11/02	P	0	1	0.47	7.37	6.34	0.1833	0.08	8.35	0.1172
NE	3/18/02	P	0	1	0.37	9.65	5.3	0.1895	0.09	8.16	0.1213
N1	3/18/02	P	0	1	0.35	8.91	5.47	0.1877	0.09	8.39	0.1202
N2	3/18/02	P	0	1	0.35	8.94	5.56	0.1878	0.09	8.41	0.1202
N3	3/18/02	P	0	1	0.35	9.09	5.61	0.1878	0.09	8.25	0.1204
N4	3/18/02	P	0	1	0.2	9.21	9.24	0.1883	0.09	8.34	0.1205
M3	3/11/02	P	x	x	1.2	6.54	7.14	0.1839	0.08	8.4	0.1171
M3	3/11/02	P	x	x	0.75	6.68	6.44	0.1829	0.08	8.42	0.1171
M3	3/11/02	P	x	x	0.3	7.23	6.24	0.1834	0.08	8.43	0.1177
M4	3/11/02	P	x	x	3.4	5.61	6.74	0.1823	0.08	8.42	0.1167
M4	3/11/02	P	x	x	1.7	5.95	6.16	0.1829	0.08	8.41	0.1171
M4	3/11/02	P	x	x	0.5	6.83	6.08	0.1835	0.08	8.42	0.1174
M4N	3/11/02	P	x	x	2.4	6.09	6.95	0.1829	0.08	8.39	0.1171
M4N	3/11/02	P	x	x	1.2	6.82	6.19	0.1835	0.08	8.43	0.1175
M4N	3/11/02	P	x	x	0.4	7.05	6.16	0.1835	0.08	8.43	0.1174
M4S	3/11/02	P	x	x	2.3	5.92	6.82	0.183	0.08	8.41	0.1172

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Date

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