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POND-DWELLING AMPHIBIANS OF LAND BETWEEN THE LAKES (KENTUCKY AND TENNESSEE): A QUANTITATIVE SURVEY

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ABSTRACT–Amphibian communities at 27 ponds in Land Between The Lakes were sampled during late winter, late spring-early summer, and early fall of 1988 to determine species composition, richness, frequency of occurrence, and relative abundance. A variety of collecting techniques, including dip-netting, seining, funnel-trapping, and capturing by hand, were uniformly used each sampling period. Of 14 species (4 salamanders and 10 frogs and toads) encountered, 8 (3 salamanders and 5 frogs) were seen in the winter sample, 12 (3 salamanders and 9 frogs and toads) in the spring-summer sample, and 8 (3 salamanders and 5 frogs) in the fall sample. Salamanders with the highest overall frequencies were *Ambystoma maculatum* and *Notophthalmus viridescens*, occurring at least once at 70.8 and 62.5%, respectively, of the ponds sampled. *Rana utricularia, R. catesbeiana*, and *R. clamitans* had the highest overall frequencies (62.5, 58.3, and 41.7%, respectively) among species of frogs and toads encountered. These same five species, in slightly different order, also ranked highest in relative abundance among the two major groups. *Notophthalmus viridescens* comprised 50.2% of the individual salamanders collected, followed closely by *A. maculatum* at 48.3%. Among frogs and toads, *R. clamitans* had the highest frequency of occurrence at 77.8%, followed by *R. catesbeiana* and *R. utricularia* at 25.3 and 13.1%, respectively. Seasonal shifts in relative frequencies and relative abundances of the these five species were observed.

In the southeastern United States, studies of amphibian communities in the pond environment have been conducted in the Coastal Plain of central Florida (Dodd and Charest, 1988; Dodd, 1992) and South Carolina (Gibbons et al., 1979; Gibbons and Semlitsch, 1981) and the Piedmont of North Carolina (Murphy, 1963). No such studies, however, have appeared from the region's Interior Low Plateaus province as mapped by Hunt (1967).

Situated on the western edge of the Interior Low Plateaus, Land Between The Lakes (LBL) is an ideal outdoor laboratory for field studies on pond-dwelling vertebrates. Throughout its forest and woods-openings are >500 ponds (some natural but most man-made) of varying physical and biotic character. Ranging from <100 m^2 to 1 ha, some are permanent, and others ephemeral. Some contain fish, and others do not. Some support aquatic vegetation, and others lack it. Many are surrounded by woodland, and others by open areas. Considering their abundance and variety, these ponds provide homes to a wide array of amphibians and other vertebrates, thus, contributing markedly to the overall biodiversity of the area.

Snyder (1972) illustrated and discussed in general the herpetofauna of LBL. In many of his accounts of amphibian species, ponds are mentioned as the known or expected habitat for these animals. Scott (1990) listed "fishless upland ponds in both forest and fields" as the home of the relatively rare (*Ambystoma talpoideum*) at LBL. Harris and Noel (1992), in a curriculum guide designed for use by middle-school students, described and depicted (with line drawings) amphibians and other vertebrates one might find in LBL's ponds. The objective of the present study was to augment the existing knowledge of LBL's pond-based, amphibian communities by determining, through an unbiased, systematic, multi-season quantitative sampling, the species composition, richness, frequency of occurrence, and relative abundance over all and certain portions of the annual cycle. The information obtained will also serve as baseline data in future assessments of the health of amphibian populations in the LBL region.

MATERIALS AND METHODS

Study Area--Land Between The Lakes is a narrow (average width about 12.9 km or 8 miles) strip of land situated astride the Tennessee-Kentucky border (Fig. 1) between the impounded lower reaches of the Tennessee and Cumberland rivers (Kentucky and Barkley lakes, respectively). Encompassing approximately 69,000 ha (170,000 acres) of mostly forested land, it extends 61 km (38 miles) from its southern boundary near Dover in Stewart Co., Tennessee, to its northern limit (a canal connecting the two reservoirs) just south of Grand Rivers in Lyon Co., Kentucky. Designated in 1963 as a national demonstration area for outdoor recreation, environmental education, and resource management, LBL is owned by the Tennessee Valley Authority whose on-site personnel operate it as a multiple-use management area (Thach et al., 1987).

A great deal has been written about the physical and biotic features of LBL. Much of this information, especially that pertaining to plants and nongame animals, appeared in a series of field guides on LBL's flora and fauna (Ellis and Chester, 1971, 1973, 1980; Snyder, 1972, 1991; Phillips, 1974; Sundberg and Richardson, 1980) and in papers from symposia concerning the natural history of the lower Tennessee and Cumberland river valleys (Snyder, 1988, 1992; Scott, 1989; Fralish and Crooks, 1989; Hamilton and Finley, 1990; Bryant, 1991; Burkett, 1991; Hatcher, 1991; Meade, 1991; Hamilton et al., 1993). Additional works on the subject include those by Ellis et al. (1971), Clebsch (1974), Jones (1974), Chester et al. (1976), Blair and Sickel (1986), Carpenter and Chester (1987), Jensen (1989), Chester and Holt (1990), Chester (1992, 1993), Driskell (1992), and Feldhamer et al. (1993).

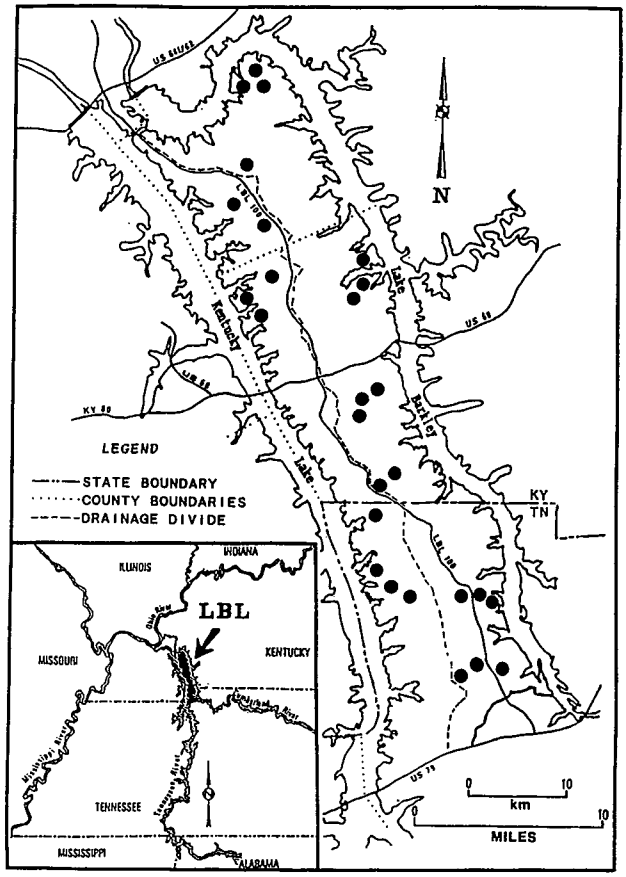

FIG. 1. Planimetric maps showing selected features of Land Between The Lakes (LBL), Kentucky and Tennessee, and its location (inset) in relation to major rivers and state boundaries of the Mid-south. Locations of ponds sampled for amphibians during 1988 are indicated by solid circles.

Selection of Study Ponds--In selecting sites for study, three criteria were used: 1) a representative sample of available pond types; 2) ponds located in all parts of LBL; 3) a manageable number of ponds, all of which could be visited at least twice during each of three proposed sampling periods (late winter, late spring-early summer, and early fall; hereafter referred to as winter, spring-summer, and fall). To meet these criteria, the existing 1:48,000-scale map of LBL (prepared by Mapping Services Branch of the Tennessee Valley Authority) was consulted. This map, on which most of the ponds in LBL are mapped, is marked off by a system of intersecting lines that divide the area into sections each 2.5 min of latitude and longitude on a side. Using this grid system, nine sections equally spaced across the length and breath of LBL were chosen, and the ponds within each were assigned a number. Three numbers from those representing ponds in each of the nine sections were then chosen randomly, and the 27 ponds corresponding to those numbers were designated as study ponds. If a pond could not be located in the field (some had been deliberately eliminated; others had succeeded to terrestrial habitats), the next closest pond that could be located was used. Figure 1 depicts the locations within LBL of each study pond.

Description of Study Ponds--Sample ponds varied in their elevation, surroundings, permanence, physical character, and fish fauna. Their elevations ranged from 122 to 175 m ($\bar{X}$ = 146, *SD* = 17.2). Ten ponds were in wooded areas, 9 were in open sites, and 8 were situated such that both woodland and open habitats bordered them to varying degrees. Fourteen ponds appeared permanent, having water on every visit. Nine ponds were ephemeral being dry during one (three ponds) or two (six ponds) sampling periods. Four ponds were dry on every visit and, consequently, were not sampled.

Pond size over the entire study, as expressed by shoreline length, averaged 50.6 m (*SD* = 36.6) and ranged from 14 to 165 m. Between the winter and the spring-summer sampling periods, mean shoreline length decreased an average of 19.5 m (*SD* = 20.0) but increased an average of 3.4 m (*SD* = 27.8) by the time of the fall sampling.

Average water conditions at the study ponds during each sampling period are given in Table 1. Dissolved oxygen was lowest but most variable during the spring-summer period and highest but least variable during the winter period. Spring-summer was the time of highest pH followed by fall and winter, respectively. Variability in pH across sampling sites was lowest during winter and nearly the same during the other two periods. Temperature, of course, was lowest during winter, highest during spring-summer, and intermediate during fall, when the greatest variability was recorded.

Vertebrates other than amphibians found in the study ponds included fish, snakes, and turtles. Fish were detected in nine ponds, snakes in six ponds, and turtles in one pond. The species encountered and their frequency of occurrence during each sampling period are given in Table 2.

Collection of Field Data--Following reconnaissance trips to each site during the fall of 1987, all study ponds were visited at least once during each of the three sampling periods of 1988. Only those ponds found containing water were sampled. The winter sampling was conducted from 28 February to 19 March; the spring-summer sampling was taken from 13 June to 26 June; and a fall sampling was completed between 21 September and 17 October.

During the first site-visit of each period, abiotic data were collected, initial biotic samples were taken, and aquatic traps (wire minnow traps) were set around the periphery and near the center of all ponds. Abiotic data routinely recorded included pond dimensions (length, width, and circumference) and water conditions (temperature, pH, and dissolved oxygen, all measured along shore). Seining, dip-netting, and hand-collecting (protocol similar among ponds) provided the initial biotic sample. Aquatic traps were commercially available hardware cloth minnow traps. Their number per pond varied, depending on pond size, ranging from two in the shallows near shore and one in deep water to six along shore and three in deep water.

On the second site-visit (which occurred 2 to 6 days following the first) of each sampling period, minnow traps and their catch were retrieved. The animals (including a small percentage of dead individuals) contained in each were placed on ice in labeled bags for transport to the laboratory.

Processing Collections--In the laboratory, animals collected on both site-visits were initially preserved in ethyl alcohol, sorted into species lots,

TABLE 1. Means (±1 *SD*) for dissolved oxygen, pH, and water temperature in selected ponds at Land Between The Lakes, Kentucky and Tennessee, during three periods of 1988. The number of ponds sampled each period equals *n*.

Sampling period	*n*	Dissolved oxygen (ppm)	pH	Temperature (°C)
Winter	23	6.92 (1.52)	6.03 (0.54)	10.30 (2.22)
Spring-summer	15	6.35 (2.42)	7.11 (0.78)	27.17 (2.43)
Fall	16	6.56 (1.55)	6.32 (0.77)	15.34 (4.43)

TABLE 2. Frequency of occurrence (percent) of species of fishes, turtles, and snakes at ponds sampled during three periods in 1988 at Land Between The Lakes, Kentucky and Tennessee. Number of ponds sampled each period is given in parentheses. See text for inclusive dates of sampling periods.

Major group/species	Sampling period		
	Winter (23)	Spring-summer (15)	Fall (16)
Fish			
Gambusia affinis	4.4	0.0	6.3
Lepomis cyanellus	8.7	3.3	12.5
Lepomis macrochirus	4.4	6.6	6.3
Lepomis gulosus	0.0	6.6	0.0
Notemigonus crysoleucas	8.7	6.6	0.0
Pimephales notatus	0.0	6.6	0.0
Pimephales promelas	3.0	6.6	18.8
Turtles			
Chelydra serpentina	0.0	0.0	6.3
Snakes			
Nerodia erythrogaster	0.0	0.0	6.3
Nerodia sipedon	0.0	33.3	25.0

counted, fixed in 5% (larvae) or 10% (adults) formalin, and stored with collection-data labels in glass jars. Identification was accomplished using a variety of field guides (Mount, 1975; Dundee and Rossman, 1989; Pfingsten and Downs, 1989; Conant and Collins, 1991) and keys (Brandon, 1964; Altig, 1970; Ballinger and Lynch, 1983; Altig and Ireland, 1984). R. Altig verified identification of tadpoles. Voucher specimens were deposited in Austin Peay State University's Museum of Zoology (APSU 4514-4737). Scientific names used are those proposed by Collins (1990).

Data Analysis--Results were summarized as discrete data involving the numbers of individuals of each amphibian species and order (the latter referred to as major groups) encountered each sampling period and over the entire study. Determinations of the frequency of occurrence (percent of sample ponds in which a taxon was found) of each species and major group, overall and during each sampling period, were made.

Data for each major group were analyzed using chi-square statistics. The goodness of fit test was applied in comparisons of numbers of individuals among sampling periods. The test of independence was used in comparisons of numbers of larvae and post-larvae within each sampling period. Statistical significance was determined at $P \leq 0.05$.

RESULTS

Species Richness--Table 3 summarizes, by major groups, the combined numbers of amphibian species encountered at the sample ponds overall and during each of the three sampling periods. The number of salamander species encountered was uniform from season to season as three of four species (Table 4) were seen each sampling period. Species richness for frogs and toads, however, was higher during the spring-summer period than during the other two periods (Table 3).

On a per-pond-basis, total species richness averaged 4.8 (range of 1 to 9) overall. For each sampling period (winter, spring-summer, and fall), it averaged 2.6 (range of 0 to 7), 3.5 (range of 0 to 7), and 2.2 (range of 0 to 5), respectively.

TABLE 3. Species richness of the major groups of amphibians encountered overall and during each sampling period of a 1988 study of ponds at Land Between The Lakes, Kentucky and Tennessee.

Major group	Sampling period			
	Winter	Spring-summer	Fall	Combined
Salamanders	3	3	3	4
Frogs and toads	5	9	5	10
Total amphibians	8	12	8	14

Frequency of Occurrence--The numbers of ponds, of those sampled overall and during the three sampling periods, where each major group and species was found are given in Table 4. Amphibians were found in >90% of the ponds during each season and overall. The most productive season was spring-summer when all 15 ponds sampled yielded specimens representing 12 of the 14 (85.6%) total species encountered. Salamanders were slightly more widespread than frogs and toads overall and during the winter period but occurred in fewer ponds than did frogs and toads during spring-summer and fall. The most frequently encountered salamanders by far were *Ambystoma maculatum* and *Notophthalmus viridescens*. Of the anurans, ranids occurred in highest frequency overall and during each sampling period except winter when *Pseudacris crucifer* ranked third and *Rana catesbeiana* ranked fourth in frequency.

Relative Abundance--The numbers of larvae and post-larvae of the various species taken in the combined samples for all ponds during the three sampling periods and the entire study are presented in Table 5. For salamanders as a major group, post-larval stages significantly ($P < 0.05$, $d.f. = 1$, $\chi^2 > 3.84$ for each sampling period) outnumbered larvae during each sampling period, with the greatest discrepancy during winter when large numbers of sexually active individuals were encountered. This was the pattern for *N. viridescens*. The number of post-larvae exceeded the number of larvae during winter for *A. maculatum*; the reverse was the case during spring-summer and fall. For *A. opacum*, larvae outnumbered post-larvae in the winter sample. Samples taken in spring-summer and fall contained zero and one *A. opacum*, respectively. Only one *A. tigrinum* (a larva) was collected during the entire study. For frogs and toads in general, tadpoles greatly outnumbered juveniles and adults during each sampling period ($P < 0.05$, $d.f. = 1$, $\chi^2 > 3.84$ for each period). This trend was due to large numbers of ranid tadpoles collected each season.

For salamanders, the winter sampling was the most productive ($P < 0.001$, $d.f. = 2$, $\chi^2 = 1145.16$), outnumbering each of the other two samples approximately nine to one (Table 5). Of the four species represented, *A. maculatum* was most abundant in the winter sample, whereas *N. viridescens* predominated in the spring-summer and fall collections. The number of frogs and toads collected in winter also ($P < 0.001$, $d.f. = 2$, $\chi^2 = 1739.55$) was significantly greater than their numbers taken during the other periods (about two to one over spring-summer and nearly eight to one over fall). Three ranid species (*R. catesbeiana, R. clamitans, and R. utricularia*) predominated in collections of anurans during all sampling periods. The seasonal pattern for *R. clamitans* and *R. utricularia* determined the trend for the major group. *Rana catesbeiana* was most abundant in spring-summer.

Figure 2 includes relative abundance (species importance) curves for each major group and the complete amphibian community during each season and for the year (total sample). The curves representing individual groups suggest low diversity and high dominance for salamanders and moderate diversity and dominance for frogs. Except for the spring-

TABLE 4. Number and percentage (in parentheses) of sample ponds where each major group and species was found during all and portions of a 1988 study of pond-dwelling amphibians at Land Between The Lakes, Kentucky and Tennessee. See Table 1 for number of ponds sampled each period.

Major group/species	Sampling period			
	Winter	Spring-summer	Fall	Combined
Salamanders	18 (78.3)	12 (80.0)	8 (50.0)	20 (83.3)
Ambystoma maculatum	14 (60.8)	7 (6.7)	4 (25.0)	17 (70.8)
Ambystoma opacum	3 (13.0)	0 (0.0)	1 (6.3)	4 (16.7)
Ambystoma tigrinum	0 (0.0)	1 (6.7)	0 (0.0)	1 (4.2)
Notophthalmus viridescens	14 (60.8)	9 (60.0)	5 (31.3)	15 (62.5)
Frogs and toads	16 (69.6)	14 (93.3)	14 (87.5)	18 (75.0)
Bufo americanus	0 (0.0)	2 (13.4)	0 (0.0)	2 (8.3)
Bufo woodhousei	0 (0.0)	1 (6.7)	0 (0.0)	1 (4.2)
Gastrophryne carolinensis	0 (0.0)	1 (6.7)	0 (0.0)	2 (8.3)
Acris crepitans	0 (0.0)	2 (13.4)	2 (12.5)	4 (16.7)
Pseudacris crucifer	7 (30.4)	2 (13.4)	0 (0.0)	7 (29.2)
Pseudacris feriarum	1 (4.3)	0 (0.0)	0 (0.0)	1 (4.2)
Hyla chrysoscelis	0 (0.0)	2 (13.4)	2 (12.5)	4 (16.7)
Rana catesbeiana	6 (26.1)	9 (60.0)	13 (81.3)	14 (58.3)
Rana clamitans	8 (34.8)	7 (46.7)	3 (18.8)	10 (41.7)
Rana utricularia	10 (43.5)	7 (46.7)	5 (31.3)	15 (62.5)
Total amphibians	21 (91.3)	15 (100.0)	15 (93.8)	21 (91.3)

summer sampling, curves for the total amphibian community indicate the fauna is dominated by four or five species followed by another group of species whose members decrease fairly equally in importance from most to least abundant. The spring-summer curve for all amphibian species shows a more uniform decrease in abundance throughout its length.

Species Documented in Ponds Not Included in the Present Study--Specimens in Austin Peay State University's Museum of Zoology document four additional species of amphibians from ponds at LBL not sampled in the present study. These are *Ambystoma talpoideum*, *Ambystoma texanum*, *Scaphiopus holbrookii*, and *Siren intermedia*. *Ambystoma talpoideum* was abundant at 11 ponds in a limited area of central LBL (Scott, 1990). Each of the three other species is known from one or only a few sites at LBL and must be considered a rare pond inhabitant in the area. Seven collections of *A. texanum* exist. Two are from ponds, the rest from terrestrial habitats; all are from sites in or near the floodplain of the Cumberland River. The occurrence of *S. holbrookii* is based on collections of one specimen each from a road in an upland forest and a pond in an upland field; the presence of *S. intermedia* is based on records from Hematite Lake (Snyder, 1972) and two shoreline ponds along the east shore of Kentucky Lake.

DISCUSSION

Compared to related studies conducted elsewhere in the southeastern United States, our results are most like those reported by Murphy (1963) for a small ephemeral pond in the Piedmont of North Carolina. Using a 3.175-mm-mesh wire drift fence and funnel traps, he monitored amphibian activity throughout 1 complete year (1961) and found a total of 16 species, 13 of which we found in our study. The three species not present in our samples but found by Murphy (1963) were *Plethodon glutinosus*, *Desmognathus fuscus*, and *R. palustris* (the only one of the three that normally inhabits ponds). *Ambystoma tigrinum was* the only species we encountered that Murphy (1963) did not.

Similarities between seasonal results of Murphy's (1963) and our study were also striking. Our winter (28 February and 19 March) samples contained eight species whereas his for the same period contained 10; seven species of the 11 (64.0%) total from both studies were the same. Our spring-summer (13 through 26 June) samples included 12 species, the same number as Murphy's for the same period; 10 of the total 14 (71.4%) species from both studies were the same. Our fall samples (21 September through 17 October) contained nine species, Murphy's (1963) samples for this period contained eight; seven of 10 (70.0%) total species from both studies were the same.

Not surprisingly, studies conducted in the Coastal Plain physiographic province produced results quite different from ours. In a temporary pond in central Florida, Dodd (1992), using a metal drift fence and pitfall traps, found a comparable number of amphibian species (16), but the species similarity (percent of total shared in common) was quite low (only 15.4% or 4 of 26). Also differing from our results was the assemblage of amphibians Gibbons and Semlitsch (1981) found associated with natural ponds, called Carolina bays, in South Carolina. In a 1-year period using drift fences and pitfall traps at two such ponds, they found 25 species. The percent similarity between their sample and ours was 33.3% (10 of 30 total species). Part of the difference in species composition noted can be attributed to sampling technique. Having used drift fences to intercept animals moving on land about the ponds, Dodd (1992) and Gibbons and Semlitsch (1981) encountered a number of species (e.g., plethodontid salamanders) that are not a normal component of a pond's actual aquatic community. Also contributing to the difference is the fact that several of the species involved are range-limited and simply do not occur in one area or the other.

In conclusion, the large number and variety of ponds at LBL support a healthy and moderately rich complex of amphibian species that adds substantially to the total amphibian fauna of the area. Varying seasonally in richness, frequency of occurrence, and relative abundance, the pond community of amphibians at LBL, as compared to those described for

TABLE 5. Number of individuals (larvae, post-larvae[1], and total) of various species collected during all and portions of a 1988 study of pond-dwelling amphibians at Land Between The Lakes, Kentucky and Tennessee. See Table 1 for numbers of ponds sampled each period.

Major group/species	Winter			Spring-summer			Fall			1988		
	Larvae	Post-larvae	Total	Larvae	Post-larvae	Total	Larvae	Post-larvae	Total	Larvae	Post-larvae	Total
Salamanders												
Ambystoma maculatum	0	470	470	36	0	36	8	0	8	44	470	514
Ambystoma opacum	14	0	14	0	0	0	0	1	1	14	1	15
Ambystoma tigrinum	0	0	0	1	0	1	0	0	0	1	0	1
Notophthalmus viridescens	0	391	391	0	61	61	0	82	82	0	534	534
Total salamanders	14	861	875	37	61	98	8	83	91	59	1,005	1,064
Frogs and toads												
Bufo americanus	0	0	0	0	2	2	0	0	0	0	2	2
Bufo woodhousei	0	0	0	0	1	1	0	0	0	0	1	1
Gastrophryne carolinensis	0	0	0	1	0	1	1	0	1	2	0	2
Acris crepitans	0	0	0	0	2	2	0	2	2	0	4	4
Pseudacris crucifer	0	10	10	3	0	3	0	0	0	3	10	13
Pseudacris feriarum	0	3	3	0	0	0	0	0	0	0	3	3
Hyla chrysoscelis	0	0	0	10	1	11	2	3	5	12	4	16
Rana catesbeiana	33	2	35	828	6	834	49	39	88	910	47	957
Rana clamitans	1,929	10	1,939	201	5	206	152	0	152	2,282	15	2,297
Rana utricularia	388	11	399	34	3	37	41	20	61	463	34	497
Total frogs and toads	2,350	36	2,386	1,077	20	1,097	245	64	309	3,672	120	3,792
Total amphibians	2,364	897	3,261	1,114	81	1,195	253	147	400	3,731	1,125	4,856

[1]Any life stage following metamorphosis.

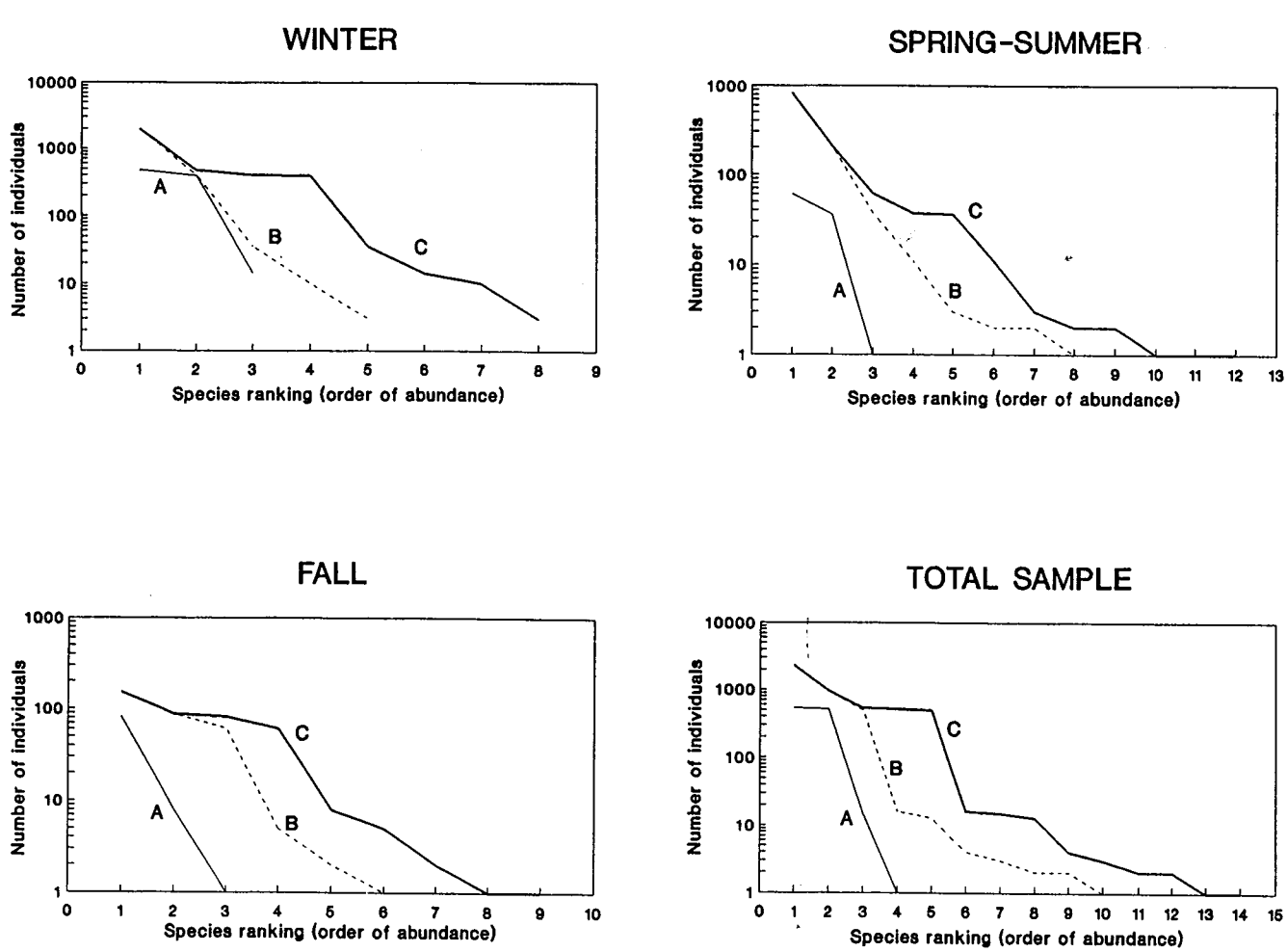

FIG. 2. Relative abundance curves for salamanders (A), frogs and toads (B), and the complete amphibian community (C) encountered during each of three sampling periods and throughout a 1-year study of selected ponds at Land Between The Lakes, Kentucky and Tennessee.

ponds in other parts of the southeastern United States, is most like that of a pond in the Piedmont of North Carolina and least like the one for ponds in the Costal Plain of South Carolina. To insure the continuance of a rich and viable amphibian fauna at LBL, efforts should be made to maintain the abundance, spacing, and variety of its ponds.

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