FIVE YEARS OF THE SOUTHWEST FLORIDA FROG MONITORING NETWORK: CHANGES IN FROG COMMUNITIES AS AN INDICATOR OF LANDSCAPE CHANGE

E. Corrie Pieterson(1), Lindsay M. Addison(1), Jorge N. Agobian(1),
Brenda Brooks-Solveson(1), John Cassani(2), and Edwin M. Everham III(1)

(1)Florida Gulf Coast University, 10501 FGCU Blvd. S. Ft. Myers, FL 33965-6565
(2)Lee County Hyacinth Control District, PO Box 60005, Ft. Myers, FL 33936

Abstract: *Amphibians have been shown to be important indicators for environmental change, particularly changes in water quality. The Southwest Florida Amphibian Monitoring Network was established in 2000 to collect long-term data on frog communities in southwest Florida. Twenty-two routes of 12 stops each are monitored monthly during the rainy season. Wind, temperature, humidity, sky condition, and habitat changes are recorded at each stop. Frog presence and abundance is indicated by calling intensity, which is tabulated using a three-level intensity code. Using data from the Network, frog communities were summarized, and factors that may explain differences in frog communities among sites and over time were investigated using measures of biological diversity, community classification, and community ordination. The data show an increased calling intensity in the exotic Cuban treefrog (*Osteopilus septentrionalis*), and a shift to native frog species requiring more permanent water. Continued monitoring may aid in understanding implications of altered hydroperiods and amphibian responses to restoration efforts. This type of citizen scientist database provides opportunities to investigate trends in environmental change on a landscape scale.*

Key Words: Amphibians, frog communities, citizen science

Amphibian populations have been identified as declining worldwide, and these declines have been identified as indicators of environmental stress (Barinaga, 1990; Wake, 1991; Vial and Saylor, 1993). Explanations for declines in amphibian populations vary from regional habitat change and environmental stress to global environmental change (Blaustein et al., 1994; Pechmann and Wilber, 1994; Blaustein and Wake, 1995). These declines generated interest in long-term data on amphibian populations and resulted in the establishment of volunteer networks that monitor amphibian populations using shared protocols to facilitate comparisons (NAAMP, 2005; DAPTF, 2005).

Although the southwest Florida region has one of the most rapidly growing human populations in the state (Smith, 2005), little has been reported on the impacts of urban sprawl on local amphibian populations. Development in southwest Florida often results in modified hydrology. Historically, human modifications to the landscape have resulted in increased runoff and loss of wetlands (Tang et al., 2005). Current regulations require wetland mitigation and retention of water (Gutrich and

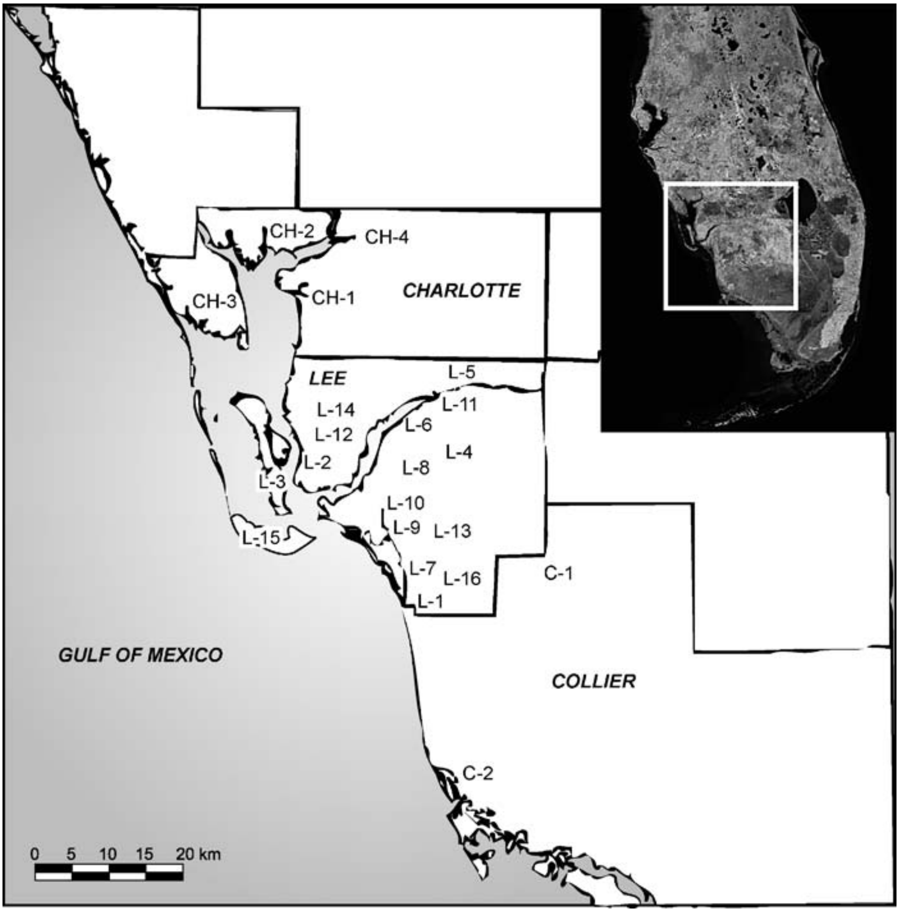

FIG. 1. Frog monitoring routes in the Southwest Florida Amphibian Monitoring Network (Frog Watch).

Hitzhusen, 2004). Native wetlands are restored through removal of invasive exotic plants, but water retention is commonly accomplished through the construction of deeper ponds (Mitsch and Day, 2004).

In 2000, the Southwest Florida Amphibian Monitoring Network (Frog Watch) was established. By 2004, the network had grown to 22 routes in Charlotte, Lee, and Collier Counties (Fig. 1), with a database of almost 6000 observations. This report analyzes the first five years of data. The goals of this analysis were to 1) investigate changes in frog communities, 2) explore the data set for patterns in space and time, and 3) examine the efficacy of citizen science in providing data to investigate landscape level changes over time.

MATERIALS AND METHODS—The 22 routes have up to 12 stops and are monitored monthly during the rainy season (June–September). Following protocols established by the North American Amphibian

Monitoring Program (NAAMP), at each stop on each route volunteers record temperature, humidity, wind speed, degree of cloud cover, and precipitation. In addition, changes to adjacent habitat are recorded (NAAMP, 2005; Frog Watch, 2005).

The routes were established by citizen science volunteers who agreed to act as route leaders. Each route leader selected the stops along his or her route, usually near home or work. Although not a fully randomized process, this did result in a geographically diverse set of routes across all three counties, through a variety of habitats.

At each stop, volunteers listen for three minutes and record the species and intensity of any frog calls heard during that time. The intensity of calls is quantified using scaled values of 1 for small groups of individuals whose calls do not overlap, 2 for small groups where there is some overlap of calls between individuals of a species, and 3 for a chorus of overlapping calls. Volunteer-based surveys that rely solely on frog calls as a means of identification have been found to accurately represent species richness and diversity, provided the sampling effort is sufficiently robust (de Solla et al., 2005). Frog Watch volunteers are trained to use the same method on each route. Therefore, it is possible to make comparisons of the presence and abundance of species over time and across different routes.

Because some routes had a greater number of stops than others, and because in some cases some routes were not visited in each of the four sampling months, it was necessary to normalize the recorded call intensities. The normalization process involved summing the total call intensity recorded for each species for a particular route. The sums were then divided by the number of times that measurements were made at each route, taking into account both the number of stops and the number of dates that the route was visited. This process may disproportionately under-report some species whose calling phenology does not include all months sampled, and may disproportionately over-represent species with louder calls, where a smaller population may appear to reach a calling intensity of three. Since the analyses involve comparisons of communities between years, the normalization procedure should be an appropriate method for incorporating the calling intensities in the analyses.

As route leaders changed through time, additional routes were added and some routes were abandoned. When comparing changes in biotic communities by route through time, the routes included in the analyses were limited to those with consistent data collection, resulting in analyses that utilized fewer than the total 22 routes.

The percent change in normalized calling intensity over time was calculated. Normalized calling for each species in 2000 were compared to the normalized calling intensities in 2004 for routes that were sampled both years. A percent change (positive or negative) was then calculated.

To compare frog communities at the landscape level, a variety of biological diversity indices were calculated following Ludwig and Reynolds (1988). These diversity measures included the Shannon Weaver Index, Simpson Index, modified Hill's Ratio, Menhinick Index, and Pielou Index. Measures of richness versus evenness were then used to create a community ordination space.

Bray-Curtis similarity indices were calculated for polar ordination (Ludwig and Reynolds, 1988) of the route data summarized from 2000 through 2004, using the normalized calling intensity as a measure of species abundance. A polar ordination for 12 routes was constructed comparing the data collected in 2001 with the data collected in 2004. These years were used because they shared 12 routes, whereas 2000 and 2004 had only six routes in common. Therefore, comparing data from 2001 and 2004, rather than 2000 and 2004, resulted in an increased sample size. This ordination was used to examine shifts within the ordination space over time.

Finally, a principal component analysis (PCA) was used to examine the frog communities, using the normalized calling intensity for routes from 2000 through 2004. PCA determines the component that accounts for the most variability within the data. Each succeeding component then accounts for the most remaining variability. This ordination process creates a variability ranking of all the analyzed components. Primer 5.2.9 software was used to carry out the PCA (Whitman et al., 2004).

RESULTS—The changes in percent calling intensity from 2000 to 2004 (Fig. 2) indicate both increases and decreases in native species' population sizes and an increasing population of exotics. However, the majority of native species show a decline in calling intensity. The increase in exotics is driven principally by

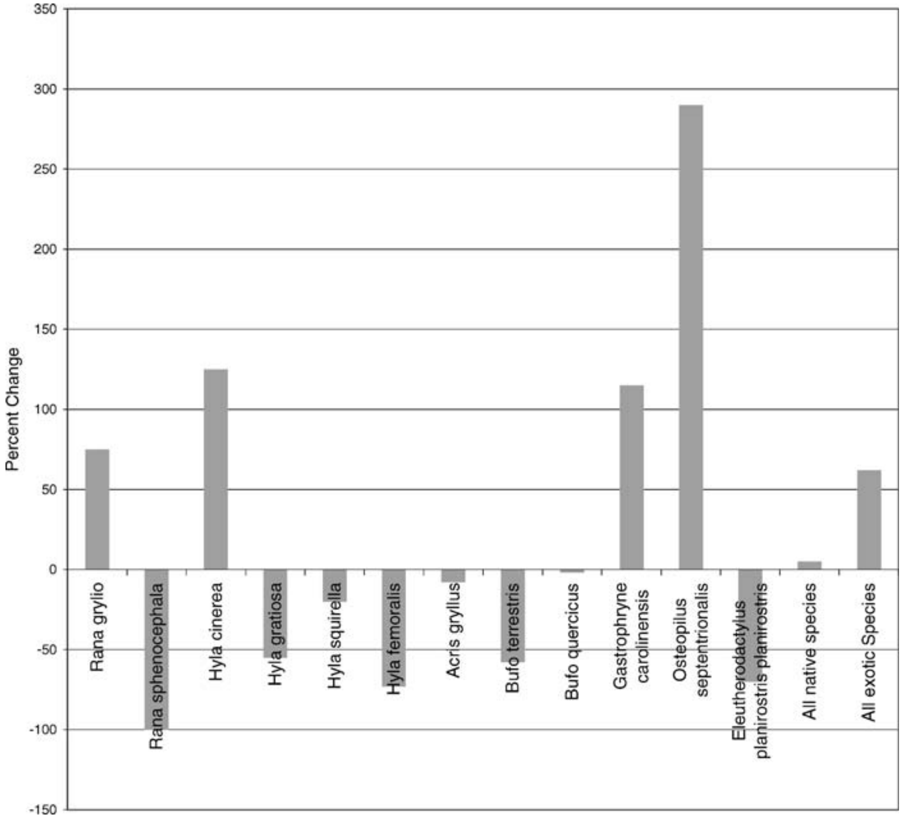

FIG. 2. Percent change in frog species from 2000 to 2004. Only species with a summed calling intensity of at least 50 in both years are included. Data is limited to routes sampled both years. All stops on all routes are pooled, so no error bars can be calculated.

a large increase in the calling intensity of *Osteopilus septentrionalis* (Duméril and Bibron).

An ordination space was created using the modified Hill's ratio as a measure of species evenness and the Menhinick Index as a measure of species richness (Ludwig and Reynolds, 1988). The modified Hill's ratio responds with lower values as a single species becomes more dominant. In Figure 3, the outlier routes include L-5, CH-3, and C-1 in decreasing order, separated along the evenness axis. The frog community in L-5, the rural community of Alva, is dominated by *Osteopilus septentrionalis*. *Hyla cinerea* (Schneider) is a dominant species in both CH-3 and C-1, although these routes are within a residential community and the area around Corkscrew Swamp Sanctuary (an old-growth cypress swamp preserve), respectively.

Bray-Curtis similarity indices, calculated from the normalized calling intensities, were used to create the ordination space in Figure 4. The first axis is defined by the dissimilarity between L-13, near Six-Mile Cypress Slough Preserve (a preserved cypress swamp) and L-14, a residential area in North Fort Myers. The

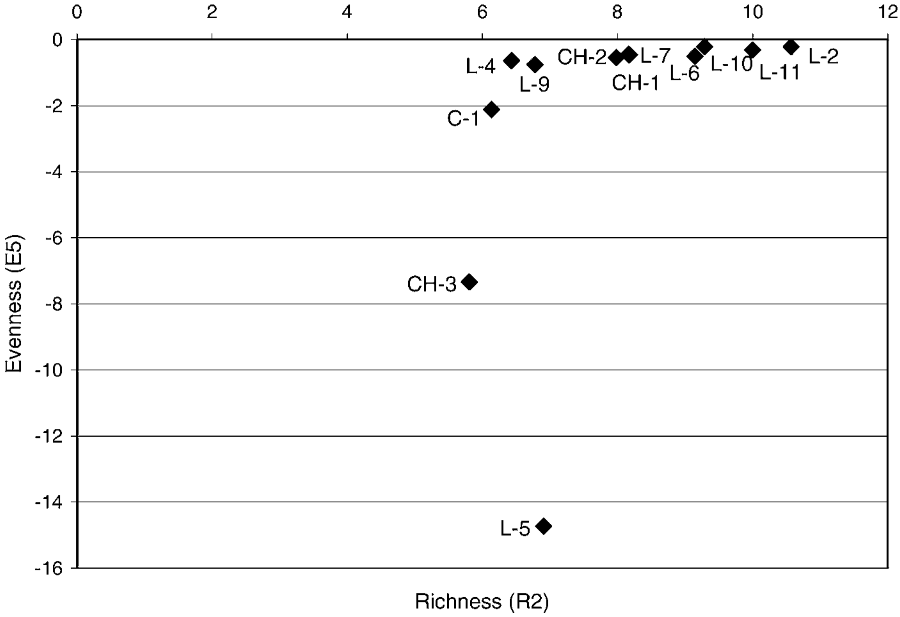

FIG. 3. Richness and evenness 2001 to 2004. Ordination of all routes using the normalized calling intensity for species abundance and calculating the modified Hill's ratio for evenness and the Menhinick Index for richness.

second axis includes two clusters. At the top of the ordination space is C-1, CH-3, and L-16, a development in Charlotte County, the route along Corkscrew Swamp Sanctuary, and the route through the Corkscrew Regional Ecosystem Watershed (a public land trust with extensive upland and wetland preserve areas), respectively. The first two were identified as outliers in the biodiversity ordination (Fig. 3) due to *Hyla cinerea* dominance. The cluster at the bottom of the ordination, L-2 (north Cape Coral), L-10 (Fort Myers), and L-3 (Pine Island) are, again, a mix of intensities of human activity, but may all have more limited permanent water habitats. It appears that this ordination separates the routes first based on human impacts and second on wetland habitat, which may indirectly relate to human activity.

The degree of change in communities is represented in Figure 5. Both of the routes showing the greatest change, L-10 in Fort Myers and L-7 around Florida Gulf Coast University, are areas of rapid human development. The two routes that changed the least through the five years of sampling, CH-2 in Charlotte County and L-6 in North Fort Myers, are also human-impacted landscapes, but are more stable and not undergoing the same degree of rapid growth, as indicated by the "changes to adjacent habitat" route data collected by volunteers.

The results of the PCA ordination (Fig. 6) show some similarities to previous ordinations. C-1 and CH-3 are again outliers, as they were in both the diversity ordination and the polar ordination. The first PCA axis accounts for 49.7% of the total variance in the data set. The species that are most important to the creation of

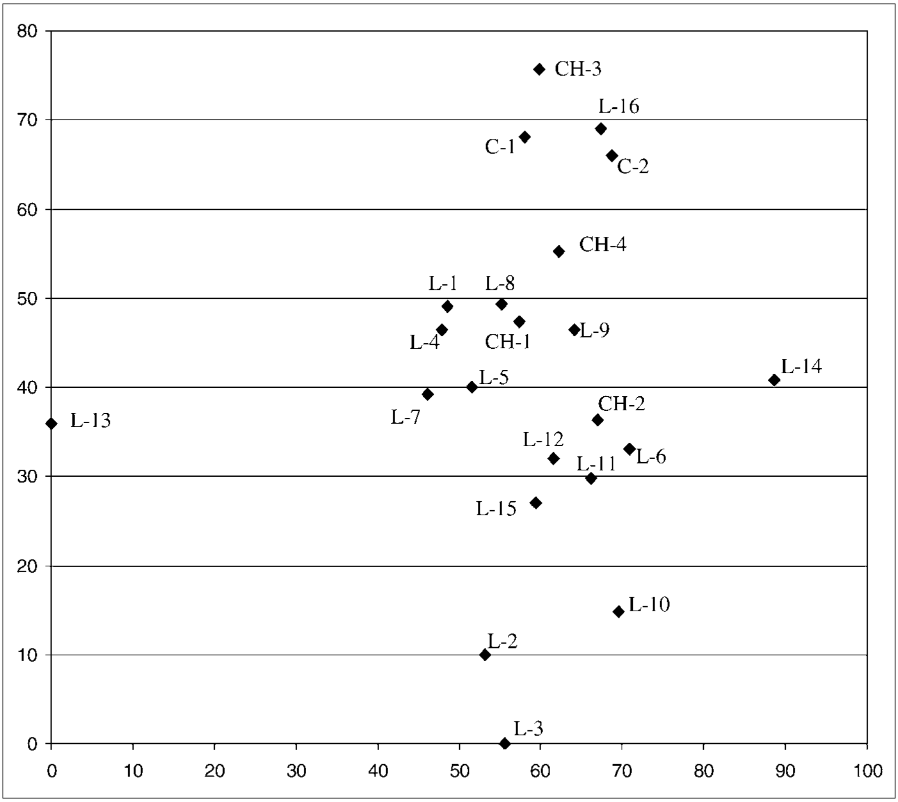

FIG. 4. Polar ordination of all routes – 2001 through 2004 data. Bray-Curtis percent similarities were calculated using normalized calling intensity for species abundances. Outlier routes L-13, L-14, CH-3, and L-3 define the boundaries of the ordination space for this data set. Each axis represents the two sampling units with the greatest dissimilarity. The other sampling units are plotted within this ordination space relative to their similarity to the four outliers.

this axis are *Hyla cinerea*, *Rana grylio* (Stejneger), and *Acris gryllus dorsalis* (Harlan), two of which may indicate the importance of more permanent water bodies. The second principal component accounts for an additional 28.4% of the variance and is loaded most heavily by *Osteopilus septentrionalis*, indicating the importance of exotics in differentiating among routes. L-5 (the rural community of Alva) becomes an outlier, as it was in the biodiversity ordination.

DISCUSSION—This initial analysis of the frog monitoring data for southwest Florida clearly indicates shifts in the species abundances as quantified by calling intensity, demonstrating the applicability of data collected by citizen scientists.

The majority of native species show a decline in calling intensity, with only a few species showing an increase in calling intensity. One of these, *Rana grylio*, is dependent on more permanent water (Ashton and Ashton, 1988), while another, *Hyla cinerea*, is common in wetlands (Ashton and Ashton, 1988). Declining species

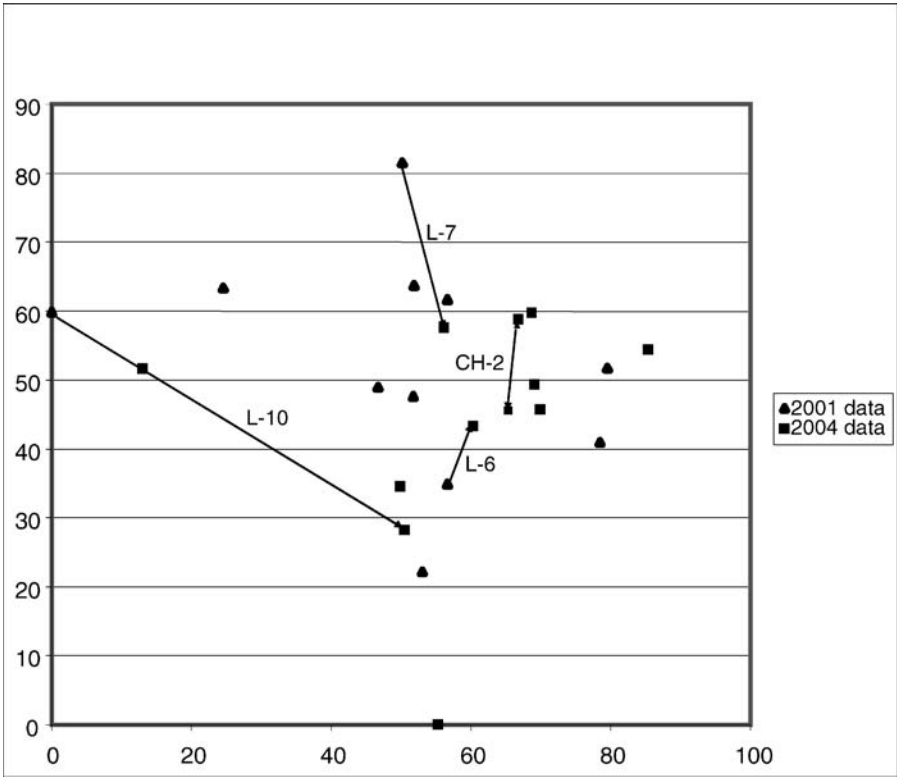

FIG. 5. Polar ordination – 2001 and 2004 data. Normalized calling intensity was used for species abundances. Data from 2001 and 2004 were treated as unique sampling units. Pairs of data points for any particular route show the magnitude of change in the ordination space for that route. The two routes with the greatest change (L-10 and L-7) and the two routes with the smallest change (L-6 and CH-2) are shown. Each axis represents the two sampling units with the greatest dissimilarity. The other sampling units are plotted within this ordination space relative to their similarity to the four outliers.

included those requiring intact upland systems such as *Hyla femoralis* (Bosc in Daudin) and *Bufo terrestris* (Bonnaterre) (Ashton and Ashton, 1988), whereas *Rana sphenocephala utricularia* (Harlan), another declining species, is common in permanent water habitats (Ashton and Ashton, 1988). Both shifts may be tied to human modifications of the landscape.

In southwest Florida, changes to the frog populations seem to be related to local human modifications of the landscape rather than to global changes, which would be expected to create more landscape-level impacts. While some frog species are able to establish metapopulations across isolated landscapes, many others can be severely affected by habitat fragmentation (Ficetola and DeBernardi, 2004). Lesbarrères and co-workers (2003) also found that anuran communities located near highways rather than in undisturbed areas suffered a significant reduction in heterozygosity, making them more vulnerable to bottleneck effects and extinction.

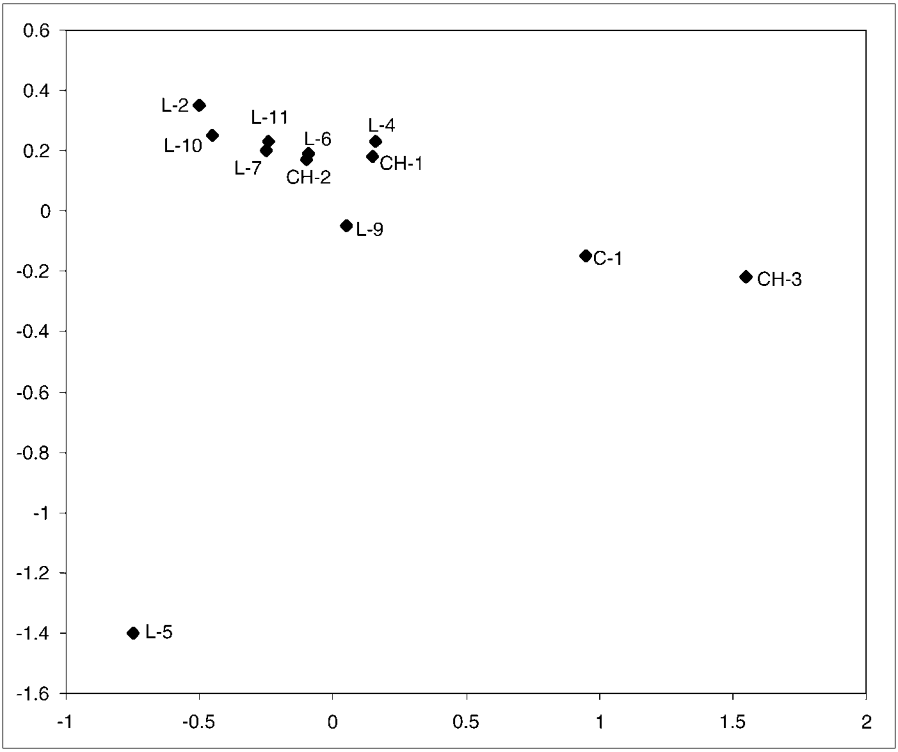

FIG. 6. PCA analysis of routes sampled in 2001 and 2004. Normalized calling intensity was used for species abundances.

These inferences must be considered in light of several inherent limitations. Chief amongst these are the small sample size, which was exacerbated by the fact that several routes had to be eliminated because they were not sampled on a regular basis. In addition to the route sampling irregularity, some routes were shifted to different locations during the course of the study, necessitating their removal from the analysis. Finally, several assumptions were built into the normalization process: that the calling intensity was directly related to the abundance of each species; that the relationship between calling intensity and abundance is the same for all species; and that differences in species' breeding phenology did not affect sampling. In addition, the routes were analyzed as a whole; therefore, fluctuations at individual stops could have been undetected or may have canceled one another out. However, the analyses were not limited to community comparisons that rely only on presence and absence data, because this would have resulted in the loss of additional information available by incorporating calling intensity. Nelson and Graves (2004) reported a positive relationship between calling intensity and population size, but their study was limited to a single species, *Rana clamitans* (Latreille in Sonnini de Manoncourt and Latreille), and the relationship tended to be weaker at higher population densities. Further long-term monitoring, resulting in increased sampling size may help to resolve these uncertainties.

An unforeseen difficulty encountered during the monitoring is directly attributable to human landscape change. During the first five years of monitoring, traffic volumes increased along most routes. Many animal species communicate in settings with substantial levels of background noise, but the effects of the noise on frog communication are not well known. Wollerman and Riley (2002) found that moderate levels of background noise reduced the ability of gravid female *Hyla ebraccata* (Cope) to detect or discriminate between males' calls. Additionally, increasing traffic noise may interfere with the ability of volunteers to detect frog calls. Background noise may play an important part in frog calling dynamics and will bear further research. For the data collection sheets used by Frog Watch volunteers, the following index for traffic noise was added to the standard NAAMP protocols: 0 – no traffic noise, 1 – only distant traffic noise, 2 – intermittent traffic with the majority of the time quiet, 4 – fairly constant traffic noise with some gaps but the majority of the time with traffic, and 5 – constant traffic.

There are additional opportunities to investigate the relationships between environmental factors such as time, weather, habitat, and calling intensities using this data. Often, illuminating these relationships requires larger datasets over longer periods of time. Citizen science monitoring efforts can provide these data in cost-effective ways.

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