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GLEN CANYON NATIONAL RECREATION AREA

BREEDING BIRD SURVEYS ALONG THE COLORADO RIVER, GLEN CANYON, ARIZONA

1996 SUMMARY PROGRESS REPORT AND EVALUATION OF THE LONG-TERM MONITORING PROGRAM

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ABSTRACT: This report summarizes the results of the 1996 field work on the breeding riparian avifauna between Glen Canyon Dam and Lee's Ferry along the Colorado River. Numbers of detections declined from 1995 for most species. Numbers of species and diversity (Shannon diversity index) also declined from 1995 for most point count stations. Total surveys were initiated in selected patches in 1996. Comparisons with point count data showed relatively poor correspondence, although unbounded point count data was more similar to total surveys than 25 meter bounded point count data. A PCA ordination revealed considerable fluctuations between 1993 and 1996 in the avifaunal composition in several patches. However, no distinctly linear trends could be discerned. Power analyses were used to test the ability of the monitoring program to detect population trends for the 12 most common species in the study area. At a power of 80% and an α=0.10, the monitoring program was found to be adequate at detecting negative 20% trends (20% declines in detections per year) in seven of the most common species. However, at more stringent power (0.90), similar declines could be detected in only one species. Recommendations are made on ways to increase the power of the monitoring program, and to better integrate it with habitat changes and the operations of Glen Canyon Dam.

INTRODUCTION

A program to monitor the breeding avifauna in the riparian zone along the Colorado River between Glen Canyon Dam and Lee's Ferry was initiated in 1992 (Figure 1). The primary goal was to better understand the relationship between breeding bird communities in the riparian zone and dam operations. Prior to 1992 little systematic work had been done on this riparian avifauna (*cf.* Brown 1989). Natural variation in bird species and abundance over different time-spans, e.g., within-season, between-year and decadal intervals, was not well known.

Fixed point count stations with radii of 25 meters were established at sites in riparian vegetation throughout the canyon (Grahame and Pinnock 1995). Initial establishment of point count stations, determination of species present, and calibration of methodology and logistics was performed during 1992. In 1993, the long-term monitoring, using 5 minute point counts at 21 stations, was implemented. With four years of data available, a preliminary analysis of the statistical power of the monitoring program to detect change when it is in fact occurring is warranted. This power analysis will determine whether the monitoring program has the ability to detect population trends, and will suggest any changes to the program that may be needed.

This report first summarizes the main results of the 1996 season, including; 1) a summary of bird species presence and abundance in 1996, 2) a comparison with previous years and an analysis of avifaunal community changes over time, and 3) comparisons of total survey (initiated in 1996) and point count methods. Then a power analysis is performed of the monitoring program using the 12 most common bird species. Recommendations for changes to the program are then made. In particular, the need to implement methods that link bird population changes with dam operations through potential effects on habitat (vegetation) is stressed.

Grahame and Pinnock (1995) analysed the results of the first three years of the program, and discussed the natural history of the breeding avifauna in the study area.

METHODS AND MATERIALS

Field Surveys

Point counts and total surveys were conducted between May 7 and July 3, 1996. Five point count surveys were conducted on May 7-8, May 21-22, June 4-5, June 18-19, and July 2-3. Two people were used for point counts, a observer and a recorder. Total surveys were conducted in selected patches containing point count stations on the June and July dates. A third person walked through the patch recording all heard or seen birds. The Appendix lists the point count stations, locations along the river corridor, and the patch number.

Data Analysis

Statistical analysis of the data was done with the SX4.1 package. Linear regression was used to compare total survey detections with two different point count data sets using 1996 data; unbounded (within 25 m as well as beyond) and bounded (only birds within the 25 m radius). Detections of each species at all point counts within a specified patch were pooled for the analysis. Comparisons of means was done with the Student's T-test, Wilcoxon Signed Rank Test and Analysis of Variance. The Bonferroni adjustment for multiple means comparisons was applied where applicable. Comparisons for all species are based on data from surveys 3-5 only, as these were the only surveys completed in all four years (see Grahame and Pinnock 1995).

Total bird detections were summarized by patch for 1993-1996 to reduce the number of samples for a Principal Components Analysis (PCA). Six patches were used (patches 1, 3, 6, 7, 9, and 10), inlcuding all patches with at least two point count stations (see Appendix; Fig. 1). Only riparian breeding species were used. The three species that are primarily upland, Canyon Wren, Rock Wren, and Say's Phoebe, were not included. The data matrix included 24 samples (6 patches X 4 years) and 18 species. A PCA was performed on the data set using a correlation matrix. Broken-stick eiegenvalues were estimated to determine whether the actual eigenvalue explained more variation than its respective random eigenvalue. Values of species richness, diversity, and evenness were also computed for all patches. Richness (S) is the number of species detected, diversity the Shannon diversity index H', where:

$$H' = -\sum_{i=1}^{s}(p_i \times \ln(p_i))$$

and evenness (J), where:

$$J = H'/\ln(S)$$

The program used in the ordinations and computation of S, H', and J was PC-ORD 2.0 (McCune and Mefford 1995).

A power analysis was performed on the data from 1993-1996. Because sample variances were high compared to means, the power analysis was performed on the "best-year" data set for each of the 12 most common species, as well as the pooled data (all species). For most species, the best year was 1994. Also, as not all surveys were completed in all years, sample sizes used to compute means and standard deviations varied from 4-6 surveys per species. The program MONITOR, written by Dr. James Gibbs of Yale University, was used for the analyses (Gibbs 1995). Because the method requires non-zero means, the value of 0.001 was substituted where point count means and standard deviations were 0.

Power is defined as:

$$Power = 1 - \beta$$

where β is the probability of making a Type II error (accepting a false null hypothesis). Power indicates how likely it is to detect a change when it is in fact occurring. Power levels are generally set at 80% or above. A power of 80% indicates that, on average, 80% of the time a change that is actually occurring will be detected. The inverse is that 20% of the time a change that is actually occurring will not be detected. The Type I error (α or rejection of a true null hypothesis) was set at either 0.05 or 0.10 for the simulations. The analysis uses a Monte Carlo simulation to generate simulated sets of count data, which are then compared with the actual inputs. Replications were set at 500. Trend projections were set at 5%, 10%, 15%, 20% and 25% (change in point count detections between years) for a five year time-frame. In most cases a two-tailed test was used (testing the null hypothesis that the trend does not differ from zero), but for some species a more limited one-tailed test was applied to determine if the monitoring program could detect declines.

RESULTS

1996 Season

In all 29 species were detected at the 22 (one new point count station was added in 1996) point counts during the 1996 season. Of these species, nine were either flyovers, raptors, or aquatic species. The most common riparian and adjacent upland breeding species are ranked in Table 1. As in previous years, House Finch and Canyon Wren were ranked first and second respectively. Bewick's Wren, which was ranked third in previous years, dropped to sixth place in 1996, and was replaced by Ash-throated

Flycatcher. Bushtit appeared among the top 12 species for the first time since the monitoring program was initiated in 1993, while Rock Wren continued its long-term decline, dropping to 13th place in 1996. Total numbers of individuals and species detected during 1996 declined from 1995.

Comparisons of Different Methods

The correspondence between total surveys and point counts (using linear regression) was strongest with unbounded point counts (unbounded: r^2=0.482, p<0.0001; bounded: r^2=0.476, p<0.0001). However, the differences were slight. Student's T-tests indicated that unbounded point count detections and total survey detections (all species) were not significantly different at the α=0.10 level ($T_{Student's}$=1.44, p=0.147). Bounded point counts and total surveys were significantly different at the α=0.10 level ($T_{Student's}$=-2.76, p=0.006).

Overall correspondence between methods was not very good for most species (Table 2). The unbounded point counts detected more individuals than either total surveys or bounded point counts (Table 3). Of the six most commonly detected species, only House Finch and Ash-throated Flycatcher showed good agreement between methods. Significant differences in total detections occurred between total and point count methods for some species. Counts of House Finch, Canyon Wren, and Bewick's Wren were significantly different between bounded point counts and total surveys. Canyon Wren showed poor agreement for unbounded counts as well. Overall, the total surveys and unbounded point counts were most similar in detections. Some rare species, e.g., Common Yellowthroat and Yellow Warbler, were more readily detected by the total survey method. Mean species detected per method was; bounded point count, 3.8; unbounded point count, 6.7; total survey, 6.7. Mean individuals detected per method was; bounded point count, 8.6; unbounded point count, 18.6; total survey, 14.7. Mean time to conduct a total survey was 18.9 minutes per patch.

Changes Over Time

The twelve most common species (Table 1) are graphed in Figure 2A-D using summed detections from surveys 3-5. Most species have fluctuated in numbers of detections over the four years of the monitoring program. Some, such as Mourning Dove, Blue Grosbeak, and Rock Wren, have declined since 1993 (Figure 2A). Other species show considerable fluctuation between years, but with no distinct linear trends discernable (Figures 2B-2C). At least one species, Blue-gray Gnatcatcher, appears to have increased since 1993 (Figure 2D).

Species richness, diversity and evenness are graphed for six patches over the four years in Figures 3-5. Again, although there has been considerable fluctuation between years, there are few obvious trends. Species diversity shows an overall decline in all patches except Patch 3, although the trend is not strong (compare 1993 values with 1996 values).

The first two axes of a PCA ordination are plotted in Figure 6. Samples are patches with two or more point count stations (see Appendix). Patches are linked between years by vectors. The first two axes account for 21% and 15% of the variance in the data set. Both were larger than their respective broken-stick eigenvalue estimates, indicating that they are larger than expected by chance and hence contain interpretive information.

No distinct linear trends over time are indicated by the ordination. Patch 1 (point counts 1-3) shows major change from 1993 to 1994, and again from 1994 to 1995. In April of 1994 prior to initiation of field work this patch was largely destroyed by fire. In the 1994 season large numbers of House Finch's, Brown-headed Cowbirds, Yellow-breasted Chats, and Mourning Doves were detected in this patch. Patch 9 (point counts 14-17) shows major change in all years. Most other patches showed relatively minor change between years.

Kendall rank correlations between the axis scores for the 24 samples (patch x year) and the original variables (bird species) are listed in Table 4. House Finch, Lucy's Warbler and Brown-headed Cowbird are most strongly correlated with axis I. Axis II shows strong correlations with Mourning Dove and Blue-gray Gnatcatcher. Axis III is most strongly correlated with two rare species, Spotted Towhee and Bullock's Oriole.

Power Analysis

Because of their rarity in the Glen Canyon reach, several species could not be used in the power analyses, including all three warbler species. The twelve most common species (Table 1) were used in the analyses.

The initial run (Table 5) for a two-tailed test at α=0.05 indicates that the current monitoring program can detect a positive 20% change per year in all twelve species at power levels above 0.90. This drops off to the five most common species at a 10% trend, and all fail the test at a 5% trend. The tests indicate that power is only adequate for declining trends in five species at 20% trend per year, and none at 10% per year. If power is set at 80%, declines can still only be detected in Canyon Wren at a 10% trend projection. Setting α to 0.10 for a two-tailed test, power is adequate for most species at 20% projections, although again only Canyon Wren meets the 10% projections (Table 6).

For those five species that failed the power test at 20% and an α of 0.10, a second analysis was done using a 1-tailed test (Table 7). Only negative trends (declines) are shown. At a trend projection of 10%, no species met the 80% power criterion. However, at a 20% trend, power is adequate for three species; Brown-headed Cowbird, Yellow-breasted Chat, and Black-chinned Hummingbird.

When the survey protocol was changed to three surveys rather than five surveys per year (Tables 8), results were similar but generally power was weaker. Power was inadequate to detect declines in Yellow-breasted Chat at 20%, although a 1-tailed test could (Table 9). Two species failed the power tests for 20% declining trends, Brown-headed Cowbird and Black-chinned Hummingbird. When the time-frame for detecting trends was increased to 10 years, power greatly increased (to $\geq$0.90) for all species. Also, increasing the sample size to 30 point count stations had the effect of improving power. Principal results of the power analyses are summarized in Table 9.

Rock Wren has shown a major decline since 1993 (Figure 2A). Detections have declined by as much as 62% between years (mean between-year decline=34.7%). 1996 detection rates (sum=17) are about a quarter of rates in 1993 (sum=75). The power analysis indicates that there is adequate power using the current monitoring program to detect declining trends of 20% (two-tailed) or less (one-tailed) in this species when they are in fact occurring over a five-year period (runs using four years give similar power). An Analysis of Variance was performed on Rock Wren detections using 1993-1996 data and five surveys per year. A repeated measures model was specified because of the repeated sampling of the same plots over time:

Total Rock Wren detections/year = year + plot + year*plot*survey

The Bonferroni adjustment was applied to the comparison of means. The results (Table 10) indicate that there is a highly significant difference between two or more of the years. Detections of Rock Wrens in the first two years of the survey are not significantly different from one another, but both are significantly higher than 1995-96 rates (two-tailed test with α=0.05). The ANOVA failed to show a difference between 1995 and 1996, but an independent T-test indicates that 1995 detections are significantly higher than 1996 ($T_{Student's}$=2.32, p=0.01 for a 1-tailed test and α=0.05). The ANOVA also indicates that declines are significantly different between plots. Some plots have shown significantly higher declines in detections than others. This suggests that subtle differences in habitat quality for Rock Wren exists along the river corridor. Overall, it appears that there has been a significant decline in Rock Wren detections in the Glen Canyon stretch of the Colorado River since 1993. Two other species have shown declines since 1993, Mourning Dove and Blue Grosbeak. Neither decline, however, is significant using a repeated measures ANOVA.

Best Point Count Stations By Species

A sum of detections by point count stations over the four years of the monitoring program indicates that many species are extremely variable in distribution along the river corridor (Table 11). Coefficients of variation (*CV*'s) range from 94% for House Finch to over 600% for several rare species. The five point count stations with the most detections for each species over the four years are ranked from most to least detections. Some relatively common species such as Bushtit and Blue-gray Gnatcatcher are frequently detected on some stations, but completely absent from others. It is unlikely that the current monitoring program will be able to detect change in species of relatively narrow distribution and large *CV*'s.

All 21 point count stations were included in the best-station analysis for at least one species. The stations least well represented were 10 and 13. These two were included in the top five for Blue-gray Gnatcatcher, Rock Wren and White-throated Swift. The stations best represented (highest rank) were 1-3, followed by 8, then 4, 16 and 17 (tied).

DISCUSSION AND RECOMMENDATIONS

The Glen Canyon avifauna monitoring program was established for several reasons. First, baseline data on bird population composition and variation over time and in different sections of the river corridor was neccesary. Second, because of concerns over possible declines in migratory (especially neotropical) riparian bird species, a monitoring program was needed in order to track species abundances in the Glen Canyon stretch of the river corridor. Third, a monitoring program was needed to determine the effects of Glen Canyon Dam operations (principally water releases) on the composition and abundance of the breeding riparian avifauna below the dam.

Four years of point count detection data has provided valuable baseline information on the avifauna in the study area. Data is available on variation in detection rates by survey time, location, and year, as well as species composition and changes over time. This stretch of the river corridor below Glen Canyon Dam has one of the best current data sets on breeding riparian avifauna in the region. Hence goal 1 above has been largely met. A power analysis was thus applied to the data to determine whether goal 2 has also been met.

The power analysis indicates that the monitoring program is only capable of detecting change over a five year period at relatively large alpha rates (0.10) and moderate power (≥ 0.80). In other words, the current program is not adequate to detect changes, particular declines, in detection rates for many species breeding in the study area. Tests using either increased sample sizes (30 point count stations) or 10-year time frames, however, gave better power estimates. Trends at 20% per year can be detected in essentially all species within either this time-frame or the increased sample size. Furthermore, only best-year means were used rather than overall four-year means. The power of the program to detect change would decrease if four-year means were used rather than best-year means.

However, there are a variety of ways to increase the power of the program. First, as noted above, sample size can be increased (eg., Thompson and Schwalbach 1995). Currently, 22 point count stations have been established in 11 different patches along the 16 miles between Glen Canyon Dam and Lee's Ferry. An additional 6-8 point count stations in suitable high-quality habitat will improve the power of the monitoring program. Second, the power analysis can be changed in a variety of ways. Species could be grouped by guilds, such as long-distance (neotropical) migrant, short-distance migrant, and resident species guilds. The current monitoring program would be more likely to detect changes in these guilds rather than in individual species. Third, the power analysis could include information on the quality of the habitat patches. Patches with more detections or lower variances in detection rates could be given more weight in monitoring. Finally, the nature of the statistical tests could be changed. Rather than using two-tailed tests, one-tailed tests could be used if concerns over possible declines are of greater importance than whether there is change at all. All of the above considerations will tend to increase the power of the program to detect changes in detections rates over time.

Thompson and Schwalbach (1995) point out that the management costs associated with a Type I error (rejecting a true null hypothesis of no change) are often less severe than those associated with a Type II error (accepting a false null hypothesis of no change). If the principal goal of a monitoring program is to detect declines in certain species, such as neotropical migrants, than alpha rates could be increased (e.g, to 0.10), thereby increasing the power of the monitoring program (compare Tables 5 and 6), and the ability of the program to detect changes in species populations when they are in fact occurring. Also, if declines are of primary concern, then using 1-tailed tests also increase power.

The principal problem with the Glen Canyon monitoring program is that it currently cannot link population changes in bird species (detection rates being an index of population size, see below) with the operations of Glen Canyon Dam. Bird populations change from year to year for a variety of factors, including those on the wintering grounds, during migration, and breeding grounds. Climate has a major impact on bird populations. For example, the low numbers of individuals and species detected in 1996 may have been partly or largely the result of the extreme drought of the previous year. The declines in the primarily upland Rock Wren, for example, are probably related to factors such as climate or changes on breeding grounds, rather than effects on riparian vegetation by operations of the dam. Clearly changes in the riparian scrub vegetation (principally the new high water zone in the Glen Canyon reach) can affect population size in the breeding riparian avifauna. However, there is no data available on changes in the breeding habitat in this zone for the study area. One of the principal recommendations of this report is to implement such a program as part of the long-term monitoring goals of the Grand Canyon Monitoring and Research Center.

Point counts are probably the best method currently available for monitoring bird populations over time in the riparian vegetation of the study area. Principal reasons for this include the relative ease of field work, low time and labor costs, relatively objective index (detection rates) of population change, and standardized counting stations and times. Ralph et al. (1993) indicate that point count detections provide a reasonable index to actual species populations, although they do not replace spot-mapping or MAPS methods. However, there are some problems with the point count method. First, some shy species or quiet or rarely vocalizing species are not easily detected. The princiapl solution to this is to combine point counts with a total survey effort, in order to detect these rarer or quieter species. A second more severe problem with point counts is observer variability. People differ in their ability to identify or hear birds, and point counts in dense riparian vegetation rely primarily on aural detections. One possible solution to this problem is to rotate the principal observers over time in order to average out observer differences.

In summary, the principal recommendations of this report are to:

1. Increase the sample size (number of patches and number of point counts) of the monitoring program.

2. Reduce the number of surveys to 3 per season, as this has relatively little effect on the ability of the program to detect change. This will decrease the time and labor costs of the project significantly.

3. Maintain the 5-minute duration of point counts.

4. Implement a total survey effort associated with each patch of vegetation during the three survey periods.

5. Have two trained observers and rotate them between point counts and total surveys to average out observer differences.

6. Establish a long-term monitoring program of the habitat (vegetation) in the study area using the techniques (or modifications as necessary) developed in Petterson et al. (1996).

7. Integrate the GLCA program with the Grand Canyon program (Petterson and Spence 1997). This can be done by increasing the radius to 50 m (also maintaing 25 m), increasing the count to 10 minutes (also maintain 5 minutes), eliminating some middle plots to reduce over-counting or double counting, and increasing the number of point count stations.

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TABLES

Table 1. Summary of relative frequency (*rf*) and rank order for the 12 most common terrestrial riparian species, based on counts of all detections both inside and outside the plot from 1993-1996 (surveys 3-5 only). Relative frequency is based on numbers of the most abundant bird species each year (House Finch). Fly-overs and strictly aquatic species are not included. Thirteen species are included because one species (Bushtit) replaced one of the twelve species (Rock Wren) from earlier years. Total bird detections and species for surveys 3-5 and all surveys are also summarized.

Species	1993		1994		1995		1996	
	rf	Rank	*rf*	Rank	*rf*	Rank	*rf*	Rank
House Finch	100	1	100	1	100	1	100	1
Canyon Wren	66	2	63	2	44	2	61	2
Bewick's Wren	55	3	46	3	35	3	21	6
Rock Wren	54	4	16	7	10	11	3	13
Ash-throated Flycatcher	50	5	41	4	34	4	33	3
Yellow-breasted Chat	44	6	31	5	12	9	30	5
Blue Grosbeak	37	7	11	9	17	7	7	9
Mourning Dove	30	8	13	8	25	5	4	12
Brown-headed Cowbird	26	9	26	6	19	6	31	4
Black-chinned Hummingbird	18	10	3	12	6	12	6	10
Bullock's Oriole	14	11	6	11	13	8	8	8
Blue-gray Gnatcatcher	6	12	9	10	11	10	12	7
Bushtit	-	-	-	-	-	-	5	11
Total House Finches (3-5)		95		205		136		115
Total Individuals (3-5)		695		948		604		470
Total Species (3-5)		24		17		17		16
Total Individuals (all surveys)		1170		1809		1295		930
Total Species (all surveys)		37		36		38		29

Table 2. Comparisons of total detections for all species and selected species between total surveys and either 25 m bounded point counts or unbounded point counts. Linear regression correlation coefficients, Student's T-tests, and T-test probability values are listed.

	Total-Bounded			Total-Unbounded		
	r^2	T	p	r^2	T	p
All Species	0.47	2.76	0.006	0.48	1.44	0.15
House Finch	0.50	1.66	0.06	0.41	0.11	0.91
Canyon Wren	0.15	2.13	0.04	0.23	3.47	0.002
Ash-throated Flycatcher	0.53	0.62	0.54	0.42	0.80	0.43
Brown-headed Cowbird	0.09	0.62	0.54	0.06	1.15	0.26
Yellow-breasted Chat	0.11	0.44	0.66	0.36	1.64	0.11
Bewick's Wren	0.26	2.32	0.03	0.17	0.80	0.43

Table 3. Comparison of total detection counts of all species and selected species by three methods, total surveys, bounded (25 m) point counts, and unbounded point counts. Flyovers, raptors, and aquatic species were excluded.

Species	Total Surveys	Bounded Pt. Cts	Unbounded Pt. Cts
All Species	265	152	336
House Finch	86	43	83
Canyon Wren	31	13	73
Ash-throated Flycatcher	25	18	35
Brown-headed Cowbird	17	23	30
Yellow-breasted Chat	18	15	35
Bewick's Wren	22	9	28
Blue-gray Gnatcatcher	11	9	13
Bullock's Oriole	7	3	5
Blue Grosbeak	17	5	8
Black-chinned Humm.	0	1	1
Bushtit	8	2	4
Mourning Dove	3	0	2

Table 4. Kendall rank correlations (τ) between the 18 riparian bird species and the first three axes of the Principal Components Analysis. The percent variance explained by each axis is listed.

Species	PCA I (21%)	PCA II (15%)	PCA III (12%)
House Finch	0.635	-0.275	0.048
Ash-throated Flycatcher	0.394	-0.394	-0.342
Brown-headed Cowbird	0.505	0.168	-0.023
Bewick's Wren	0.525	-0.190	-0.048
Yellow-breasted Chat	0.446	-0.004	-0.317
Blue Grosbeak	-0.099	0.455	-0.051
Mourning Dove	0.242	0.481	0.142
Black-chinned Hummingbird	-0.066	0.495	0.109
Bullock's Oriole	0.130	0.284	0.511
Blue-gray Gnatcatcher	0.254	-0.491	0.085
Bushtit	-0.094	0.012	-0.071
Yellow Warbler	0.407	-0.022	0.143
Lucy's Warbler	0.537	0.131	-0.005
Common Yellowthroat	0.289	0.289	-0.238
Bell's Vireo	0.109	0.145	0.399
Northern Mockingbird	0.127	0.236	-0.381
Spotted Towhee	-0.311	0.114	-0.417
Black-headed Grosbeak	-0.135	-0.027	-0.386

Table 5. Power analysis for the twelve most common riparian breeding species. The type I error was set at $\alpha=0.05$, replications=500, surveys=5/year, years=5, for a two-tailed test. Trend projections are 5-25% changes in detection rates on a yearly basis. The best year survey mean and standard deviations used in the analyses are indicated for each species.

	Power to detect a positive trend over 5 years				
	5%	10%	15%	20%	25%
Total Species[94]	0.99	1.00	1.00	1.00	1.00
Total Individuals[94]	0.97	1.00	1.00	1.00	1.00
House Finch[94]	0.40	0.96	1.00	1.00	1.00
Canyon Wren[94]	0.53	0.98	1.00	1.00	1.00
Ash-throated Flycatcher[94]	0.27	0.90	1.00	1.00	1.00
Brown-headed Cowbird[94]	0.15	0.55	0.87	0.99	1.00
Yellow-breasted Chat[94]	0.19	0.69	0.98	1.00	1.00
Bewick's Wren[94]	0.35	0.90	1.00	1.00	1.00
Blue-gray Gnatcatcher[94]	0.09	0.32	0.63	0.91	0.99
Bullock's Oriole[95]	0.12	0.36	0.75	0.94	1.00
Blue Grosbeak[94]	0.11	0.37	0.77	0.96	1.00
Black-chinned Hummingbird[93]	0.14	0.50	0.87	0.99	1.00
Mourning Dove[95]	0.26	0.86	1.00	1.00	1.00
Rock Wren[93]	0.33	0.92	1.00	1.00	1.00

	Power to detect a negative trend over 5 years				
	5%	10%	15%	20%	25%
Total Species[94]	0.91	1.00	1.00	1.00	1.00
Total Individuals[94]	0.92	1.00	1.00	1.00	1.00
House Finch[94]	0.28	0.75	0.93	0.96	1.00
Canyon Wren[94]	0.38	0.86	0.96	0.99	1.00
Ash-throated Flycatcher[94]	0.18	0.60	0.79	0.92	0.96
Brown-headed Cowbird[94]	0.08	0.25	0.42	0.50	0.65
Yellow-breasted Chat[94]	0.15	0.37	0.56	0.75	0.82
Bewick's Wren[94]	0.22	0.60	0.86	0.94	0.97
Blue-gray Gnatcatcher[94]	0.07	0.13	0.22	0.34	0.40
Bullock's Oriole[95]	0.07	0.19	0.33	0.35	0.46
Blue Grosbeak[94]	0.08	0.16	0.26	0.41	0.48
Black-chinned Hummingbird[93]	0.13	0.23	0.44	0.52	0.65
Mourning Dove[95]	0.21	0.54	0.82	0.87	0.92
Rock Wren[93]	0.25	0.55	0.81	0.95	0.97

Table 6. Power analysis for the twelve most common riparian breeding species. The type I error was set at $\alpha=0.10$, replications=500, surveys=5/year, years=5, for a two-tailed test. Trend projections are 5-25% changes in detection rates on a yearly basis. The best year survey mean and standard deviations used in the analyses are indicated for each species.

	Power to detect a positive trend over 5 years				
	5%	10%	15%	20%	25%
Total Species[94]	0.99	1.00	1.00	1.00	1.00
Total Individuals[94]	0.99	1.00	1.00	1.00	1.00
House Finch[94]	0.53	0.98	1.00	1.00	1.00
Canyon Wren[94]	0.67	0.99	1.00	1.00	1.00
Ash-throated Flycatcher[94]	0.43	0.94	1.00	1.00	1.00
Brown-headed Cowbird[94]	0.27	0.71	0.97	1.00	1.00
Yellow-breasted Chat[94]	0.29	0.83	0.99	1.00	1.00
Bewick's Wren[94]	0.47	0.97	1.00	1.00	1.00
Blue-gray Gnatcatcher[94]	0.20	0.53	0.84	0.98	1.00
Bullock's Oriole[95]	0.22	0.54	0.85	0.99	1.00
Blue Grosbeak[94]	0.21	0.54	0.83	0.99	1.00
Black-chinned Hummingbird[93]	0.27	0.67	0.94	1.00	1.00
Mourning Dove[95]	0.42	0.93	1.00	1.00	1.00
Rock Wren[93]	0.48	0.95	1.00	1.00	1.00

	Power to detect a negative trend over 5 years				
	5%	10%	15%	20%	25%
Total Species[94]	0.98	1.00	1.00	1.00	1.00
Total Individuals[94]	0.95	1.00	1.00	1.00	1.00
House Finch[94]	0.41	0.79	0.97	0.99	1.00
Canyon Wren[94]	0.51	0.90	0.98	1.00	1.00
Ash-throated Flycatcher[94]	0.33	0.71	0.90	0.95	0.98
Brown-headed Cowbird[94]	0.18	0.43	0.65	0.78	0.84
Yellow-breasted Chat[94]	0.24	0.56	0.76	0.87	0.90
Bewick's Wren[94]	0.34	0.74	0.90	0.98	0.99
Blue-gray Gnatcatcher[94]	0.16	0.29	0.44	0.51	0.60
Bullock's Oriole[95]	0.19	0.34	0.48	0.57	0.65
Blue Grosbeak[94]	0.16	0.31	0.43	0.57	0.65
Black-chinned Hummingbird[93]	0.20	0.43	0.60	0.73	0.83
Mourning Dove[95]	0.30	0.66	0.89	0.95	0.99
Rock Wren[93]	0.39	0.73	0.92	0.98	0.99

Table 7. Power analysis for selected riparian species. The type I error was set at $\alpha=0.10$, replications=500, surveys=5/year, years=5, for a one-tailed test. Trend projections are 5-25% changes in detection rates on a yearly basis. The best year survey mean and standard deviations used in the analyses are indicated for each species.

	Power to detect a negative trend over 5 years				
	5%	10%	15%	20%	25%
Brown-headed Cowbird[94]	0.34	0.67	0.80	0.91	0.96
Yellow-breasted Chat[94]	0.41	0.73	0.85	0.95	0.97
Blue-gray Gnatcatcher[94]	0.28	0.42	0.59	0.74	0.79
Bullock's Oriole[95]	0.31	0.49	0.65	0.76	0.83
Blue Grosbeak[94]	0.23	0.45	0.59	0.69	0.79
Black-chinned Hummingbird[93]	0.35	0.65	0.75	0.88	0.93

Table 8. Power analysis for selected riparian breeding species. The type I error was set at α=0.10, replications=500, surveys=3/year, years=5, for a two-tailed test. Trend projections are 5-25% changes in detection rates on a yearly basis. The best year survey mean and standard deviations used in the analyses are indicated for each species.

	Power to detect a positive trend over 5 years				
	5%	10%	15%	20%	25%
Ash-throated Flycatcher[94]	0.31	0.76	0.99	1.00	1.00
Brown-headed Cowbird[94]	0.18	0.51	0.88	0.99	1.00
Yellow-breasted Chat[94]	0.25	0.69	0.94	1.00	1.00
Bewick's Wren[94]	0.33	0.87	0.99	1.00	1.00
Mourning Dove[95]	0.33	0.75	0.99	1.00	1.00
	Power to detect a negative trend over 5 years				
	5%	10%	15%	20%	25%
Ash-throated Flycatcher[94]	0.25	0.50	0.75	0.87	0.91
Brown-headed Cowbird[94]	0.16	0.33	0.46	0.58	0.67
Yellow-breasted Chat[94]	0.19	0.42	0.58	0.72	0.78
Bewick's Wren[94]	0.25	0.51	0.77	0.88	0.93
Mourning Dove[95]	0.22	0.48	0.72	0.83	0.90

Table 9. Summary of the power analysis results for 5 and 3 surveys per year over a 5-year period. Power was set at ≥ 0.80 with the Type I error at $\alpha = 0.10$ at trend projections of 10% and 20%. One-tailed tests are listed for those species that failed the 2-tailed 20% decline test. A + indicates a power level of 0.80 or better for the species, while a - indicates power levels below 0.80.

5 Surveys/Year

Species	10% 2-tailed		20% 2-tailed		20% 1-tailed
	+	-	+	-	-
HOFI	+	-	+	+	
CNWR	+	+	+	+	
ATFL	+	-	+	+	
BHCO	-	-	+	-	+
YBCH	+	-	+	+	
BEWR	+	-	+	+	
BGGN	-	-	+	-	-
BUOR	-	-	+	-	-
BLGR	-	-	+	-	-
BCHU	-	-	+	-	+
MODO	+	-	+	+	
ROWR	+	-	+	+	

3 Surveys/Year

Species	10% 2-tailed		20% 2-tailed		20% 1-tailed
	+	-	+	-	-
HOFI	+	-	+	+	
CNWR	+	-	+	+	
ATFL	-	-	+	+	
BHCO	-	-	+	-	-
YBCH	-	-	+	-	+
BEWR	+	-	+	+	
BGGN	-	-	-	-	-
BUOR	-	-	-	-	-
BLGR	-	-	-	-	-
BCHU	-	-	-	-	-
MODO	-	-	+	+	
ROWR	+	-	+	+	

Table 10. Results of an Analysis of Variance for Rock Wren (summed detections over 21 point counts and five surveys) for the years 1993-1996. The model used is a repeated measures design. The Bonferroni adjustment was applied to the comparison of means T-test. The two groups of means are significantly different at an $\alpha=0.05$ for a two-tailed test.

Source	DF	Sum of Squares	Mean Square	F	P
Year	3	21.133	7.0444	12.15	<0.0001
Plot	20	26.791	1.3395	2.47	0.0005
Interaction (YearXplotXsurvey)	396	214.467	0.5416		
TOTAL	419	262.390			

Year	Mean	N	Groups
1993	0.714	105	|
1994	0.638	105	|
1995	0.333	105	|
1996	0.162	105	|

Table 11. Summary of best point count stations (most detections over 1993-1996) for each species, number of stations seen in (N; at least 1 detection over the four years), along with an overall coefficent of variation. All terrestrial species detected that either breed or could potentially breed are listed except for strictly aquatic species and raptors. Stations are ranked below from most number of occurrences to least number. Stations in parentheses indicate ties.

Species	N	Best Five Plots	CV
Ash-throated Flycatcher	21	16,18,17,12,2	128%
Black-chinned Hummingbird	17	3,2,1,6,12	282%
Bewick's Wren	21	16,17,15,5,11	127%
Black-headed Grosbeak	3	11,12,19	-
Blue-gray Gnatcatcher	17	13,14,18,20,8	262%
Brown-headed Cowbird	21	1,2,3,4,8	220%
Blue Grosbeak	21	20,21,11,3,4	214%
Bullock's Oriole	17	2,8,3,1,4	262%
Bushtit	13	19,15,9,7,14	648%
Canyon Wren	21	4,1,2,3,5	104%
Common Yellowthroat	8	21,4,2,1,3	562%
Great-tailed Grackle	2	21,18	-
House Finch	21	5,17,19,1,6	94%
Indigo Bunting	1	17	-
Lazuli Bunting	6	11,16,7,20,21	807%
Lesser Goldfinch	1	15	-
Lucy's Warbler	18	15,14,16,6,2	333%
Marsh Wren	1	2	-
Mourning Dove	21	2,1,3,9,8	191%
Northern Mockingbird	4	2,3,4,19,-	-
Rock Wren	21	7,13,3,8,10	173%
Red-winged Blackbird	2	1,3	-
Say's Phoebe	19	3,5,16,19,21	353%
Song Sparrow	1	2	-
Spotted Towhee	3	8,11,20,-,-	-
Violet-green Swallow	21	2,1,5,17,3	231%
White-throated Swift	17	10,9,1,20,8	469%
Yellow-breasted Chat	21	17,3,16,8,4	159%
Yellow Warbler	11	17,16,1,2,3	543%

Plot Ranks

Highest — Lowest

3 2 1 8 (4,16,17) (5,11,19,20,21) 15 (6,7,9,12,14,18) (10,13)

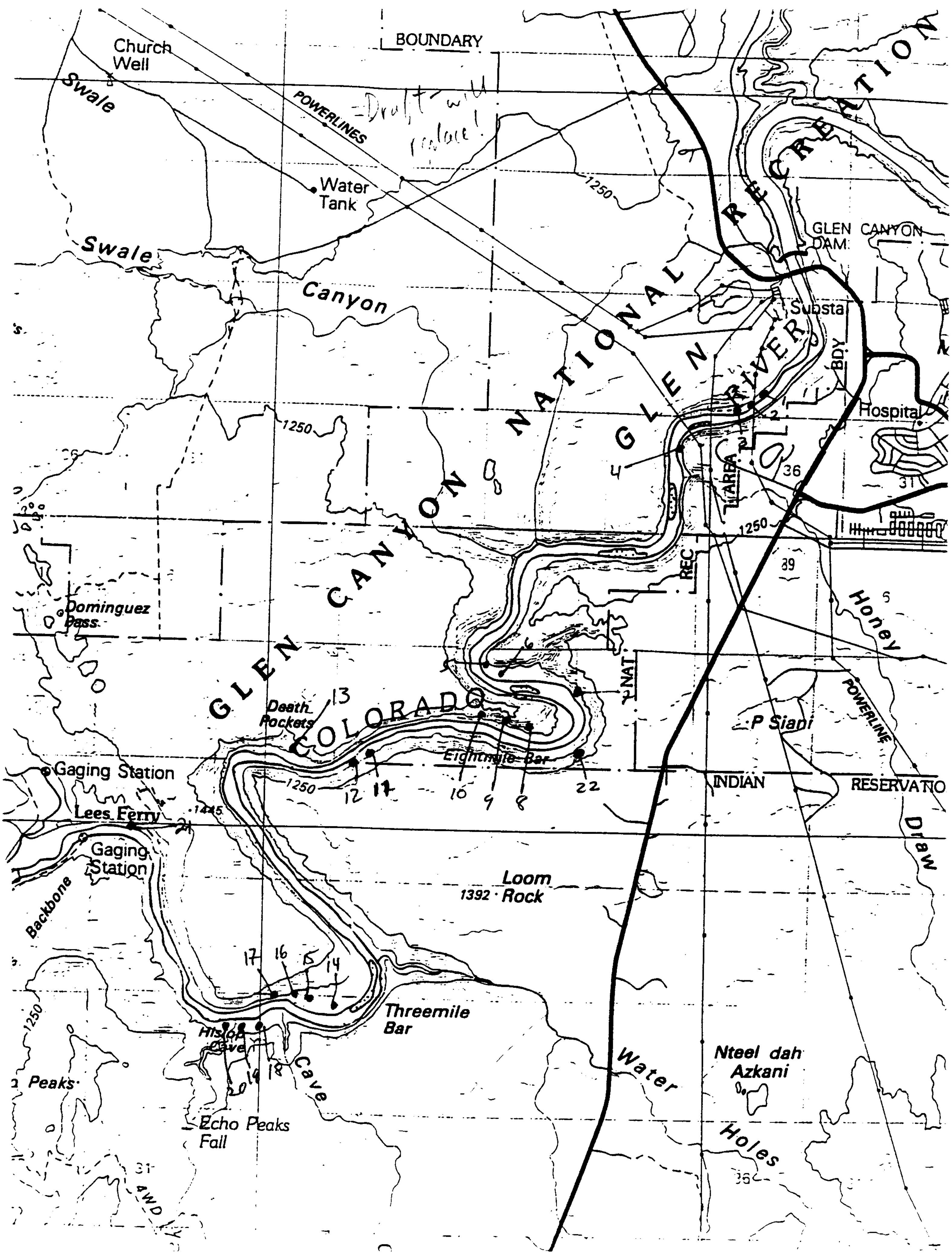
APPENDIX

Patches and point count stations are numbered sequentially downstream from Glen Canyon Dam, except for station 22, which was established in 1996 at RM -8.8L.

Point-Count Station	Patch	River Mile
1	1	-14.4R
2	1	-14.2R
3	1	-14.0R
4	2	-13.6L
5	3	-10.2L
6	3	-9.9L
7	4	-9.4L
8	6	-8.6R
9	6	-8.4R
10	6	-8.2R
11	7	-7.1L
12	7	-6.9L
13	8	-6.5R
14	9	-3.5R
15	9	-3.3R
16	9	-3.1R
17	9	-2.9R
18	10	-2.7L
19	10	-2.5L
20	10	-2.3L
21	11	-0.4R
22	5	-8.9L

FIGURES

Figure 1. Glen Canyon study area, from Glen Canyon Dam to Lee's Ferry, with the 22 point count stations and their patch boundaries indicated.



BOUNDARY
Church Well
Swale
POWERLINES
Draft – will replace!
Water Tank
1250
Swale
Canyon
GLEN CANYON NATIONAL RECREATION
GLEN CANYON DAM
Substa
GLEN
RIVER
BDY
Hospital
AREA
36
31
1250
REC
89
Honey
Draw
6
NAT
POWERLINE
P Siani
INDIAN
RESERVATIO
Dominguez Pass
GLEN CANYON
COLORADO
Death Pockets
Eightmile Bar
Gaging Station
1250
Lees Ferry
1445
Gaging Station
Backbone
Loom Rock
1392
Threemile Bar
Hislop Cave
Cave
Water Holes
Nteel dah Azkani
Peaks
Echo Peaks Fall
4WD
31
35

Figure 2A-D. Total summed detections from surveys 3-5 for selected breeding species between 1993-1996. Species acronyms are:

ATFL Ash-throated Flycatcher
BCHU Black-chinned Hummingbird
BEWR Bewick's Wren
BGGN Blue-gray Gnatcatcher
BHCO Brown-headed Cowbird
BLGR Blue Grosbeak
BUOR Bullock's Oriole
CNWR Canyon Wren
HOFI House Finch
MODO Mourning Dove
ROWR Rock Wren
YBCH Yellow-breated Chat

FIGURE 2A

Summed Counts for Surveys 3-5

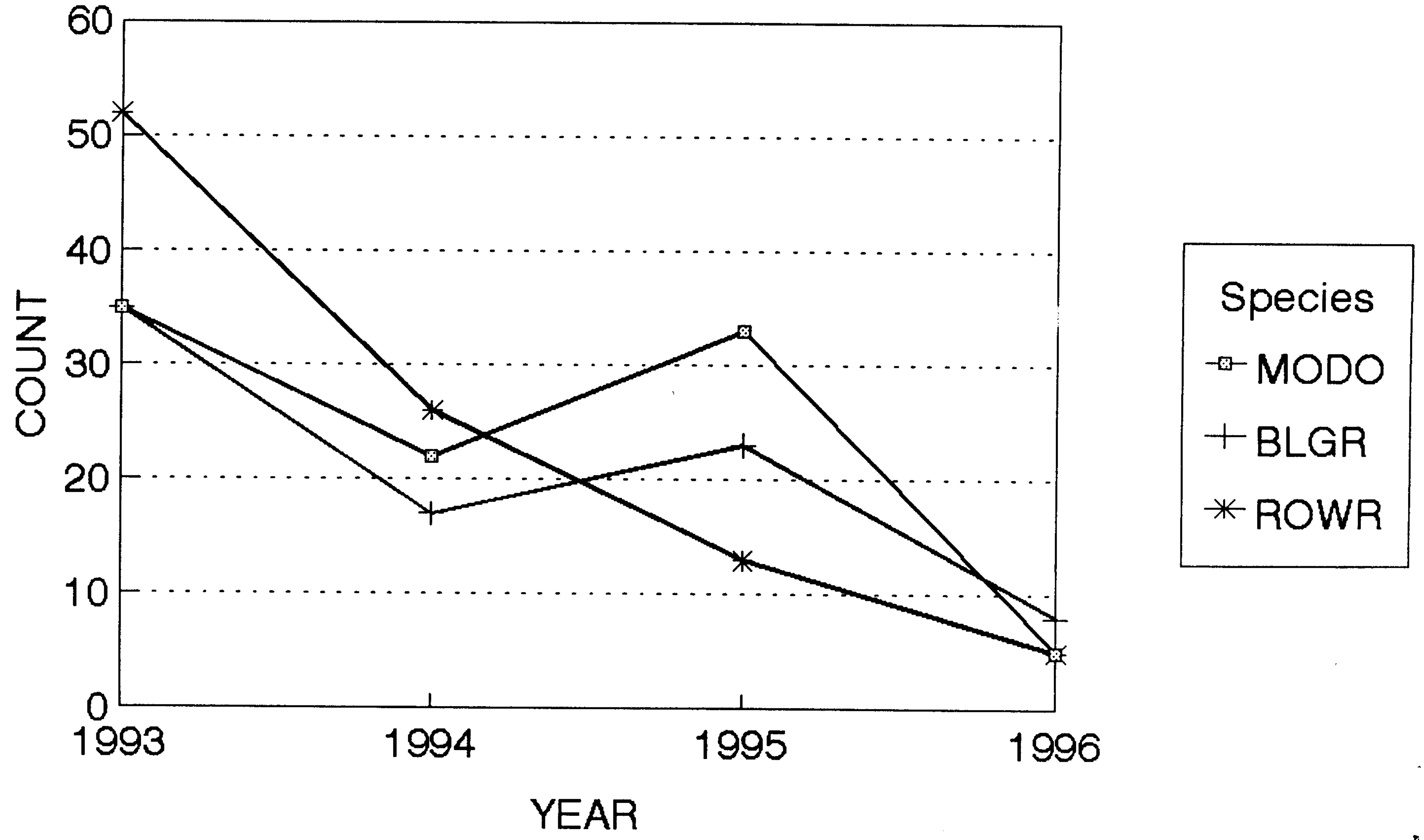


FIGURE 2B

Summed Counts for Surveys 3-5

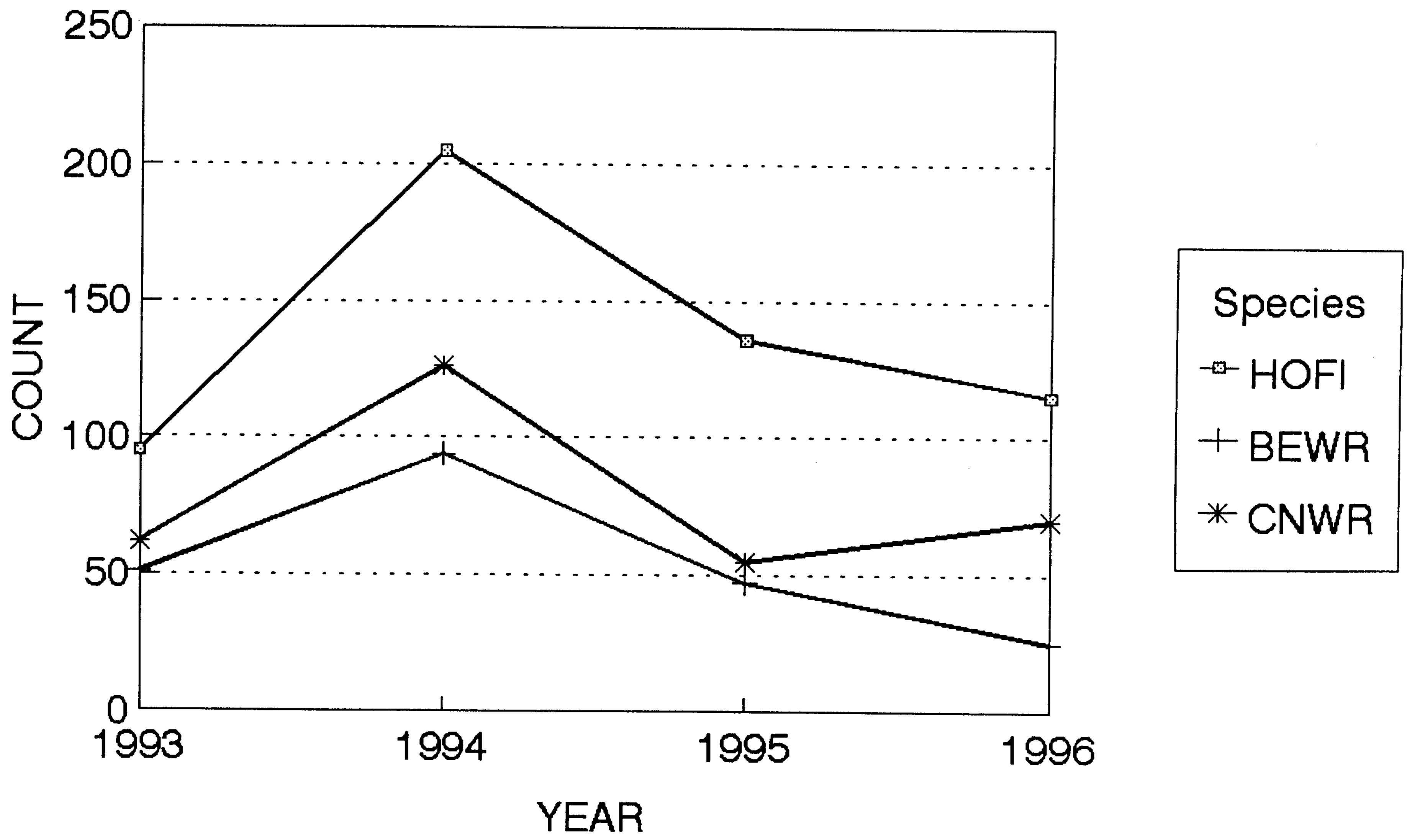


FIGURE 2C

Summed Counts for Surveys 3-5

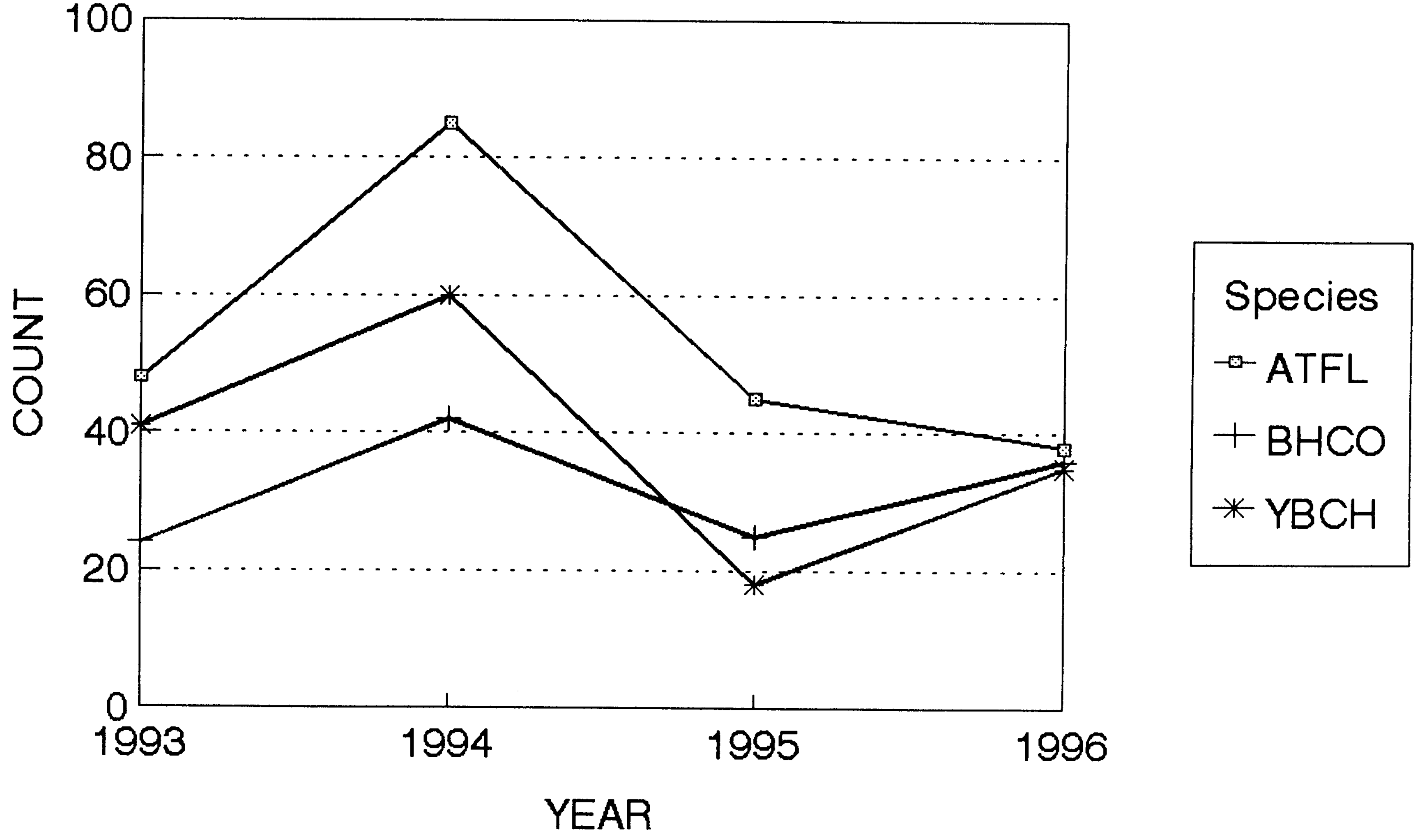


FIGURE 2D

Summed Counts for Surveys 3-5

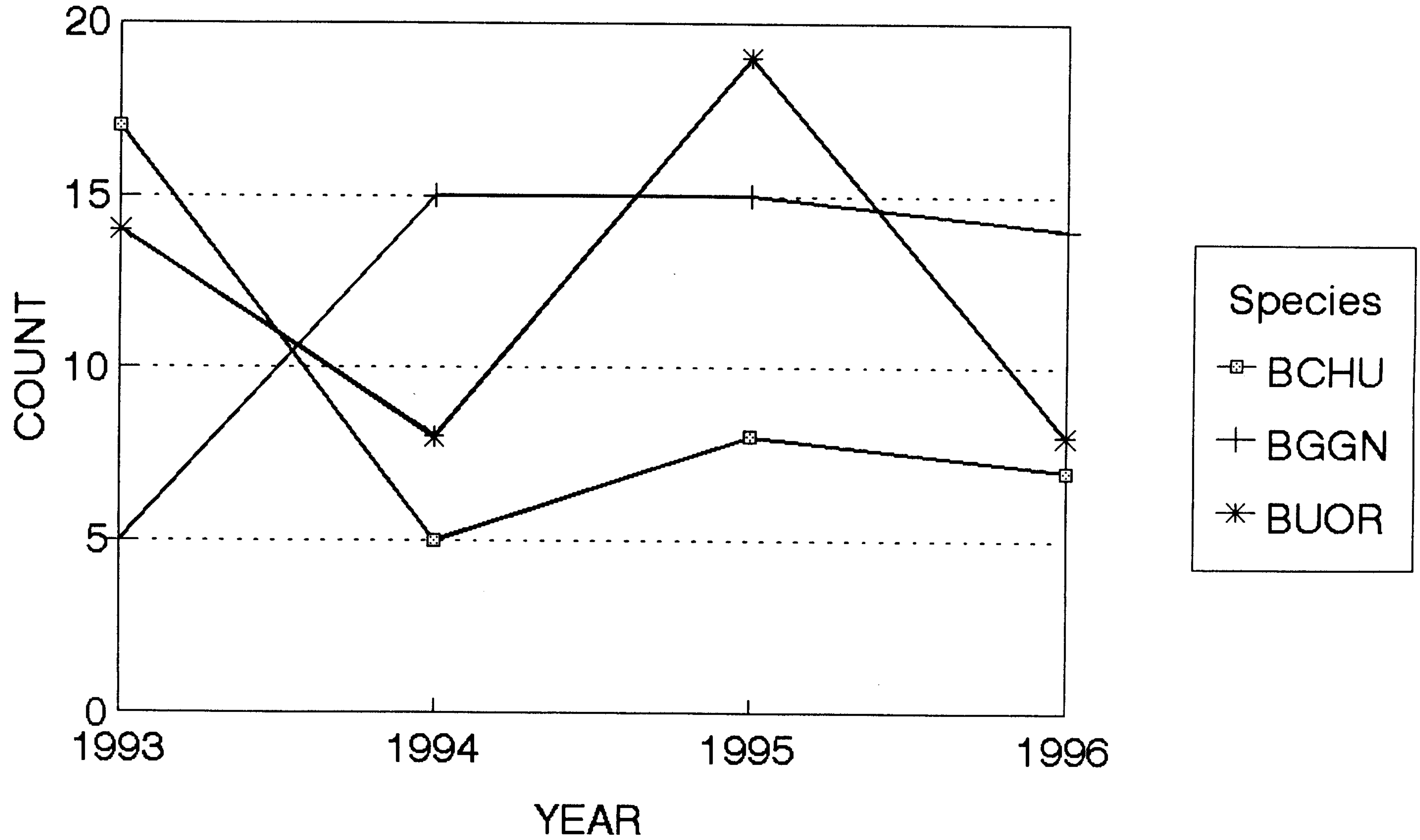


Figure 3. Plot of patch species diversity (H′) for the years 1993-1996. Refer to Figure 1 and the Appendix for patch locations.

FIGURE 3

Patch Species Diversity

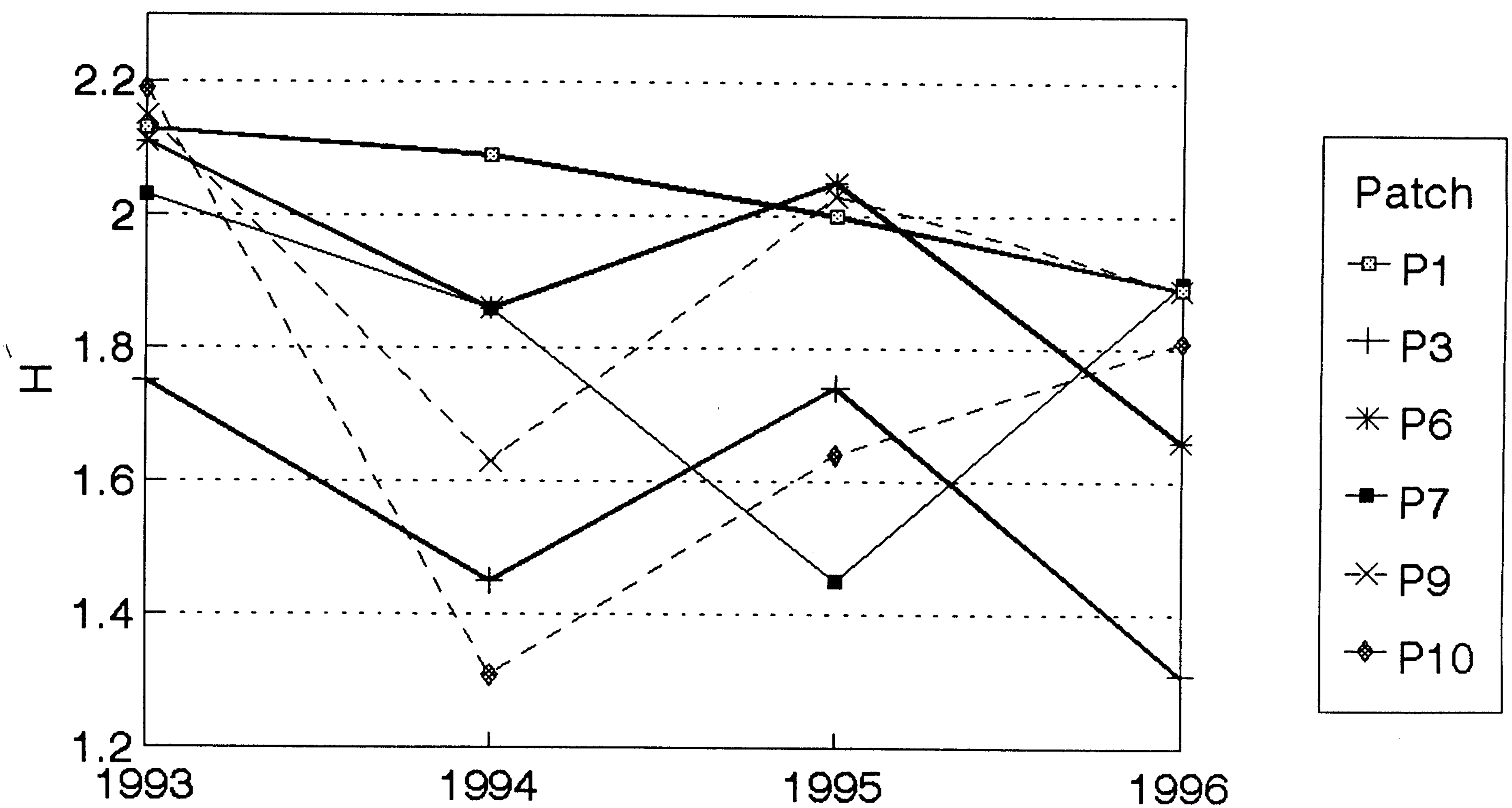


Figure 4. Plot of patch species evenness (J) for the years 1993-1996. Refer to Figure 1 and the Appendix for patch locations.

FIGURE 4

Patch Species Evenness

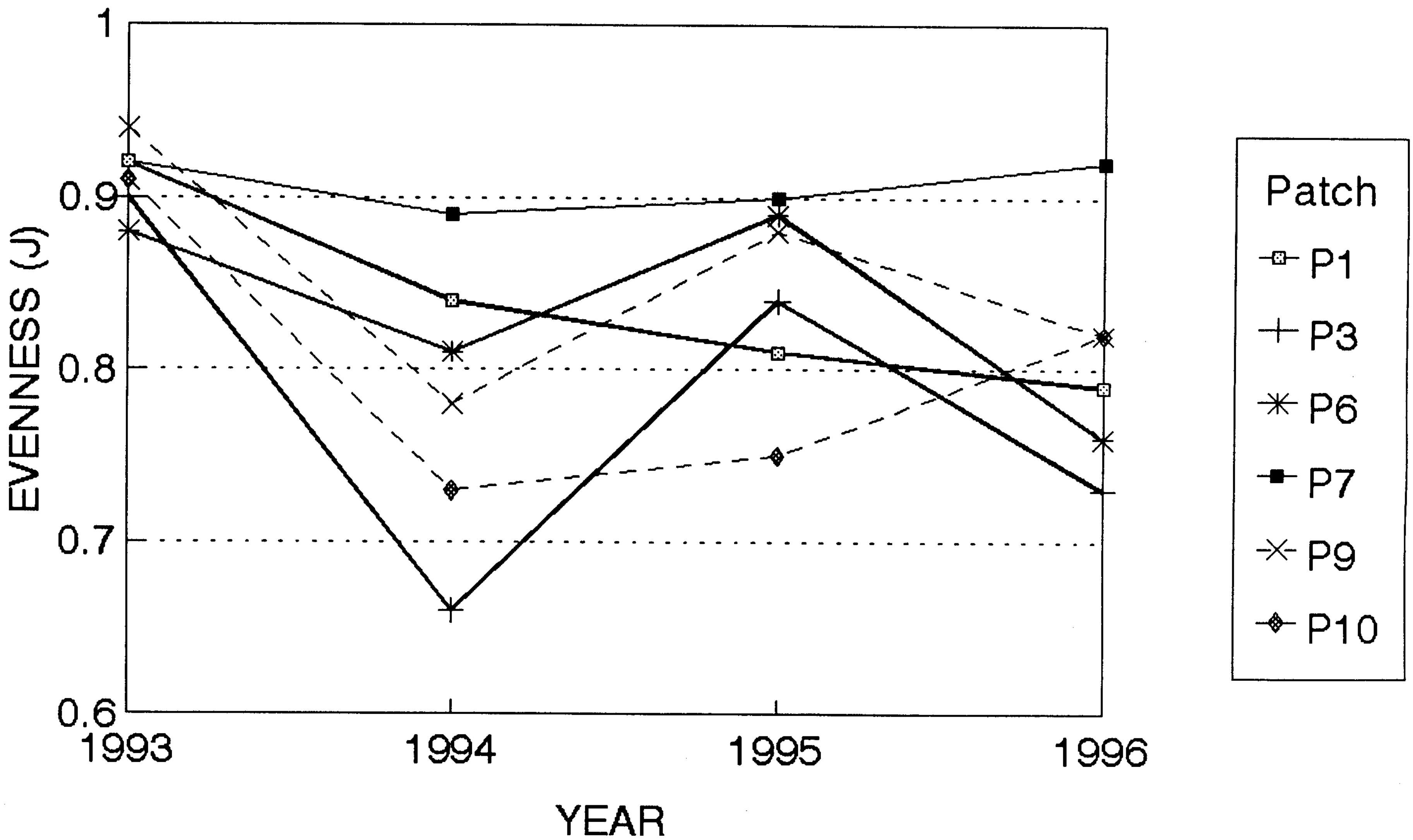


Figure 5. Plot of patch species richness (S) for the years 1993-1996. Refer to Figure 1 and the Appendix for patch locations.

FIGURE 5

Patch Species Richness

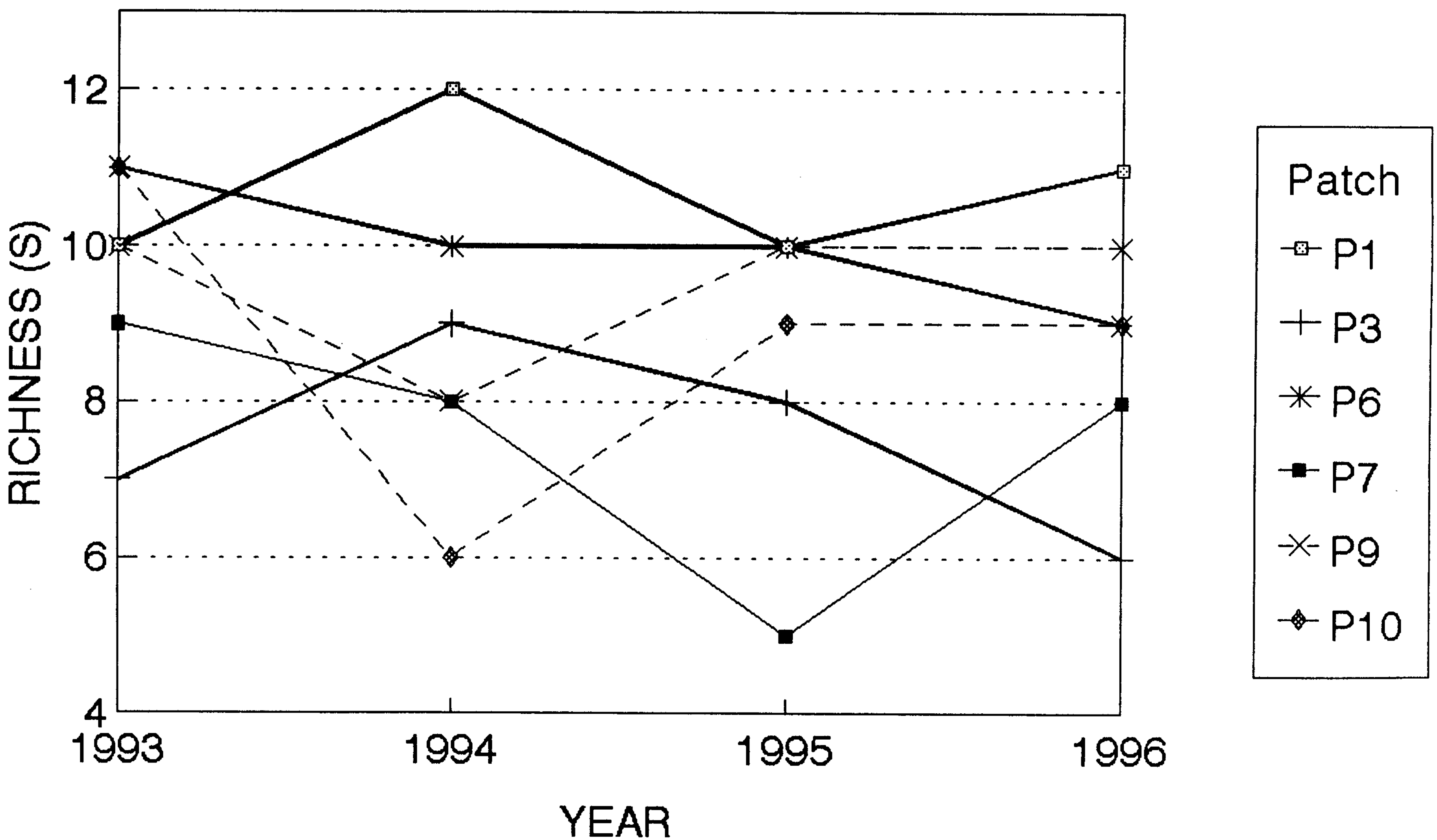
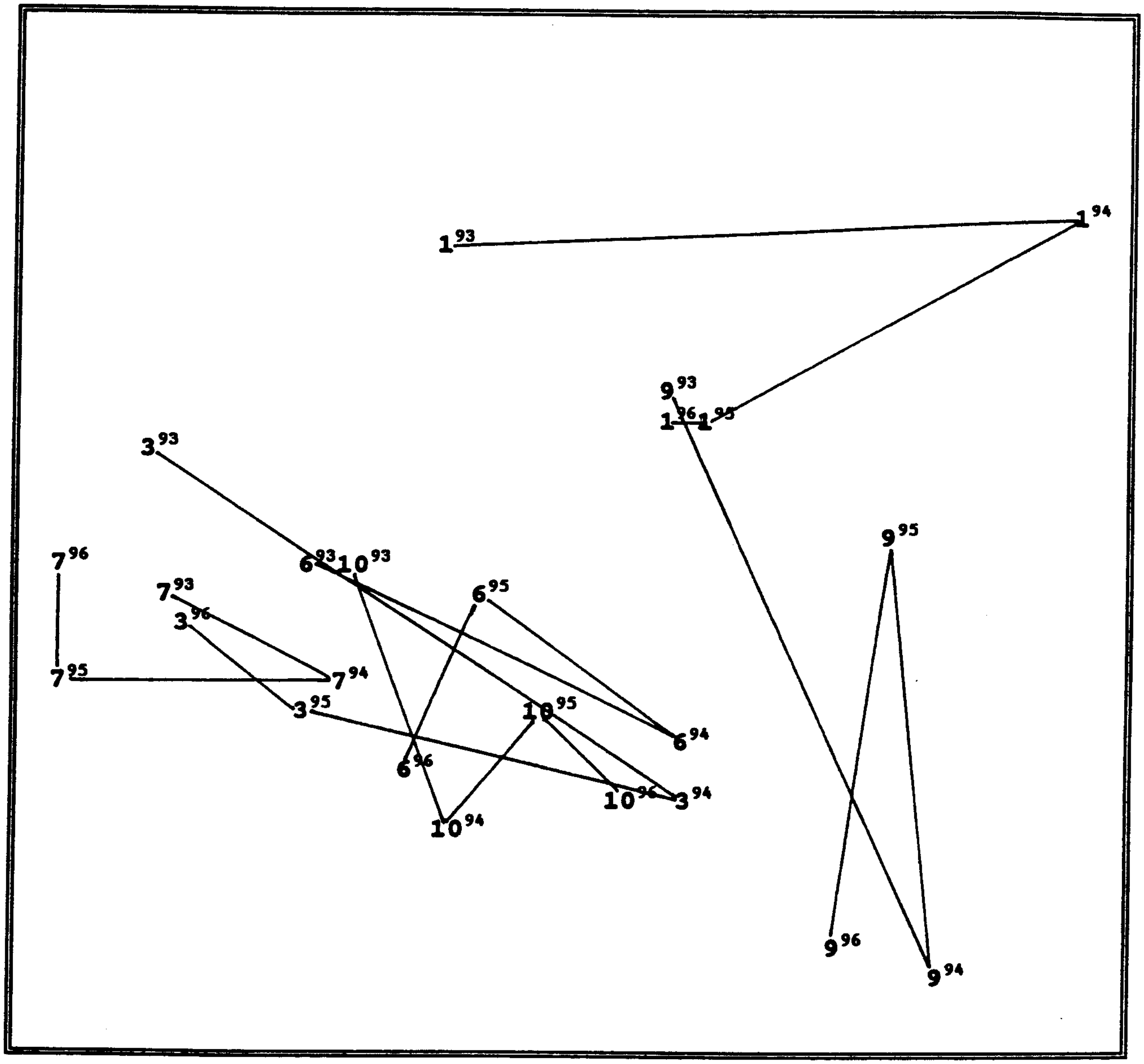


Figure 6. A Principal Ccomponents Analysis for patches 1, 3, 6, 7, 9, and 10. The first two axes area plotted, with PCA axis I (X-axis) and PCA axis II (Y-axis). Each sample represents a patch in a particular year, indicated as a superscript. Vectors connect the patches in a temporal sequence for the years 1993-96. Refer to Figure 1 and the Appendix for patch locations.

FIGURE 6



1 93
1 94
9 93
1 96
1 95
3 93
9 95
7 96
6 93
10 93
7 93
6 95
3 96
7 95
7 94
3 95
10 95
6 94
6 96
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3 94
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