A Quantitative Analysis of Shorebird Monitoring Programs

A report for the period 1 October 1989-30 September 1999 for the contract,
A Shorebird Monitoring Program for Western North America

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Summary

A large data set describing shorebird distribution and abundance in the United States was analyzed to investigate how best to monitor shorebirds. Optimal timing for the monitoring period was investigated for each of 25 regions that together covered the coterminous United States. A two-month period was defined for each region. Most of the periods were in late summer and early fall. Analytic methods were developed to estimate trends and their standard errors and to carry out power analyses. Estimates of trend in the mean number of birds recorded per survey, during the proposed survey intervals, were prepared for 37 shorebird species. Standard errors were obtained for each estimate. Bias was investigated by study of the data set and comparison of trend estimates from it with estimates from the Breeding Bird Survey. Major conclusions and recommendations were:

1. Precision of estimated trends based on the current data set is adequate for many purposes and can probably be improved. Standard errors of the estimated annual rate of change in mean number recorded per survey for the 37 species were largely in the 0.01-0.03 range. With improvements in sampling and analytic methods, they can be brought below 0.02 for most species, an acceptable level of precision.

2. Estimates based on the current data set are subject to large biases which make them unreliable despite their adequate precision. A comparison of the trend estimates obtained in this study and estimates from the Breeding Bird Survey showed wide disagreement, and in four cases the estimates obtained in this study were clearly unrealistic. Changes in which sites are surveyed each year appear to be the most serious source of bias but other major sources cannot be ruled out.

3. The potential bias can probably be reduced to acceptable levels. The most important tasks are developing a comprehensive list of shorebird concentration sites to serve as a sampling frame for the monitoring program and insuring that most sites are surveyed in most years. Other tasks include preparing and up-dating site descriptions, and implementing a training program for observers.

4. A well-designed monitoring program during the non-breeding period is feasible and would be useful in many ways. Such a program would reveal large-scale changes in where shorebirds spend the migration and wintering periods, help identify habitat declines at the monitored sites and provide information on movement patterns. Pilot studies for such a program could begin in 2000.

5. A program of surveys on the breeding grounds should be evaluated to augment results from the non-breeding period. Despite the utility of surveys during the non-breeding period, they probably cannot ever provide reliable estimates of change in size of the breeding population. Full confidence in the estimates would require that changes in movement behavior be excluded as the cause of the trend in numbers recorded per survey. Some indication of whether such changes occurred might be obtained through banding studies, but it is difficult to see how the movements hypothesis could ever be fully excluded.

6. The five conclusions above should be reviewed by the FWS and the Research and Monitoring Working Group for the US Shorebird Conservation Plan. The conclusions above lead to several additional tasks, most notably preparing a comprehensive list of shorebird concentration sites and evaluating the feasibility of surveys on the breeding grounds. Current funding is sufficient to carry out the needed analyses but it is important that whatever course is followed for the rest of the project be supported by the sponsor and by shorebird specialists.

Introduction

This Report, prepared under a contract from the USFWS, contains recommendations for monitoring shorebird populations in North America north of Mexico. The goal of the monitoring program is assumed to be estimating temporal trend in size of the breeding populations of as many species as possible. The recommendations are based on analyses of a large data set kindly provided to me by Drs. Brian Harrington of Manomet and Susan Skagen of the USGS in Colorado.

I assume that concentration sites are surveyed up to several times and used to estimate the mean number of birds present at the site during the study period. The estimates are then combined to yield an estimate of the average number of birds present during the study period throughout the study area and this estimate is used as an index to population size on the breeding grounds. I also examine the desirability of using peak counts instead of means.

The general issue of how reliable we might expect such an index to be can be divided into three topics that I regard as roughly equal in importance:

1. Precision of sample means/survey
2. Bias in sample means/survey as an index to the true means/survey
3. Reliability of the true means/survey as an index to size of the breeding population

These topics are used as the major headings in this report.

Data Used in the Analysis

Each record in the data set provided by Drs. Harrington and Skagen (referred to below as the ISS-Skagen data set) includes the number of each shorebird species recorded during one survey of a site. I removed duplicate records and records from outside the coterminous United States and Canada. This left 70,266 records collected mainly during 1975-98 throughout the United States.

I assumed that surveys would be carried out in a fairly brief period, for example 1 to 2 months, and that the period should be approximately the same throughout the study area but (like the Breeding Bird Survey) could be adjusted to account for latitudinal differences.

To explore when the surveys should be conducted I identified sites and years in which at least 20 surveys were carried out during January-June or July-December (or in both periods). This provided a sample of 22,019 records from 269 sites, well-distributed across the study area (Fig. 1). I sub-divided the study area into 25 regions based on the locations of the sites (I would have liked to use the regions delineated by the Research and Monitoring group but their regions were too large and their sub-regions were too small for this analysis).

I then calculated the mean number of shorebirds per survey during each month in each region (weighting means per site and years within sites

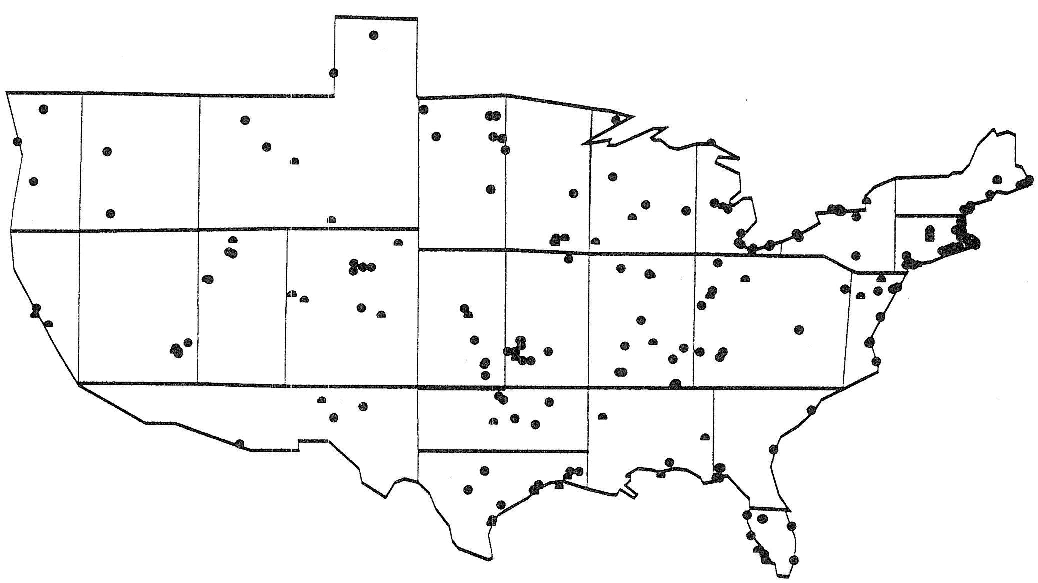


Figure 1. Stratum borders and sites used to define the monitoring periods.

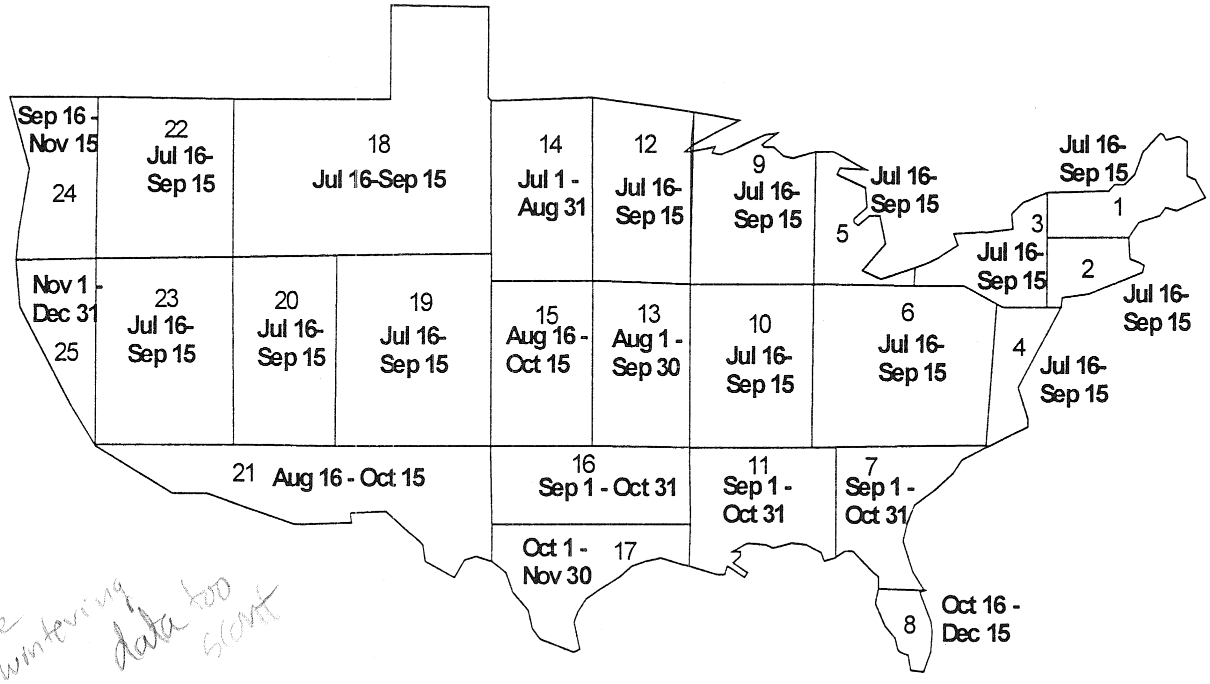


Figure 2. Survey periods used in each stratum (stratum numbers are also shown).

equally). For each species, I identified the two-month period (starting on the month or half-month) in each region during which the maximum number of individuals/survey was recorded. I then combined results across species, identifying the two-month period which captured the most species-specific intervals. Finally, I examined how variable the results were between regions. In all but three regions, the best period was late summer or fall and I therefore selected late summer or the fall as the monitoring period. In most regions this was July 15 to September 15 but it was somewhat later in the southern and western parts of the United States (Fig. 2). Although I carried out this analysis so that I could prepare the rest of the report, it seems possible that the results will be of value in other contexts. The tables for each species are contained in Appendix 1. Appendix 2 provides figures for each species, each figure containing 12 maps of the study area, one for each month, with mean number recorded per survey.

Estimation Method

Suppose that several sites are surveyed one or more times during each of several years and we compute the average number of birds recorded per survey. Methods for making these estimates are discussed below; for now I focus on how to estimate the long-term trend given several years of such estimates $\bar{y}_j$, $j = 1,\ldots,L$ where L = the number of years.

One approach for estimating the trend is to fit a first-order, exponential curve to the annual estimates as shown below. The usual method for doing this

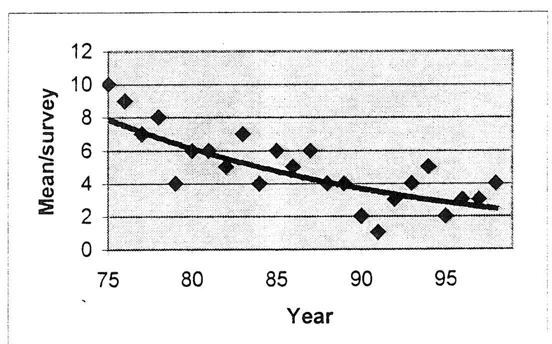


Figure 3. Fitting an exponential curve to annual means/curve.

(least squares estimation) is to find values, b_o and b_1, such that the curve

$$\hat{\bar{Y}}_j = e^{b_o + b_1 X_j}$$

minimizes the sum of the squared deviations,

$$\sum_{j}^{L}(\bar{y}_j - \hat{\bar{Y}}_j)^2,$$

between the observed values, $\bar{y}_j$, and the predicted values, $\hat{\bar{Y}}_j$. The formulas for the coefficients are

$$b_1 = \frac{cov(X_j, \ln \bar{y}_j)}{Var(X_j)}$$

$$b_o = \left(\frac{1}{L}\sum_{j}^{L}\ln \bar{y}_j\right) - b_1\bar{X}$$

where the X_j are the years (e.g., in my analysis X_1 = 1975).

The estimated trend, using the approach above, is $\exp(b_1)$. The trend is the annual rate of change in population size. For example, a value of 1.03 means an increase of 3% per year, and 0.98 means a decline of 2% per year.

This approach is slightly different from the "route regression" methods used to analyze Breeding Bird Survey data, but it gives similar results and is used here because it seems to provide a better foundation for carrying out power calculations.

Precision of Sample Means Per Survey

This section provides estimates of the standard errors (SE) of trends in the mean number of shorebirds recorded/survey. The objective was to determine whether the program is providing information of sufficient precision to be useful. If the standard error of the trend estimate is 0.02 then the 95% confidence interval is about 0.04 so an estimated trend of 0.96 (i.e., a 4% decline per year) would be just significant. To put this decline in perspective, if a population declined at 4%/year it would decline by 56% in 20 years. Thus an estimate that the population had declined by 56% in 20 years would be just significant (at the 5% level) if the standard error was 0.02. This seems like a minimum level of precision.

A few other values for just significant declines are given in Table 1. If the standard error was >0.025 then even a 64% decline in a 20-year data set would not be significant. If the standard error was less than 0.01, then quite small declines would be significant. Such a high level of precision is nice, of course, but it is questionable whether conservation action would (or should) be taken due to population declines of less than 30-40%. If achieving this high level of precision requires scarce resources then it might be

Depends on pop'n size

Table 1. Declines that would be just significant with various standard errors.

Standard error (SE)	Maximum significant annual decline	Decline during 20 years
0.005	0.99	18%
0.01	0.98	33%
0.02	0.96	56%
0.025	0.95	64%

argued that they should be used for other needs. Thus, a reasonable goal for precision in the shorebird monitoring program seems to be that standard errors of the trend for a 20-year data set should be in the 0.01 to 0.02 range.

The methods described above (see *Estimation Method*) were used to estimate trends from a subset of the ISS-Skagen data set. I restricted the analysis to (1) sites that were visited 3^+ times in 3^+ years and at which the mean number of individuals per survey was ≥ 1.0 (except for Wilson's plover for which I used 0.1) and (2) years in which 5^+ such sites were surveyed. This subset of the data included 11,680 records at 209 sites. Trend estimates and their standard errors were obtained for 37 species (Table 2). Estimated standard errors varied from 0.0 to 0.047; 16 of them were ≤0.02 (Appendix 3 describes the methods; Appendix 4 provides the annual means/survey for each species). The existing program is thus achieving reasonably good precision even when a fairly small subset of the data is analyzed.

Eleven species were not recorded frequently enough for inclusion in the current analysis, and I investigated the feasibility of including them in the future (Table 3). Two species (mountain plover, purple sandpiper) can probably be included though purple sandpiper would require a special survey outside the proposed monitoring periods. Four species (black oystercatcher, black turnstone, surfbird, rock sandpiper) could probably be included if surveys of rocky coastlines in the western United States and Canada are feasible. Three species (Pacific golden-plover, bar-tailed godwit, red phalarope) probably cannot be included though it is possible that useful information on them might be obtained in California (during the proposed survey period). If the study area was extended to Hawaii, Guam, and perhaps elsewhere in the south Pacific then these species might be included. The final species, American woodcock, is probably not worth including because it would take a special effort and is covered by the BBS and other programs.

Table 2. Shorebird trend estimates based on a subset[a] of the ISS-Skagen data set.

Species	Sites	Mn birds/ survey	No. of records	Estimated trend	SE	Potential SE[b]
Black-bellied Plover	100	76	362,464	0.978	0.019	0.008
Lesser Golden-Plover	12	5	3,735	0.988	0.016	0.018
Snowy Plover	22	22	18,928	1.163	0.013	0.013
Wilson's Plover	15	3	1,728	0.986	0.025	0.017
Semipalmated Plover	130	59	453,134	1.006	0.026	0.007
Piping Plover	32	7	11,166	1.005	0.025	0.009
Killdeer	133	34	276,842	0.999	0.000	0.009
American Oystercatcher	19	15	17,427	1.034	0.028	0.011
Black-necked Stilt	24	496	553,804	1.688	0.033	0.018
American Avocet	44	474	1,007,639	1.152	0.042	0.013
Lesser Yellowlegs	109	18	106,477	1.022	0.029	0.007
Greater Yellowlegs	13	10	8,898	1.060	0.012	0.018
Solitary Sandpiper	28	5	10,032	0.945	0.018	0.009
Willet	56	20	46,920	0.940	0.028	0.009
Spotted Sandpiper	83	4	24,128	0.983	0.010	0.005
Upland Sandpiper	7	2	1,265	1.061	0.002	0.019
Whimbrel	15	14	13,649	0.995	0.025	0.014
Long-billed Curlew	9	2	750	1.207	0.011	0.016
Hudsonian Godwit	10	77	57,329	1.073	0.014	0.018
Marbled Godwit	30	233	262,622	1.375	0.028	0.015
Ruddy Turnstone	76	18	73,059	0.984	0.015	0.007
Red Knot	41	124	272,118	0.939	0.016	0.010
Sanderling	110	146	882,397	1.023	0.000	0.009
Semipalmated Sandpiper	147	263	2,339,622	0.965	0.022	0.008
Western Sandpiper	88	142	582,303	0.981	0.047	0.013
Least Sandpiper	169	94	904,083	0.976	0.037	0.011
White-rumped Sandpiper	22	5	8,499	1.069	0.022	0.012
Baird's Sandpiper	41	45	108,179	0.924	0.037	0.014
Pectoral Sandpiper	86	64	381,861	1.008	0.024	0.012
Dunlin	43	97	160,633	1.021	0.033	0.013
Stilt Sandpiper	71	106	434,545	0.916	0.035	0.014
Buff-breasted Sandpiper	18	4	4,329	0.941	0.015	0.015
Short-billed Dowitcher	88	79	412,933	0.980	0.015	0.010
Long-billed Dowitcher	48	247	654,520	0.972	0.040	0.016
Common Snipe	27	6	7,337	1.026	0.013	0.013
Wilson's Phalarope	37	444	772,646	1.287	0.025	0.016
Red-necked Phalarope	28	74	111,938	1.284	0.021	0.018

[a] Analysis for each species used (1) sites surveyed 3+ times in 3+ years and in which the mean number of birds/survey was ≥ 1.0 (except for WIPL it was 0.1), and (2) years in which 5+ such sites were surveyed.

[b] Estimated SE if all sites were surveyed every year and the number of surveys/year was equal to the average number in the actual data set.

Table 3. Feasibility of including the species recorded too rarely for inclusion in the current analysis.

Species	Description	Conclusion
Mountain Plover	Recorded frequently during the survey period in CO, KS, and TX but at sites only surveyed in 1-2 years (which therefore don't enter this analysis)	Precision probably would be adequate if sites were surveyed each year
Purple Sandpiper	Recorded frequently outside the survey period in the northeastern US	Would require a special winter survey but precision would probably then be adequate.
Black Oystercatcher Black Turnstone Surfbird Rock Sandpiper	Breed in remote northern areas; winter along rocky coast of the US and Canada (and south of there) during the proposed survey period.	Precision might be adequate if these areas were surveyed though the feasibility of counting in this habitat is uncertain.
Pacific Golden-Plover Bar-tailed Godwit Red Phalarope	Breed in northern areas; then move largely outside the US and Canada during non-breeding seasons; small numbers occur in winter along the coast of California	Conceivable that surveys in winter in California might yield adequate precision
American Woodcock	Rarely recorded and adequately covered by other surveys	Special survey for this species probably not warranted.

At present, I am unsure of how representative the sites I used are of shorebird sites in general. The periods I used might also not be the best ones. For both these reasons, the precision in an operational program might differ from the estimates I obtained. I cannot think of any reason, however, that the precision in an operational program would be consistently higher or lower than the levels I achieved. It thus seems reasonable to conclude that a non-breeding survey of the sort I analyzed would achieve adequate precision for nearly all of the shorebirds.

Peak Counts vs. Mean Counts

There has been some interest among shorebird biologists in using peak counts as an index rather than mean counts. When peak counts in each site-year are substituted for means, there is little change in standard errors. The average standard error using peak counts was about 1% larger than the average using means. The likelihood of bias when using peak counts is discussed in the next section.

Opportunities for Increasing Precision

Several opportunities exist for increasing precision, perhaps at little cost. For example, few sites were surveyed throughout the study period (1975-1998). As discussed in the next section, retaining sites would substantially reduce the potential bias in the estimates, so it may be of interest to determine how precision would be affected if sites were retained. This analysis can be carried out using the equations in Appendix 3. I estimated the precision that would be obtained if all of the sites included in the analysis for each species were each retained throughout the study period. In this analysis I assumed that the number of visits per site-year was equal to the average number actually made in the data set. The results (right hand column in Table 2) were that precision was substantially increased. All of the standard errors were ≤ 0.02 and 13 were ≤ 0.01.

Improvements in the analytic methods can probably also be made and will further reduce the standard errors. I used simple means as the estimates of the true mean number present per survey at a site but polynomial regression might yield more precise estimates, especially in cases where the numbers build up and decline in a fairly smooth manner. I experimented with this approach and found that standard errors were reduced by up to 50% (results varied widely among species). An even better approach would be to model the arrival and departure of shorebirds during the monitoring period using weather, habitat, and perhaps other factors. This approach could substantially increase precision, especially in cases where numbers present fluctuate widely, but in ways that can be predicted from external variables. Such a modeling effort would also help us understand shorebird movements which would be useful in its own right.

Estimated precision may also be increased in the future by adjusting the equations used to estimate the standard error of the trend to account for the fraction of the sites surveyed. This adjustment, known as the

finite population correction (fpc) in sampling theory, is used whenever a substantial proportion (e.g., >0.1) of the statistical population – sites in our case – is included in the sample. At present, no comprehensive list of sites exists so I made the simplifying assumption that the sampled fraction is negligible. If a list of sites is produced, however, then the fpc may turn out to be appreciable at least for some species.

In conclusion, precision of the estimated means/survey was adequate for nearly all of the 48 species considered in this analysis or would be if most sites were surveyed in most years and a few other modifications in the program were made. The current program produces estimates with adequate precision for many analyses. For example, estimates that means/survey had declined by 50% during a 20-year period would be statistically significant at the 5% level for most species, and smaller declines would be significant for some species. Precision can probably be improved substantially in which case regional estimates might also be feasible

Bias of Sample Means/Survey as an Estimate of True Means/Survey

High precision does not guarantee high accuracy. One must also consider sources of error that are not included in estimates of precision. This section is restricted to the question "How well do means/survey in the sample track the true mean number of birds present in the study area during the study period?" How well the true mean number present in the study area tracks the size of the breeding populations is discussed in the next section.

If a constant fraction of the birds present was recorded each year, then the sample mean would provide an excellent estimate of the trend in true means present. Thus, "bias" in this case, refers to bias in the trend estimate, not simply to over- or under-counting. Some of the most important sources of bias in the ISS-Skagen data set are (1) non-representative sites being included; (2) changes in which sites are surveyed during the study; (3) change in average proportion of birds present that are detected (due to change in observer ability, habitat, or other factors).

Among these factors, I have little ability to evaluate numbers 1 and 3 at present. The second factor, changes in sites being surveyed, however, clearly caused serious problems for the present analysis. To take a particularly extreme example, the mean number of black-necked stilts per survey increased from about 0.01 during most of the survey period to more than 1200 in 1995 after which it declined drastically (Fig. 4). This increase was caused by 5 sites in Utah which were only surveyed during 1991-96 and from which large numbers of black-necked stilts were reported. One site had particularly large numbers. In 1995 and 1996 more than 99% of the reported black-necked stilts came from this site.

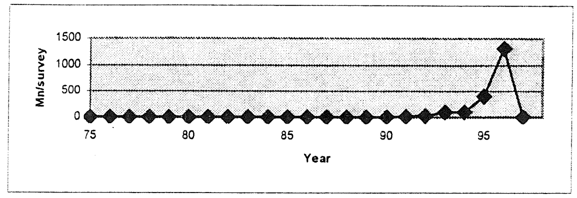


Figure 4. Trend in mean number of black-necked stilts recorded per survey.

This is an extreme example, of course, but major changes occurred throughout the program in which sites were surveyed. For example, in the analyses of precision above, the average number of years per site during the 29-year study period was 6.0 and these years tended to be approximately sequential. Thus sites with large numbers of birds (of a given species) tended to have large effects on the overall trend if they were surveyed early or late in the period. Clearly most species were not affected by site changes as much as black-necked stilts were because their population trends were close to 1.0 (Table 2). The problem, however, as exemplified by the black-necked stilts data, is that when trends were significantly different from 1.0, it was difficult to determine whether this resulted from a true decline in mean numbers present or from a tendency to add poorer sites and lose good ones in later years of the study.

As noted above, many sources of bias may be affecting the current trend estimates. One way of assessing their combined effect is to compare them to estimates derived from the Breeding Bird Survey (BBS). Eleven species were recorded frequently enough in both programs for the comparison (Table 4). The shorebird program indicated unrealistic increases for black-necked stilts, long-billed curlews, marbled godwits and Wilson's phalaropes. For each of these species, the lower bound on the increase (e.g., 80-fold for Wilson's phalaropes) was far above plausible levels indicating that bias, rather than sampling error, caused the problem. The estimates for American avocets and upland sandpipers showed similar, though smaller, bias. The other species

Table 4. Estimated change in population size using BBS data and the ISS-Skagen data set.

Species	Data set	Estimated 20-yr change (and 95% CI)
KILL	BBS	0.92 (0.87-0.98)
	ISS-Sk.	0.98 (0.96-1.02)
BNST	BBS	1.88 (0.53-6.14)
	ISS-Sk	35,273 (15,886-75,961)
AMAV	BBS	1.10 (0.71-1.67)
	ISS-Sk.	16.9 (3.7-69.2)
LEYE	BBS	0.29 (0.15-0.56)
	ISS-Sk.	1.55 (0.48-4.66)
WILL	BBS	0.90 (0.74-1.10)
	ISS-Sk.	0.29 (0.08-0.92)
SPSA	BBS	0.87 (0.67-1.13)
	ISS-Sk.	0.71 (0.47-1.06)
UPSA	BBS	1.29 (1.08-1.55)
	ISS-Sk.	3.27 (3.03-3.52)
LBCU	BBS	0.75 (0.49-1.17)
	ISS-SK.	43.1 (29.8-61.8)
MAGO	BBS	1.06 (0.79-1.46)
	ISS-Sk.	583 (254-1,297)
COSN	BBS	0.96 (0.82-1.10)
	ISS-Sk	1.67 (1.01-2.76)
WIPH	BBS	0.72 (0.52-1.00)
	ISS-Sk.	155 (80-295)

showed more similar trends to those indicated by the BBS. The estimates from the BBS and ISS-Skagen data sets for killdeer were quite close (declines of 2% and 8%) as were the estimates for spotted sandpipers (declines of 13% and 29%). The estimates for common snipes were a bit farther apart (4% decrease vs. 67% increase) as were the estimates for willets (declines of 10% and 71%). The estimates for lesser yellowlegs were still farther apart (71% decline vs. 55% increase). As usual with bias, it is difficult to know exactly what conclusion should be drawn from these examples, especially because the BBS estimates also have biases. Everyone would probably agree, however, that the potential bias is quite large and should not be ignored. My own feeling is that estimates of precision and the statistical methods that they support (e.g., tests, confidence intervals) are probably not warranted with the current data set because of the danger that conclusions would be misleading due to bias.

Reducing the Potential for Bias

Two major sources of bias may be distinguished in the current program: selection bias and measurement bias. Selection bias refers to the possibility that trends at the surveyed sites, as a group, differ from the overall trend. This is especially likely when sites enter and leave the program frequently, but it would be a problem even if this were not the case. The only effective way to remedy this problem is by defining the set of sites that will comprise the population to be surveyed. "Site" in this context could be a relatively small location like a Refuge, all of which would be surveyed at once, or it could be a region like the Prairie Potholes which might be stratified (e.g., using sections) and then sampled rather than censused. Once such a description exists, it can be used to insure that the sample remains representative of the population. There is no need that the surveyed sites be a simple random sample from the population. For example, a large number of sites might be chosen beforehand for their intrinsic interest. These would be assigned to one group all of which would be surveyed. A sample (perhaps a stratified sample) of the remaining sites could then be selected. Under this plan, in each year an estimate of the overall mean number of birds (of each species) present during the study period would be made. Accordingly, no problem would be caused by increasing or decreasing the number of sites surveyed as long as it was done under a designed protocol. Perhaps the single most important task in developing an improved shorebird monitoring program is creating a comprehensive list of shorebird sites that can serve as the foundation for designing the sample selection process.

Measurement bias, refers to a temporal trend in the proportion of the birds present that are detected during the survey. Changes in the proportion might occur as a result of changes in observer skill or interest, changes in habitat, or perhaps changes in other factors (e.g., disturbance frequency). A first step in remedying this problem is to prepare, for each site in the population, a description of which areas should be surveyed and how the surveys should be conducted. An assessment should also be made of the probability that the visibility conditions will remain approximately the same over long periods of time. Consideration should be given to excluding sites where this is unlikely to be true. In addition, a training and/or evaluation program is needed for participants in the program.

Peak Counts vs. Mean Counts

If peak counts are used as the index, then a discussion of bias requires that we specify what parameter we are using peak counts to estimate. One possibility is the trend in true peak numbers present where "true peak" might, for example, be defined as the average of the peak numbers occurring at each site anytime during the study period. Although this is

a reasonable parameter, the relation of peak count in the sample to true peak at a site obviously depends on sample size since the peak count would tend to increase with sample size. This means that the number of visits per site would have to be standardized or that the relationship between sample size, sample peak, and true peak would have to be specified. Standardizing number of visits seems difficult and counter productive and modeling the relationship between sample size and peak numbers seems difficult and arbitrary. Thus, this approach does not seem useful.

Another parameter that we might use peak counts to estimate is trend in mean number present. Bias is then the difference between trend in the mean of the peak counts in the samples and trend in actual mean numbers present. The comments made above about bias with means all apply to bias with peak counts. Thus, rapid replacement of sites causes the potential for serious bias as would changes in habitat or observer skill or interest. I see little basis for choosing one metric over the other on the basis of bias, though investigators more familiar with the field conditions certainly might.

In conclusion, trend estimates made using standard methods from the current data set are subject to bias of such magnitude that the estimates are of little value. Instead, the data must be "corrected", a process that may well be useful but is subjective and will be carried out differently by different analysts. Steps that might substantially reduce the potential bias include:

1. Construction of a list of sites that would constitute the statistical population.
2. Restricting surveys or at least analyses to agreed upon survey times for each region such as the ones used in this report.
3. Preparing guidelines for surveying each site that standardize the surveys.
4. Monitoring conditions at each site both to assist with when surveys were conducted and to record changes in detectability.
5. Developing a training program for surveyors.

Reliability of True Means/Survey as an Index to Size of the Breeding Population

The relationship between the sample mean/survey for a given species and size of the breeding population is affected by many factors. They can be subdivided into three categories: what proportion of the birds enter the study area during the study period, how long they remain in the study area, and what fraction of them are recorded on surveys. Under this scheme, we may write (without making any assumptions),

$$\bar{y}_j = B_j\left(\frac{F_j G_j P_j}{N}\right)$$

where

$\bar{y}_j$ = the mean number of individuals (of a given species) recorded/survey in year j,

B_j = the number of birds in the breeding population at a specified time of year, for example the end of the breeding season,

F_j = the fraction of the B_j birds that enter the study area during the study period in year *j*,

G_j = the average proportion of the study period in year *j* during which the $B_j F_j$ birds are present in the study area,

P_j = the detection rate of birds during the surveys (more specifically, the ratio of $\bar{y}_j$ to the actual mean number of birds present in the study area during the study period),

N = the number of sites in the study area (assumed constant between years).

B_j is the quantity we hope to monitor using $\bar{y}_j$. As can be seen from the expression, any temporal trend in F_j, G_j, or P_j will cause a temporal trend in $\bar{y}_j$ which will mis-lead us about the trend (if any) in B_j. The previous two sections have dealt with random and systematic influences on the P_j and have presented evidence that these sources of error can probably be reduced to acceptable levels by changes in survey design. Movements, however, present a much more serious challenge. It is difficult to imagine how one could be sure that a trend in mean counts was not caused by a change in movements. Global climates will continue to change and to affect broad-scale movements of animals in unpredictable ways. Habitat changes anywhere within the range of a species might cause changes in its distribution and abundance in the study area during the study period without there being any change in the species' population size. Changes in predator populations or the level of human disturbance might also cause a change in mean abundance during the surveys. The importance of these problems is worth emphasizing: ***surveys during the non-breeding period will only yield a useful index to population size if trends in movements can be excluded as the cause of observed changes in the index.***

In theory, trends in movements might be measured by including, as part of the monitoring program, an effort to mark and track or resight shorebirds. Detecting small, long-term trends in the fraction of birds entering the study area during the study period or the average time they remain there, however, would be difficult and expensive if it is even possible. I could investigate the parameters of a program that would provide the needed information, but I doubt that such a program would be practical. The section below, *Breeding Ground Surveys*, presents an alternative approach that I believe may be more feasible.

Peak Counts vs. Mean Counts

If peak counts, rather than mean counts, are used as the index, then the issue becomes not only how changes in F_j or G_j would affect the index, but also how changes in internal movements within the study area during the study period might affect the index. Thus, even if no trends occur in F_j and G_j changes might occur in how concentrated birds are within the study area during the study period, and these might cause bias in the index. I am inclined to recommend use of mean counts rather than peak counts, in part because I have never heard of a survey using peak counts. The issue is complex, however, and I could work more on it if the FWS or specialists working on the shorebird monitoring program wish.

Breeding Grounds Surveys

Given the present, and probably future, difficulties of using surveys during the non-breeding period to make inferences about trend in population size, it seems worthwhile to examine the feasibility of conducting a long-term program on the breeding grounds. For most species, this means surveys in the arctic, or at least in remote northern areas, and this alone might seem to preclude such surveys. I believe, however, that a relatively modest sample might provide estimates of substantial precision, and that such estimates, along with information gained during the non-breeding period might yield far more reliable estimates of trend in population size than could be gained from the non-breeding period alone. In this section, I describe the analytic tools for predicting accuracy of the estimates given samples of different sizes. I propose carrying out an analysis using existing data during the next few months to further evaluate the feasibility of breeding ground surveys.

If surveys are made on a series of plots, covered at least once each year, and if the study area is large relative to the surveyed area (as would be true for a breeding ground survey), then the standard error of the estimated trend may be written as

$$SE(e^b) = \sqrt{\frac{C_1}{n}\left[\frac{C_2}{m} + C_3\right]}$$

where n is the number of sites surveyed, m is the number of visits per site per year, C_1 is a constant that depends only on the number of (sequential) years of data from which the trend is estimated, C_2 is a measure of variability within sites, and C_3 is a measure of variability in the true means/site. Appendix 3 contains the derivation of the *SE*. The formula for the *SE* applies if all n sites are visited the same number (m) of times each year. A value of m>1 implies that a study period is defined (e.g., the first 3 weeks of incubation) and that a *random sample* (including a systematic sample) of m times is selected for surveys at each site. This implies leaving the site and then returning to it. This would be appropriate at the few sites with biologists in residence during the breeding period, but if a special trip has to be made to reach the site, then it is almost surely worthwhile to visit a new site rather than re-visiting an old site (*i.e.*, increasing n reduces both C_2 and C_3 whereas increasing m only reduces C_2). I therefore assume that m=1 which also means that we need only estimate the sum of $C_2 + C_3$, not each term separately, to make an estimate of precision. Assuming that m=1 leaves open the possibility that surveyors might spend a few days in a given location and survey each plot twice; the mean of the results would be used as the estimate.

The power analysis, assuming m=1, requires that advance estimates be made of C_2+C_3. Given such an estimate, and since C_1 is a known constant, we can calculate the *SE* that would be obtained with different numbers of sites (n) or the number of sites that would be needed to achieve a given *SE* such as 0.02. To estimate C_2+C_3 we need the means/survey from several widely scattered sites in each of several years. The data do not all need to come from the same years, but there must be at least some overlap in years and the more the better. It is essential that the sites used in estimating C_2+C_3 show roughly the same site-to-site variation as would be true in the sampled population. It is therefore important that the sites be as widely distributed as possible or substantial under estimates of C_2+C_3 (and over-estimates of precision) might occur.

I have begun collecting the needed data for this analysis and plan (pending FWS approval) to complete this analysis during the next 3-6 months.

Discussion and Conclusions

As noted in the Introduction, to be confident in a program for monitoring shorebird population size by using surveys during the non-breeding period we need to believe that:

1. The trend estimate is precise enough to be useful (i.e., $SE < 0.02$).
2. The trend has low bias when used to estimate trend in the true means present during the study period.
3. The trend in true means/survey provides a reliable index to change in size of the breeding population.

Regarding the first two points, this investigation reveals that the current program is achieving satisfactory precision, and that many opportunities exist to increase precision, perhaps substantially. Bias of the estimates, however, is high and essentially precludes the statistical analyses routinely carried out on standardized surveys such as the BBS or waterfowl counts. Analysts intimately familiar with the species, habitats, and data collection methods certainly could extract useful information about trends, but the process of doing so would necessarily be subjective, and different analysts might well reach widely different conclusions. To reduce the bias to acceptable levels, a comprehensive list of shorebird concentration sites is needed, sites to be surveyed should be selected under some kind of random sampling plan, and most sites to be included in the program need to be surveyed in most years. Preparation of site descriptions including guidelines for how to survey the sites, and development of a training program for surveyors will also help reduce bias. At present, it appears likely that bias could be reduced to an acceptable level if these steps are carried out. Furthermore, recording birds during a relatively brief period (e.g., two months) appears to be sufficient for monitoring purposes, though recording abundance year-round as done at present would certainly provide additional information of use.

At a recent meeting at Patuxent, shorebird experts developing the monitoring component of the Shorebird Conservation Plan discussed the possible need for several new, species-specific surveys. In contrast, the analyses reported here suggest that for most species a single survey might achieve adequate accuracy. One way to pursue this issue would be to compare the precision likely to be achieved by the species-specific surveys with precision of the survey described here (Table 2). Managers could then decide whether the increase in precision that would result from the species-specific survey was worth the added cost.

It seems likely that the sort of program evaluated in this report would provide much useful information about shorebird populations. Some indication of change in population size would certainly be provided (but see next paragraph). Perhaps more importantly, valuable information would be obtained on use of specific sites. If conditions deteriorated, the monitoring program would reveal the problem so it could be studied and hopefully remedied. The sites to be surveyed could be rotated between years (under a designed plan) so information could be obtained on a wide variety of sites. The influence of weather or other factors on shorebird movements could be investigated. Surveyors could be asked to search for marked birds if more intensive studies were being made. Large-scale changes in where birds spend their migration and wintering periods would be revealed and might lead to valuable insights about changes at the regional or global level. I suspect shorebird biologists could identify many other uses for such a monitoring program.

Even with the modifications to increase precision and reduce bias, and despite the many uses such a program would have, it probably cannot be relied on as an index to population size on the breeding ground. The reason is simply that observed changes in means/survey during the non-breeding period could be the result of changes in movement behavior rather than change in population size. Thus, a program to monitor movements would also have to be implemented. The feasibility, however, of monitoring movements for large numbers of species on a continuing basis is questionable and I find it hard to imagine a program that would clearly rule out change in movements as an explanation for change in means/survey.

In contrast, I believe it might be feasible to survey shorebirds on their breeding grounds. Several species, of course, are already being monitored by the Breeding Bird Survey, but for most species new surveys in the far north would be needed. This may turn out to be impractical due to costs, but we need a careful evaluation of this issue before reaching any conclusion.

In summary, the major conclusions and recommendations are:

Need to partition population size vs. maintenance habitat quality

1. A commitment should be made to improve and continue the current program of conducting surveys on the non-breeding grounds.

2. The program should be improved by (a) developing a comprehensive list of shorebird concentration sites and using it as the sampling frame for the program, (b) preparing descriptions of each site and how it should be surveyed, and (c) undertaking a pilot study to test the new procedures.

– Might this be too massive

3. A detailed evaluation is needed of whether surveys on the breeding grounds are feasible. Investigators familiar with shorebirds in northern North America should be encouraged to participate in the evaluation by contributing data and helping to decide how many sites might be surveyed and what the costs would be. The needed analytic methods are contained in this report so the analysis can be completed quickly once the data have been collected and agreement has been reached on how many sites might be included in the program.

agreed

Appendix One

Mean number of individuals/survey in each stratum

The tables in this Appendix report the mean numbers of birds recorded per survey at the sites I used in the analysis (see main report for details) during each month of the year. The survey periods used in the analysis are indicated in the title of each table.

Table A1.1. Mean birds/survey in stratum 1 (survey period was JUL 16-SEP 15).

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BASA								0.2				
BBPL					69	8	0.8	12	7	6	0.6	
COSN				1	0.1				0.4	0.6	0.2	
DUNL					0.1				0.1	5	1	
GRYE				19	28	0.4	3	3	4	4	0.4	
KILL				9	2	1	1	0.5	0.9	0.3	0.1	
LESA				0.1	95	0.1	8	10	2			
LEYE				0.1			6	4	2	0.3		
PEEP						2	17	74	159	0.6		
PESA								0.1	0.8	1		
RUTU							0.5	2	0.3	1		
SAND						0.1	1	2	2	2	5	
SBDO					4	0.7	21	25	1	0.1		
SEPL					4	0.1	2	16	10	1		
SESA					2	0.1	82	150	55	4	0.2	
SOSA					0.2		0.3	0.4	0.3	0.1		
SPSA					0.1	0.7	0.5	1	0.2			
WHIM							2	0.4				
WILL					0.9	0.5	0.2	0.1				
WRSA					0.1			0.6	0.8	0.4	0.3	
YESP						0.1	2	1	0.4	0.2		

Table A1.2. Mean birds/survey in stratum 2 (survey period was JUL 16-SEP 15).

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	No	Dec
AMOY			0.5	1	2	1	1	2	1	0.9		0.6
AMWO	1	0.8	1	0.4	0.1							
BBPL			0.1	18	82	10	5	54	79	62	3	3
COSN			0.9	1	0.1				0.2	1	0.	
DOSP							0.2	0.3	0.1			
DUNL			0.4	26	40	0.2		0.4	7	119	21	86
GRYE		0.3	0.2	0.7	0.8	0.4	3	12	11	11		
HUGO							1	2	0.4	0.2	0.	
KILL		0.7	0.9	0.7	1	1	4	3	3	7		
LBDO								0.4	0.5	0.9	0.	
LESA				0.1	6	0.3	20	14	7	0.2		
LEYE				2	0.1	2	18	13	5	0.6	0.	
LGPL								0.1	1	2	0.	
PEEP					4	0.3	7	10	1	0.2	0.	
PESA				4			0.4	0.7	1	5	0.	
PIPL		1		1	1	1	1	0.6	0.2			
PUSA	5		5	3								5
REKN					31	2	12	15	5	5		0.8
RUTU				0.1	35	2	1	9	1	0.5	0.	0.1
SAND	10	11	7	3	2	5	24	57	59	65	3	18
SBDO					1	1	58	35	6	0.9		
SEPL				0.1	4	0.4	18	129	35	5	0.	
SESA				0.5	109	18	158	289	61	6	0.	
SOSA				0.1	0.9		0.4	0.2				
SPSA		1			1	0.4	1	0.9	0.2			
STSA							0.3	0.7	0.4	0.1		
WESA							0.1	0.2	0.3	0.1		
WHIM							0.9	0.7	0.6			
WILL		3		0.5	3	3	3	1	0.3			
WRSA						0.8		2	2	0.9	0.	
YESP							0.1	0.2				

Table A1.3. Mean birds/survey in stratum 3 (survey period was JUL 16-SEP 15).

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BASA								0.2	0.3			
BBPL					0.5	0.2		0.6	0.7	2	1	
COSN				2			0.8	0.6	2	0.8	0.1	
DOSP						0.1	0.5	0.3	2	2		
DUNL				2	14	0.4			0.4	15	18	
GRYE				2	1	0.1	0.2	0.8	2	2	0.2	
KILL				5	6	5	14	14	19	9	0.3	
LBDO									0.3	0.1		
LESA					18	0.2	5	5	3			
LEYE				5	4	1	6	5	8	2		
LGPL								0.2	1	3		
PEEP					0.8	0.7	2	19	16	1		
PESA				13	2		0.7	2	13	4		
REKN								0.2	0.1			
RNPH									0.3			
RUTU					0.8	0.1	1	1	0.8			
SAND					0.3	0.1	3	4	5	3	0.5	
SBDO					21	0.2	1	0.8	0.1			
SEPL					6	0.6	0.6	3	3	0.8		
SESA					8	5	13	29	6	0.5		
SOSA				0.3	0.9		0.4	0.3	0.1			
SPSA				0.2	5	2	4	3	0.7			
STSA							0.1	0.2	0.6			
UPSA							0.2					
WESA						0.2			0.1			
WHIM					2	0.1	0.1	0.1				
WRSA					0.3	0.2		0.9	0.8	0.5		
YESP				1								

Table A1.4. Mean birds/survey in stratum 4 (survey period was JUL 16-SEP 15).

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	No	Dec
AMAV				0.2	0.7	0.2	0.1	0.2	0.4	0.2	0.	
AMOY			0.1	0.2	0.1	3	3	3	3	2		2
BBPL	0.9			14	10	3	3	24	16	18	2	7
BBSA								0.1	4	0.1		
BNST				3	1							
COSN	0.4			2				0.1	0.5	0.7	0.	0.1
DOSP					26	2	17	5	4	2	0.	0.1
DUNL	0.2		0.7	47	128	0.5	5	0.1	3	313	43	222
GRYE	0.2	0.2	1	9	7	0.9	3	12	24	38	1	3
HUGO							0.2	0.5	0.2	0.2	0.	
KILL	2	0.1	0.4	0.3	0.4	1	4	5	10	6		0.8
LBDO					1		0.2	2	4	6		0.1
LESA				3	59	0.2	29	35	27	4	0.	7
LEYE			1	6	7	0.6	55	101	73	15		0.1
LGPL					0.1			0.1	2	0.7	0.	
MAGO								0.2	0.1	0.1		0.1
PEEP				7	99	1	34	99	53	10		13
PESA					0.1		1	8	38	17		
PIPL				0.1		2	3	1	0.8	0.2	0.	
PUSA											0.	2
REKN				0.2	2	13	7	32	7	14	1	1
RUTU					18	41	2	13	5	1		0.6
SAND	16	11	7	22	67	56	151	518	152	145	8	68
SBDO	0.4			1	29	2	78	61	7	0.7	0.	1
SEPL					23	1	7	72	25	9		0.1
SESA	0.6			7	126	161	225	494	50	12	0.	
SNPL									0.3			
SOSA							0.2	0.5	0.3			
SPSA					1	0.3	2	2	0.5			
STSA							4	9	2	0.8		
UPSA					0.2							
WESA	0.1	7	10		14	2	14	32	37	26	2	21
WHIM				0.2	2	0.1	8	7	0.4			
WILL				1	2	12	10	6	3	0.3	0.	
WIPH							0.1	0.2	0.2			
WIPL					0.7							
WRSA					0.7	0.9	0.1	0.8	0.7	0.9	0.	
YESP				1	0.2		0.7	0.4	0.5	0.3	0.	0.1

Table A1.5. Mean birds/survey in stratum 5 (survey period was JUL 16-SEP 15).

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	No	Dec
BASA							0.4	2	1	0.3	0.	
BBPL					2	0.5		1	2	2		
BBSA								0.2	0.3			
COSN				4	0.2		0.1	0.5	2	3	0.	
DOSP				0.1			12	7	5	1	0.	
DUNL				56	373	1	0.1	0.1	3	57	8	3
GRYE			0.8	11	3		1	2	3	2		
HUGO										0.2	0.	
KILL			7	10	10	15	32	36	37	22	1	
LBDO					0.7		13	2	3	5		
LESA				0.7	7	0.1	18	11	4	0.6	0.	
LEYE			1	16	8	0.2	26	38	47	16	0.	
LGPL					0.1			0.5	3	2		0.5
MAGO							0.1	0.2	0.1			
PEEP					0.7	3	13	8	2	0.8		
PESA			1	106	0.6		18	18	45	36	0.	
REKN								0.1	0.5			
RNPH					0.1			0.4	0.3			
RUTU					0.5	0.1	0.1	0.9	0.4			
SAND					0.4		0.6	1	5	1		
SBDO				0.1	1	0.1	88	30	5	4		
SEPL					12	0.6	15	19	10	2		
SESA					5	10	186	102	17	0.6		
SOSA				0.1	3	0.1	0.9	0.5	0.2			
SPSA				0.6	4	2	3	2	0.5	0.1		0.5
STSA					0.1		6	9	6	0.6		
WESA							0.2	0.3		0.1	0.	3
WHIM					2		0.1		0.1			
WILL					0.1		0.2	0.1	0.2			
WIPH							0.1	0.4	0.3			
WRSA					0.3	0.4	0.1	0.3	0.5	0.2	0.	
YESP							0.3					

Table A1.6. Mean birds/survey in stratum 6 (survey period was JUL 16-SEP 15).

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BBPL					0.1	0.1		0.5	0.1	0.6	0.2	
BBSA									0.2	0.1		
COSN				0.5				0.1	0.1	1	0.1	
DUNL					0.6					12	13	
GRYE			0.2	1	0.1		0.5	0.7	0.6	1	0.5	
KILL		1	3	3	1	12	29	36	27	19	10	11
LESA				0.2	0.5	0.3	8	5	6	1	2	
LEYE			1	9	0.2	0.1	6	5	3	0.7	0.1	
LGPL				0.2	0.1			0.2	0.4	0.1		
MAGO				0.2								
PEEP				0.4			3	16	13	0.6	0.2	
PESA			13	1	0.2		3	17	10	10	0.8	
SAND								0.1	0.6	0.2		
SBDO					1		0.9	0.7	0.2		1	
SEPL				0.1	3	0.6	0.7	2	2	0.3		
SESA					6	2	0.7	4	5	0.3		
SOSA				0.8	0.2		1	2	0.5	0.1		
SPSA				0.7	3	1	3	3	2	0.8		
STSA							0.9	0.3	2	0.2		
UPSA								0.7				
WESA							0.1	0.2	1	0.2		
WILL				0.7	0.1							
WRSA					0.1	0.4			0.1	0.2	0.1	
YESP							0.3	0.1				

Table A1.7. Mean birds/survey in stratum 7 (survey period was SEP 1-OCT 31).

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
AMAV	91	82	81	52	12							
AMOY	0.4	0.3	0.9	2		12	5	3	3	2	2	
BBPL	10	15	26	47	41	23	5	14	35	51	28	
BNST			0.6	6	6							
COSN	0.1	4	2	0.4						2		
DOSP	146	78	249	739	432							
DUNL	87	159	247	361	206						67	
GRYE	4	2	6	4	0.4		0.1					
KILL	0.7	5	3	2	4		5	3	2	4	6	15
LBCU											0.2	
LBDO					0.3		20	26	15	20		
LESA	0.5	0.6	10	20	8	3	0.1				0.2	
LEYE	2	2	28	30	2		0.1	0.5	0.4	0.3	0.8	
MAGO	5	5	5	2	0.2	3	5	11	17	4		
PEEP	101	85	63	215	1444							
PIPL			0.1	0.1			2	7	5	3	5	
REKN	0.7	0.5	1	2	4	783	205	179	150	120	92	
RUTU	9	5	5	7	7	16	6	7	13	16	28	
SAND	10	6	7	19	6	15	21	33	56	55	55	
SBDO	0.1		0.5	8	3	360	29	20	27	35	19	
SEPL	0.2		0.4	135	467	217	60	25	57	92	92	
SESA				61	545		2	4	4	0.6	8	
SNPL						5	6	2	4	2	3	
SOSA			0.2	0.3	0.8		0.1					
SPSA				0.6	2		0.1	0.1	0.2			
STSA				1								
WESA	17	15	57	24	11	0.7			0.4	1	3	
WHIM				0.1	0.6	2	0.8	0.3	1	1	0.5	
WILL	5	7	14	25	3	31	19	14	18	12	21	
WIPL	0.1		0.3	0.4		10	3	2	2	1	2	
YESP	25	10	43	75	10							

Table A1.8. Mean birds/survey in stratum 8 (survey period was OCT 16-DEC15).

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	No	Dec
AMAV							3	15	10	26	1	7
BBPL	2	4	6	6	5	0.3	0.6	5	11	17	2	10
BNST						32	43	21	0.3			0.5
COSN												
DUNL								0.1		6	2	51
GRYE							0.8	2	2	2		2
KILL						1	2	1	1	1		0.8
LBDO							4	7	13	11	3	2
LESA							15	3	3	2		21
LEYE							9	43	32	36	8	83
PEEP							119	180	310	18	5	25
PESA							0.7	1	0.3	1		
PIPL								0.5	0.6	0.1		1
REKN	2				0.1		4	25	26	8		6
RUTU	9	10	7	13	12	1	0.2	3	5	5		8
SAND	40	53	61	26	7		7	12	24	43	6	46
SBDO					0.4		6	7	13	32	4	25
SEPL						3	1	5	7	6		1
SESA				0.1	0.3		0.6	2	0.8	5		
SOSA								0.2	0.1			
SPSA							0.2	0.4	0.9	0.6	0.	0.5
STSA							5	42	32	5	2	13
WESA							7	6	68	32	5	170
WILL	9	20	4	39	5	1	6	8	14	21	2	11
WIPH							0.1	1	2			
WIPL						1		0.4	0.1			

Table A1.9. Mean birds/survey in stratum 9 (survey period was JUL 16-SEP 15).

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
AMAV								0.3				
BASA							1	3	2	0.4	0.3	
BBPL					0.3	0.1		0.3	5	6		
BBSA								0.2	0.2			
COSN			1	2		0.1	0.1	0.4	1	2	2	
DOSP										3		
DUNL					4	0.6			0.4	19	8	
GRYE				0.4			0.1	2	2	5	0.1	
KILL			2			7	16	8	7	4	2	
LBDO							0.1	12	5	6	0.7	
LESA					3	0.3	19	12	5	0.5		
LEYE				0.4	0.5	0.7	24	17	21	5	0.3	
LGPL									2	1		
PEEP						0.7			0.3			
PESA					0.4	0.1	20	24	19	18	4	
RNPH								0.4	0.6			
RUTU					0.1	0.1		0.2	0.3	0.2		
SAND							0.2	0.4	1	0.7		
SBDO					0.4	0.1	2	0.6	0.4			
SEPL					2	0.9	0.7	1	0.9	0.2		
SESA					6	15	3	10	3	0.2		
SOSA					0.5	0.3	8	7	2	0.2		
SPSA				0.4	0.6	3	9	5	1	0.1		
STSA							0.6	2	1	0.5		
WESA								0.2	0.1			
WIPH					0.1	0.5	0.4	0.2	0.1	0.1		
WRSA					0.5	3	0.1					

Table A1.10. Mean birds/survey in stratum 10 (survey period was JUL 16-SEP 15).

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
AMAV								0.3	0.1	0.3	1	
BASA					0.1		0.1	0.2	0.6	0.1	0.1	
BBPL				0.8	1			0.6	0.2	0.2	0.3	
BBSA								0.1	0.3			
BNST				0.1	0.4	1	2	0.7	0.1			
COSN	2	1	3	1	0.3	0.1	0.1	0.1	1	4	6	4
DOSP							0.6	0.9	0.6	0.3	1	
DUNL	4	0.5	0.2	0.4	2			0.1	1	4	2	1
GRYE	4	16	53	48	2		5	4	8	6	7	5
KILL	6	5	7	5	8	15	48	41	42	29	26	10
LBDO	0.1			1	2		0.6	0.5	0.6	0.3	0.2	
LESA	0.1	0.3	2	4	40	0.6	20	43	67	102	60	33
LEYE	3	7	56	74	17	0.8	45	17	22	14	8	5
LGPL			0.5	0.1				0.1	0.4	0.2	0.1	
PEEP		1	5	11	35	0.2	5	21	10	5	2	0.1
PESA	0.2	0.7	27	17	33	0.8	25	101	53	16	2	0.3
PIPL								0.3	0.1			
REKN				0.6				0.1				
RUTU				0.1	0.3			0.1	0.2	0.1		
SAND					0.1		0.1	0.4	1	0.1		
SBDO				0.4	2		0.1	0.4	0.7	0.6		0.1
SEPL				2	21	0.1	1	5	5	0.6		
SESA	0.6		0.8	7	45	2	13	33	16	3	0.4	
SOSA			0.1	7	3	0.1	4	3	0.8	0.2		
SPSA			0.1	1	3	0.4	3	3	2	0.3	0.1	
STSA				0.6	1		0.4	2	3	1		
UPSA				0.3	0.2		0.1	0.1	0.1			
WESA					0.5		1	1	0.8	0.5	0.1	0.3
WILL			0.1	1	0.3		0.1	0.3	0.2			
WIPH				0.2	0.3			0.1	0.1			
WRSA			0.4	0.6	5	3	0.4	0.8	1	0.1		
YESP			0.4	0.1								

Table A1.11. Mean birds/survey in stratum 11 (survey period was SEP 1-OCT 31).

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
AMAV									0.1	0.2		
BBPL								0.1	0.1	2	0.3	0.7
BBSA									0.4			
BNST					0.9	0.1	0.8	4	2	0.3		
COSN			6	2					3	42	6	2
DOSP								1	2	12		
DUNL					2					11	14	6
GRYE			4	3			2	0.6	1	4	2	0.9
KILL			7	7	5	1	9	21	46	22	10	7
LBDO				34	0.1		0.1	0.2				0.4
LESA			40	31	37	0.1	10	12	32	57	30	2
LEYE			20	8	8	1	2	4	15	12	1	0.6
LGPL			4		0.4				0.2			
PEEP					42		14	78	118	17	3	
PESA			18	13	0.9		9	40	41	7	2	
PIPL							0.3					
SAND							0.2	0.2	0.2		0.4	0.8
SBDO							0.3	0.7	0.2	0.3	0.2	0.4
SEPL				0.3	3			0.4	0.5	0.1		
SESA					6	1	2	2	3	0.1		
SOSA				5	1		0.2	0.2	0.3	0.1		
SPSA					0.1		2	1	0.5	0.3	0.1	0.2
STSA							0.4	1	1	2	0.1	
WESA							0.4	0.8	1	0.5		2
WIPH					0.1		0.1	0.1	0.1	0.2	0.3	
WRSA						0.4						

Table A1.12. Mean birds/survey in stratum 12 (survey period was JUL 16-SEP 15).

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	No	Dec
BASA				0.3	1		0.2	0.5	1	0.6		
BBPL					0.1			0.1	0.2	0.2	0.	
BBSA							0.1	0.4	0.3			
COSN			0.9	1	0.2			0.4	7	9	1	2
DOSP					0.7		0.4	0.2	0.4	2		
DUNL					3				0.1	1	0.	0.7
GRYE			0.1	0.7	0.3		6	2	3	5		
HUGO					3							
KILL	2	1	8	6	6	11	63	34	36	46	1	4
LBDO				0.1	0.1			0.2	0.4	2	0.	
LESA				0.1	5		26	8	6	0.8	0.	
LEYE			0.2	3	5	0.2	120	38	17	10	0.	
LGPL				2	6	0.2	0.3	0.3	8	3	0.	
PEEP				0.2	0.8		0.3	0.1	0.6	0.2		
PESA			0.7	3	13	0.2	74	96	18	10		0.1
PIPL				0.8	2							
RNPH								0.1	0.3			
RUTU					0.8				0.1			
SAND				0.1	0.7		0.4	0.5	1	0.4	0.	
SBDO					2		2	0.3	0.1			
SEPL					1		1	1	1	0.3		
SESA				0.1	14	4	27	17	6	0.4		
SOSA					0.2		3	0.9	0.2	0.1		
SPSA				0.2	5	0.7	1	0.9	0.3			
STSA					0.7		6	4	3	1		
WESA							0.2		0.1			
WILL				0.4	0.5		1	0.2				
WIPH				0.3	0.4		0.8	0.2	0.1			
WRSA					6	1						
YESP			0.1	0.9	0.4							

Table A1.13. Mean birds/survey in stratum 13 (survey period was AUG 1-SEP 30).

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
AMAV				2					0.2	0.4	0.1	
BASA			0.6	1	4		0.1	1	0.6	0.6	0.1	
BBPL			0.1		0.5			0.3	0.2	0.5	0.7	
BBSA							1	11	3			
COSN			3	3				0.1	0.8	7	15	14
DUNL					0.5					0.4	0.9	
GRYE			0.3	2	0.3		0.2	0.3	0.2	1	0.7	
HUGO				0.8	0.1							
KILL			10	4	5	14	47	74	81	74	82	5
LBDO				0.7	1		0.2	0.2	0.2	5	1	
LESA				2	3		4	3	3	3	3	0.9
LEYE			0.4	17	6	0.2	3	4	3	1	0.1	
LGPL			0.2	5	0.1	0.1		0.1	0.5	0.4	0.7	
PEEP			0.1	2	0.6		2	1	0.2	1		
PESA			0.7	10	6	0.2	2	25	18	3	0.6	0.1
PIPL					0.2		0.3	0.2				
RUTU								0.1	0.2			
SAND							0.2	0.5	2	0.2		
SBDO							0.1	0.1	0.2			
SEPL				1	1		0.3	0.7	0.4			
SESA				2	29	4	4	6	1	0.1		
SOSA			0.2	0.6	1		1	0.7	0.4	0.2		
SPSA				2	3		2	1	0.8	0.1		
STSA					1		2	0.8	0.6	0.3	0.1	
UPSA				0.7	0.2		9	3	0.1			
WESA				0.1	0.1		1	2	0.4	0.1		
WILL				1			0.1		0.1			
WIPH				1	2			0.2	0.1			
WRSA				0.6	15	13	0.1	0.1		0.1		

Table A1.14. Mean birds/survey in stratum 14 (survey period was JUL 1-AUG 31).

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	No	Dec
AMAV				5	4	0.5	6	4	3	1		
AMWO				0.4	8							
BASA				10	24	0.7	17	11	7	0.7		
BBPL				0.1	2	0.2	0.1	1	0.2	5	0.	
BBSA					0.2			0.5	0.2	0.3		
BNST				2	2	0.4						
COSN					0.3			0.4	0.1	0.4	0.	
DUNL				0.1	3						0.	
GRYE			0.2	3	0.7		0.4	0.4	2	1	0.	
HUGO				6	2	0.2	0.1		0.2	0.1		
KILL			18	2			0.2	0.9	2	4		
LBCU				3	3							
LBDO				6	24	0.2	15	7	16	19	0.	
LESA				0.4	50	21	22	5	2			
LEYE				5	6	12	196	250	4	0.4		
LGPL					1	0.2			0.8	84	1	
MAGO				3	0.9	3	1	0.9	0.1			
PEEP				0.2	1	0.4						
PESA				0.1	9	1	98	8	62	3	0.	
PIPL				3	4	3		0.1				
PUSA				1	2							
REKN									0.3			
RNPH					59	12	30	39	8			
RUTU					0.1	0.8	0.1		0.1			
SAND				5	25	5	3	0.7	9	0.2		
SBDO				4	6	0.2	11	0.7	6			
SEPL					0.5		1	3				
SESA				4	43	7	114	119	1	0.4		
SOSA				0.2	0.5		0.2	0.6	0.1			
SPSA					0.9		6	3	0.4			
STSA					32	0.7	18	32	7	1		
UPSA					0.4		0.2	0.2				
WESA				0.7	3				0.1			
WILL				0.6	1	0.8	1	0.8				
WIPH				0.5	42	11	132	96	0.4			
WIPL				2	3							
WRSA				15	35	8						

Table A1.15. Mean birds/survey in stratum 15 (survey period was AUG 16-OCT 15).

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	No	Dec
AMAV			0.1	3	1	100	305	710	294	233		
BASA			10	9	8	0.3	141	1173	44	16		
BBPL					0.6	0.5	0.3	2	8	37		
BBSA					10			0.5	3	0.2		
BNST						2	3	2	2			
COSN			0.5	1		0.1	0.2	0.3	4	0.7	0.	
DOSP								2	4	4	0.	
DUNL					0.5	4	0.4	1	0.6	0.9	0.	
GRYE			1	4	0.1	0.3	11	16	11	56	0.	7
HUGO				0.9	0.3	0.5			0.2			
KILL			4	0.5	2	42	78	83	169	129		
LBCU				0.2		0.4		0.1	0.1			
LBDO			0.3	1	5	6	503	1485	1601	953		
LESA				2	5	14	551	794	747	974	1	
LEYE			4	10	5	30	1094	764	272	104		
LGPL			0.1	5	0.9				7	3	0.	
MAGO				0.2	0.1	0.3	0.4	1	3	0.2	0.	
PEEP				2	10	93	267	263	1101	277	2	15
PESA				1	6	2	169	870	285	179		
PIPL				0.2			0.1	0.3	0.2	0.1		
REKN							0.2	0.9	2			
RNPH						5			2	0.1		
RUTU					0.2			0.3	0.4	0.2		
SAND						0.9	0.5	3	15	17	0.	
SBDO			0.3			0.5	3	20	9	1		
SEPL				0.5		0.2	5	19	14	5		
SESA				0.3	1	90	1034	1202	548	77		
SNPL				0.1		23	15	79	18	1		
SOSA					0.1		1	0.9	0.2			
SPSA				0.2	4	0.8	4	8	0.8			
STSA				0.1	0.9	168	1191	1463	752	269	0.	
UPSA				0.2	0.2	0.5	0.5	0.4				
WESA				0.3		6	714	937	441	80		
WHIM					0.4	0.1						
WILL				0.5	0.2	0.1	4	2	20	0.1		
WIPH			0.1	0.7	5	47	28	33	25	0.3		
WRSA			0.2		5	440	3	3	0.3	0.9		
YESP						1	11	3	22	0.2		

Table A1.16. Mean birds/survey in stratum 16 (survey period was SEP 1-OCT 31).

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
AMAV				0.5			0.3	1	1	3	0.3	
BASA		0.1	12	23	2		0.7	0.3	1	0.2		
BBPL			0.1	0.1	0.3			0.2	0.1	0.8	0.4	0.3
BBSA					0.1			0.6	3			
COSN	5	7	9	3					0.4	5	4	2
DOSP			0.2	7	0.2		0.5	0.1	0.1	0.8		
DUNL	0.2	0.2	0.2	0.4	0.1					2	3	0.1
GRYE	2	4	7	4	0.3	0.1	0.4	0.2	0.5	3	2	2
HUGO				2	1							
KILL	7	11	27	7	4	7	18	19	12	33	22	22
LBDO		6	6	4	2		0.6	2	0.8	21	4	1
LESA	0.9	8	201	57	4	0.2	4	7	10	30	12	6
LEYE	0.7	1	14	70	7	0.5	5	7	8	5	1	0.8
LGPL			1	0.7	0.1				0.1	0.1	0.1	
PEEP				2	9		13	9	18	8	0.9	0.2
PESA			8	14	6		2	8	10	5	1	0.2
REKN									0.3			
REPH											0.2	
SAND					0.5			0.1	2	0.2		
SBDO				0.3			0.2	0.2	0.1			
SEPL				4	0.4		0.2	0.6	0.7	0.2		0.1
SESA				18	2	0.1	2	1	0.4			
SOSA	0.2		1	2	0.2		2	0.7	1	0.1		
SPSA				3	5	0.1	2	3	0.8	0.1		
STSA			0.1	1	2	0.2	3	5	10	3	0.3	
UPSA			0.2	5	0.6	0.3	0.2	5	0.3			
WESA		0.7	0.2	1	1		10	10	13	4	0.7	
WILL				2	0.7	0.1	2	0.5				
WIPH			0.8	16	38		0.1	1	0.5			
WRSA				0.5	13	1						
YESP									0.3			

Table A1.17. Mean birds/survey in stratum 17 (survey period was OCT 1-NOV 30).

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
AMAV						4	10	35	27	29	34	22
AMOY						0.3	0.1	0.3	0.7	1	0.5	0.1
BASA				0.1	5		0.3		0.2	0.1		
BBPL			8	1	2	4	3	6	8	9	10	5
BBSA							0.1	1	2			
BNST				6	2	9	23	18	23	8		
COSN			0.4	0.2				0.1	0.1	0.6	1	1
DOSP			4	109	26	6	21	25	8	14	194	43
DUNL				20	23	1	0.3	0.1	0.1	52	143	92
GRYE			1	3	0.3	0.4	3	4	3	4	2	2
HUGO				0.2	0.1							
KILL	0.2		3	3	2		2	7	2	6	5	3
LBCU				0.4		0.3	2	1	0.8	1	0.5	1
LBDO				10		0.2	0.2	2	0.1	2		
LESA			2	4	0.9	0.5	6	12	9	19	30	6
LEYE		0.1	4	16	4	0.5	21	23	4	11	7	0.4
MAGO						0.7	2	3	2	0.9	0.7	0.2
PEEP				3	6		38	80	45	57	142	27
PESA				2	1	0.1	0.1	3	1	0.4	0.1	
PIPL						0.1	3	9	18	16	18	3
REKN					0.1	4	3	12	37	48	51	8
RUTU				2	17	1	1	7	7	5	3	1
SAND						7	22	50	57	53	52	26
SBDO							0.1		0.2	2		
SEPL				2	4	0.2	0.2	0.7	0.7	0.3	0.3	
SESA				1	4	0.1	2	2	0.4	1	1	
SNPL						0.2	1	1	1	0.5	0.4	0.5
SOSA			0.2	0.2	0.1		0.5	0.3	0.3	0.1		
SPSA					0.2		0.4	0.3	0.1	0.3		
STSA				0.5	0.4		0.9	6	8	1	1	2
UPSA					0.8		0.1		0.1			
WESA				15	13	0.1	3	7	11	34	51	3
WHIM				1	0.9	0.1						
WILL			0.2	2	0.8	10	38	29	16	19	21	27
WIPH				1	0.2	0.5	1	6	1	0.2		
WIPL						0.8	5	3	0.3			
WRSA				0.4	1	1	0.1		0.3	0.1		

Table A1.18. Mean birds/survey in stratum 18 (survey period was AUG 1-SEP 30).

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	No	Dec
AMAV				70	0.3	0.5	37	60	27	1		
AMOY				1	1	1	1					
AMWO				5		2	1	2				
BASA			0.3	0.7			17	57	21	1		
BBPL					0.6		0.5	7	21	0.8		
BBSA				0.1			0.1	2	0.8			
BNST				4	3	8	3	2				
COSN				0.1			0.1	1		0.1		
DOSP							218	307				
DUNL					2		0.4		0.2			
GRYE				0.4		0.2	4	5	11	2		
HUGO				13	1	0.1	63	263				
KILL			2			0.2	6	6	4			
LBCU				0.2		0.6	0.3	0.8	0.2			
LBDO					79		18	63	136	83		
LESA					2		9	83	0.8			
LEYE				2		0.3	116	90	12	6		
MAGO				10		4	37	14	3			
PESA							2	15	3	0.6		
PIPL							2	2				
REKN					0.6		0.2	0.1	0.3		0.	
RNPH					39		344	304	46	0.1		
RUTU							0.2	0.2	6	0.7		
SAND							5	4	16			
SBDO					0.6	0.1	0.7	0.7		6	0.	
SEPL					1		14	25	2			
SESA					0.1		106	149	33			
SOSA				2		0.3	0.3	0.4				
SPSA					0.1		0.5	0.4				
STSA							240	176	30	2		
UPSA				0.2	0.4	0.1	0.1					
WESA					0.5		0.2	3	0.5			
WILL				0.2		0.4	11	4	3			
WIPH				0.1	238	30	12	9	3			
WIPL					0.3							
WRSA						0.2	0.2	0.4				

Table A1.19. Mean birds/survey in stratum 19 (survey period was JUL 16-SEP 15).

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
AMAV	1	3	0.1	1	1	0.9	1		2		0.4	
AMOY			0.6	0.2	0.1	0.7	1					
AMWO				22	22	6		1				
BASA				0.4			0.1					
BBPL										0.2		
BBSA							0.9	1	0.1		0.1	
BNST			0.4	9	0.6			0.7				
COSN										0.6	0.1	
DOSP				1	0.4	0.2			1	0.7		
DUNL					7		1	25	3			
GRYE				2		0.1	4	9	6	0.1		
HUGO				6	0.8	0.2	1	0.2				
KILL				1	1	2	7	0.5	3			
LBCU				0.1	0.1	0.3						
LBDO								2	12	3		
LESA				0.9	1	1				1		
LEYE				0.6	0.1		0.6	0.6	0.2			
LGPL			0.5	0.2	0.4	0.7	1	0.4	0.3			
MAGO				0.3	0.1				0.2			
PEEP				0.1	0.1			0.1	0.3	0.2	0.4	
PIPL		4						5	4			
PUSA		0.1								0.1	0.1	0.5
REKN				0.1	0.6			0.3	0.9	0.4	0.2	
SAND				0.3	0.1		0.2		0.5			
SBDO			24	3	6	0.3	0.6		0.4	4	0.8	
SEPL				0.1	0.1	0.3		0.1				
SESA					0.1		5	2	1			
SOSA			3	3	1	0.1	0.2	0.8		0.1		
SPSA							0.4	0.2				
STSA					0.1			0.5				
UPSA					0.4	0.1	0.3					
WESA				0.1	0.6		2		1			0.5
WHIM				0.2	0.1	0.7			1			
WILL				0.5	0.2	0.8	0.2	0.1				
WIPH				0.4	8	1	15	30	0.9	2		
WIPL				0.3	0.1			0.1	0.1			
WRSA				0.5		0.2	0.9	5		0.4	0.1	
YESP							0.1	0.2				

Table A1.20. Mean birds/survey in stratum 20 (survey period was JUL 16-SEP 15).

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
AMAV			73	495	297	503	1008	2088	1526	424	37	
AMWO							0.4					
BASA				0.8	0.1		4	1	1	0.6		
BBPL			0.1	18	61	0.1		0.2	1	0.5		
BBSA								0.5				
BNST				502	308	454	479	881	787	0.7		
COSN			0.1	0.1	0.1	0.1		0.2	0.7	0.6	0.3	2
DOSP							4	12	109	1822	188	
DUNL					0.1					0.2		
GRYE	2		0.1	0.6	0.2	0.6	4	11	6	6	3	6
KILL		6	3	3	2	9	10	22	30	6	2	1
LBCU			2	4	5	3	5	1				
LBDO			0.2	59	351	1	7	69	5	6	0.3	
LESA				0.6	12		5	6	3	2		
LEYE				1	2	0.1	2	3	6	0.2		0.2
LGPL					0.1				0.4	0.2		
MAGO				43	5	0.3	206	595	1061	412	23	
PEEP				1	0.2	0.6	7	3	2			
PESA									4	2	0.1	
REKN				0.1	2							
RNPH					669	4	14	47	4	0.1		
SAND				0.4	17			0.1	0.2	0.1		
SEPL				0.2	2		0.5	0.8	0.4			
SNPL			4	13	15	14	26	21	6	0.4		
SOSA						0.2	0.1	0.2	0.1			
SPSA				5	0.3	0.4	0.7	1	0.4			
UPSA							0.3					
WESA				78	2	5	115	164	74	29	0.6	
WHIM					0.8	0.1			0.1			
WILL				28	5	10	12	2	0.2	0.1		
WIPH				3	321	986	5989	2102	31	45	0.1	
YESP							2	1	1	4		

Table A1.21. Mean birds/survey in stratum 21 (survey period was AUG 16-OCT 15).

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
AMAV			0.8	13	19	12	12	22	7	3	3	2
BASA	0.3		0.4	3	1		1	2	3	1	2	0.2
BBPL			2	7	8	5	4	2	0.7	0.1	0.2	
BNST			0.1	3	5	5	10	17	3			
COSN	0.3	0.2	3	3	2		0.5	0.8	2	2	3	
DOSP					0.3							
DUNL			0.3	13	1		0.5	0.5	2	0.2	3	0.1
GRYE	6	2	3	1	0.3	0.4	3	7	9	5	29	0.8
HUGO					0.3			0.2				
KILL	0.1	3	7	24	17	9	9	13	11	11	4	2
LBCU					0.2	0.1		0.9	0.1			
LBDO	0.2		0.4	1	4	0.4	0.4	3	3	2	3	0.1
LESA	0.3	12	8	21	18	0.4	4	7	9	5	8	5
LEYE				0.7	1	0.1	3	4	5	1	0.8	
PEEP					0.1	0.1	0.4	3	3	0.5	0.7	0.1
PESA			0.1	0.1	0.2			0.1	0.2	0.2		
REKN				0.9	0.1							
RNPH			1	23	22	0.5	0.4	2	2	0.2		
SAND							0.1	0.3	0.8	0.2		
SBDO			0.1	0.6	0.7		0.5	0.3	0.4	0.1		
SEPL					0.3			0.2	0.3	0.1	0.1	
SNPL	2	0.8	8	9	12	6	5	5	2	0.8	0.6	0.1
SOSA							0.2	0.5	0.4	0.1		
SPSA				0.6	0.6	0.4	2	3	0.8	0.2		0.1
STSA	0.1				0.4		0.4	0.7	0.3		1	
UPSA					0.3		0.1	2	0.1			
WESA	2	0.3		15	8	0.1	3	8	5	2	4	0.1
WILL				0.3				0.2				
WIPH	0.1			4	6	1	13	43	7	0.5	0.2	

Table A1.22. Mean birds/survey in stratum 22 (survey period was JUL 16-SEP 15).

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	No	Dec
AMAV						8	2	0.4	0.4	0.1		
BASA							0.2	1	3	0.1		
BBPL									0.9	0.6		
BNST							0.2					
COSN								0.7	2	0.2		
DOSP							43	154	128	208	2	
DUNL							0.1			1	1	
GRYE						0.3	0.3	0.6	0.4	0.1	0.	
KILL						6	4	7	14	10	0.	
LBDO							2	7	13	32	0.	
LESA							2	3	2	0.4		
LEYE							3	0.9	2	0.1		
MAGO							0.2	0.1	0.1			
PEEP						0.6	335	303	291	171		
PESA								0.2	3	3	0.	
RNPH							0.6	1	0.4			
SAND							0.2	0.1	0.3			
SEPL							0.2	0.4	0.5	0.1		
SESA							0.2	0.2	0.1			
SPSA						1	0.4	0.4	0.1			
STSA							0.1		0.1	0.2		
WESA						20	172	130	59	3		
WIPH						83	322	105	3			
YESP							1	3	6	4	0.	

Table A1.23. Mean birds/survey in stratum 23 (survey period was JUL 16-SEP 15).

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
AMAV		0.4	0.9	11	6	4	12	17	12	2		
BASA								0.2	0.2			
BBPL				0.4								
BNST			1	5	11	18	19	25	7			
COSN	0.2			0.3	0.2			0.1		0.5		
DUNL	0.1	0.6		0.1	0.1					0.1	0.3	
GRYE	2	1	1	1	0.1		0.9	1	2	5	0.3	0.5
KILL	63	9	18	4	4	6	18	21	26	14	10	8
LBCU			0.1	0.3								
LBDO	2	1	8	19	6	0.1	3	6	4	7		5
LESA	40	46	19	24	3		4	12	5	16	59	21
LEYE				1	0.3		1	4	3	0.2		
MAGO				0.5	0.1		0.3	0.2	1			
PEEP				42	5		30	56	31	1		
PESA								0.1	0.7	1		
RNPH				0.7	1		0.3	2	8	0.1		
SEPL				0.4	0.8			1	0.1			
SESA	0.4				0.1			0.1				
SNPL				0.1	0.2			0.3				
SOSA				0.1				0.1	0.2			
SPSA			0.1	0.2	1	0.8	2	2	0.8	0.3		
WESA				7	4		1	5	7	0.3		
WHIM						0.4	0.1					
WILL				2				0.3				
WIPH			0.8	11	19	8	34	82	11			

Table A1.24. Mean birds/survey in stratum 24 (survey period was SEP16-NOV 15).

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BASA				0.5			1	2	1			
BBPL	182	150	113	70	25	65	146	296	209	295	510	383
BBSA									0.6			
COSN	0.3	1	3	3	0.2		0.3			1	2	0.5
DOSP								27	18	13		
DUNL	3801	9500	4918	2119	567	8	3	2	44	2247	10100	6350
GRYE	2	10	4	15	2	2	10	3	5	3	3	2
KILL	0.4	2	3	3	4	1	0.9	0.5	4	2	1	
LBCU				0.3	0.2	5	0.1		0.3			
LBDO	0.3		1	4	4		0.1	0.3	17	14	21	23
LESA	11		0.7	51	20		106	147	159	186	85	315
LEYE					0.2			5	6			
LGPL			0.2	0.5	1			2	8	2		
MAGO				0.2	1	3	5	1	2			
PEEP				2	2			114	164	26		
PESA								0.1	37	15		
REKN				0.1	19		0.4	4	1			
RNPH					54			7	5	0.1		
RUTU					17		4	3	7			
SAND	235	250	255	370	857	102	143	382	1634	1531	645	625
SBDO				408	218	3	656	41	19			
SEPL				65	65	24	140	89	33	16	30	26
SESA					0.1		0.6					
SNPL	0.3	0.5	3	4	4	17	7	3	4	0.7	3	9
SOSA				0.5	0.1							
SPSA					1			0.1	0.2			
STSA									0.2			
WESA	264	400	300	3507	609	457	825	655	903	247	350	525
WHIM				2	45	35	142	101	15	1		
WILL								0.3	0.7			
YESP								10	8	2		

Table A1.25. Mean birds/survey in stratum 25 (survey period was OCT 16-DEC 15).

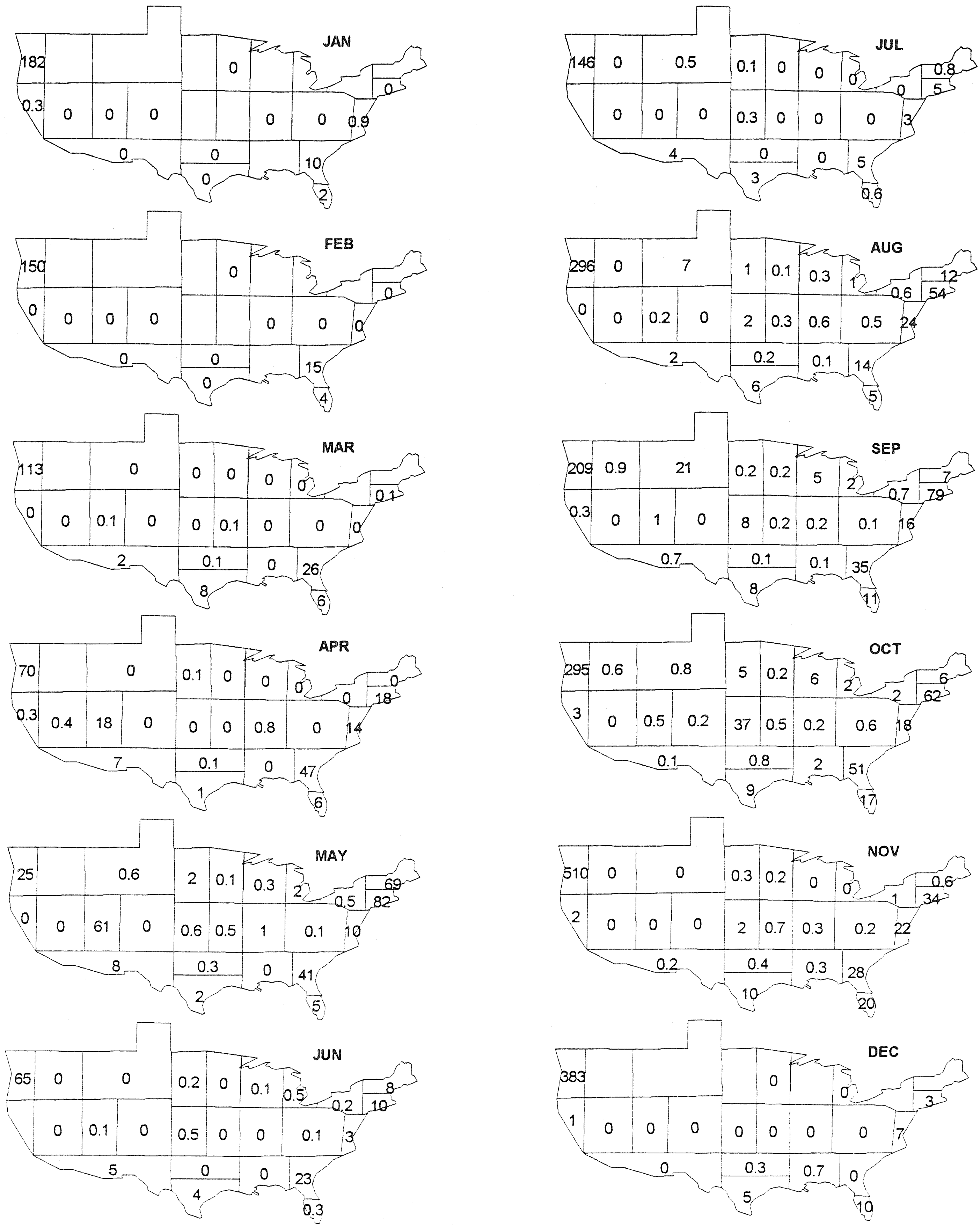
Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BBPL	0.3			0.3					0.3	3	2	1
DUNL										0.3		
KILL	14	1	0.2	1	1			0.8	2	19	20	2
MAGO	3			0.5	0.3			0.4		0.5	10	7
SAND	58	61	84	369	165			18	227	251	218	162
SNPL	5	7		0.3				0.2	1	4	4	9
SPSA			0.2						0.3			
WESA			0.4	1					0.3			
WHIM			0.2	3	4			4	0.5	0.3	0.2	0.3
WILL	19	12	5	22					0.8	2	8	22

Appendix Two

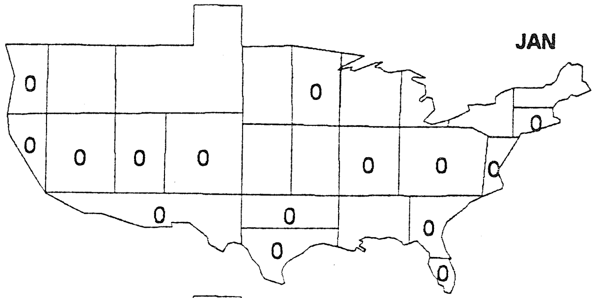
Mean numbers of individuals/survey in each month

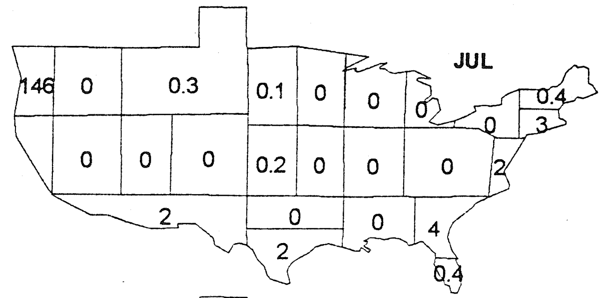
This appendix contains one page for each species in the ISS-Skagen data set, including a few general taxa (e.g., yellowlegs species). Each page contains 12 maps of the United States (and a little of Canada), one for each month, showing the mean numbers of individuals recorded per survey in each of the 25 strata that I used in the analysis. The data came from sites surveyed 20+ times during Jan-Jun and/or Jul-Dec in at least one year. Details are provided in the main report.

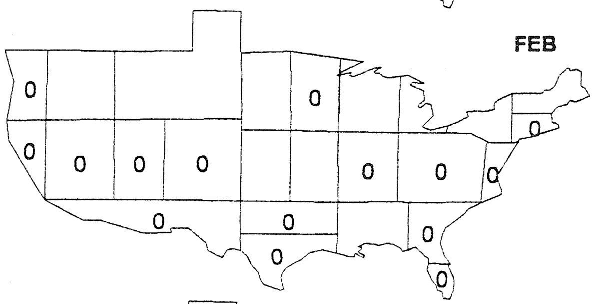
BLACK-BELLIED PLOVER

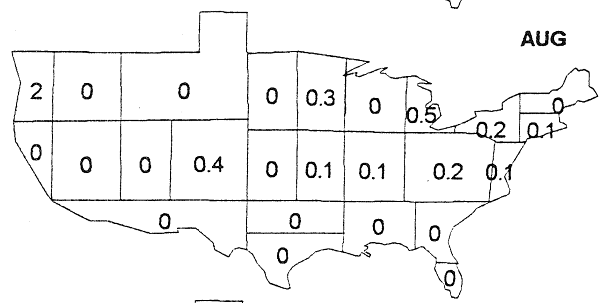


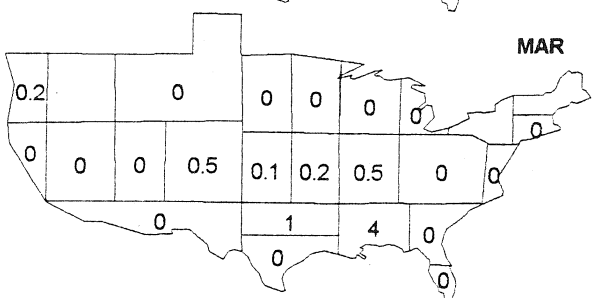
Lesser Golden-Plover

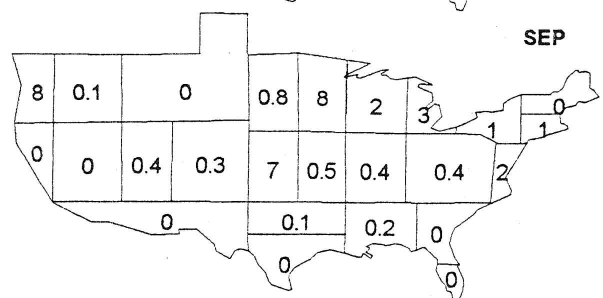


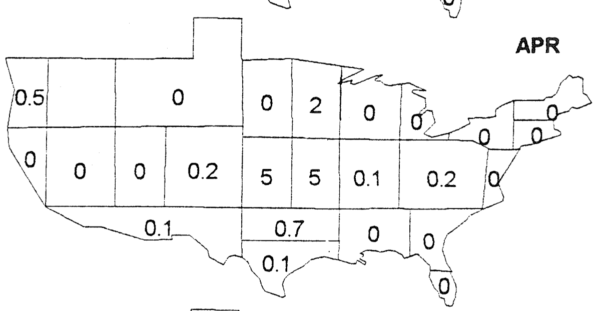


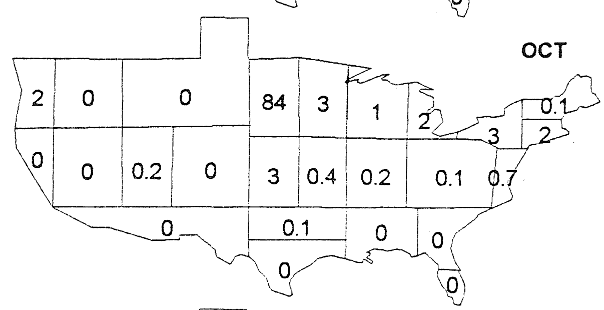


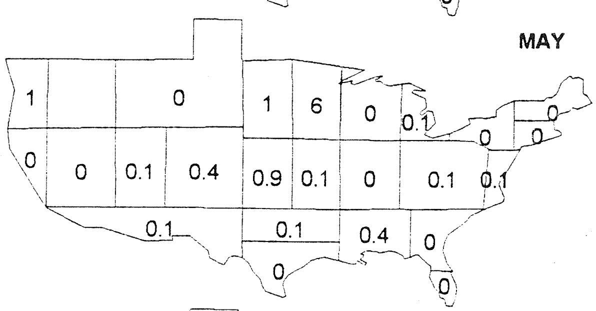


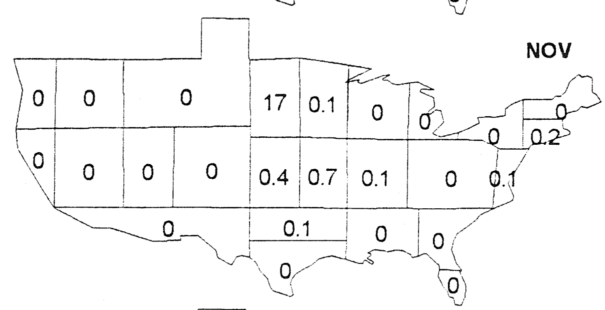


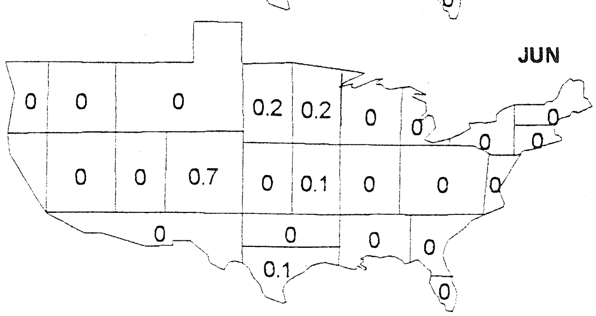


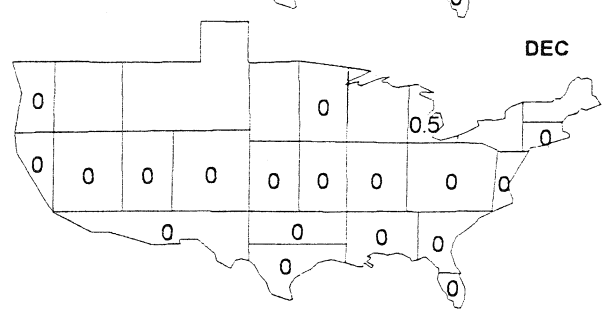




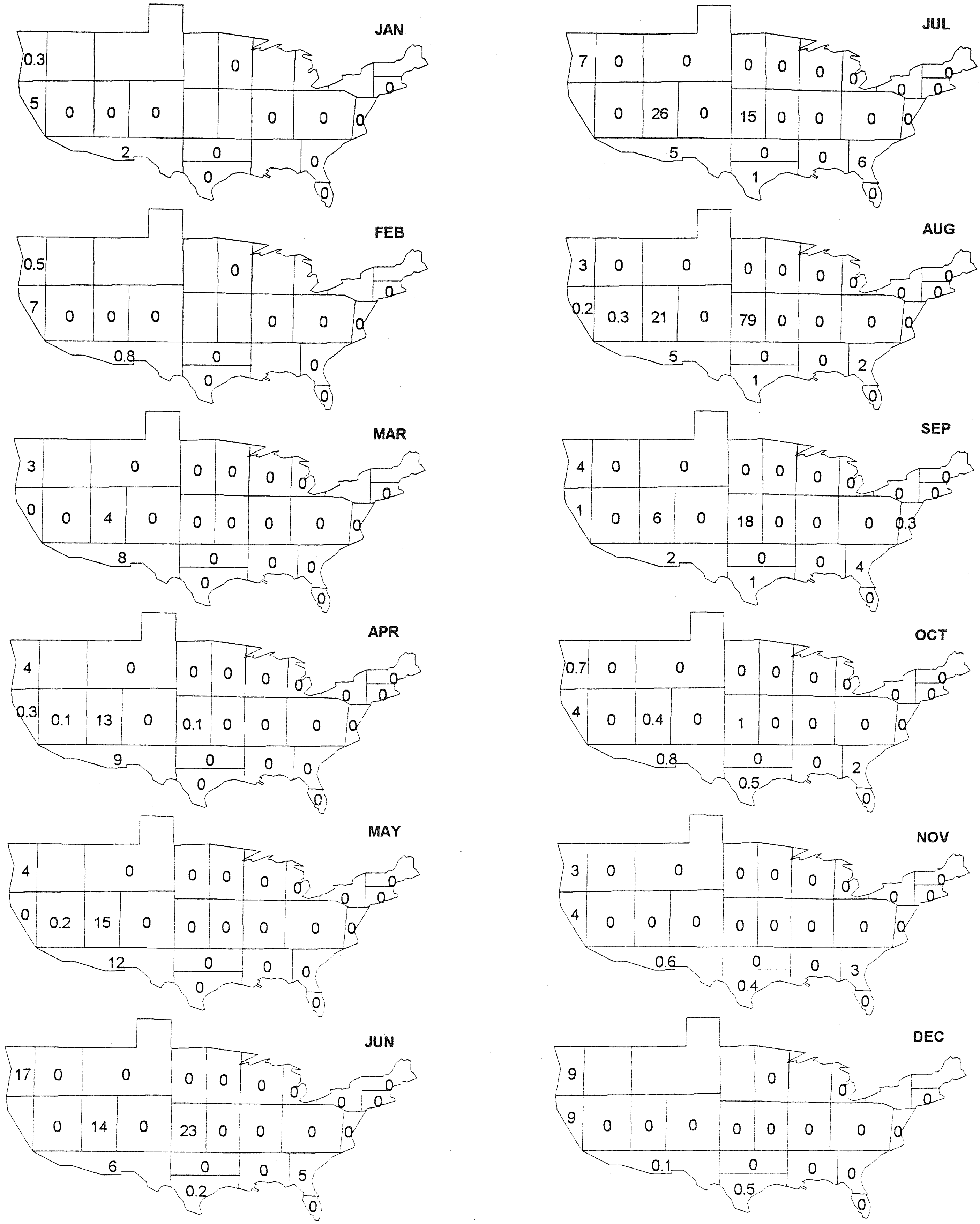




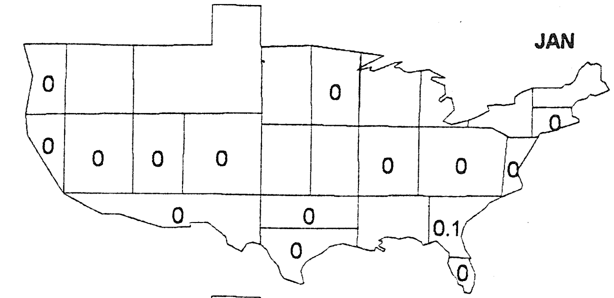


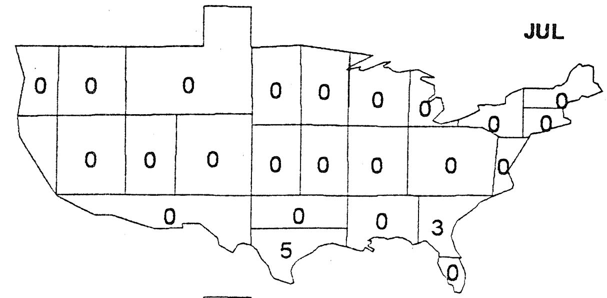


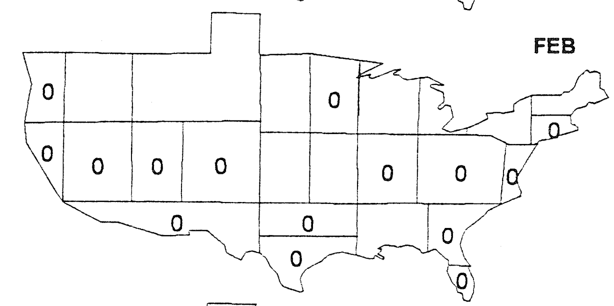
SNOWY PLOVER

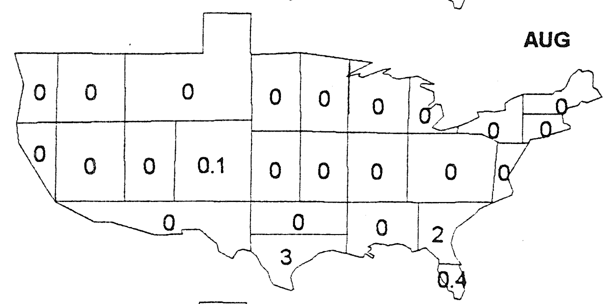


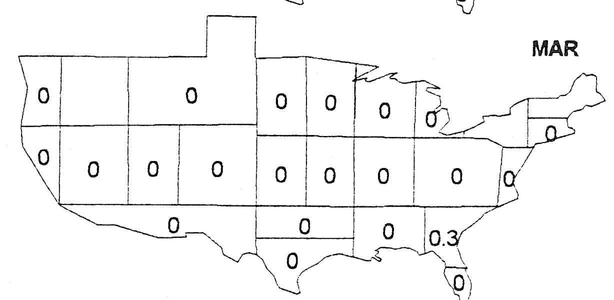
WILSON'S PLOVER

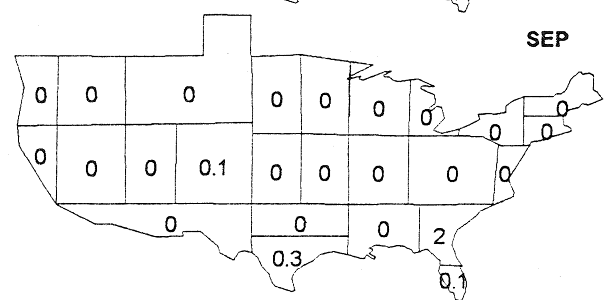


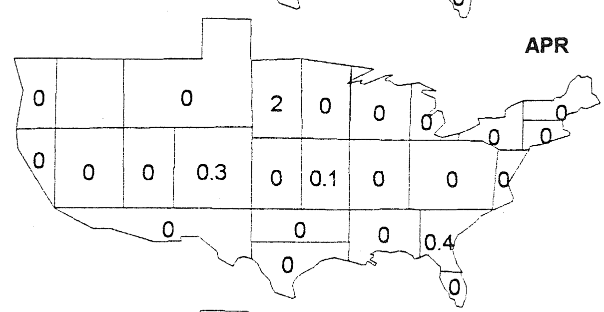


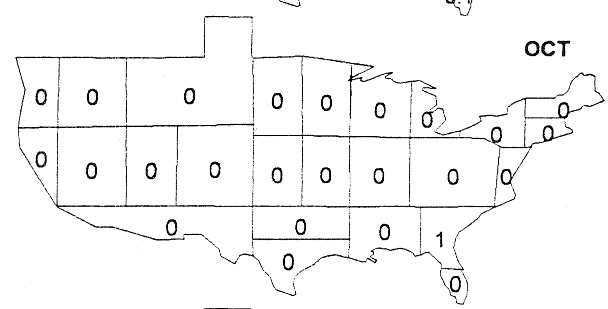


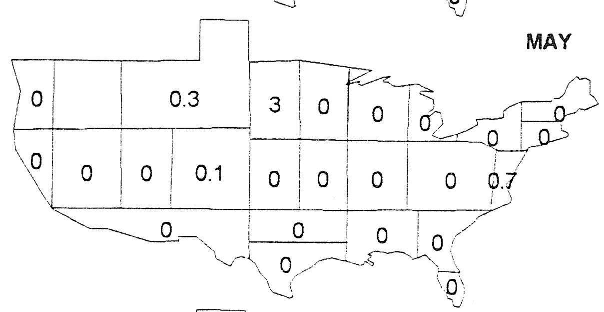


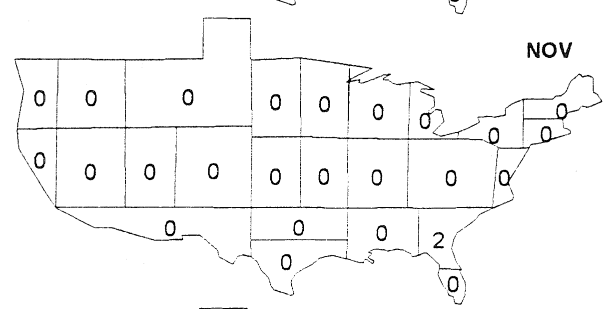


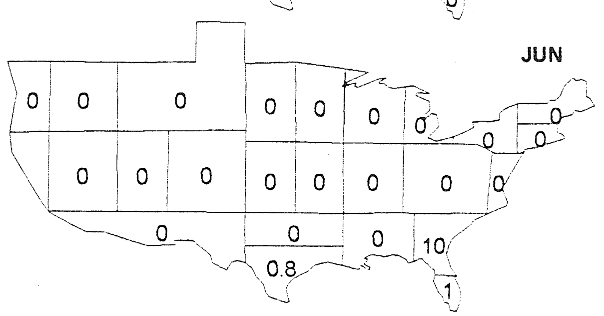


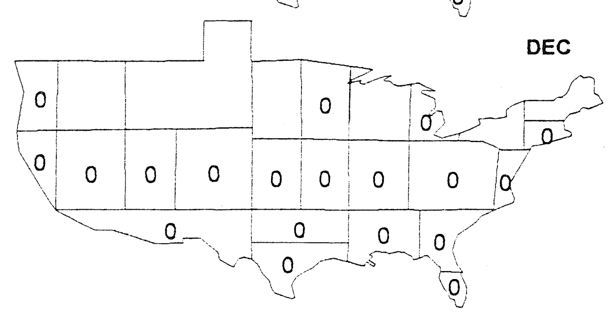




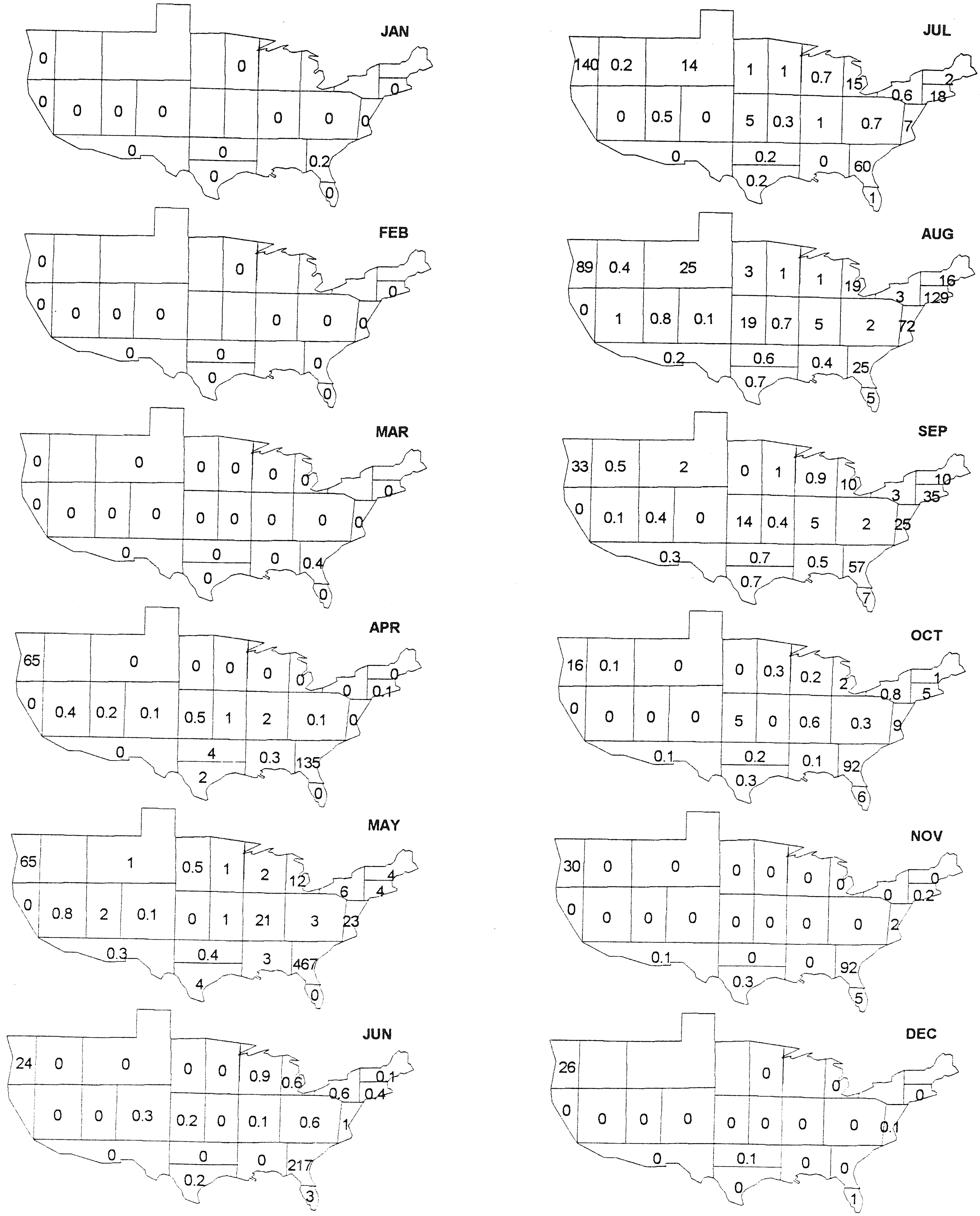




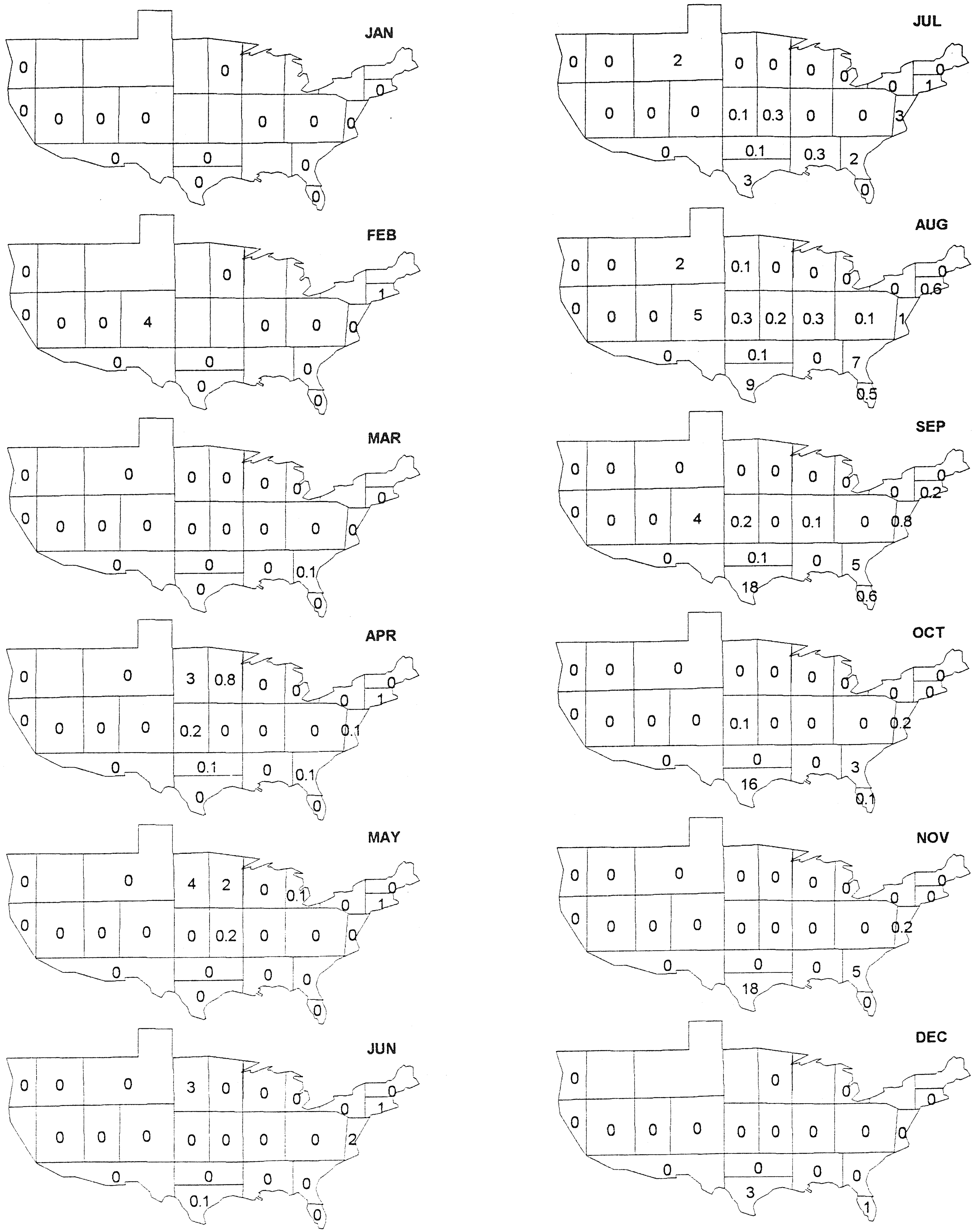




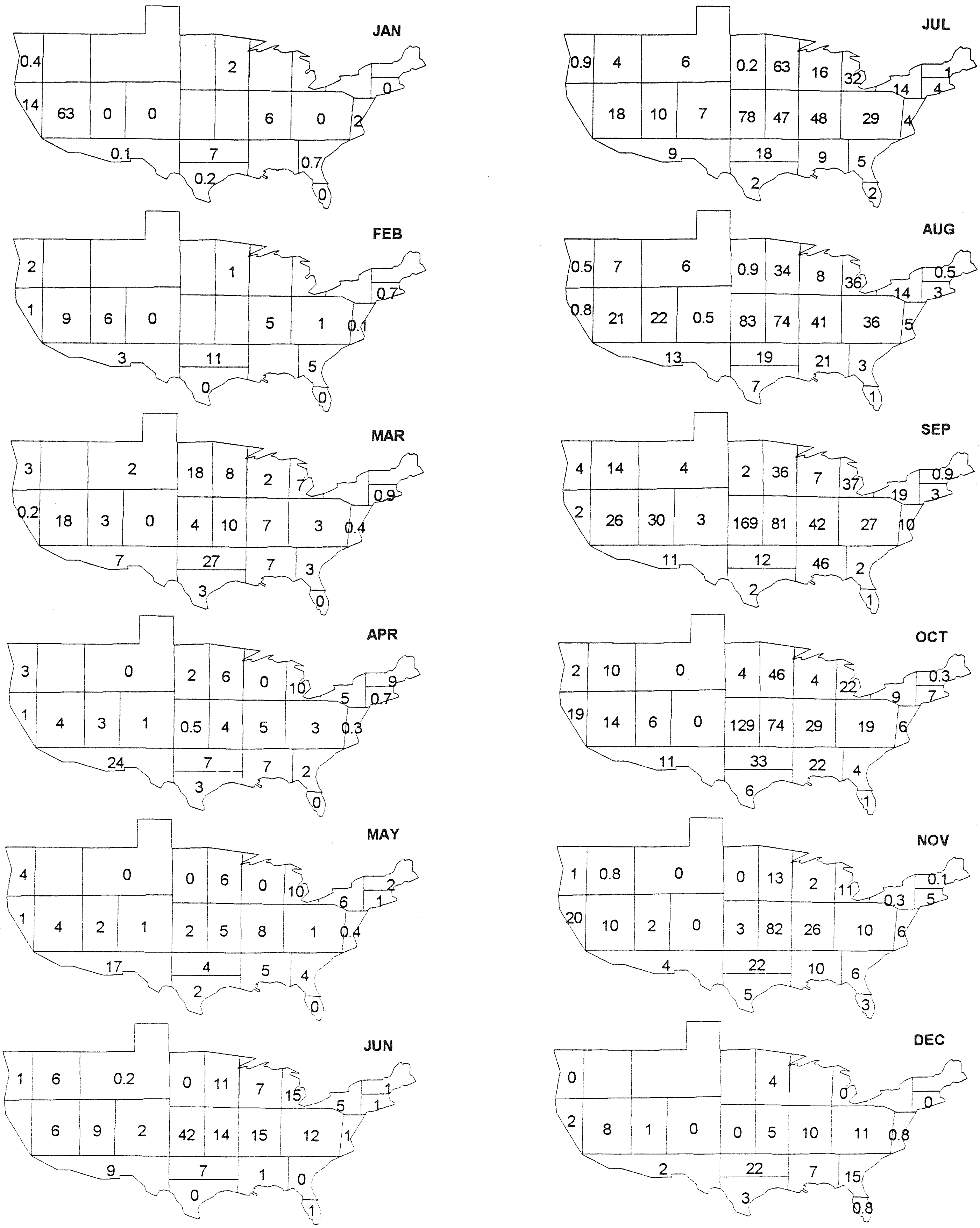
SEMIPALMATED PLOVER



PIPING PLOVER



KILLDEER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0.1 7 0.7 0.2 0
FEB
2 1
0.7
1 9 6 0 5 1 0.1
3 11 5 0 0
MAR
3 2 18 8 2 7
0.9
0.2 18 3 0 4 10 7 3 0.4
7 27 7 3 3 0
APR
3 0 2 6 0 10 9
5 0.7
1 4 3 1 0.5 4 5 3 0.3
24 7 7 2 3 0
MAY
4 0 0 6 0 10 2
6 1
1 4 2 1 2 5 8 1 0.4
17 4 5 4 2 0
JUN
1 6 0.2 0 11 7 15 1
5 1
6 9 2 42 14 15 12 1
9 7 1 0 0 1
JUL
0.9 4 6 0.2 63 16 32 1
14 4
18 10 7 78 47 48 29 4
9 18 9 5 2 2
AUG
0.5 7 6 0.9 34 8 36 0.5
14 3
0.8 21 22 0.5 83 74 41 36 5
13 19 21 3 7 1
SEP
4 14 4 2 36 7 37 0.9
19 3
2 26 30 3 169 81 42 27 10
11 12 46 2 2 1
OCT
2 10 0 4 46 4 22 0.3
9 7
19 14 6 0 129 74 29 19 6
11 33 22 4 6 1
NOV
1 0.8 0 0 13 2 11 0.1
0.3 5
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DEC
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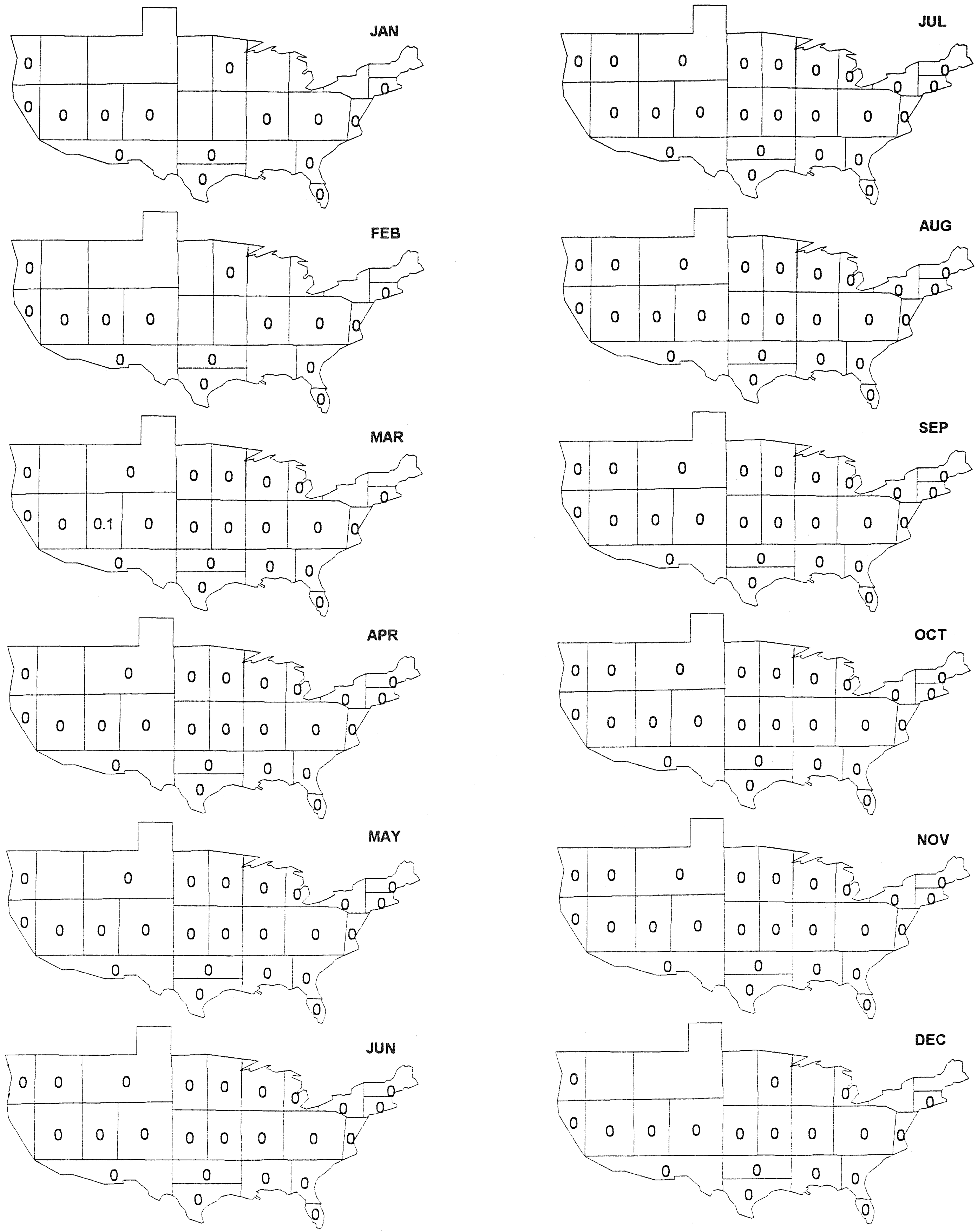
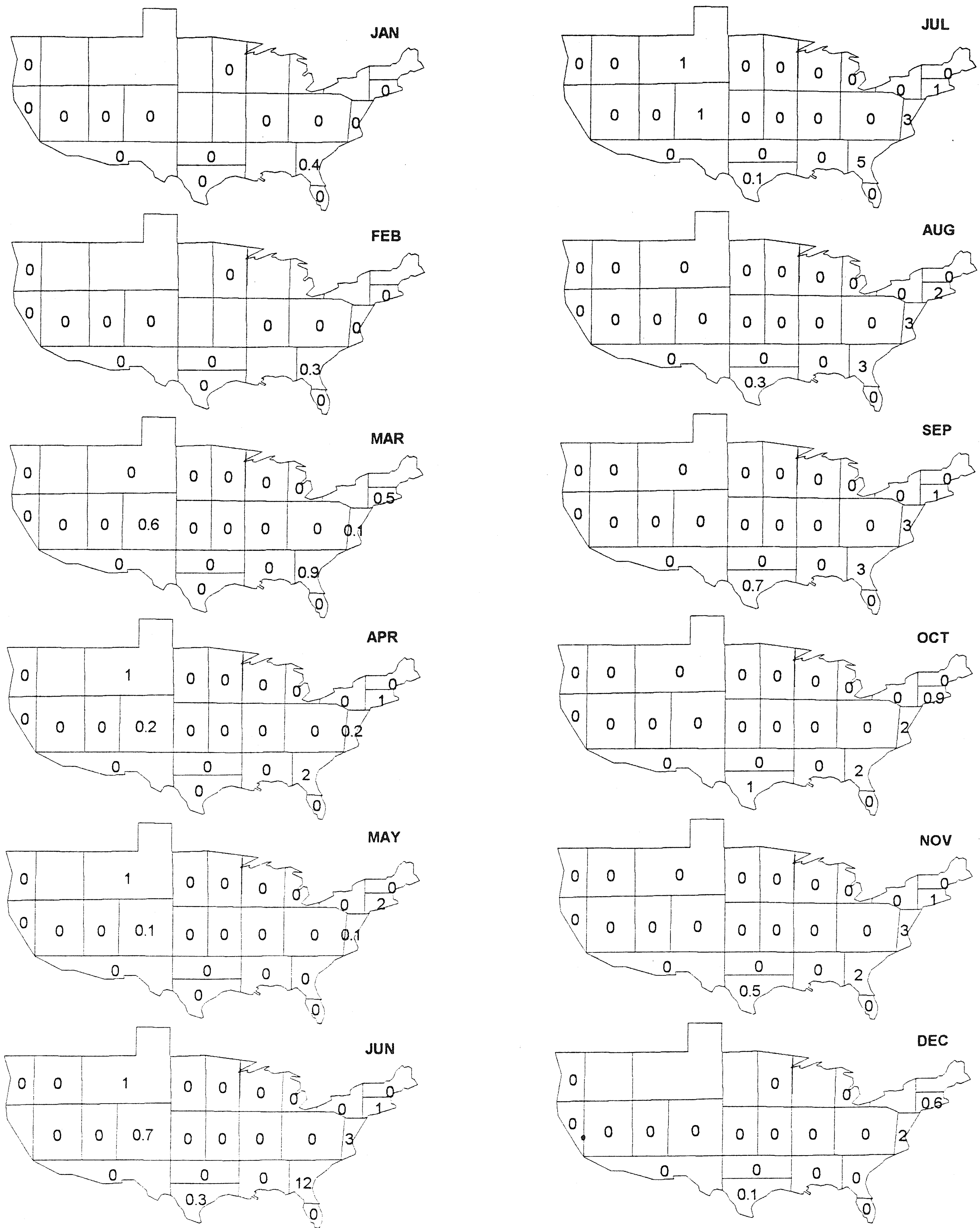
0
2 8 1 0 0 5 10 11 0.8
2 22 7 15 3 0.8

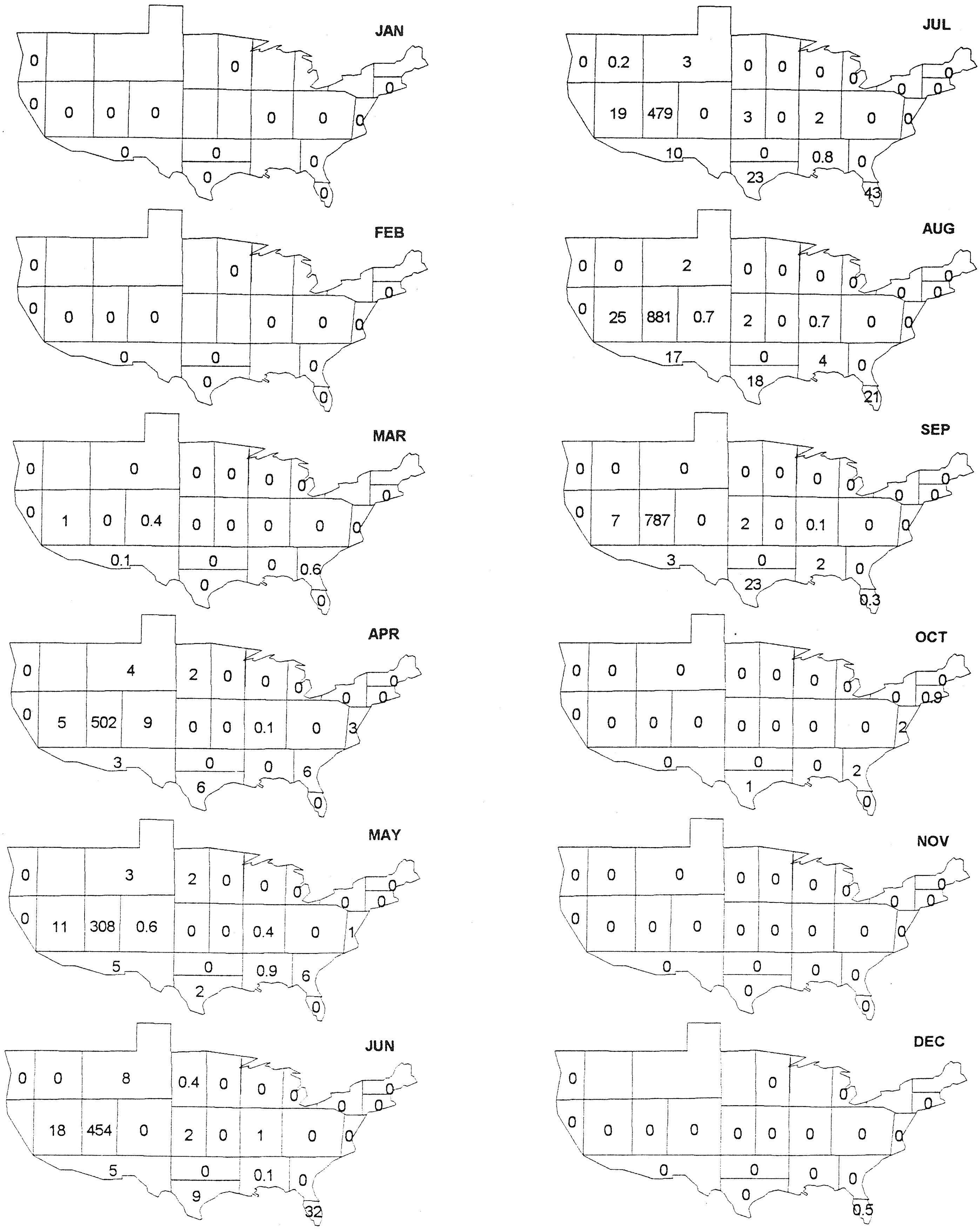
MOUNTAIN PLOVER



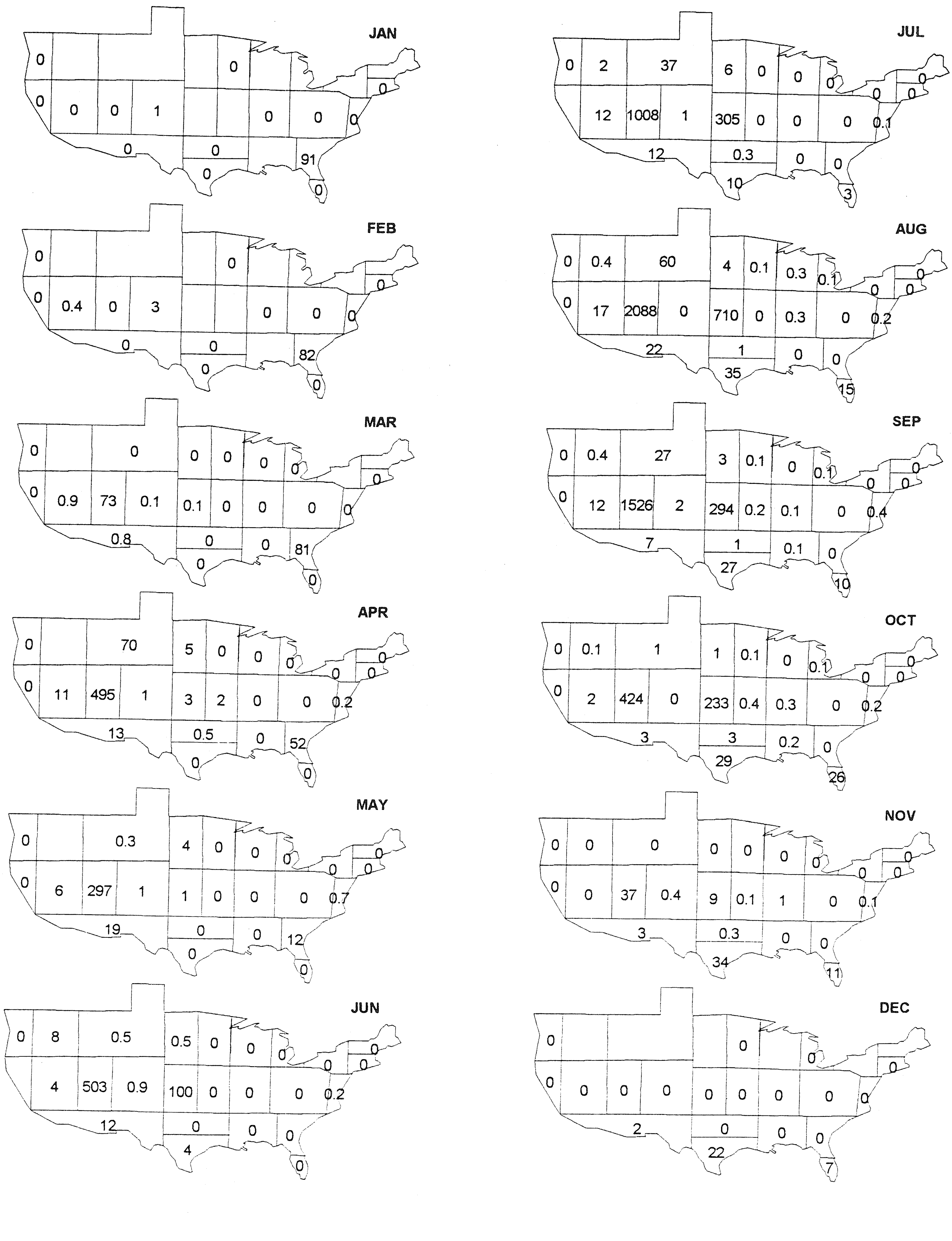
AMERICAN OYSTERCATCHER



BLACK-NECKED STILT

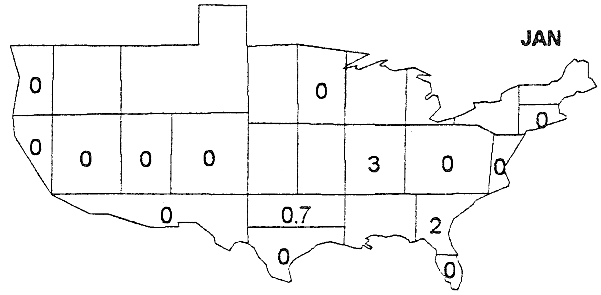


AMERICAN AVOCET

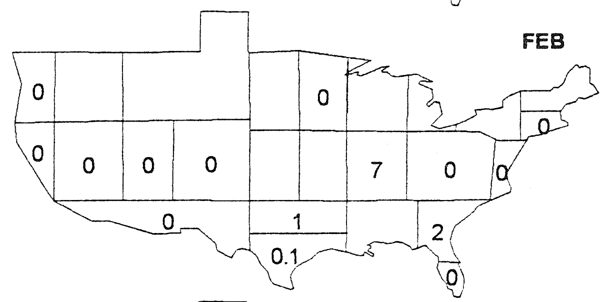


LESSER YELLOWLEGS

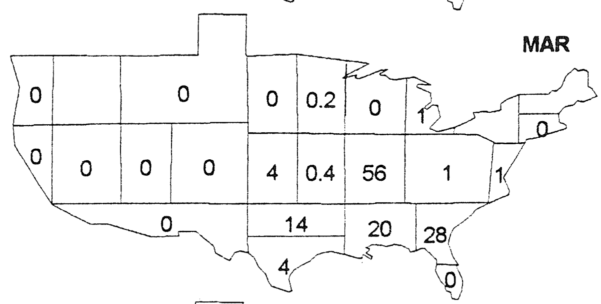
JAN



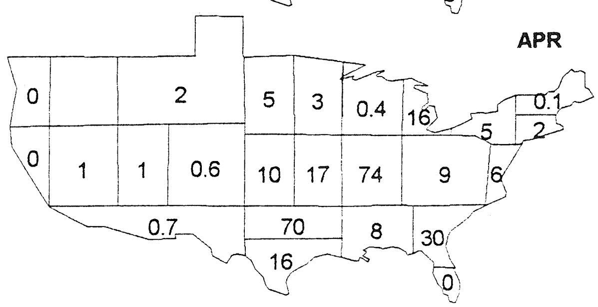
FEB



MAR



APR



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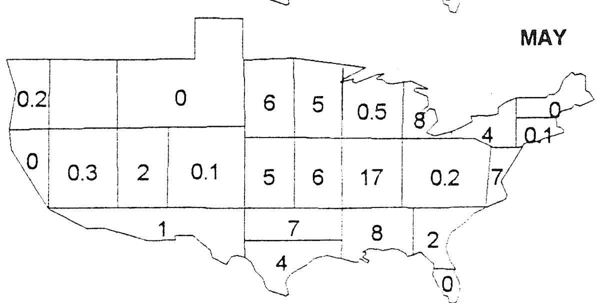
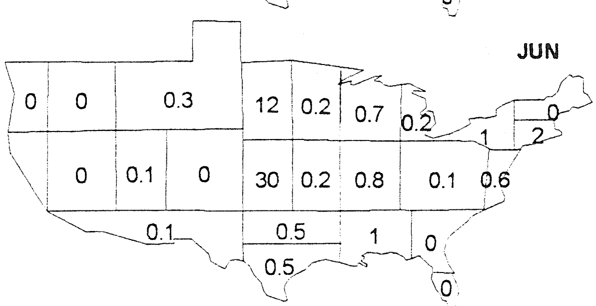


JUN



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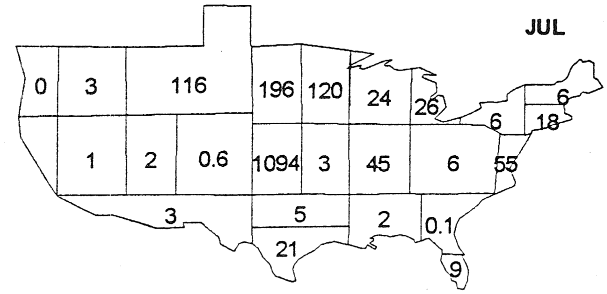
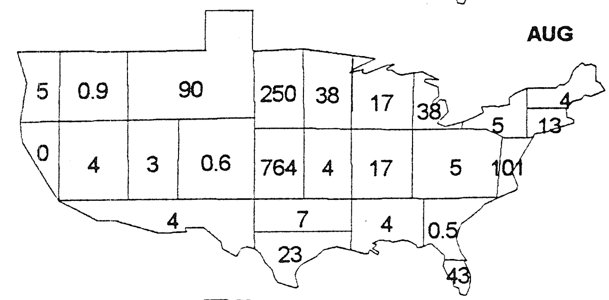


AUG



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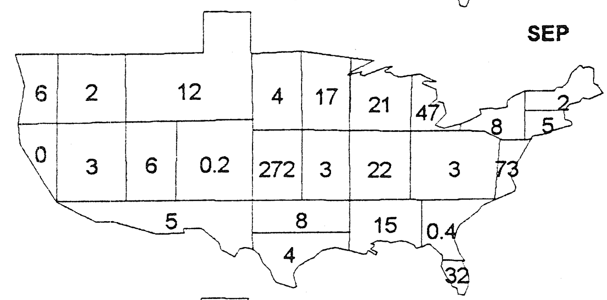
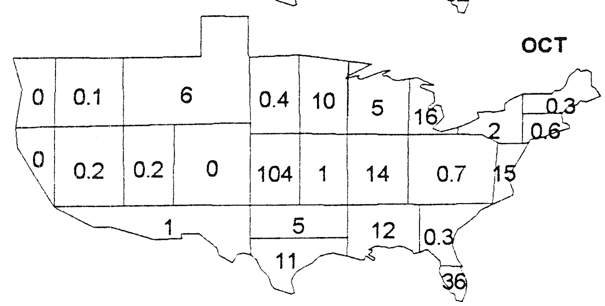
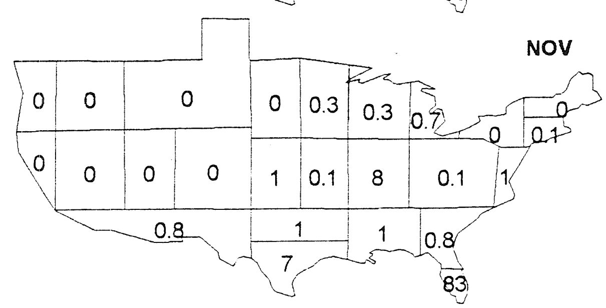


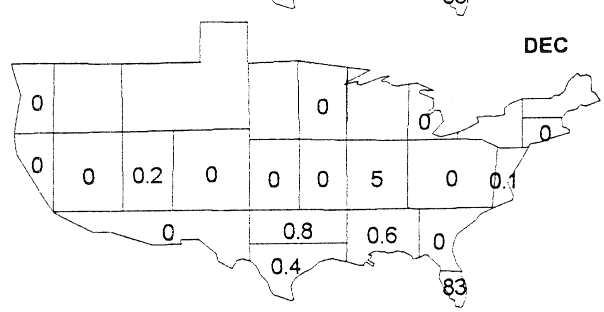
OCT



NOV

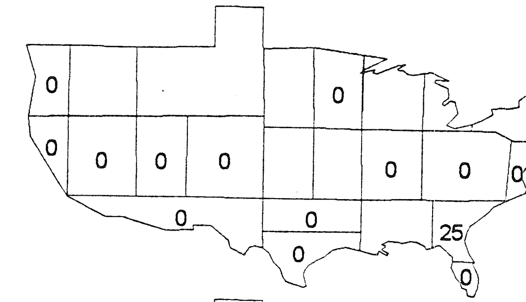


DEC



YELLOWLEGS species

JAN



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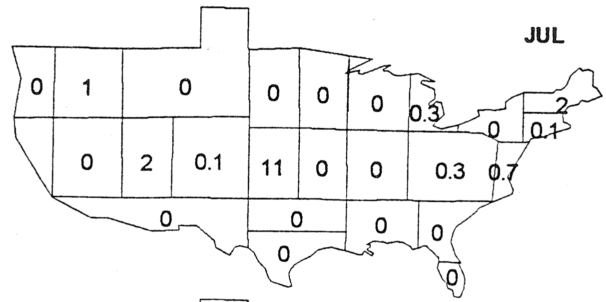

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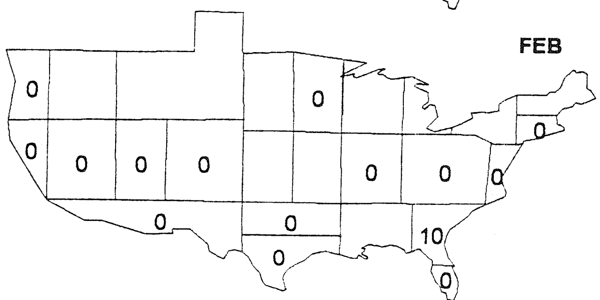

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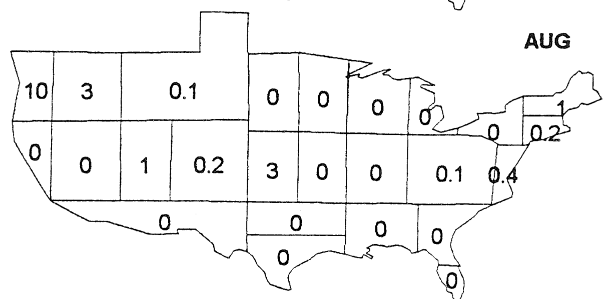
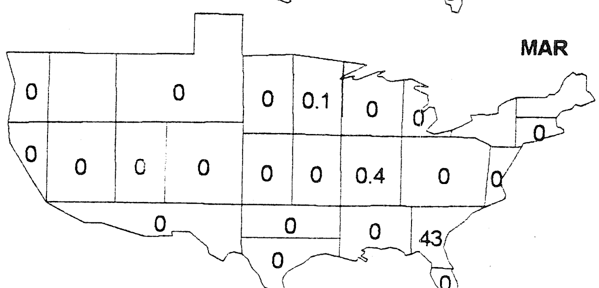


MAR



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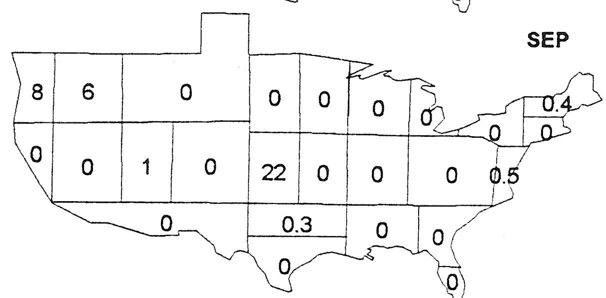
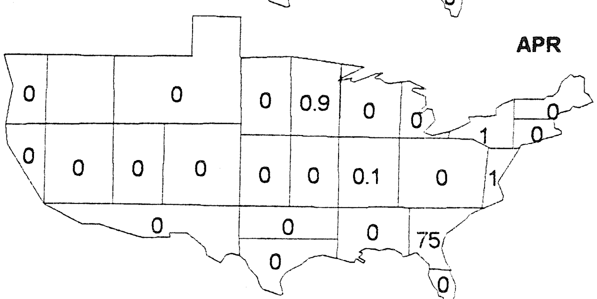
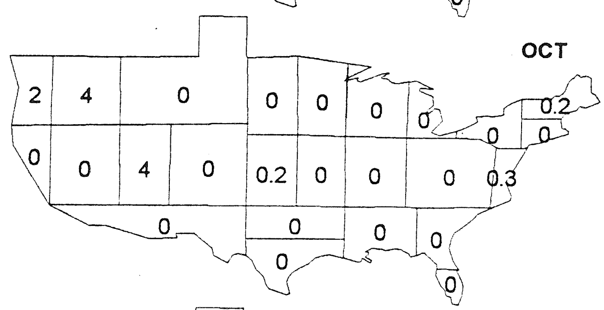


APR



OCT



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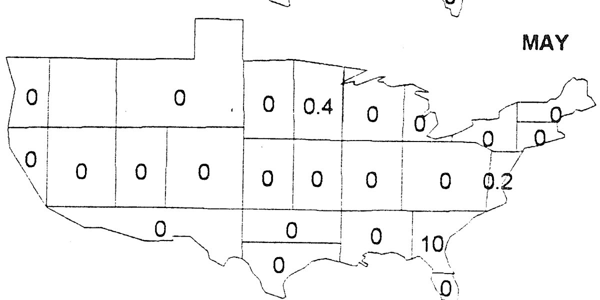
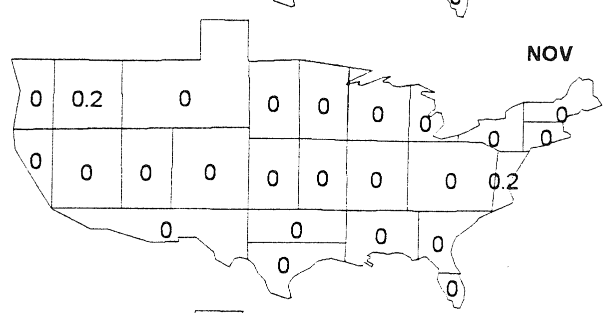
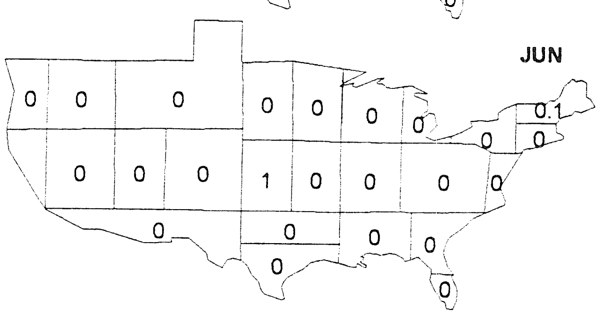


NOV



JUN



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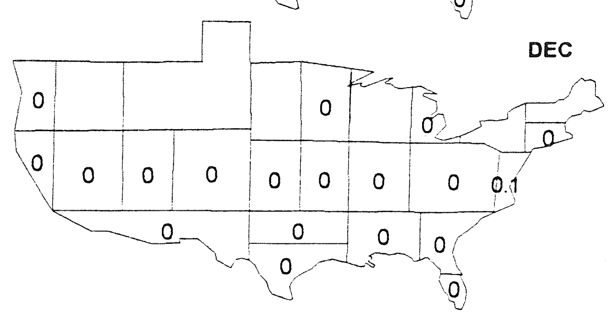
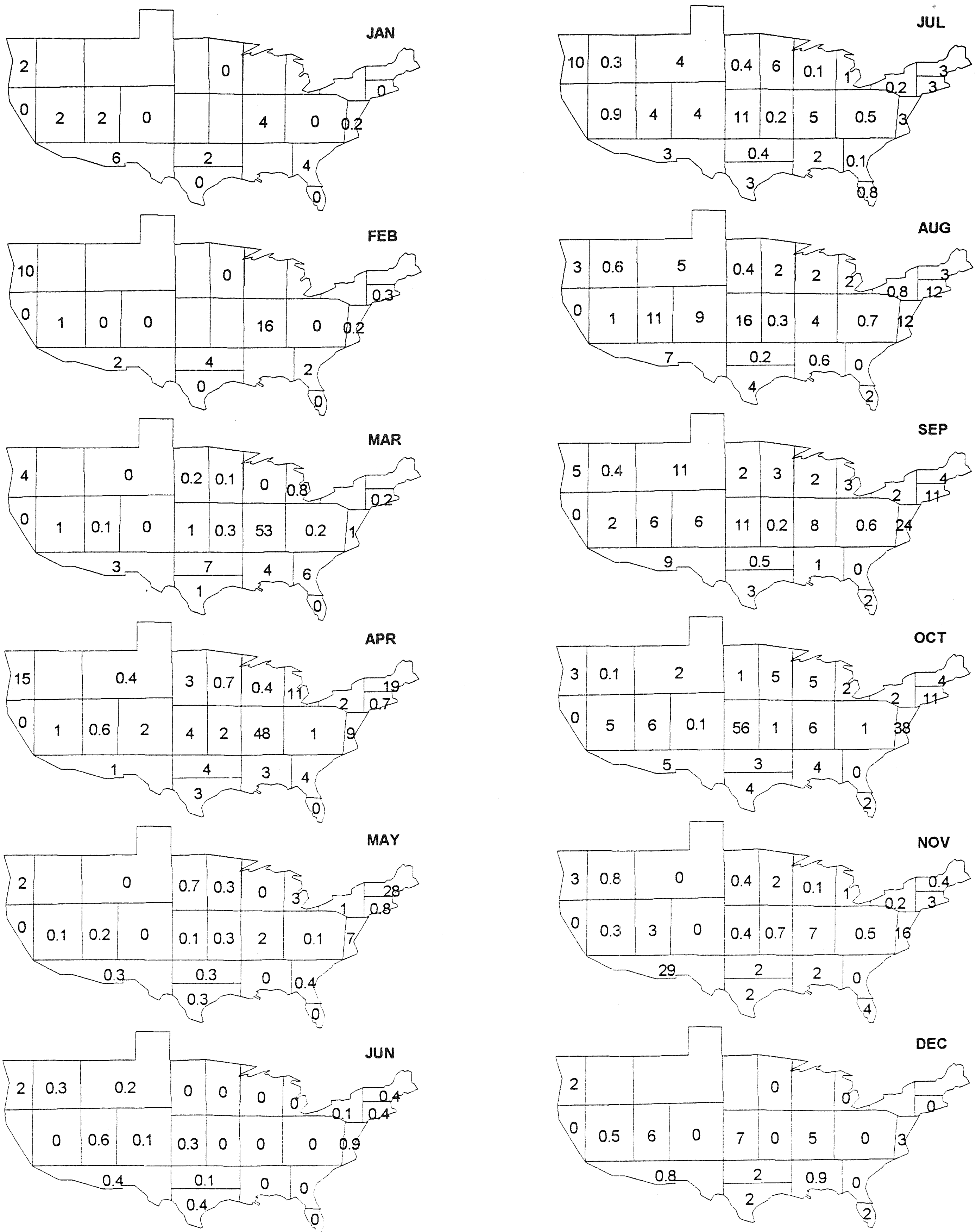
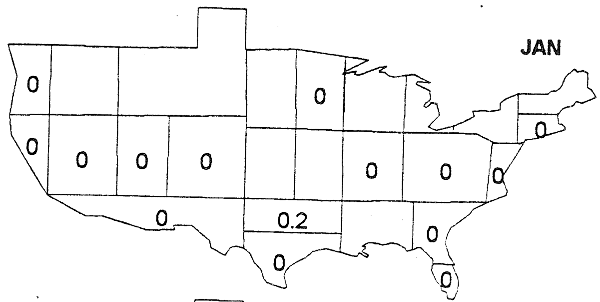
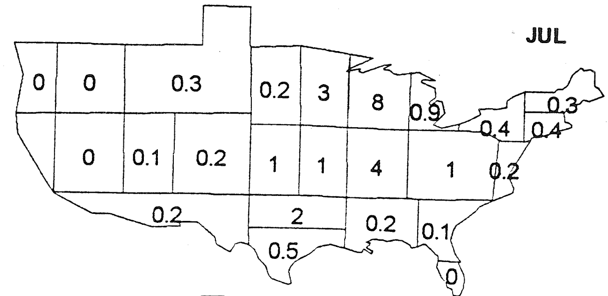


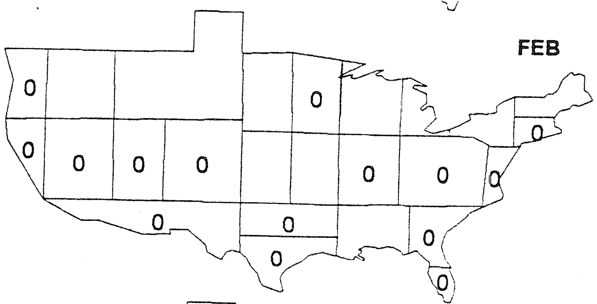
GREATER YELLOWLEGS

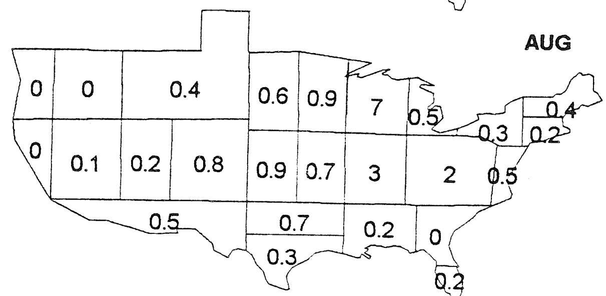


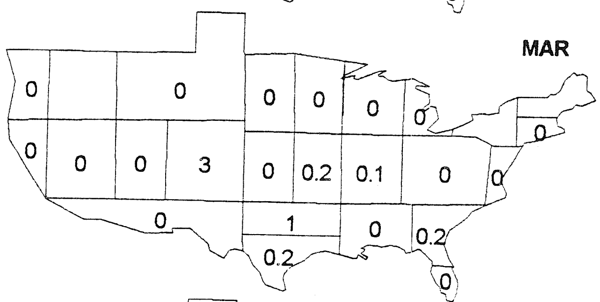
SOLITARY SANDPIPER

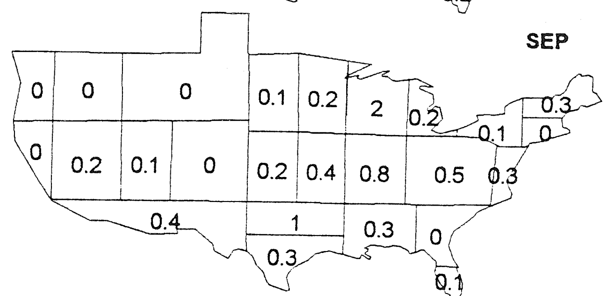


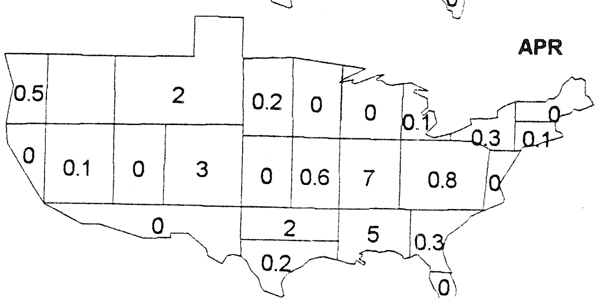


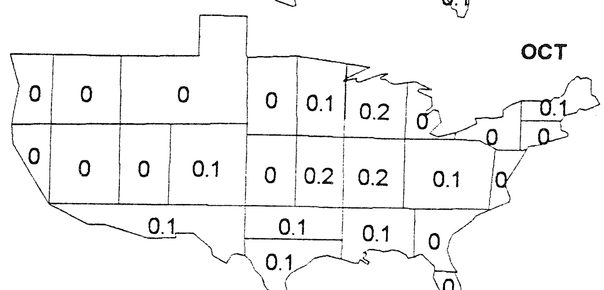


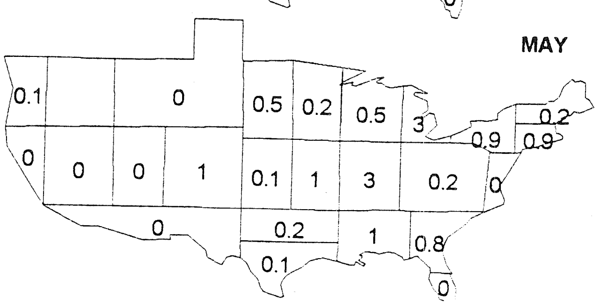


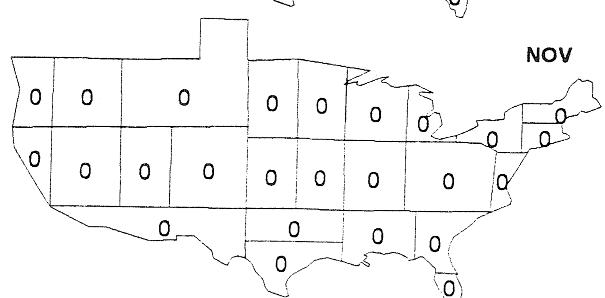


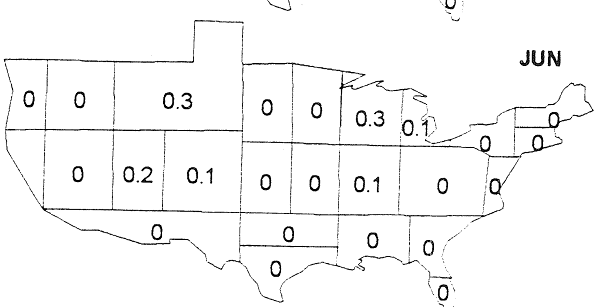


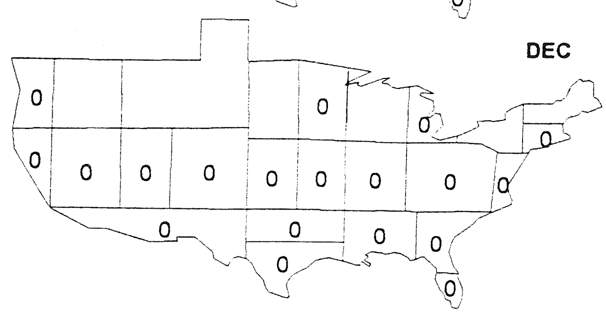




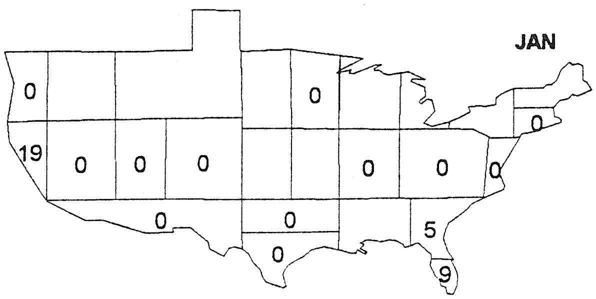








WILLET


JAN
0 0
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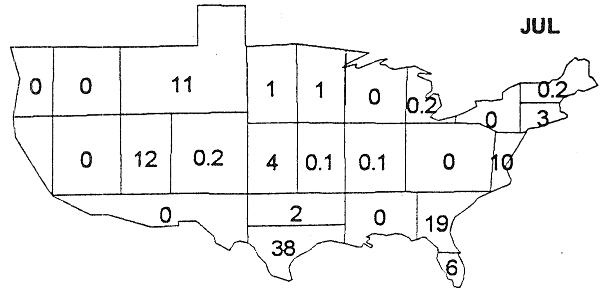
0 0 5
0 9


JUL
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0 3
0 12 0.2 4 0.1 0.1 0 10
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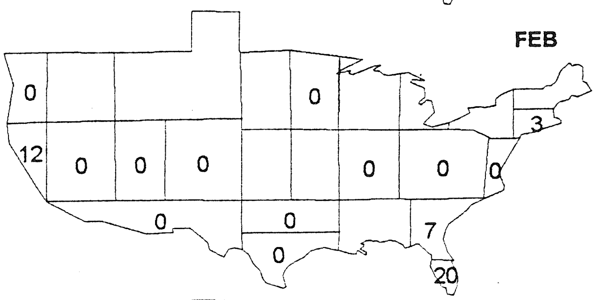
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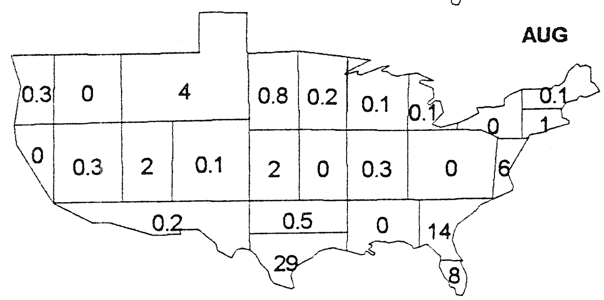
0 0
3
12 0 0 0 0 0 0
0 0 7
0 20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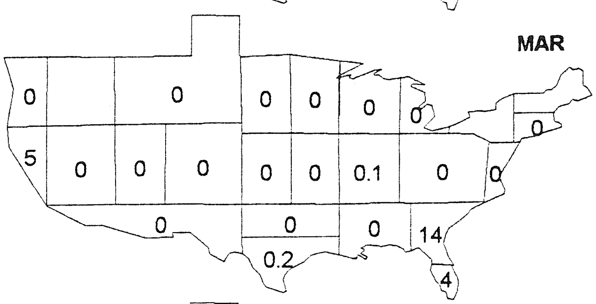
0 1
0 0.3 2 0.1 2 0 0.3 0 6
0.2 0.5 0 14
29 8


MAR
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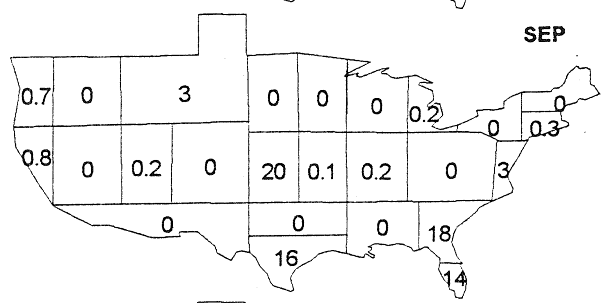
0 0 0 14
0.2 4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0 0.3
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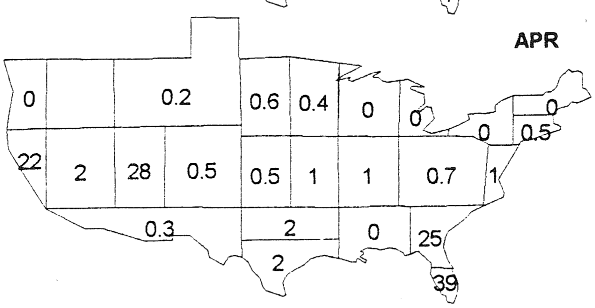
0 0 0 18
16 14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0 0.5
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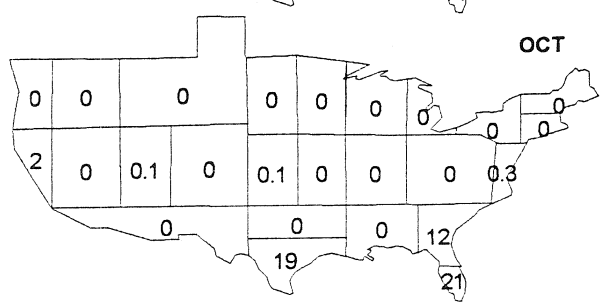
OCT
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0 0
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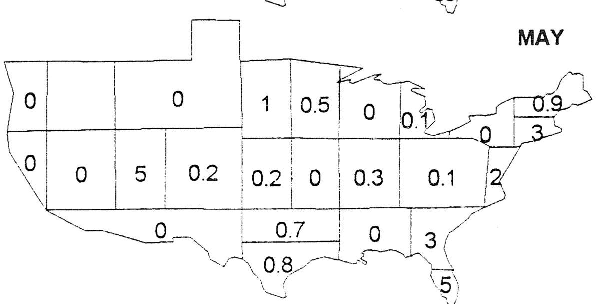
0 0 0 12
19 21


MAY
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0 3
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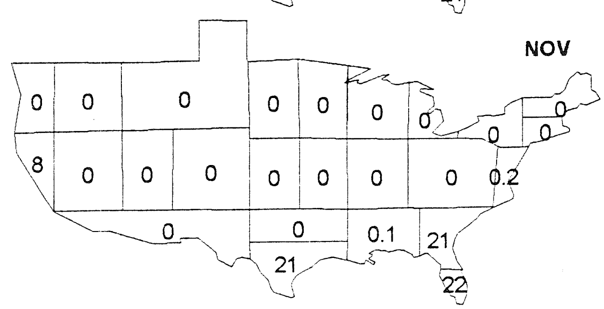
0.8 5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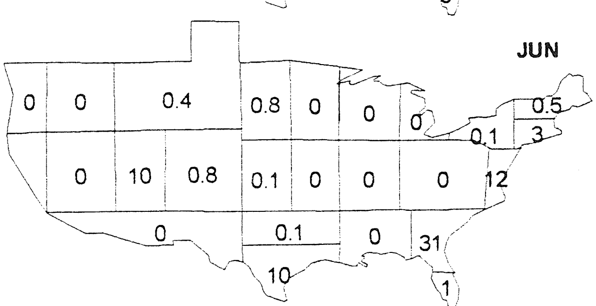
0 0
8 0 0 0 0 0 0 0 0.2
0 0 0.1 21
21 22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0.1 3
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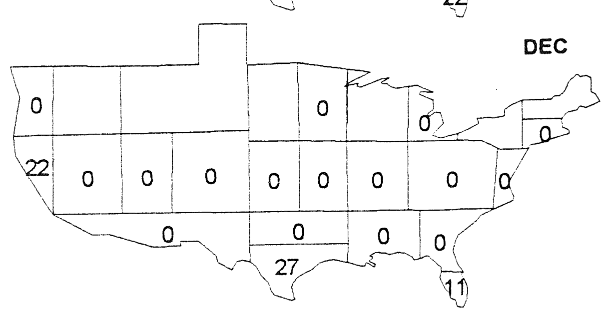
0 0.1 0 31
10 1


DEC
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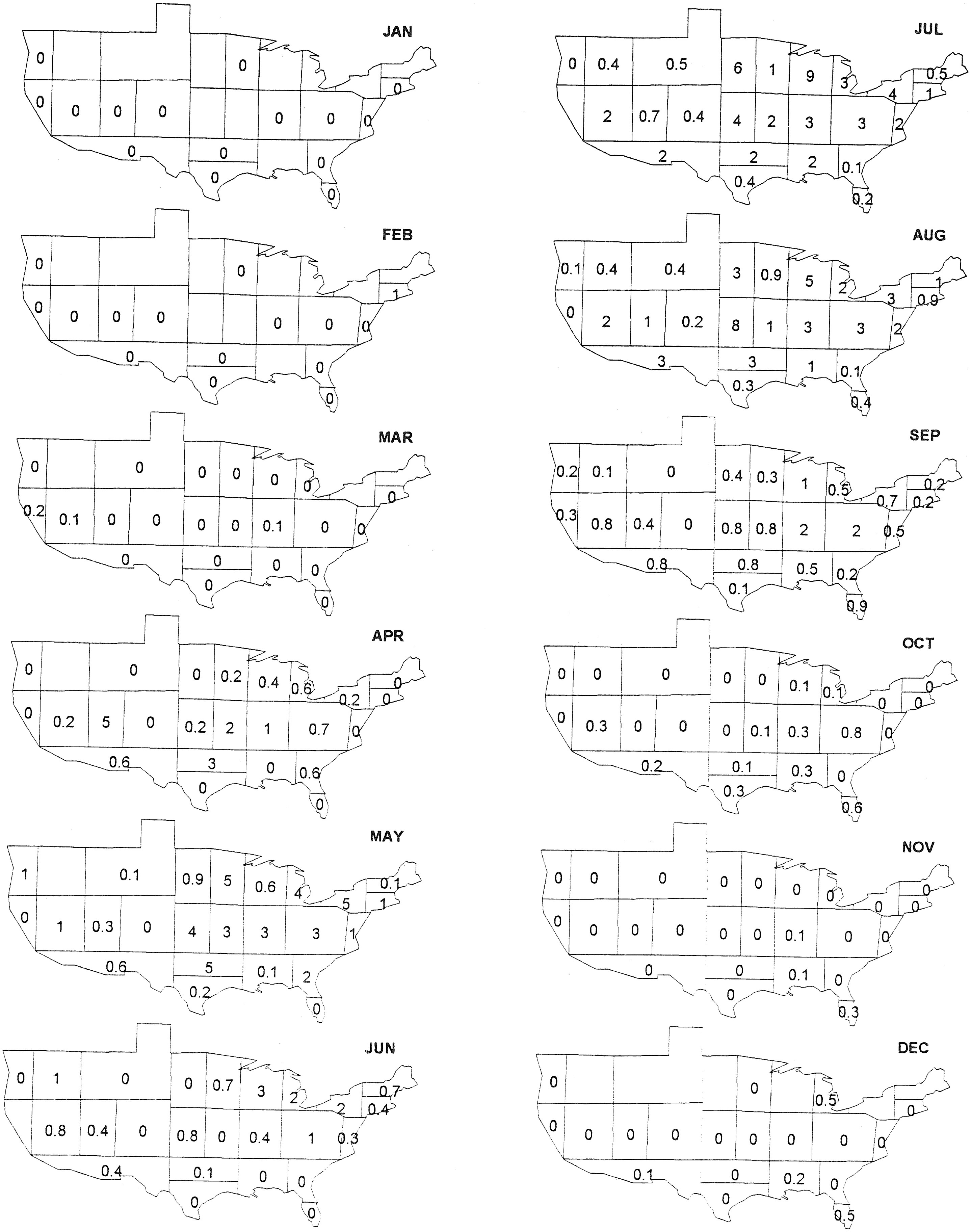
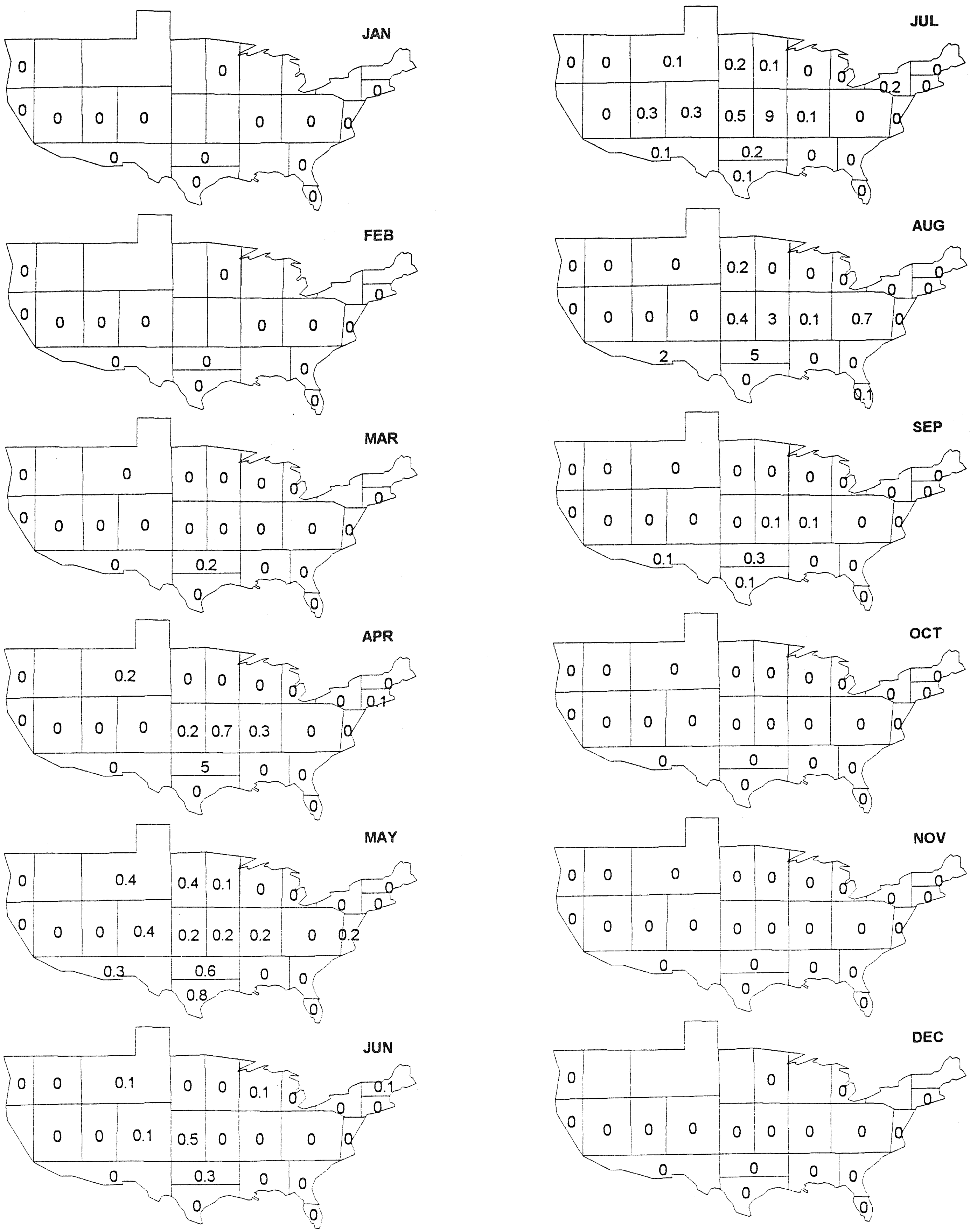
0
22 0 0 0 0 0 0 0 0
0 0 0 0
27 11

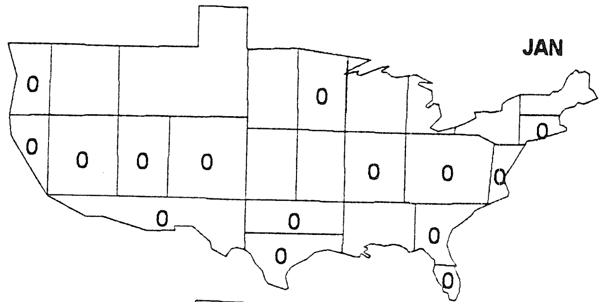
SPOTTED SANDPIPER

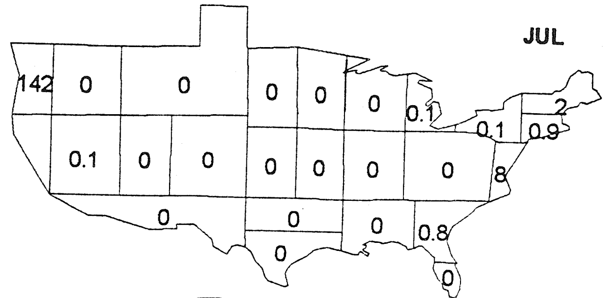


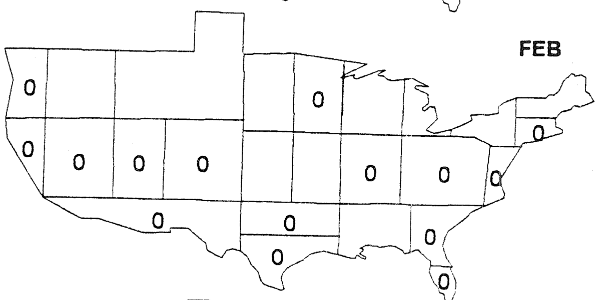
UPLAND SANDPIPER



WHIMBREL


JAN
0 0
0
0 0 0 0 0 0 0
0 0 0
0 0
0


JUL
142 0 0 0 0 0
0.1 2
0.1 0.9
0.1 0 0 0 0 0 0 8
0 0 0 0.8
0 0


FEB
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0
0 0 0 0 0 0 0
0 0 0
0 0
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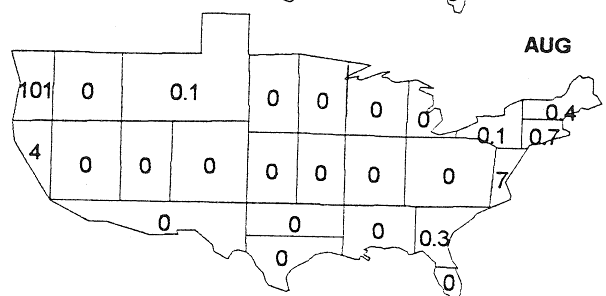
AUG
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0.4
0.1 0.7
4 0 0 0 0 0 0 0 7
0 0 0 0.3
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MAR
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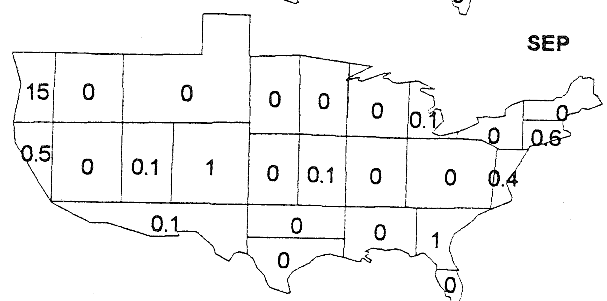
0
0.2 0 0 0 0 0 0 0 0
0 0 0 0
0 0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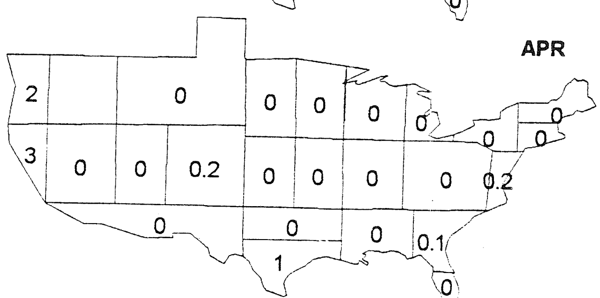
0 0.6
0.5 0 0.1 1 0 0.1 0 0 0.4
0.1 0 0 1
0 0


APR
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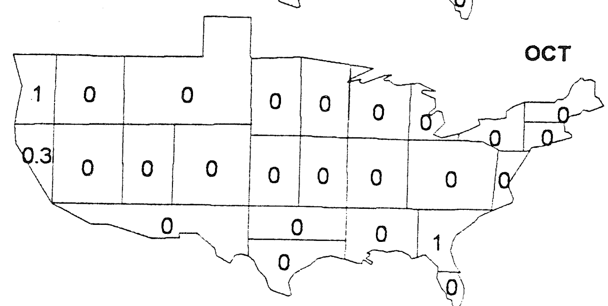
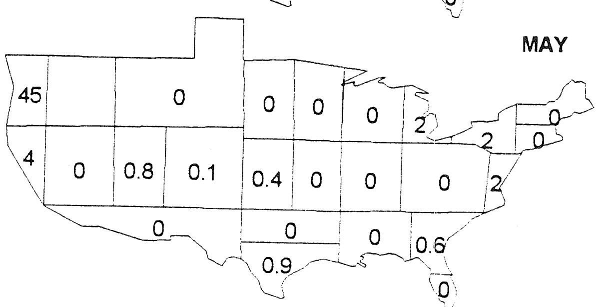
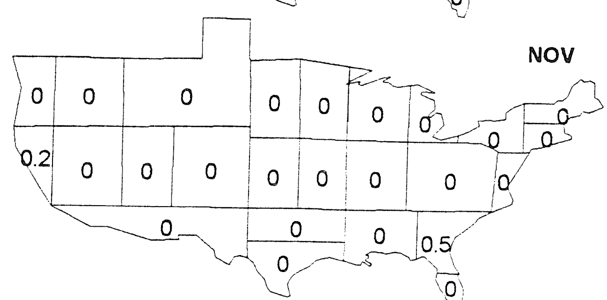
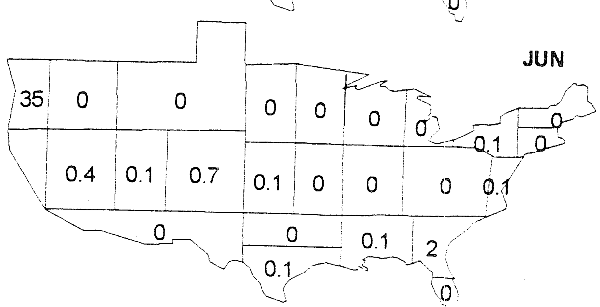
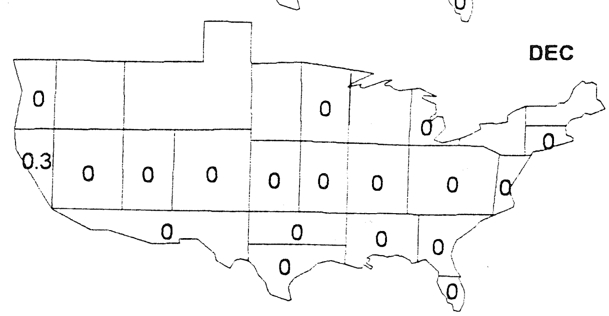
0
0 0
3 0 0 0.2 0 0 0 0 0.2
0 0 0 0.1
1 0


OCT
1 0 0 0 0 0 0
0
0 0
0.3 0 0 0 0 0 0 0 0
0 0 0 1
0 0

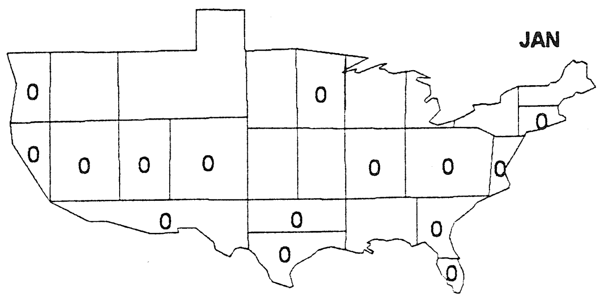

MAY
45 0 0 0 0 2
0
2 0
4 0 0.8 0.1 0.4 0 0 0 2
0 0 0 0.6
0.9 0

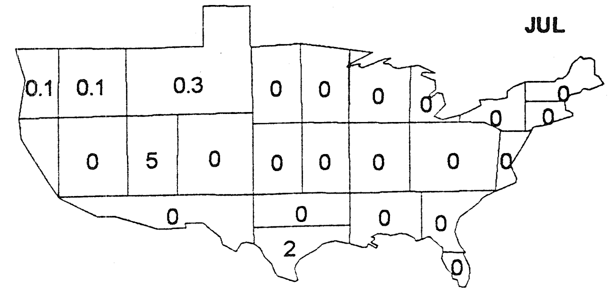

NOV
0 0 0 0 0 0 0
0
0 0
0.2 0 0 0 0 0 0 0 0
0 0 0 0.5
0 0

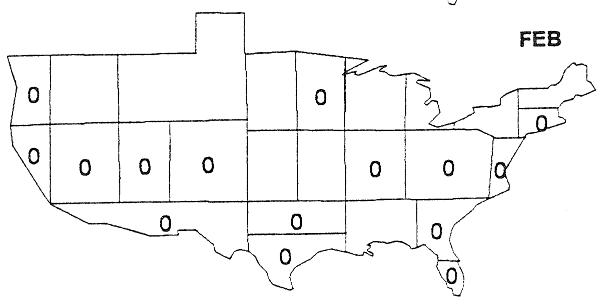

JUN
35 0 0 0 0 0 0
0
0.1 0
0.4 0.1 0.7 0.1 0 0 0 0.1
0 0 0.1 2
0.1 0

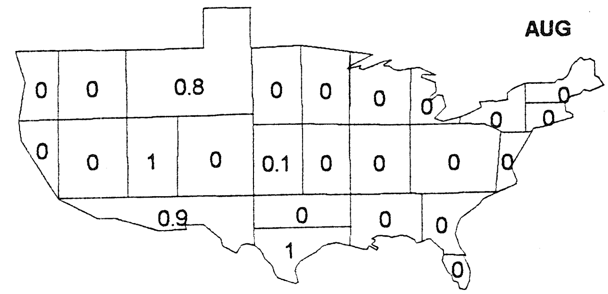

DEC
0 0 0
0
0.3 0 0 0 0 0 0 0 0
0 0 0 0
0 0

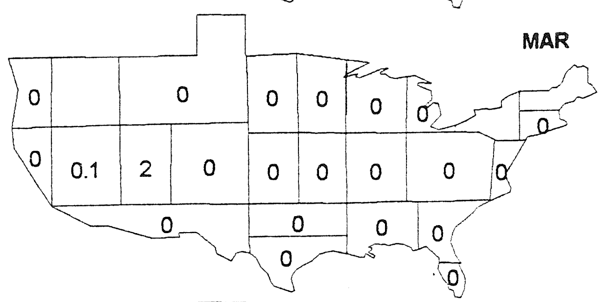
LONG-BILLED CURLEW

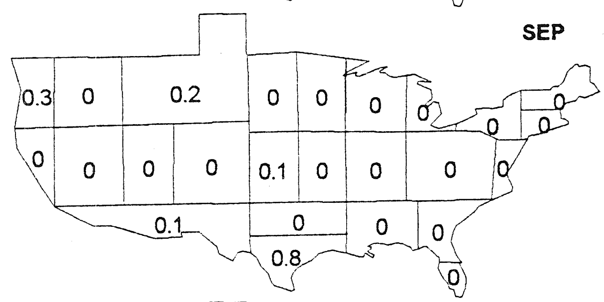


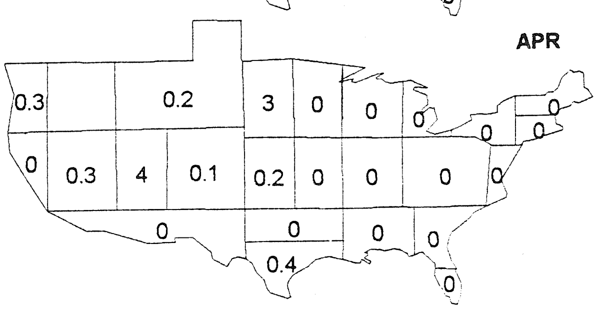


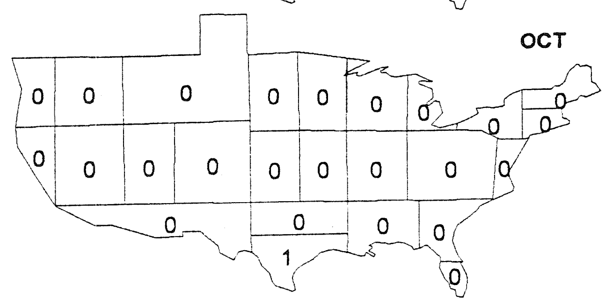


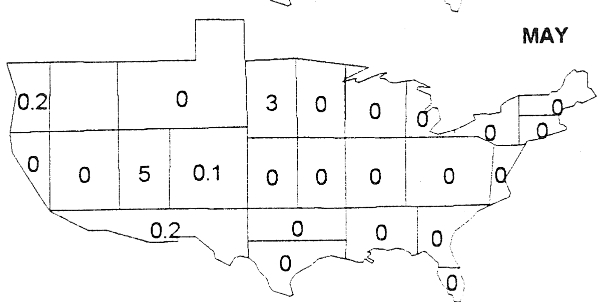


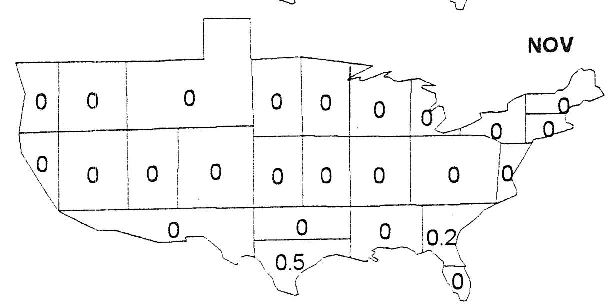


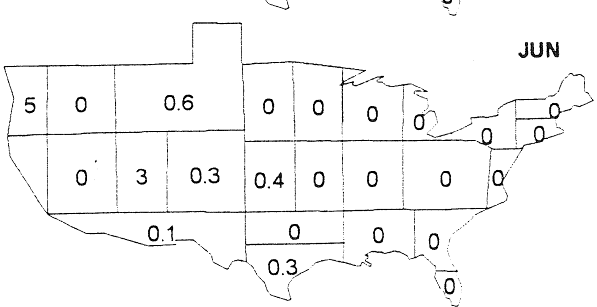


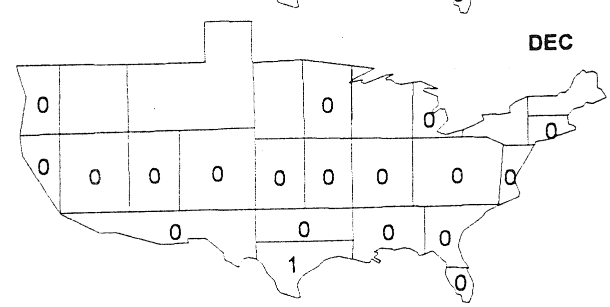




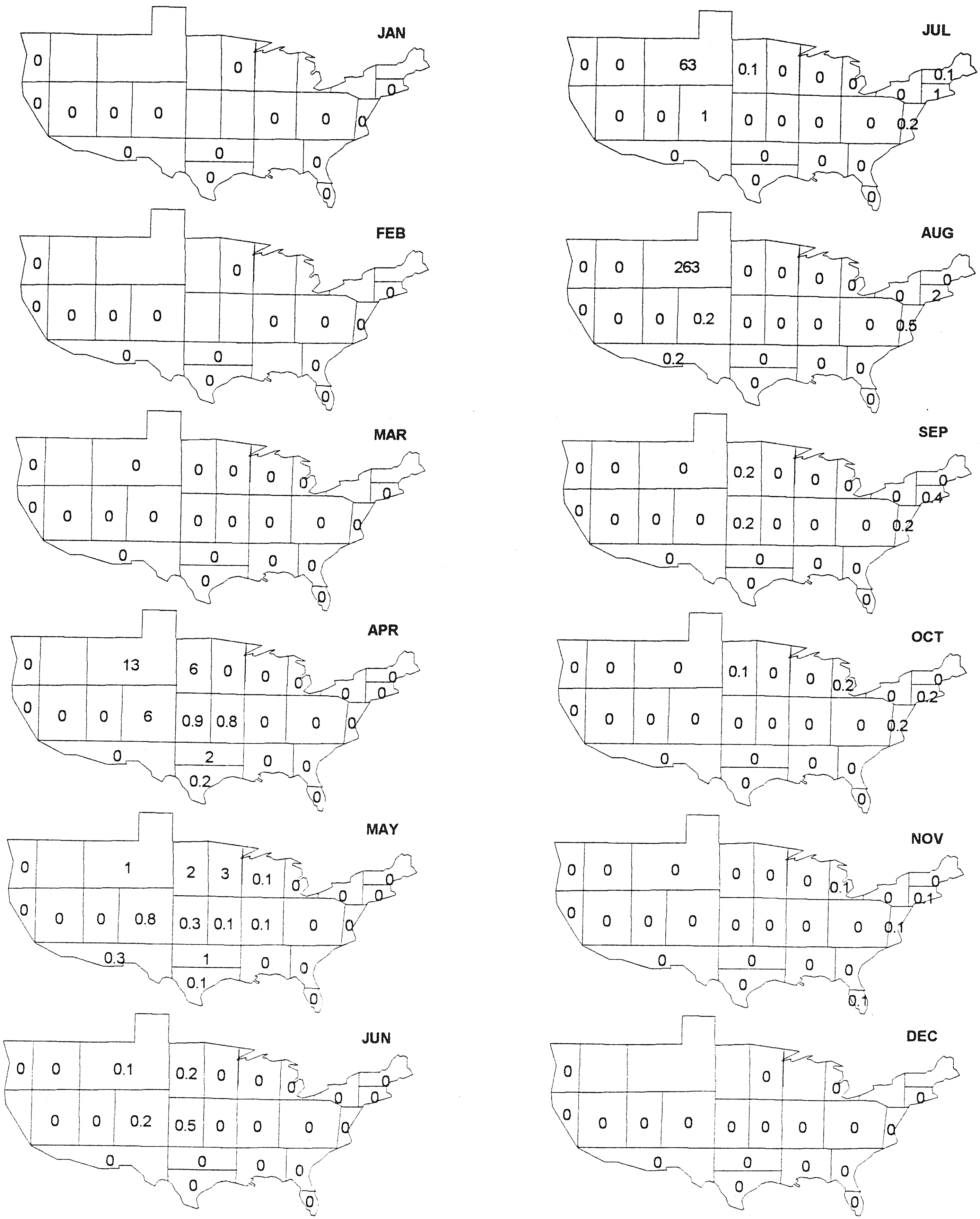




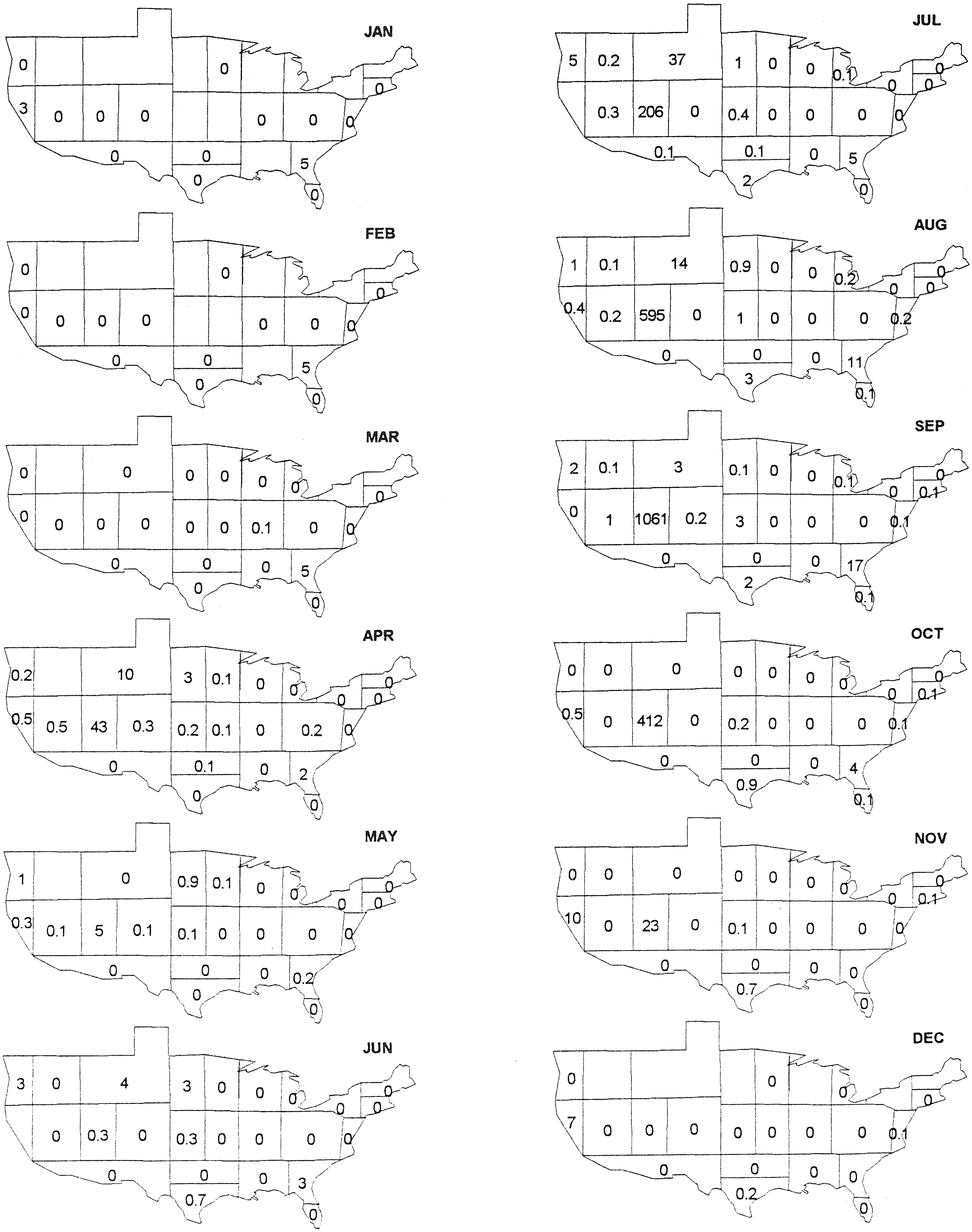




HUDSONIAN GODWIT

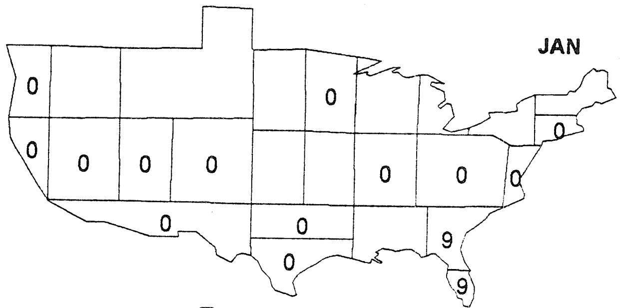


MARBLED GODWIT

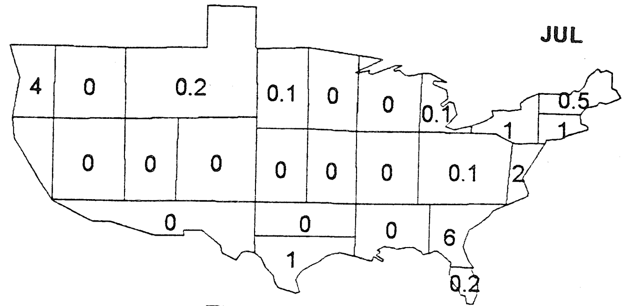


RUDDY TURNSTONE

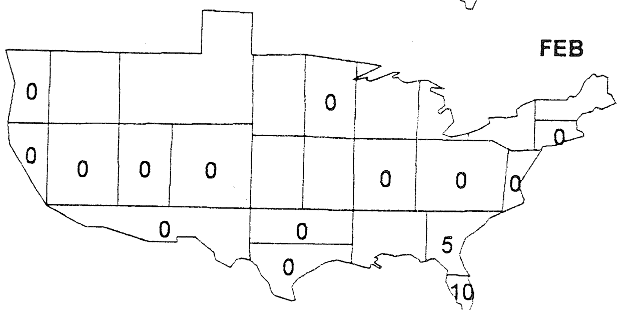
JAN



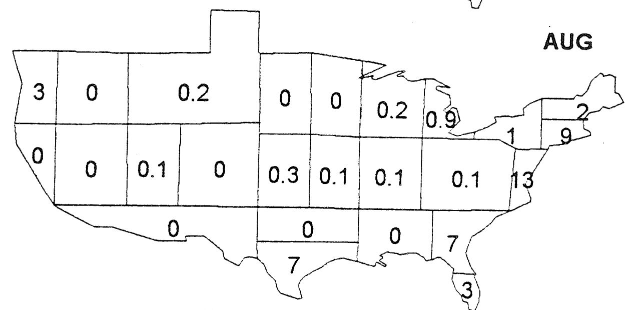
JUL



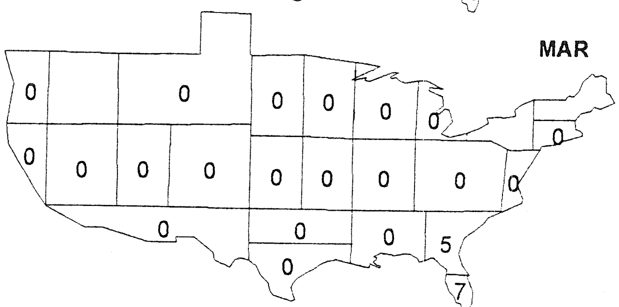
FEB



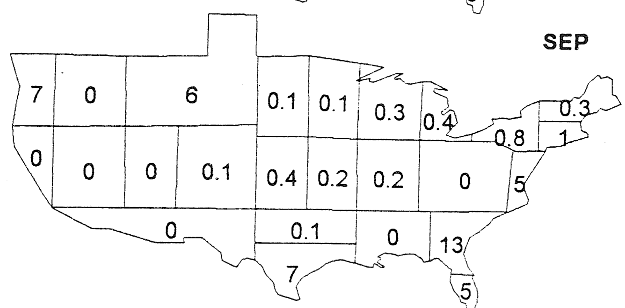
AUG



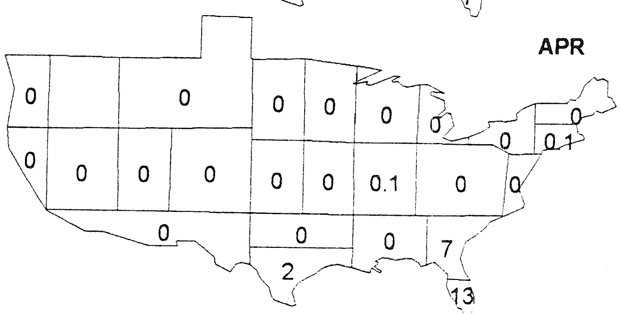
MAR



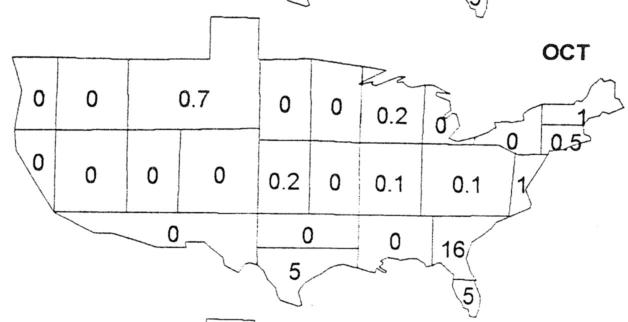
SEP



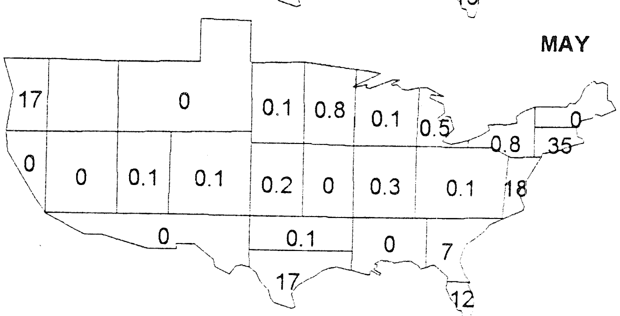
APR



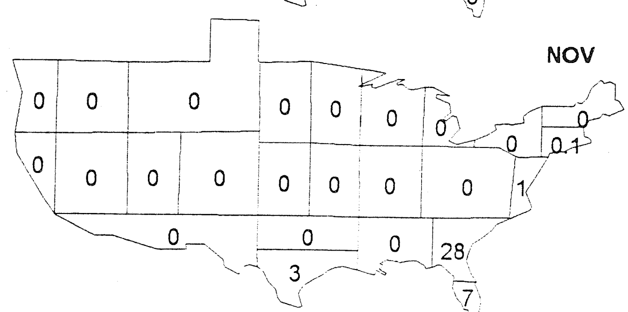
OCT



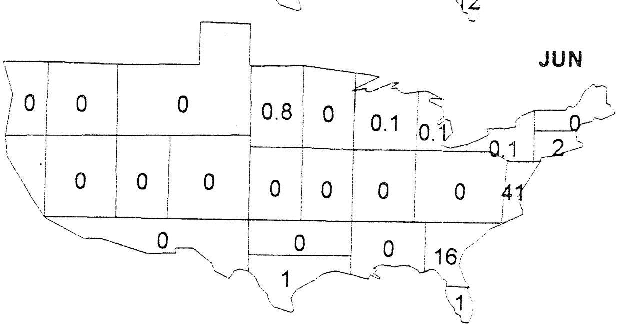
MAY



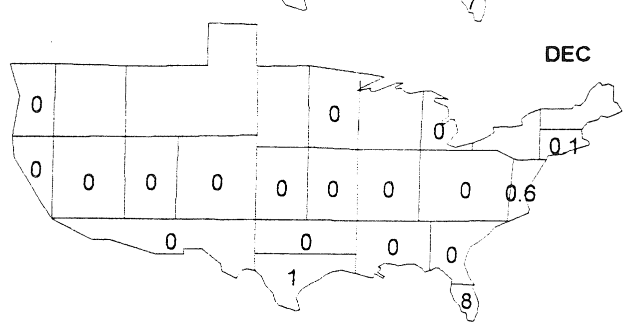
NOV



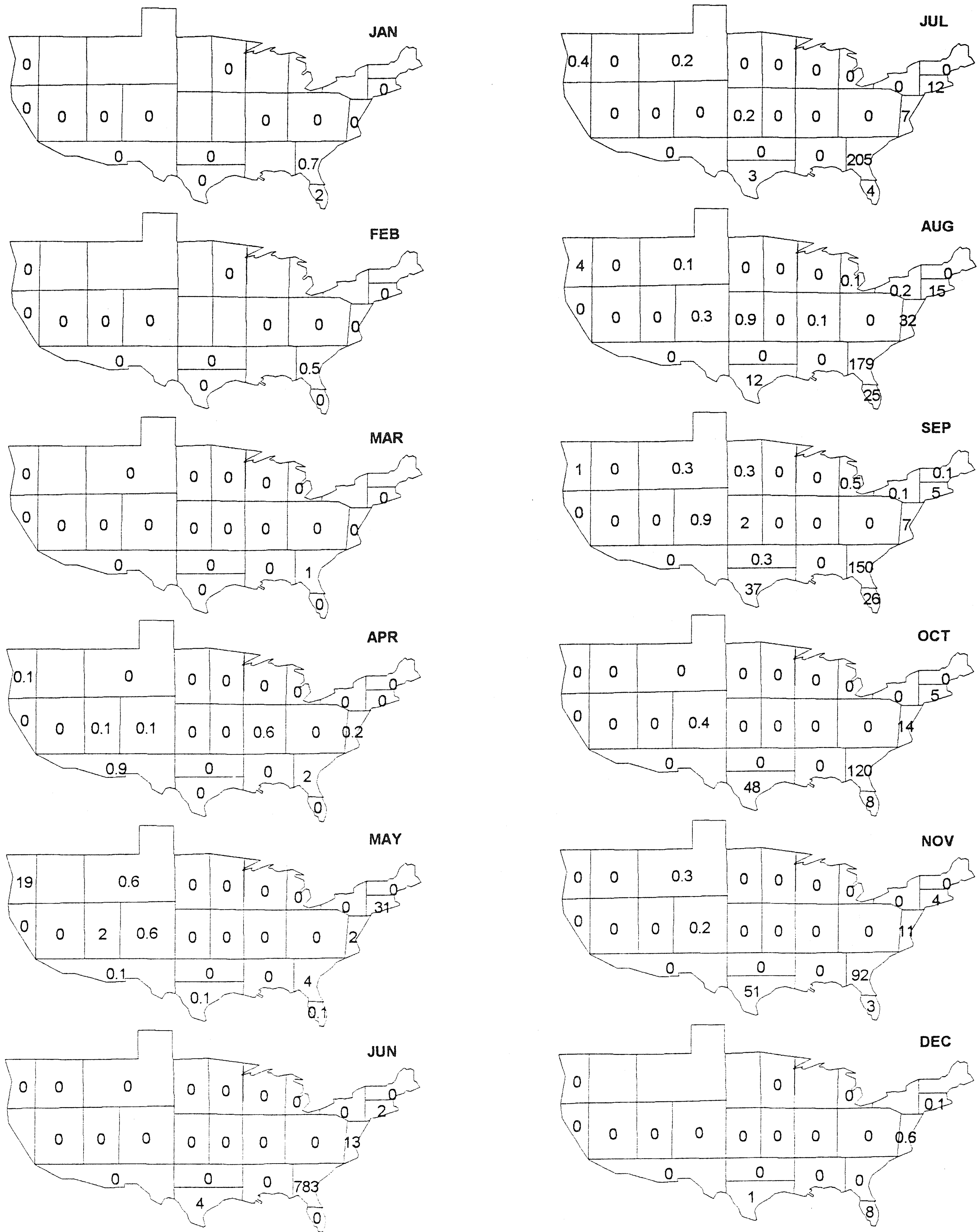
JUN



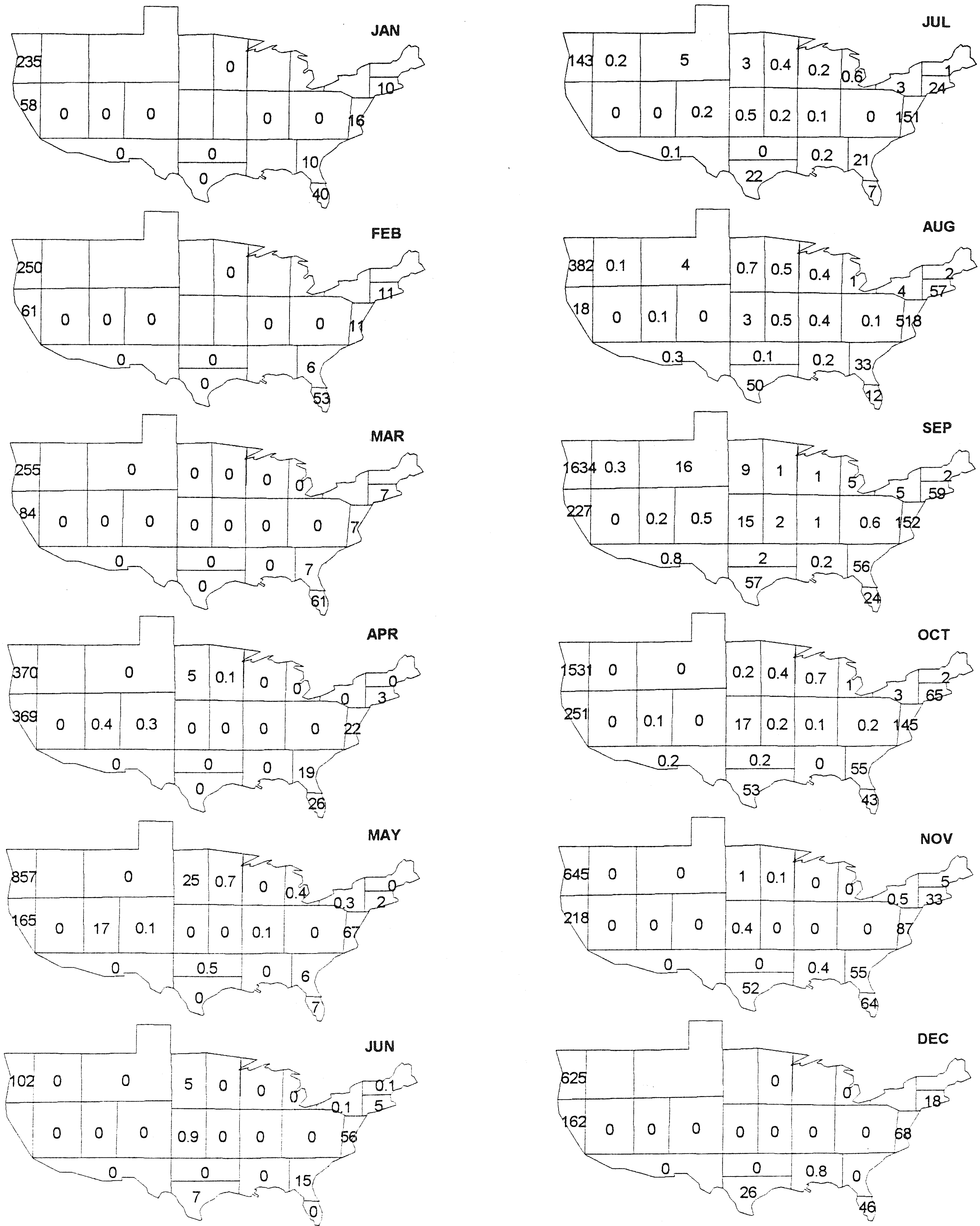
DEC



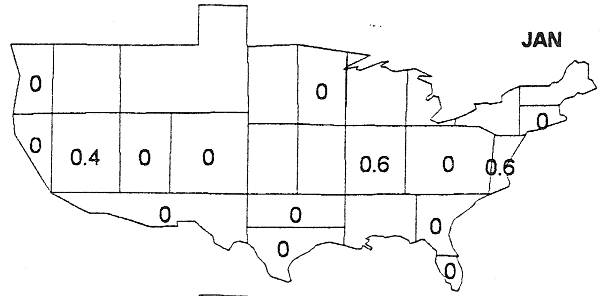
RED KNOT

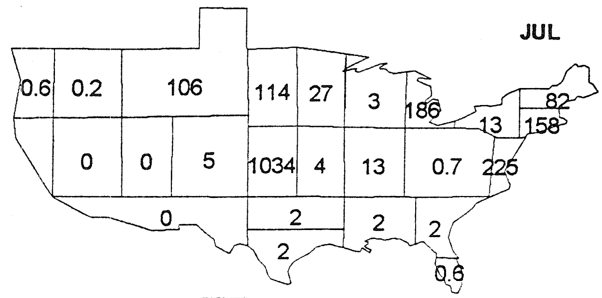

JAN
0 0 0
0 0 0 0 0 0 0
0 0 0.7 0 2
JUL
0.4 0 0.2 0 0 0 0 0 0 12
0 0 0 0.2 0 0 0 7
0 0 0 205 3 4
FEB
0 0 0
0 0 0 0 0 0 0
0 0 0.5 0 0
AUG
4 0 0.1 0 0 0 0.1 0.2 0 15
0 0 0 0.3 0.9 0 0.1 0 32
0 0 0 179 12 25
MAR
0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0
0 0 0 1 0 0
SEP
1 0 0.3 0.3 0 0 0.5 0.1 0.1 5
0 0 0 0.9 2 0 0 0 7
0 0.3 0 150 37 26
APR
0.1 0 0 0 0 0 0 0 0
0 0 0.1 0.1 0 0 0.6 0 0.2
0.9 0 0 2 0 0
OCT
0 0 0 0 0 0 0 0 0 5
0 0 0 0.4 0 0 0 0 14
0 0 0 120 48 8
MAY
19 0.6 0 0 0 0 0 0 31
0 0 2 0.6 0 0 0 0 2
0.1 0 0 4 0.1 0.1
NOV
0 0 0.3 0 0 0 0 0 0 4
0 0 0 0.2 0 0 0 0 11
0 0 0 92 51 3
JUN
0 0 0 0 0 0 0 0 0 2
0 0 0 0 0 0 0 13
0 0 0 783 4 0
DEC
0 0 0 0.1
0 0 0 0 0 0 0 0 0.6
0 0 0 0 1 8

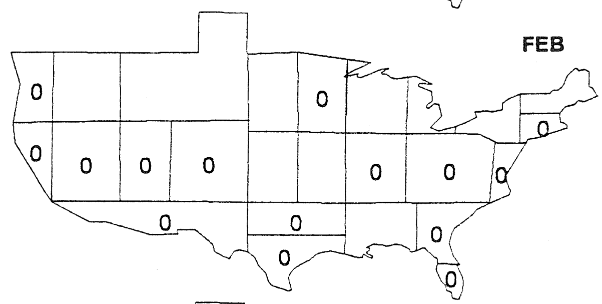
SANDERLING

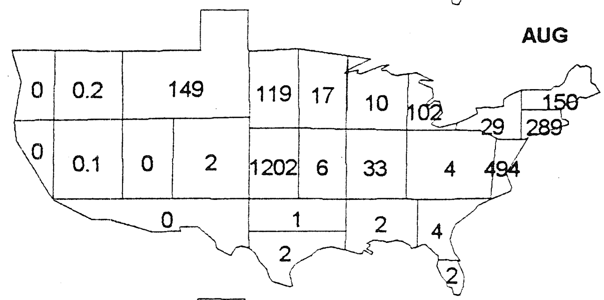

JAN
235 0 10
58 0 0 0 0 0 16
0 0 10 0 40
FEB
250 0 11
61 0 0 0 0 0 11
0 0 6 0 53
MAR
255 0 0 0 0 0 7
84 0 0 0 0 0 0 0 7
0 0 0 7 0 61
APR
370 0 5 0.1 0 0 0 3
369 0 0.4 0.3 0 0 0 0 22
0 0 0 19 0 26
MAY
857 0 25 0.7 0 0.4 0 0.3 2
165 0 17 0.1 0 0 0.1 0 67
0 0.5 0 6 0 7
JUN
102 0 0 5 0 0 0 0.1 0.1 5
0 0 0 0.9 0 0 0 56
0 0 0 15 7 0
JUL
143 0.2 5 3 0.4 0.2 0.6 1 3 24
0 0 0.2 0.5 0.2 0.1 0 151
0.1 0 0.2 21 22 7
AUG
382 0.1 4 0.7 0.5 0.4 1 2 4 57
18 0 0.1 0 3 0.5 0.4 0.1 518
0.3 0.1 0.2 33 50 12
SEP
1634 0.3 16 9 1 1 5 2 5 59
227 0 0.2 0.5 15 2 1 0.6 152
0.8 2 0.2 56 57 24
OCT
1531 0 0 0.2 0.4 0.7 1 2 3 65
251 0 0.1 0 17 0.2 0.1 0.2 145
0.2 0.2 0 55 53 43
NOV
645 0 0 1 0.1 0 0 5 0.5 33
218 0 0 0 0.4 0 0 0 87
0 0 0.4 55 52 64
DEC
625 0 0 18
162 0 0 0 0 0 0 0 68
0 0 0.8 0 26 46

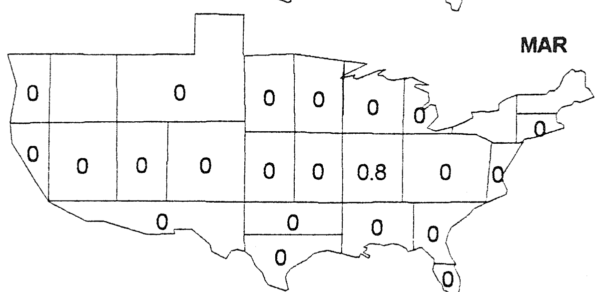
SEMIPALMATED SANDPIPER

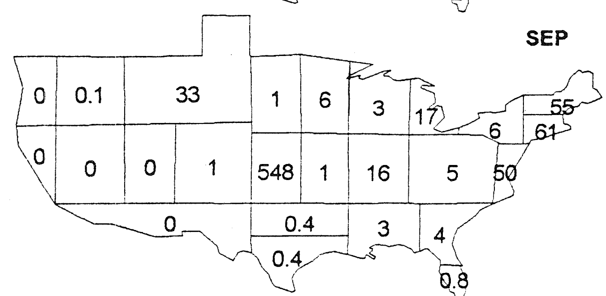


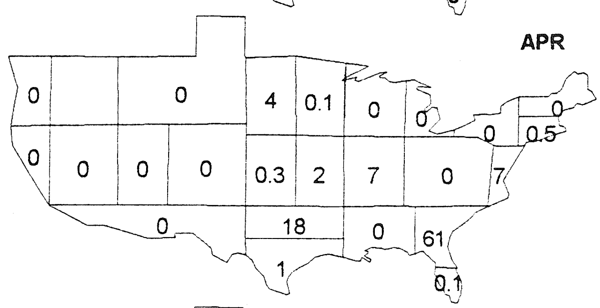


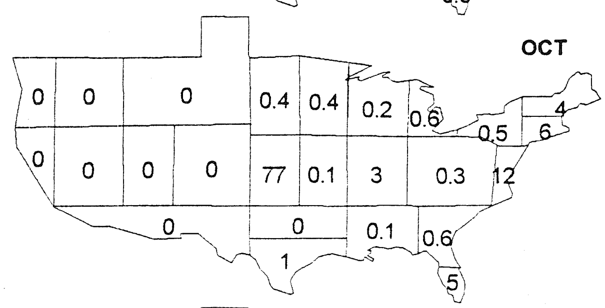


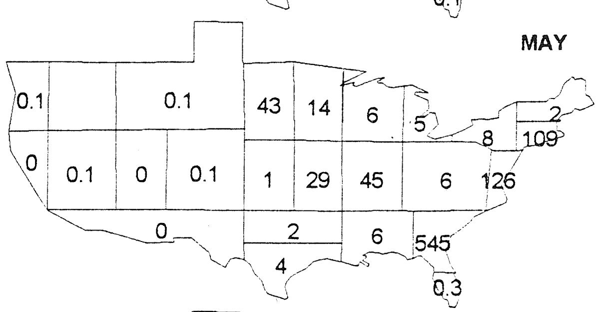


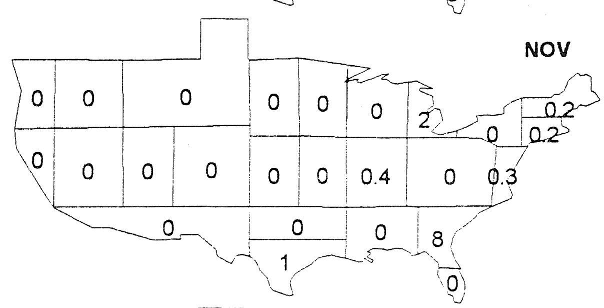


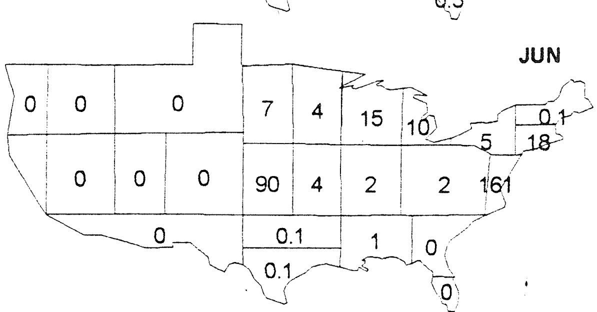


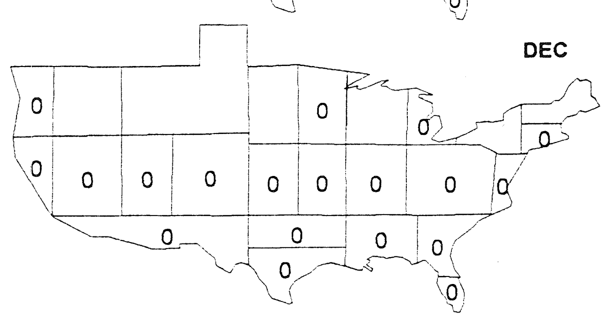




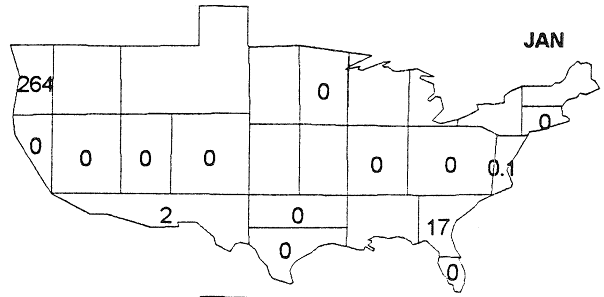




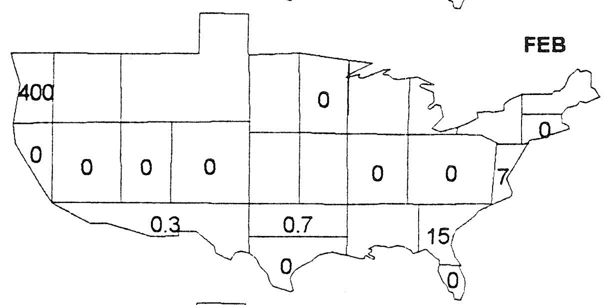




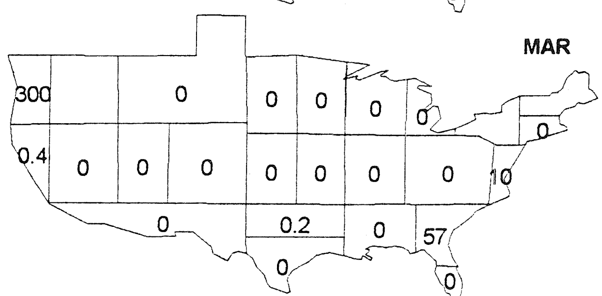
WESTERN SANDPIPER



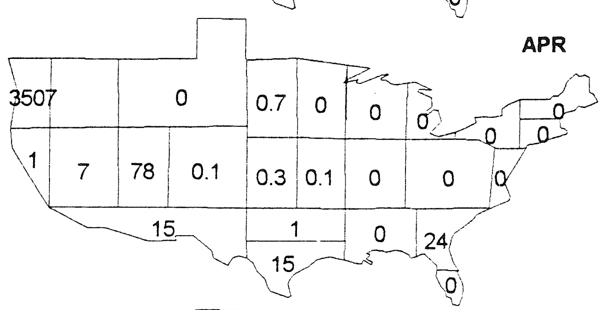
JAN



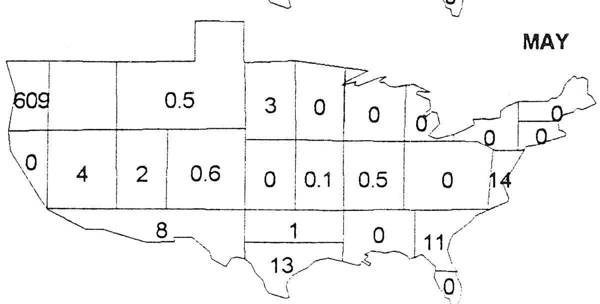
FEB



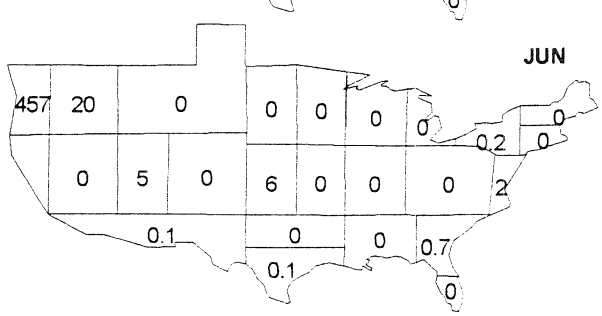
MAR



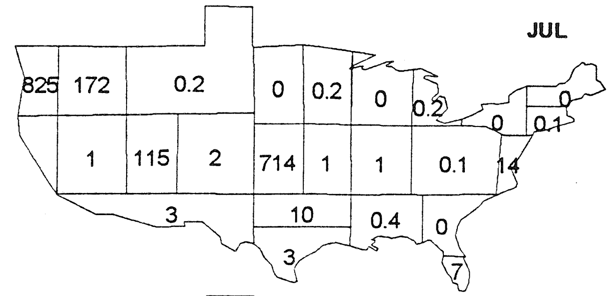
APR



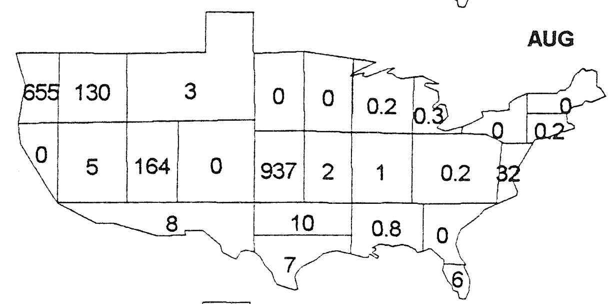
MAY



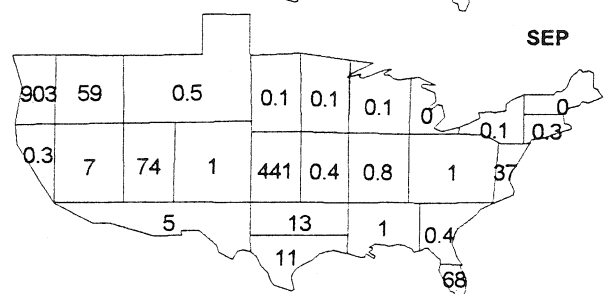
JUN



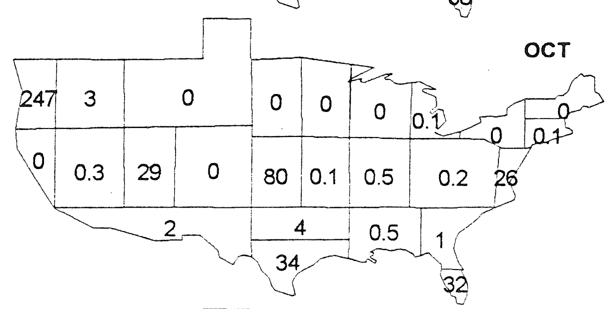
JUL



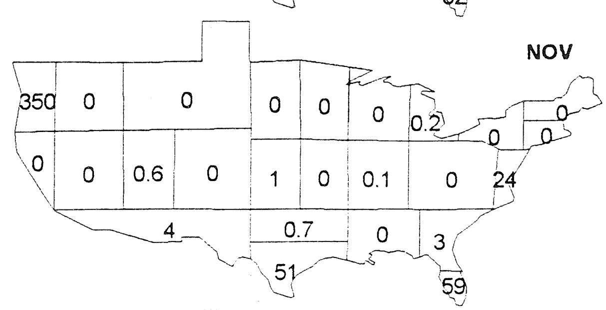
AUG



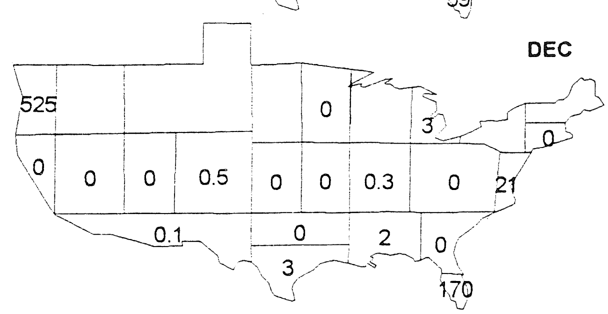
SEP



OCT

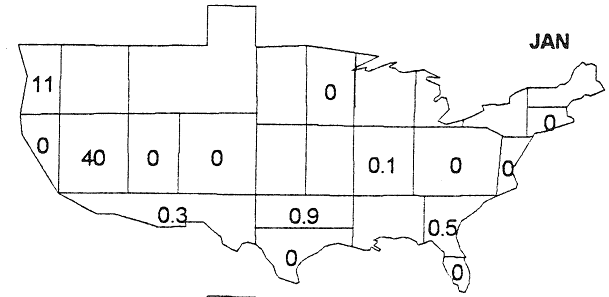


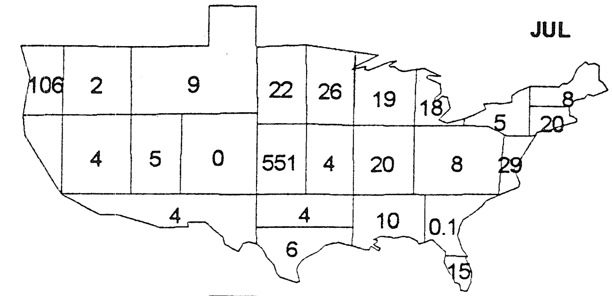
NOV

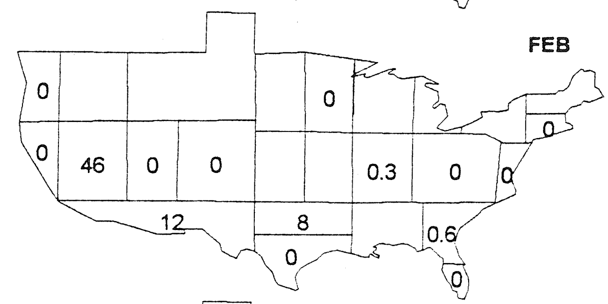


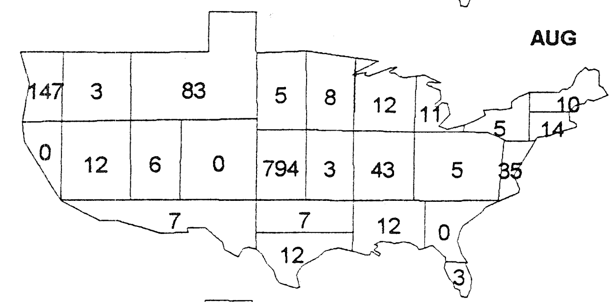
DEC

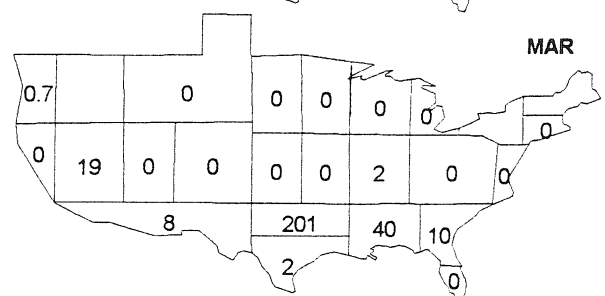
LEAST SANDPIPER

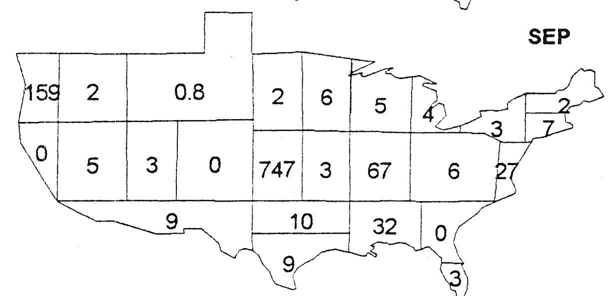


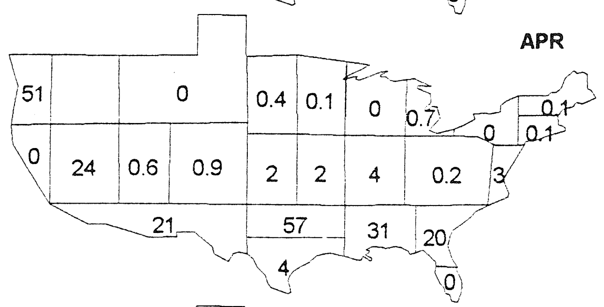


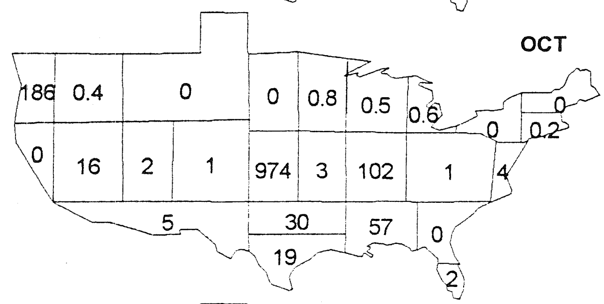


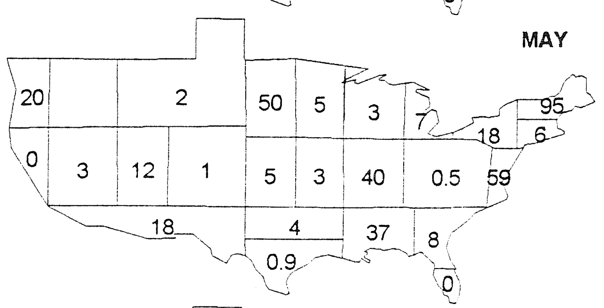


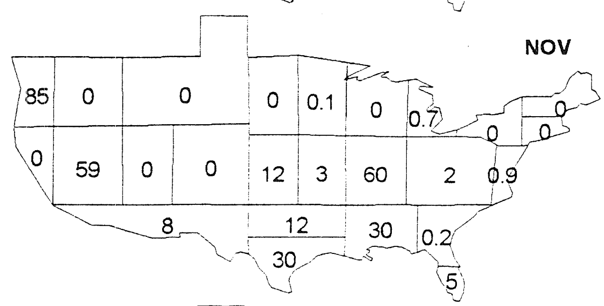


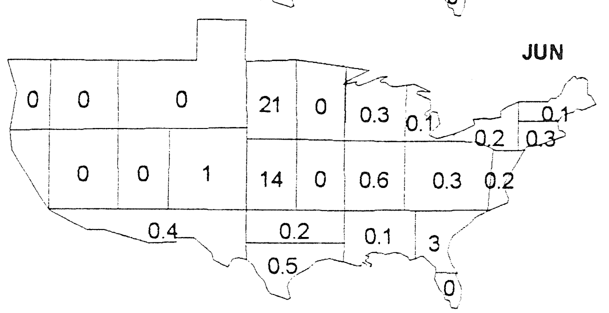


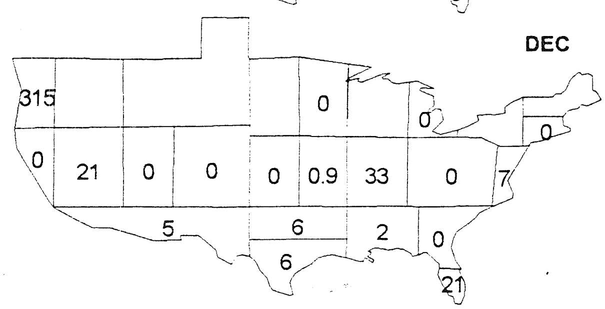




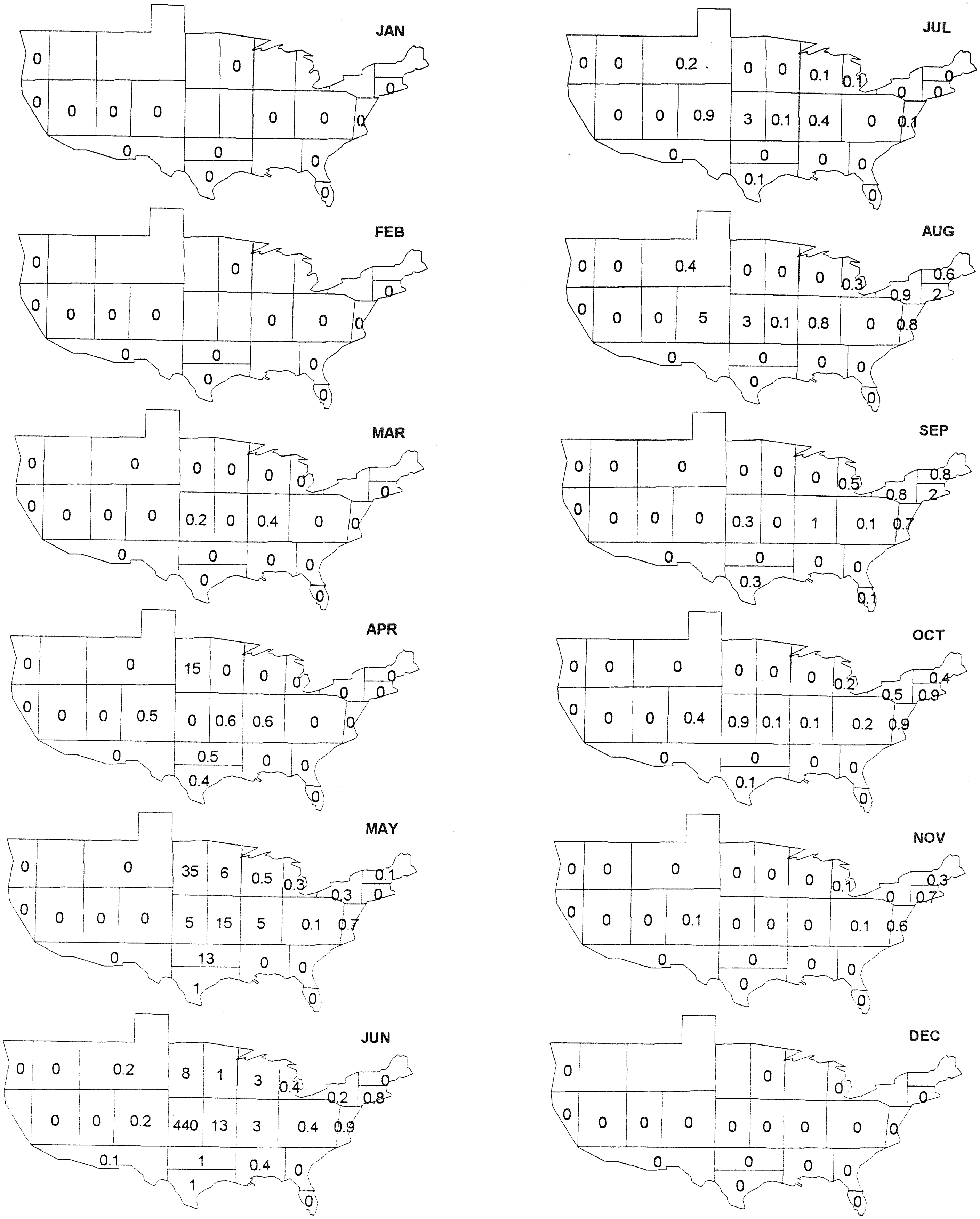




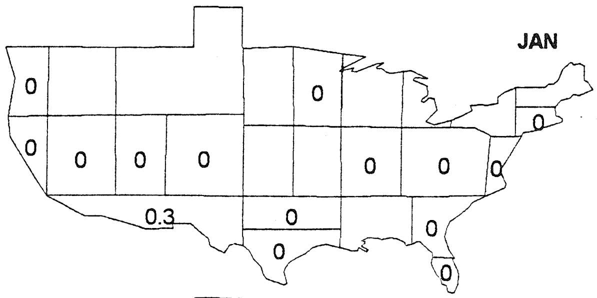


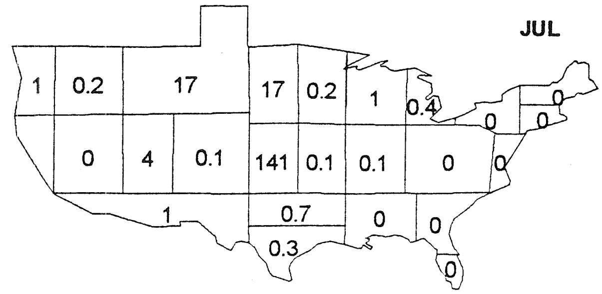


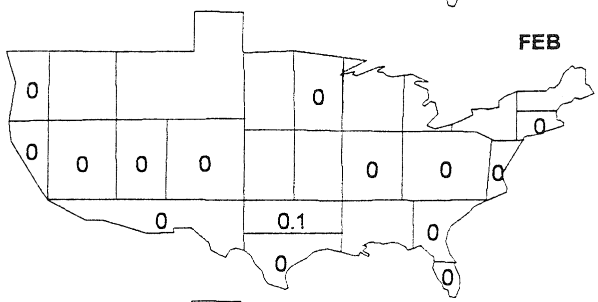
WHITE-RUMPED SANDPIPER

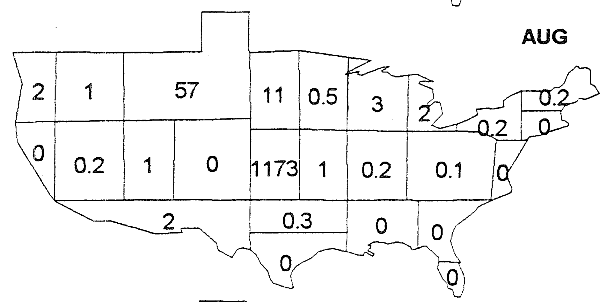


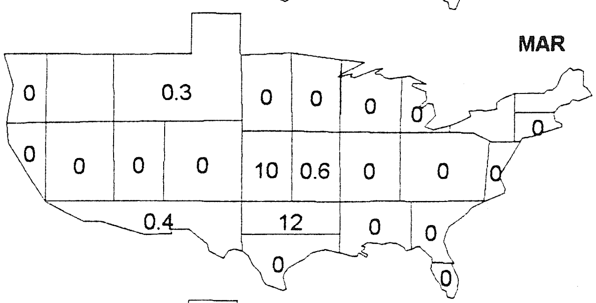
BAIRD'S SANDPIPER

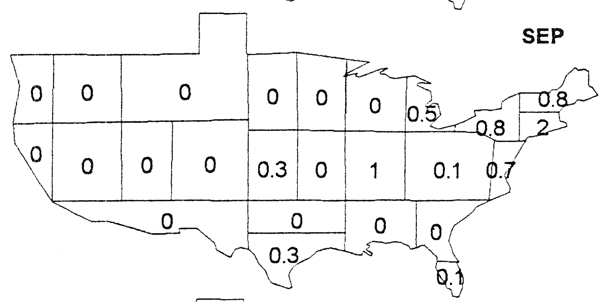


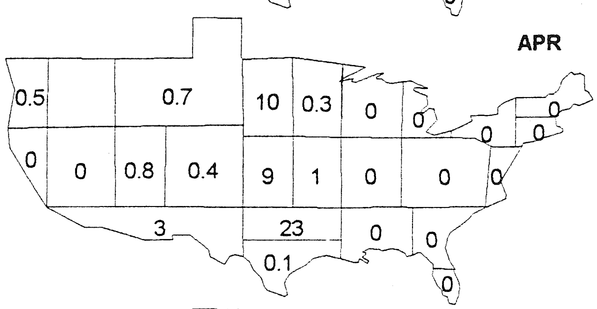


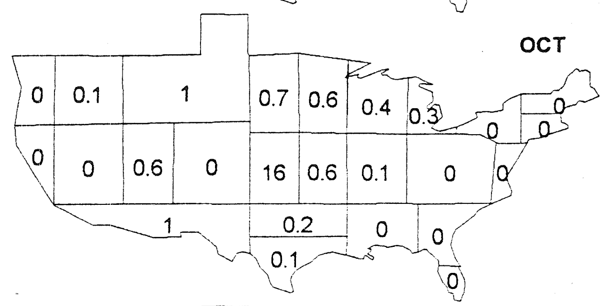


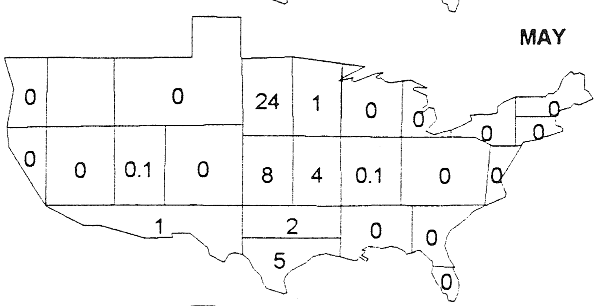


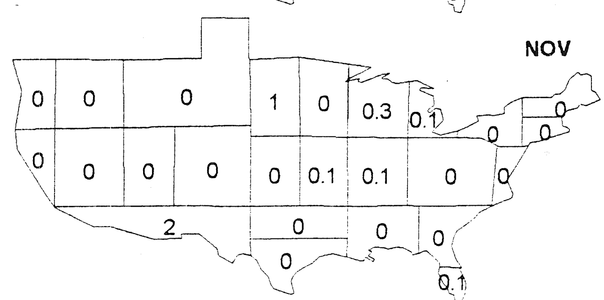


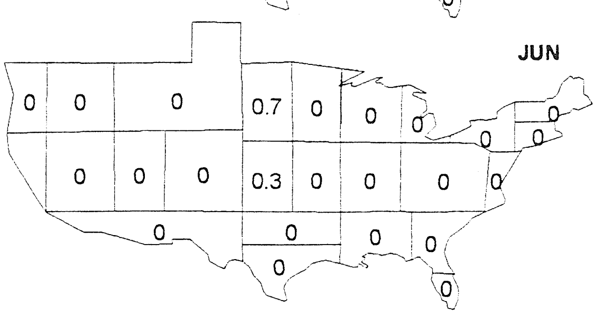


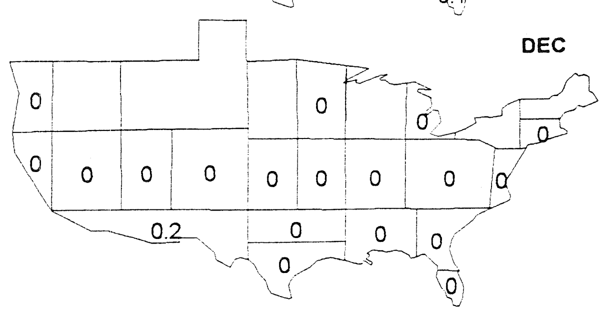




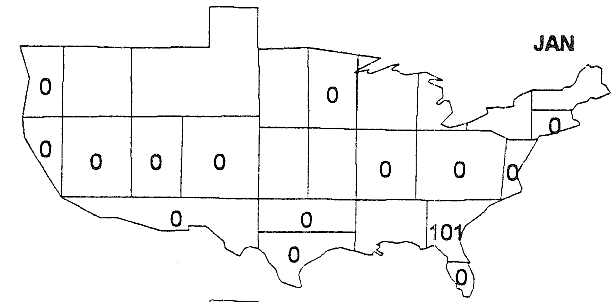


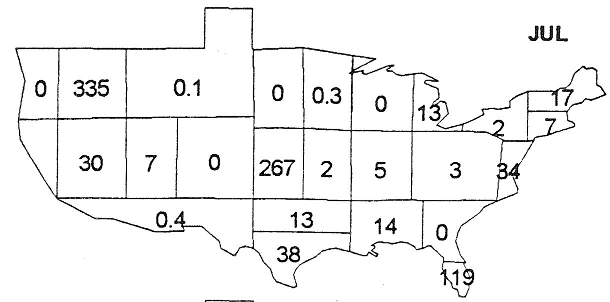


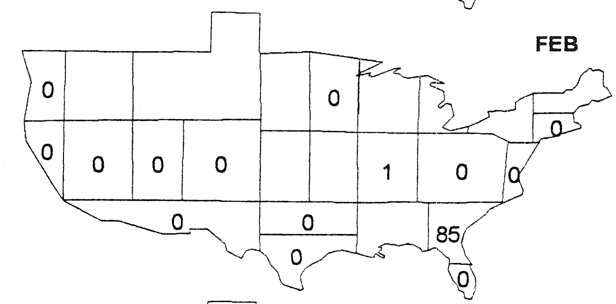


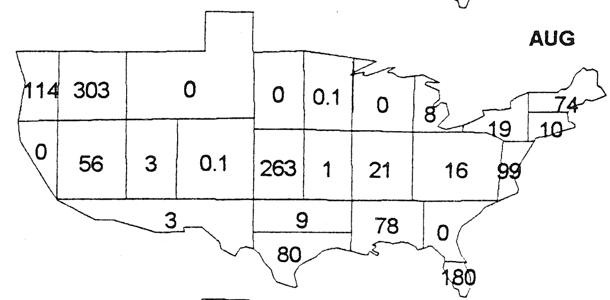


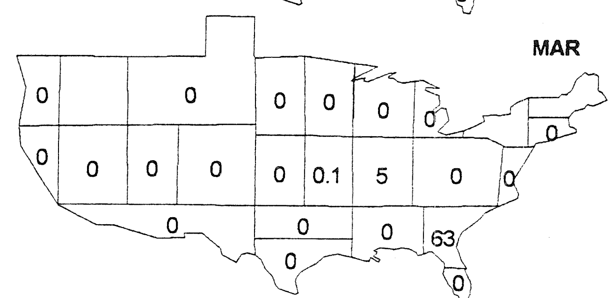
PEEP

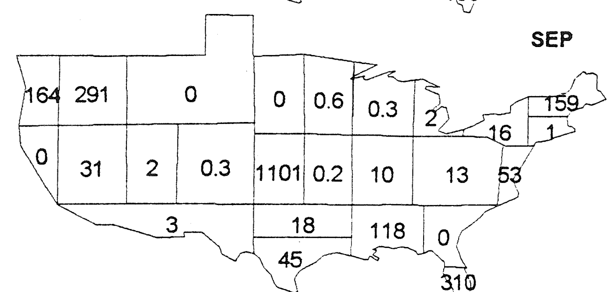

JAN
0
0
0
0 0 0
0 0
0
0
0 0
101
0
0

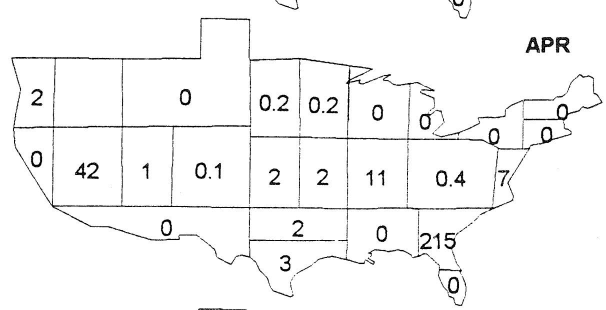

JUL
0 335 0.1
0 0.3
0 13
17
2 7
30 7 0
267 2 5 3 34
0.4 13
14 0
38
119

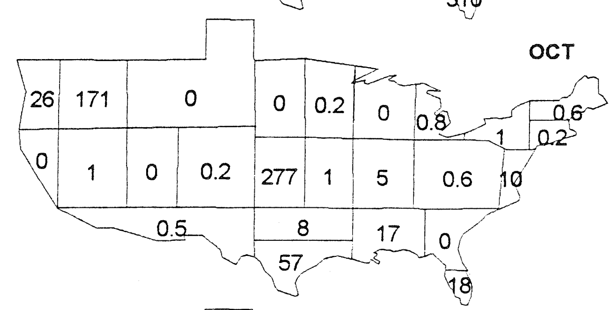

FEB
0
0
0
0 0 0
1 0
0
0 0
85
0
0

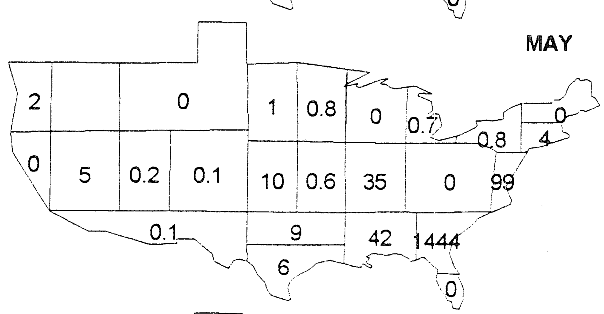

AUG
114 303 0
0 0.1
0 8
74
19 10
0
56 3 0.1
263 1 21 16 99
3 9
78 0
80
180

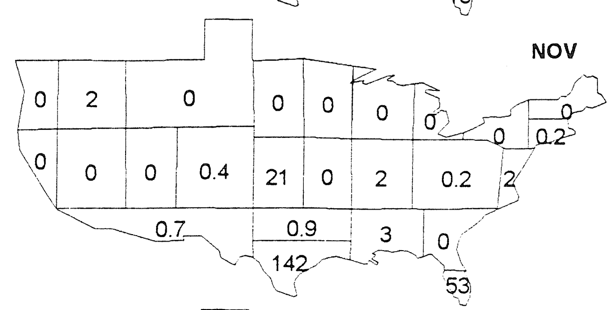

MAR
0 0
0 0 0 0
0
0 0 0 0
0 0.1 5 0 0
0 0
0 63
0
0

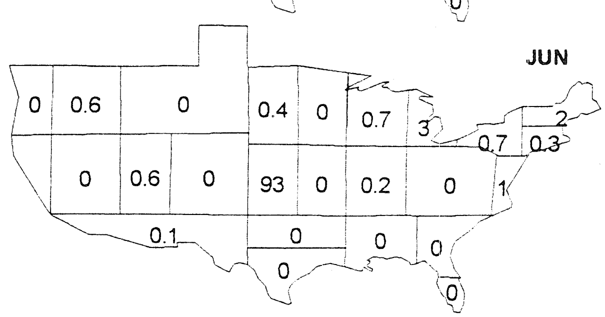

SEP
164 291 0
0 0.6 0.3 2
159
16 1
0
31 2 0.3
1101 0.2 10 13 53
3 18
118 0
45
310

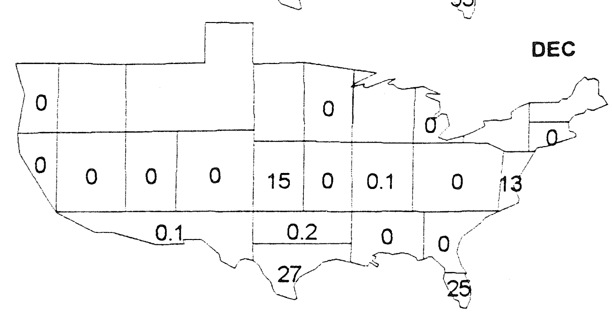

APR
2 0
0.2 0.2 0 0
0
0 0
0
42 1 0.1
2 2 11 0.4 7
0 2
0 215
3
0


OCT
26 171 0
0 0.2 0 0.8
0.6
1 0.2
0
1 0 0.2
277 1 5 0.6 10
0.5 8
17 0
57
18

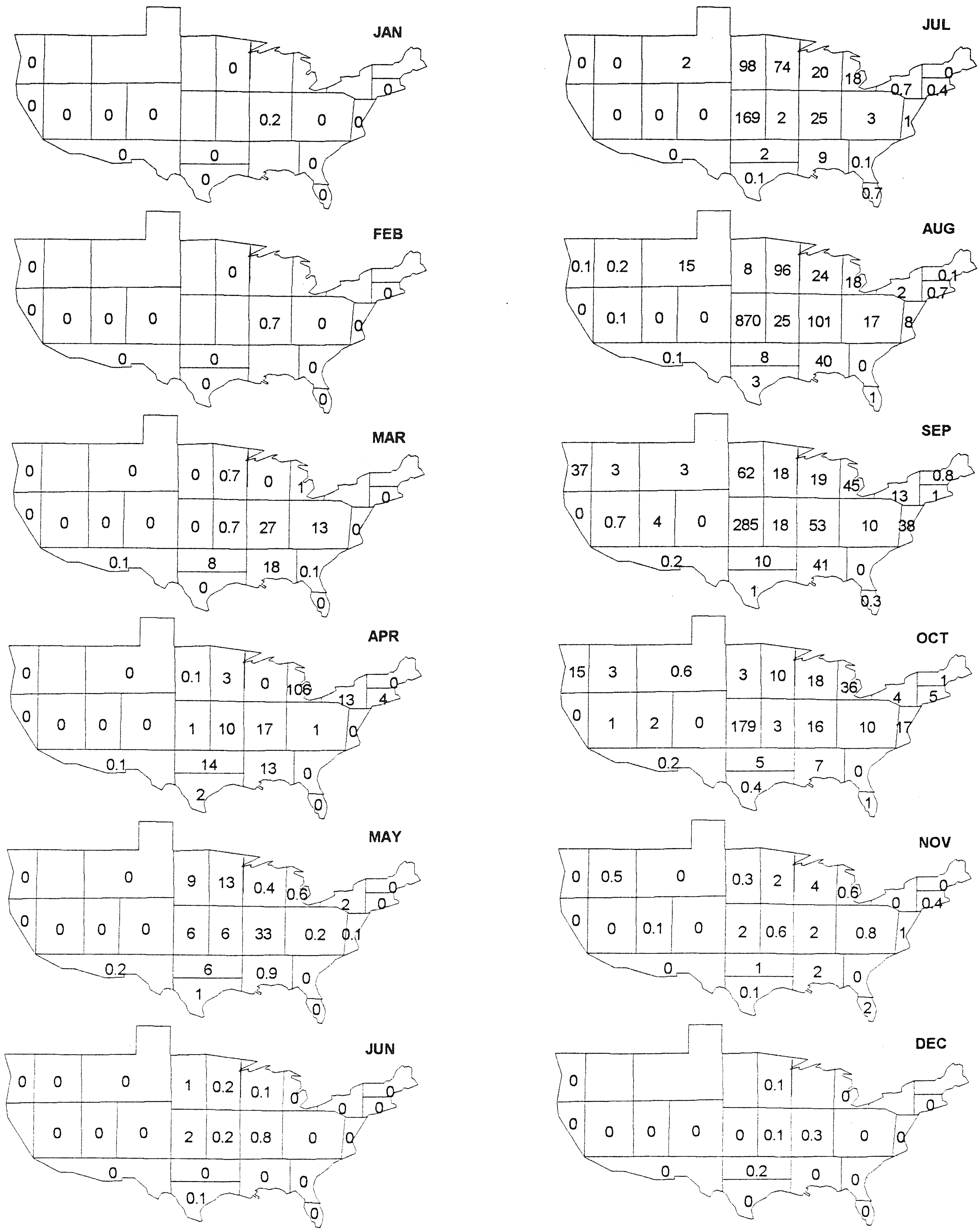

MAY
2 0
1 0.8 0 0.7
0
0.8 4
0
5 0.2 0.1
10 0.6 35 0 99
0.1 9
42 1444
6
0


NOV
0 2 0
0 0 0 0
0
0 0.2
0
0 0 0.4
21 0 2 0.2 2
0.7 0.9
3 0
142
53

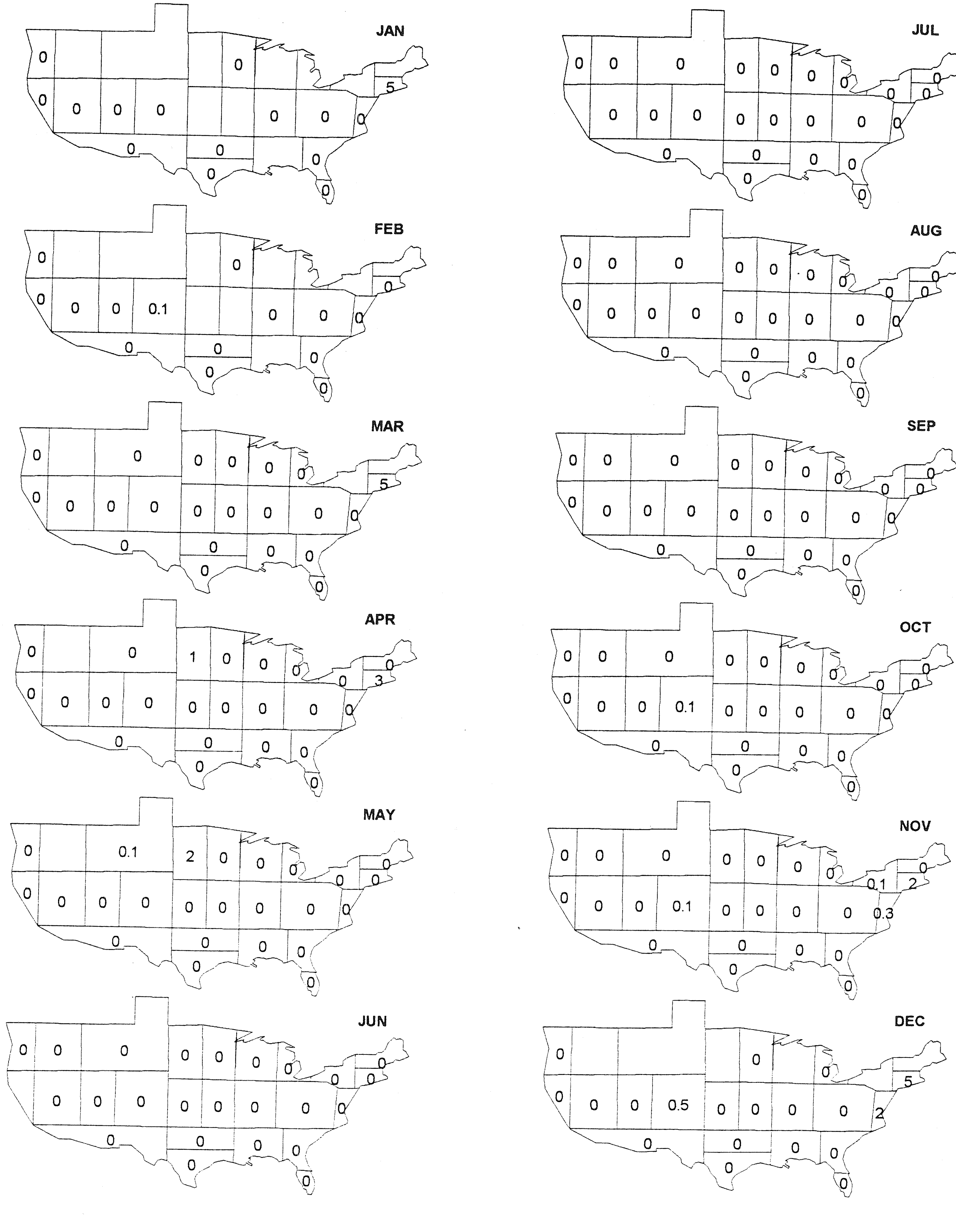

JUN
0 0.6 0
0.4 0 0.7 3
2
0.7 0.3
0 0.6 0
93 0 0.2 0 1
0.1 0
0 0
0
0


DEC
0
0 0
0
0
0 0 0
15 0 0.1 0 13
0.1 0.2
0 0
27
25

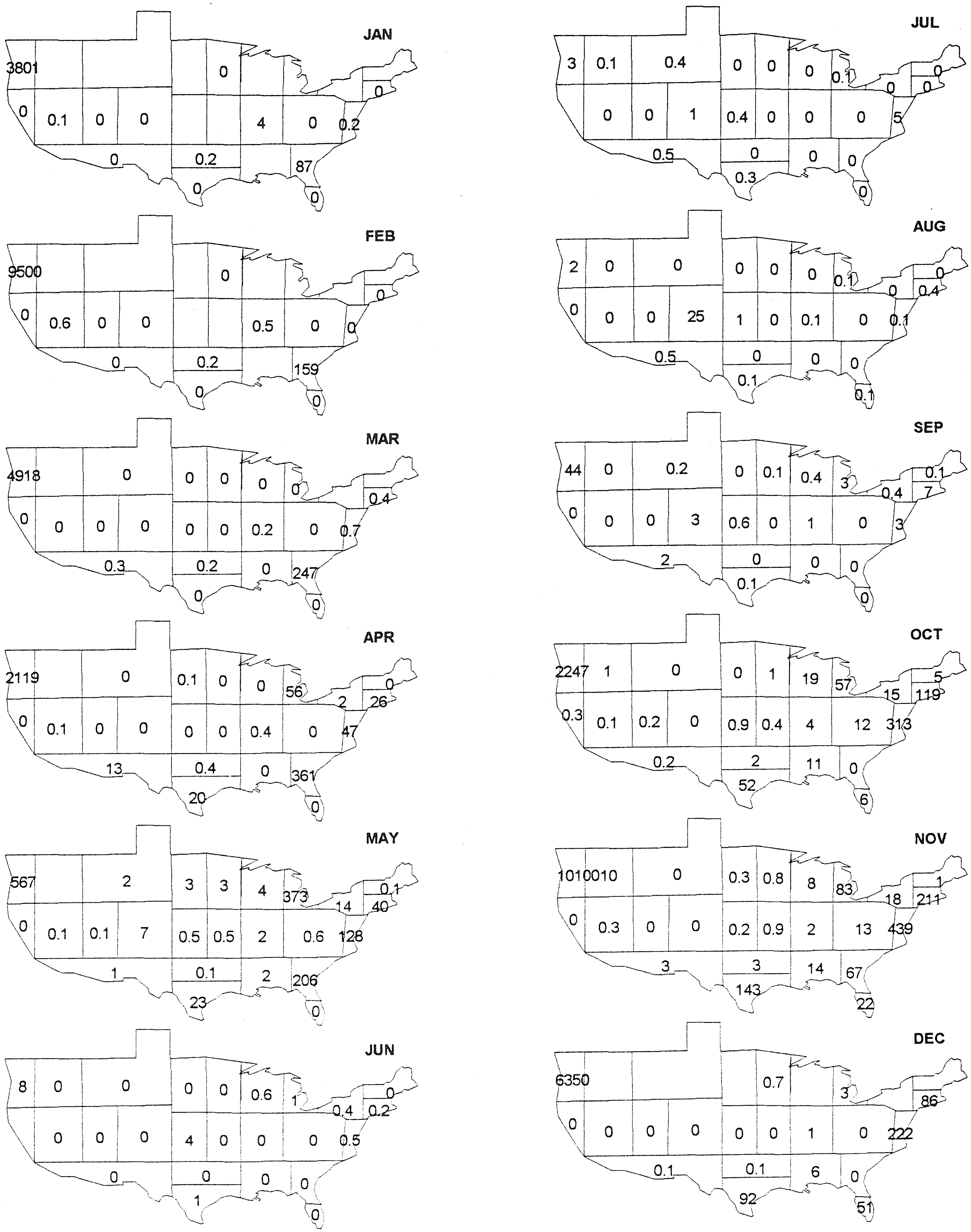
PECTORAL SANDPIPER



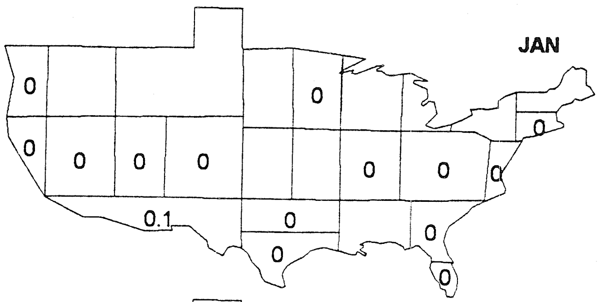
PURPLE SANDPIPER

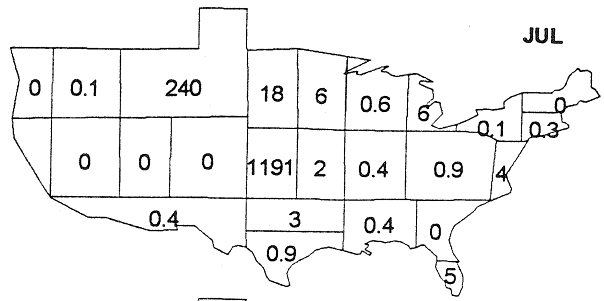


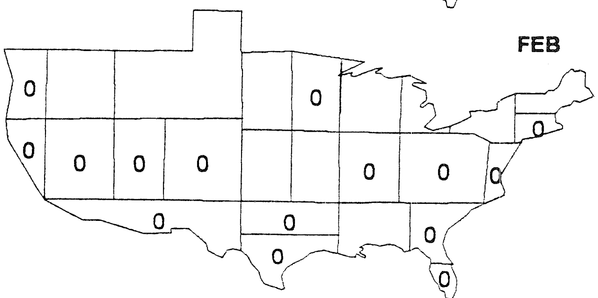
DUNLIN

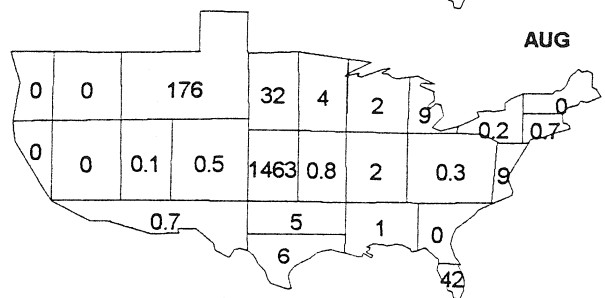

JAN
3801 0 0 0.1 0 0 4 0 0.2 0 0.2 87 0 0 0
FEB
9500 0 0 0.6 0 0 0.5 0 0 0 0.2 159 0 0 0
MAR
4918 0 0 0 0 0 0.4 0 0 0 0 0 0 0.2 0 0.7 0.3 0.2 0 247 0 0
APR
2119 0 0.1 0 0 56 2 26 0 0 0.1 0 0 0 0 0.4 0 47 13 0.4 0 361 20 0
MAY
567 2 3 3 4 373 14 40 0.1 0 0.1 0.1 7 0.5 0.5 2 0.6 128 1 0.1 2 206 23 0
JUN
8 0 0 0 0 0.6 1 0.4 0.2 0 0 0 0 4 0 0 0 0.5 0 0 0 0 1 0
JUL
3 0.1 0.4 0 0 0 0.1 0 0 0 0 0 1 0.4 0 0 0 5 0.5 0 0 0 0.3 0
AUG
2 0 0 0 0 0 0.1 0 0.4 0 0 0 0 25 1 0 0.1 0 0.1 0.5 0 0 0 0.1 0.1
SEP
44 0 0.2 0 0.1 0.4 3 0.4 7 0.1 0 0 0 3 0.6 0 1 0 3 2 0 0 0 0.1 0
OCT
2247 1 0 0 1 19 57 15 119 5 0.3 0.1 0.2 0 0.9 0.4 4 12 313 0.2 2 11 0 52 6
NOV
1010010 0 0.3 0.8 8 83 18 211 1 0 0.3 0 0 0.2 0.9 2 13 439 3 3 14 67 143 22
DEC
6350 0.7 3 86 0 0 0 0 0 0 1 0 222 0.1 0.1 6 0 92 51

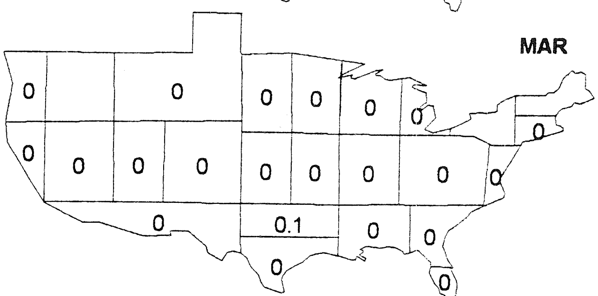
STILT SANDPIPER

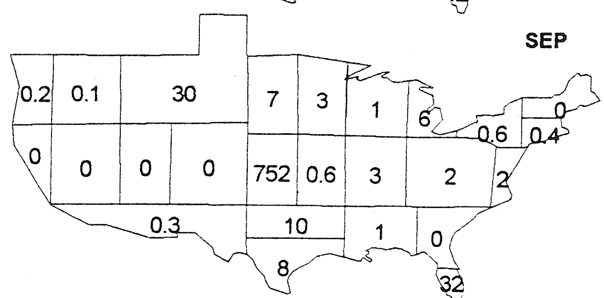


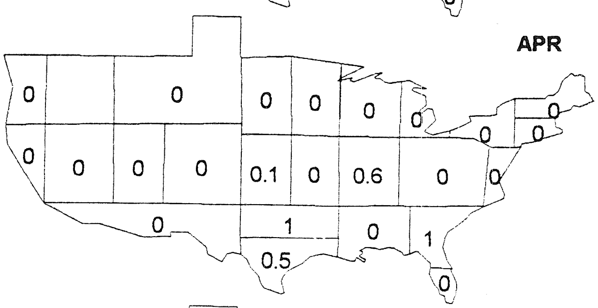


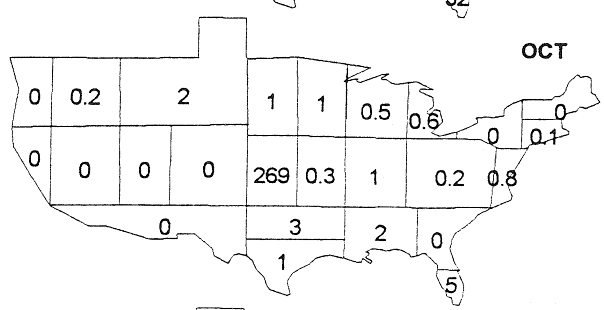


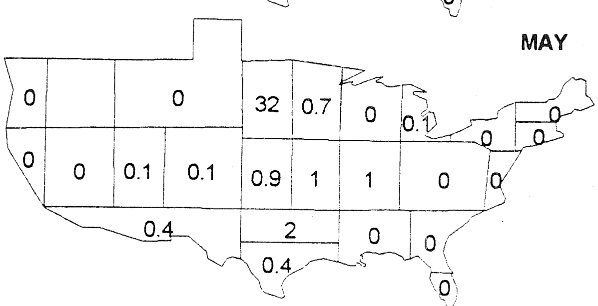


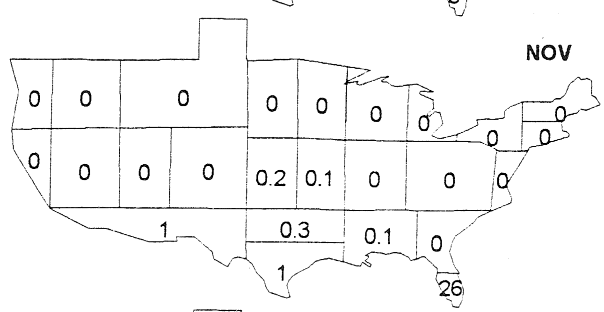


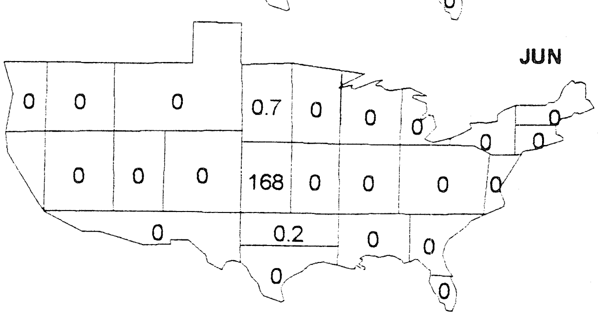


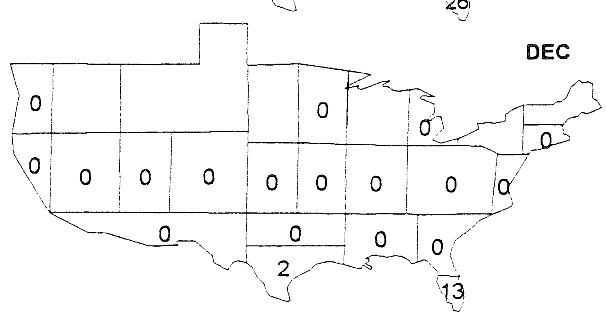




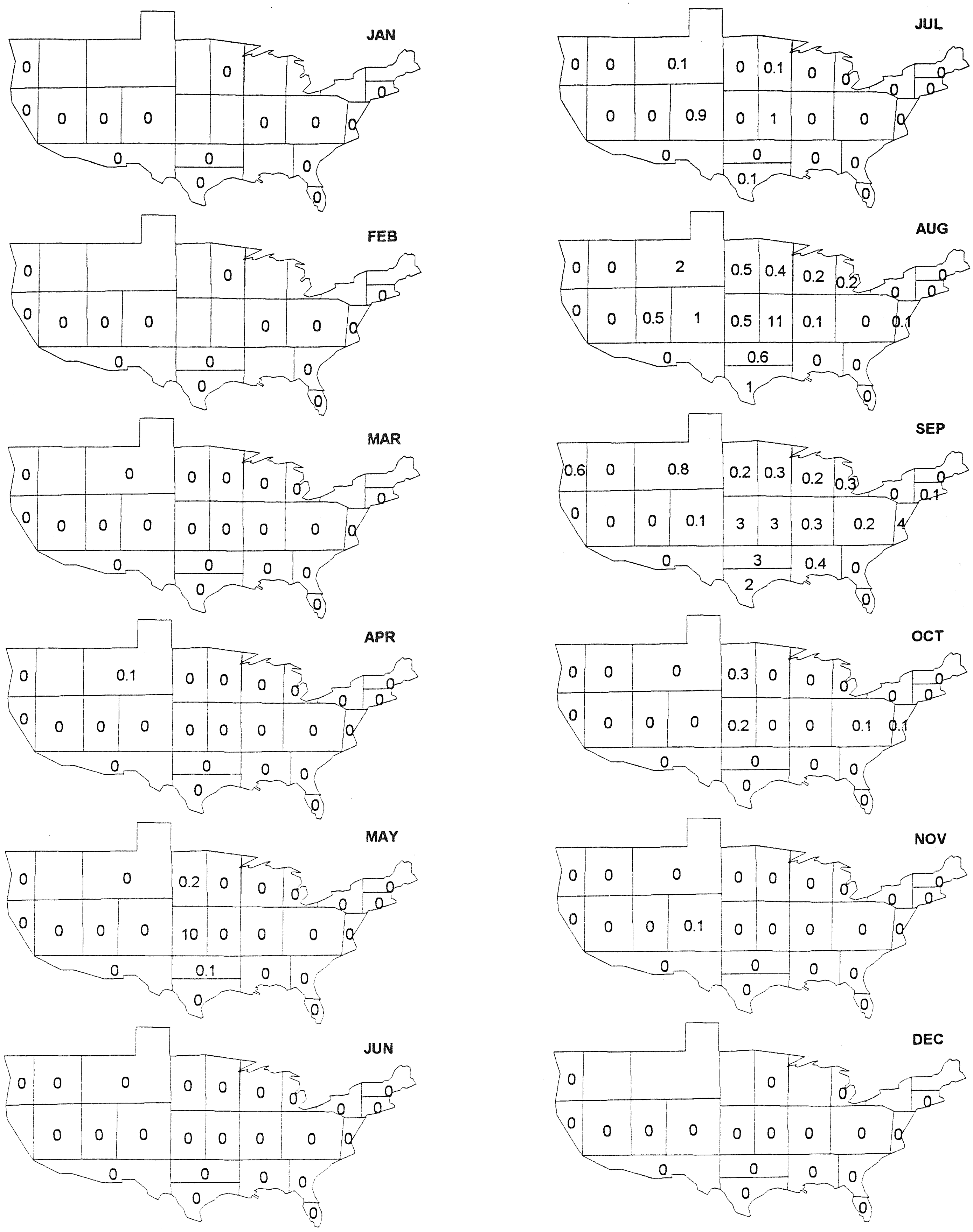




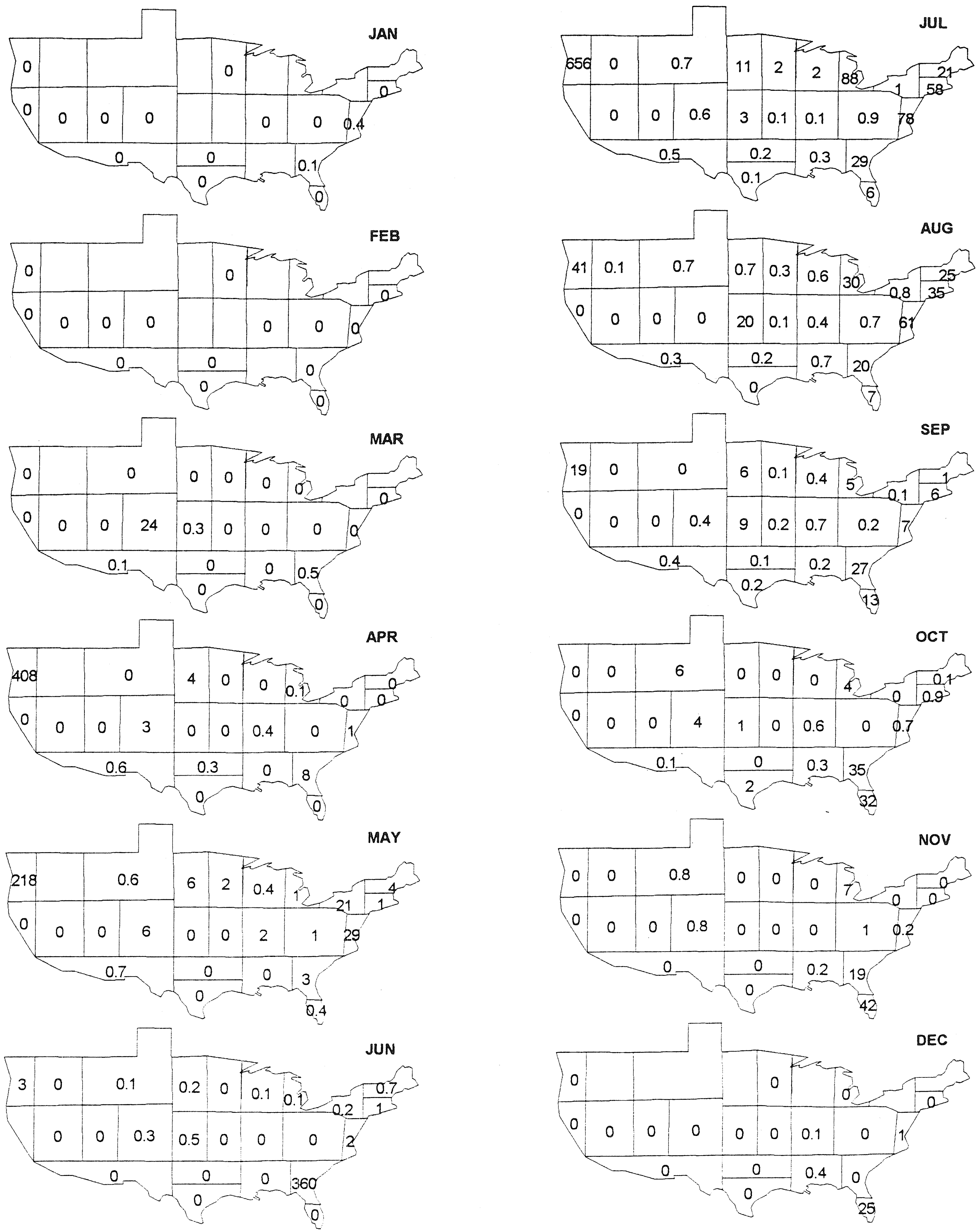




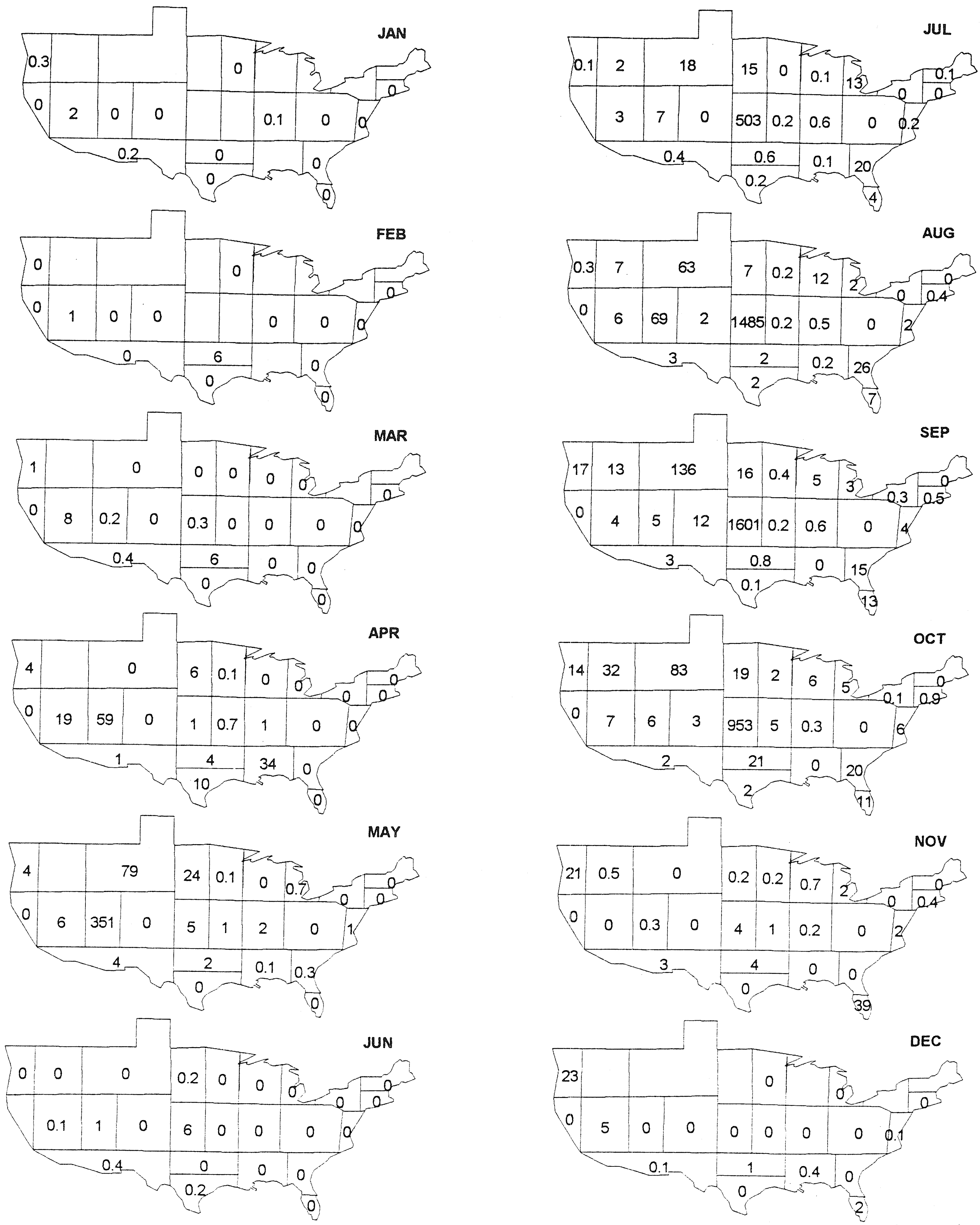
BUFF-BREASTED SANDPIPER



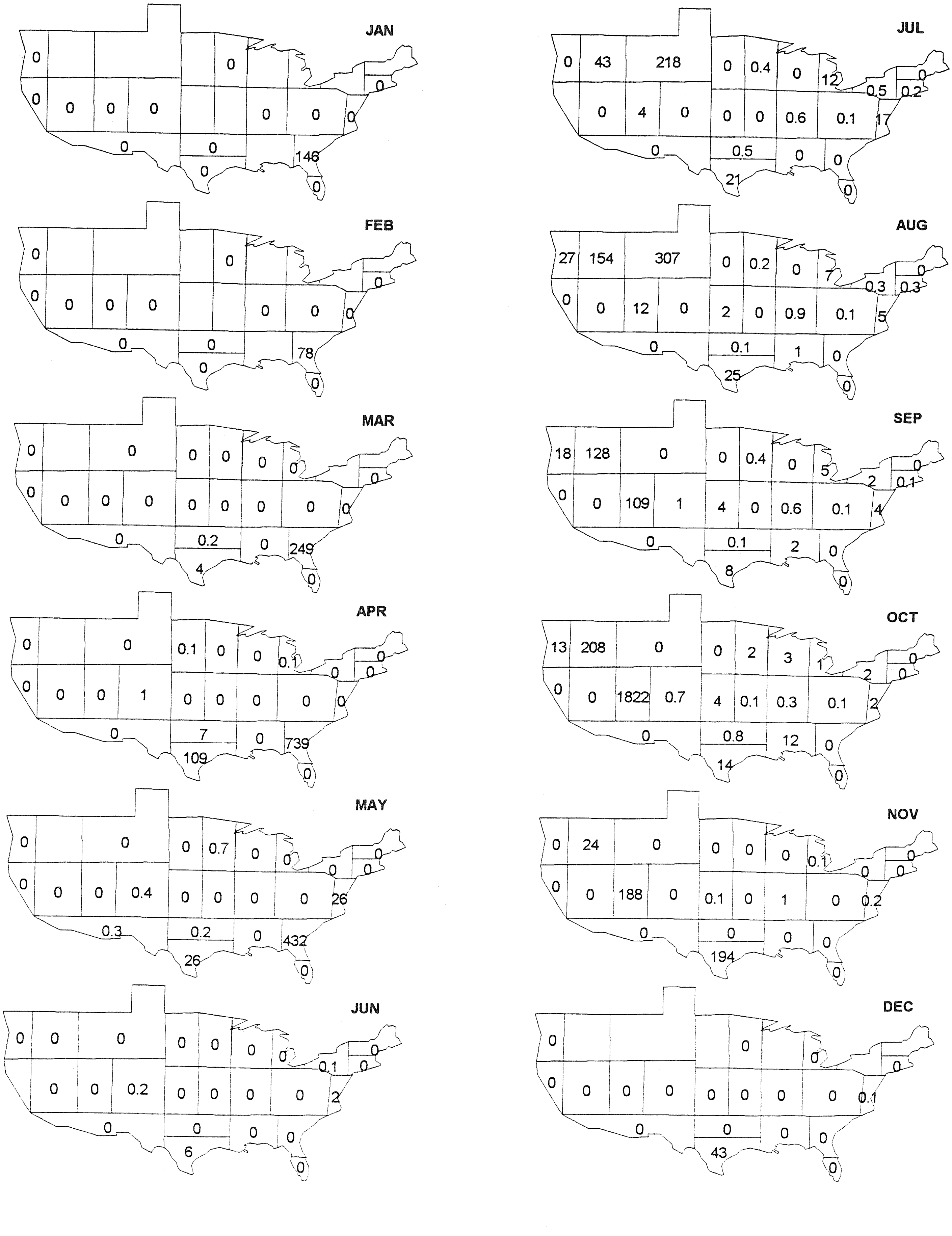
SHORT-BILLED DOWITCHER



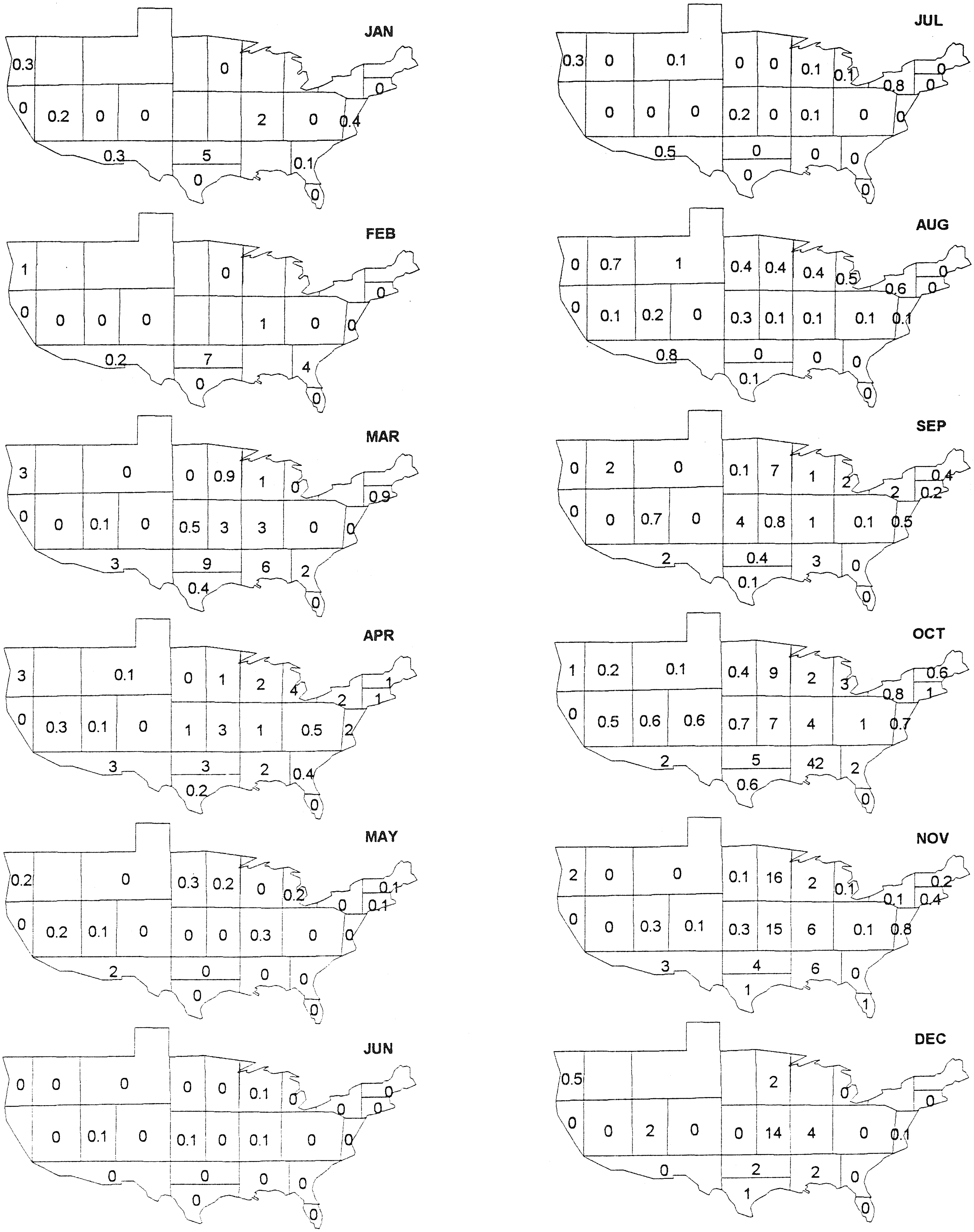
LONG-BILLED DOWITCHER



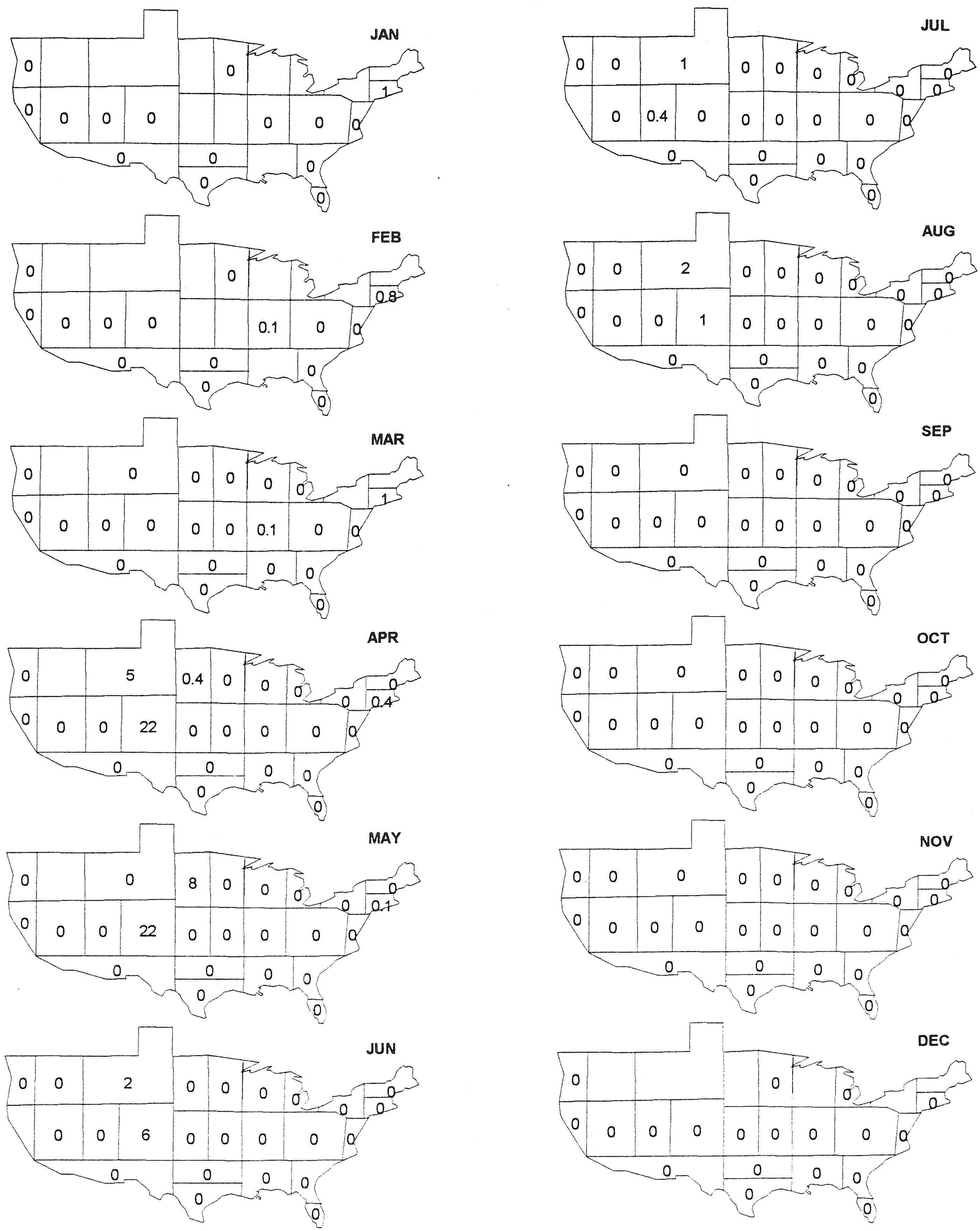
DOWITCHER species



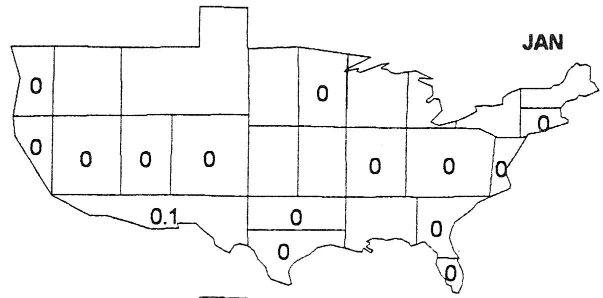
COMMON SNIPE

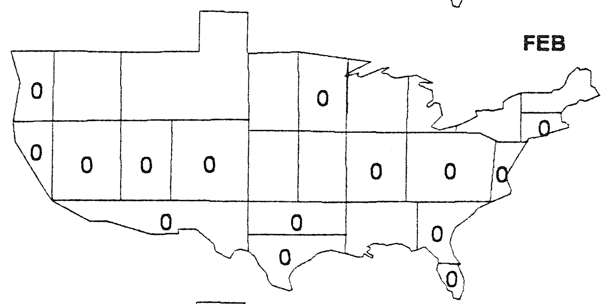


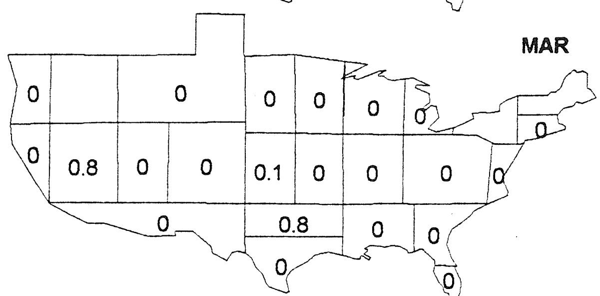
AMERICAN WOODCOCK

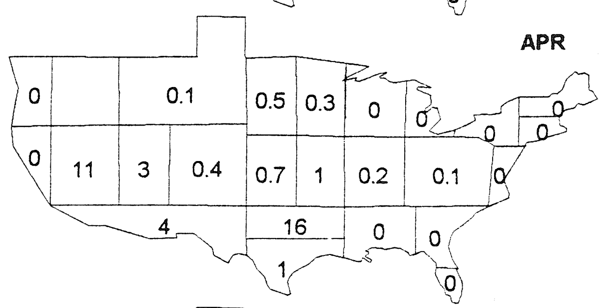


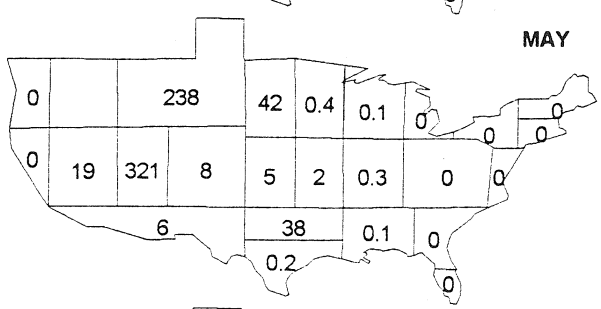
WILSON'S PHALAROPE

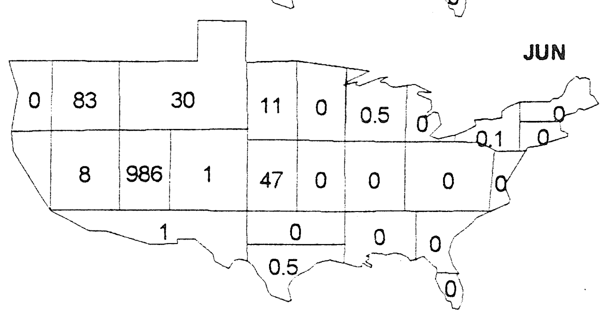


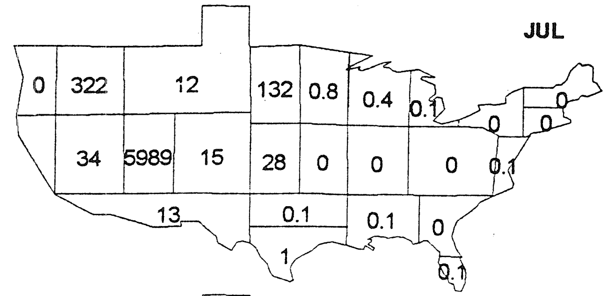


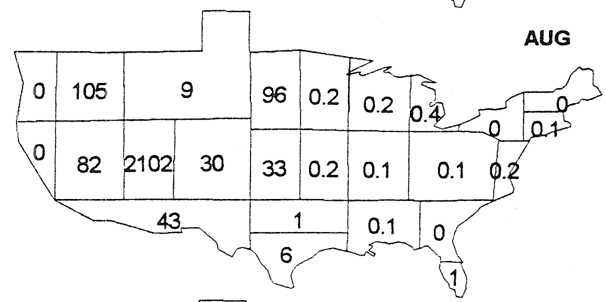


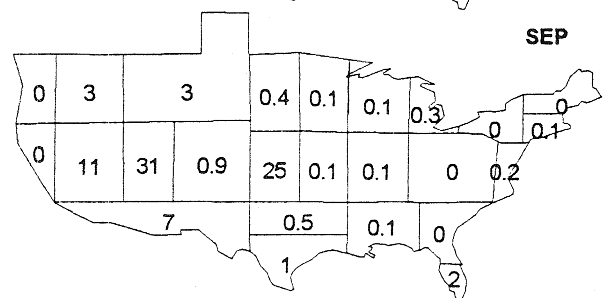


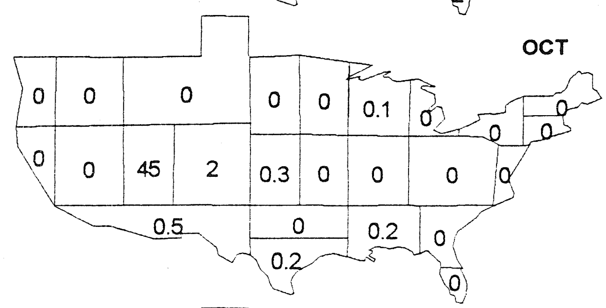


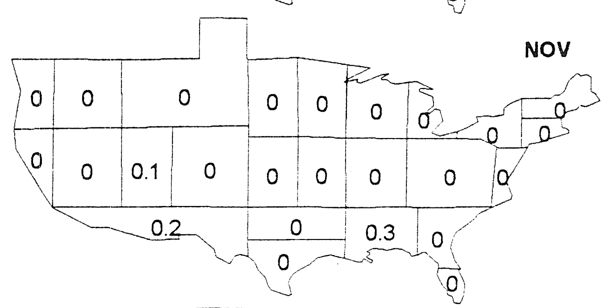


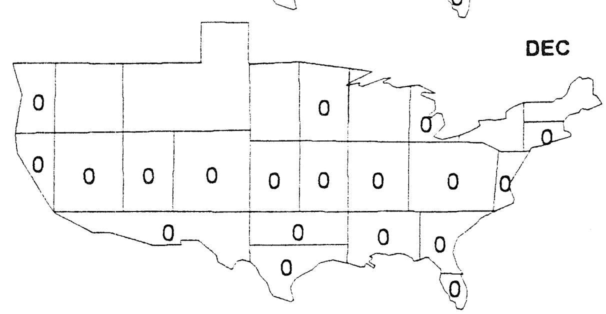




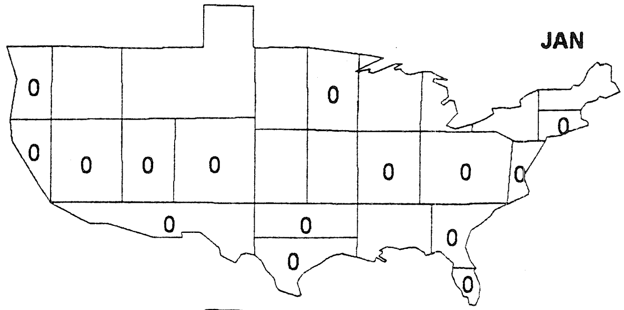


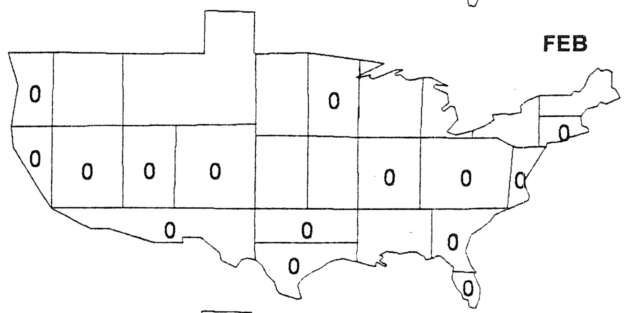


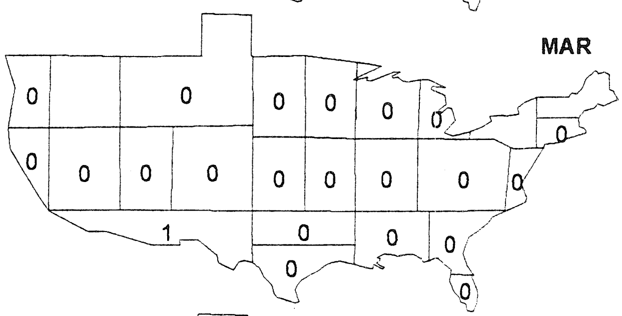


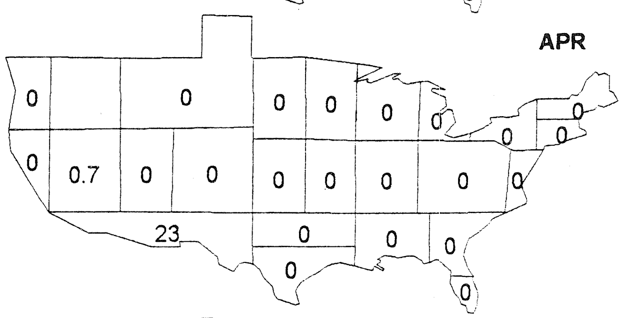


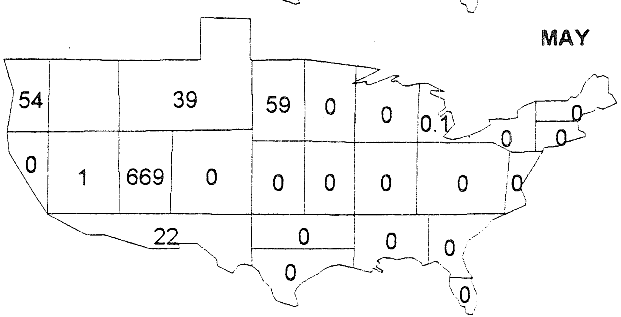
RED-NECKED PHALAROPE

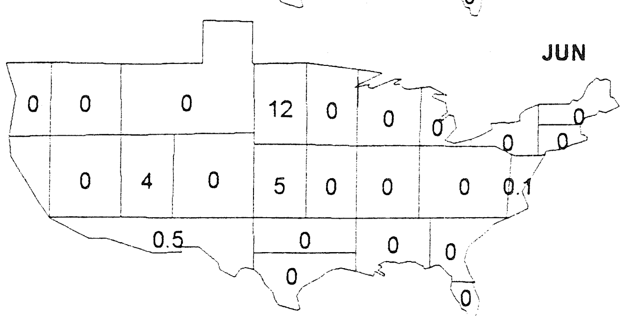


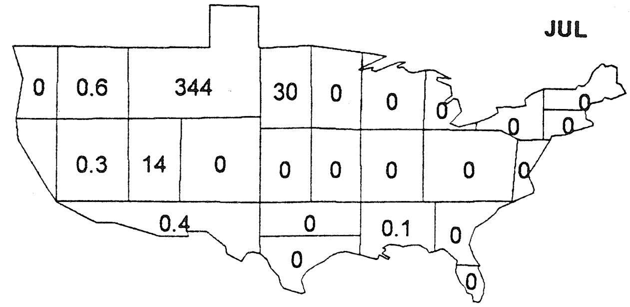


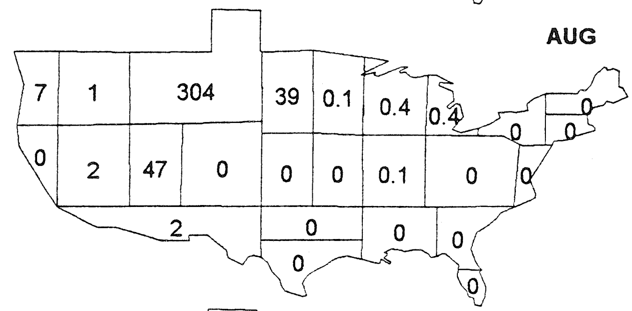


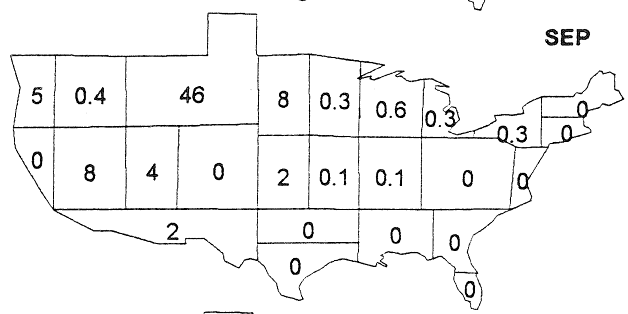


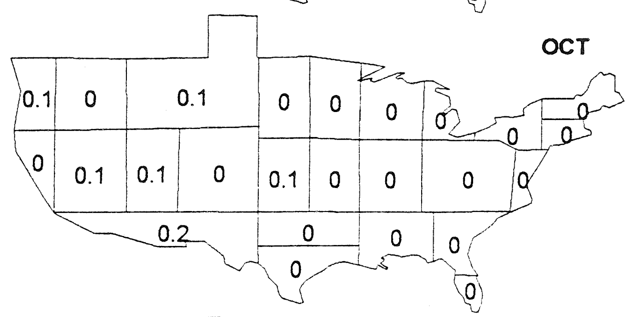


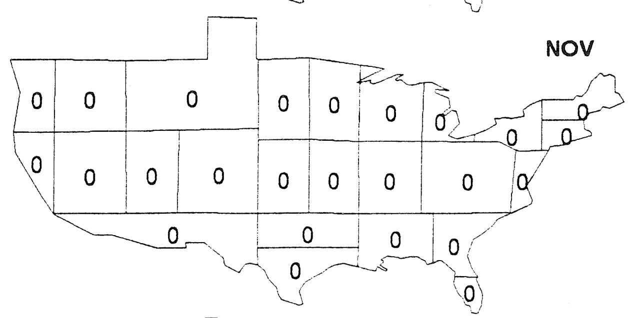


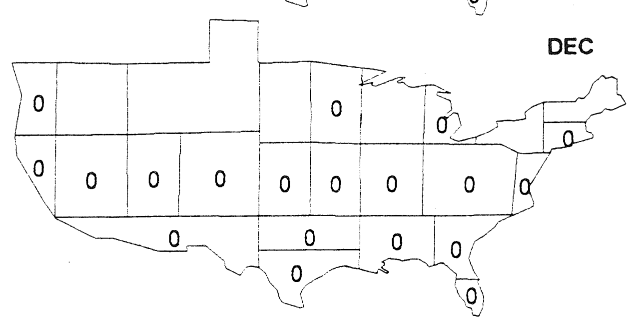












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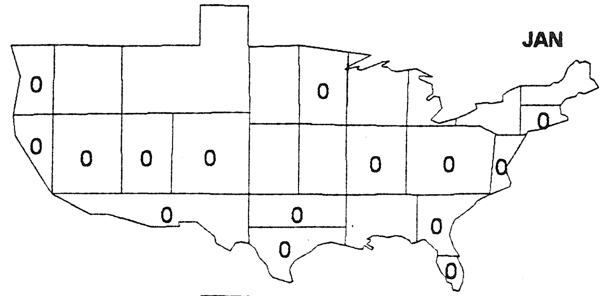

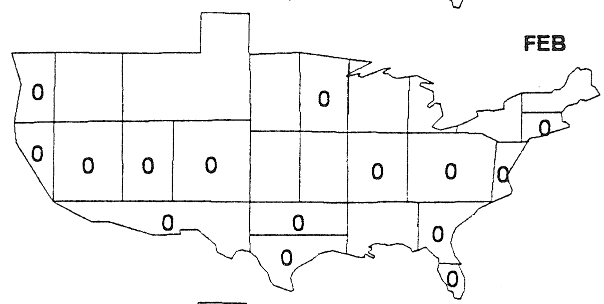

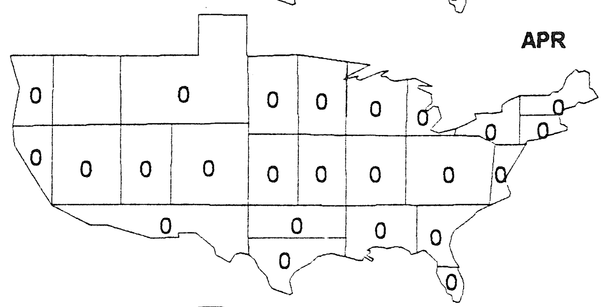

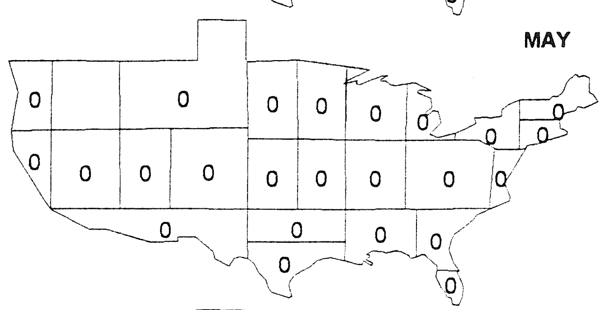

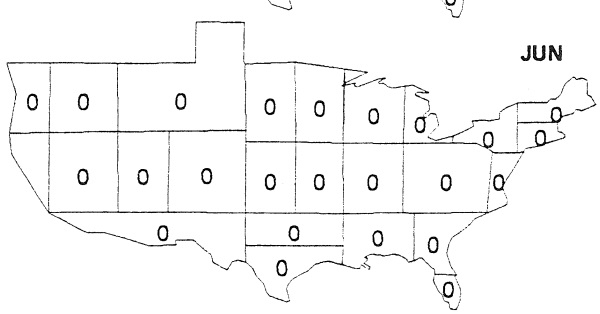

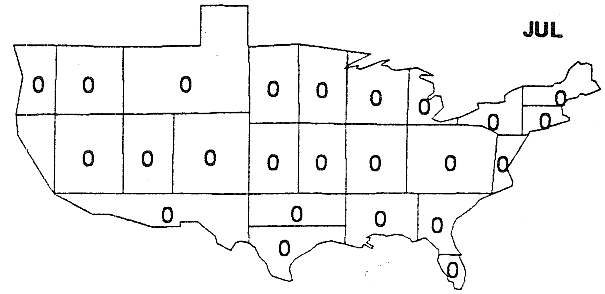

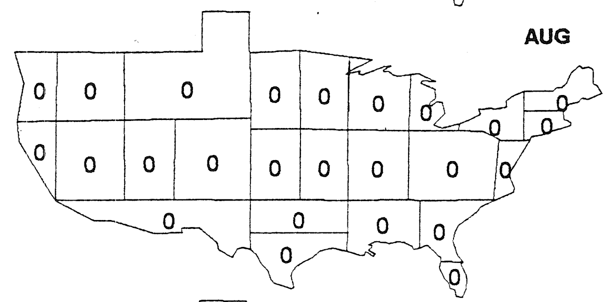

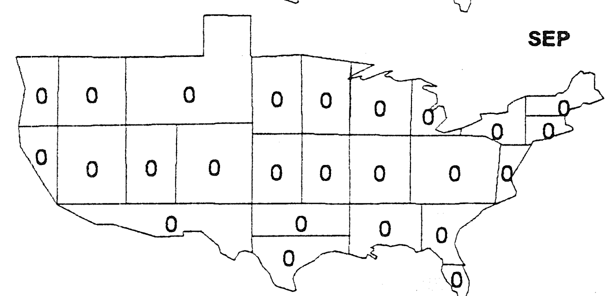

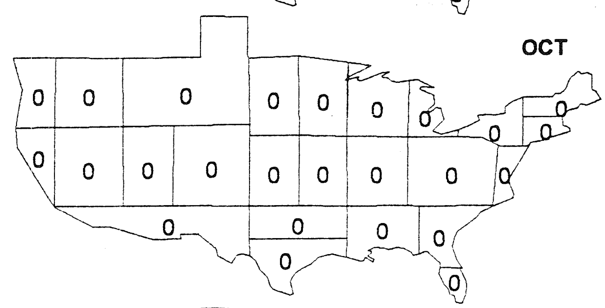

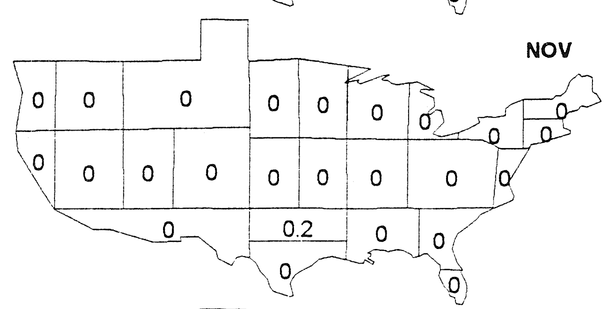

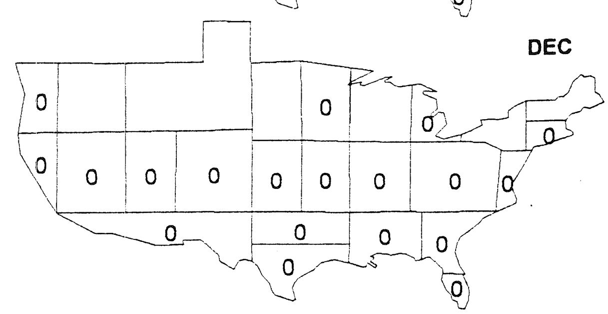

Appendix Three

Derivation of formulas for the standard error of the estimated trend, exp(b_1)

This appendix presents the derivation of formulas for the standard error of the trend estimate, e^b, discussed in the main report. General formulas to calculate the estimated standard error and to carry out power analyses are provided and then special cases applicable to specified sampling plans and analytic methods are discussed. I am not aware of these formulas having been derived before.

Notation and assumptions

Sample values and estimates are denoted with lower case letters, population or "true" values are denoted with upper case letters. For example, *SE(y)* is the true standard error of the random variable *y*, *se(y)* is an estimate of *SE(y)*. I also use the "hat" to indicate an estimate, for example $\hat{\bar{Y}}$ means an estimate of $\bar{Y}$. Notation is developed for the case in which surveys always cover entire sites but cases in which sites are sub-divided and surveys cover only part of a site are also discussed. The mean of all possible surveys that might be conducted in a specified area and period is referred to below as the mean/potential survey. The word population refers to the statistical population (not the shorebird population) and consists of all the places and times at which surveys might occur. The entire statistical population thus has two dimensions, space and time. I often use population in referring to one of the dimensions such as the "number of sites in the population" meaning the set of all sites that might be included in the sample.

Let

L = the number of years for which we have data

X_j = the value of year j (e.g., if we had data from 1981 to 1990 then L would be 10 and X_1 would be 1981)

N = the number of sites in the population; assumed constant between years

n_j = the number of sites surveyed in year j

$n_{j1,j2}$ = the number of sites surveyed in both of two years, $j1$ and $j2$

m_{ij} = the number of surveys in year j at site i

M = the total number of times in a year at which surveys might be conducted; M is used in some of the formulas for explanatory purposes but its numerical value does not need to be specified

y_{ijk} = the number of birds recorded (or that would be recorded) at time k in year j at site i

$\bar{Y}_{ij} = \sum \bar{y}_{ijk} / M$, $k=1,\ldots,M$, = the mean number of birds/potential survey in year j at site i

$\bar{Y}_j = \sum \bar{Y}_{ij} / N$, $i = 1,\ldots,N$, = the mean number of birds/potential survey at all sites in the population in year j

$\bar{y}_j$ = an estimate of $\bar{Y}_j$, for example $\bar{y}_j = \sum \bar{y}_{ij} / n_j$

$E(\bar{y}_{ij})$ = the expected value of $\bar{y}_{ij}$, that is the average value of $[(\bar{y}_{ij})_1 + (\bar{y}_{ij})_2 + \ldots]$ where each element in the series is an estimate obtained in year *j* from site *i* using the same sampling and analytic methods as was used to obtain $\bar{y}_{ij}$

$E(\bar{y}_j)$ = the expected value of $\bar{y}_j$, that is the average value of $[(\bar{y}_j)_1 + (\bar{y}_j)_2 + \ldots]$ where each element in the series is an estimate obtained in year *j* using the same sampling and analytic methods as was used to obtain $\bar{y}_j$

$b = b_1 = \dfrac{cov(X_j, \ln \bar{y}_j)}{Var(X_j)}$ is the estimated trend, as discussed in the main report (for simplicity, the subscript is omitted in this appendix)

$\beta = \dfrac{Cov[X_j, \ln E(\bar{y}_j)]}{Var(X_j)}$, the least squares, exponential curve fitted to the expected values of the estimated means/year; defined as the "true" trend that *b* is used to estimate

The $E(\bar{y}_{ij})$ and $E(\bar{y}_j)$ must be estimated to estimate the standard error of the trend. Formulas for the estimators are provided below. Note that none of the definitions involve the number of birds actually present and that none of them specify a particular sampling plan or analytic method.

The major assumption in the derivations is that survey days are selected independently in different sites and years. As a result, the covariance of the means at two sites in a given year, $Cov(\bar{y}_{i1,j}, \bar{y}_{i2,j})$, equals 0.0 and the covariance of the means at a given site in two years, $Cov(\bar{y}_{i,j1}, \bar{y}_{i,j2})$, equals 0.0. The assumption of independent selection within years (at different sites) might be suspect if surveys are made largely on the same days, for example weekends, though the actual covariance would presumably be substantial only for sites fairly close together. The assumption of independent selection within sites (in different years) is probably reasonable even if surveys are conducted largely on weekends because of year-specific differences in migration phenology. If surveys do not cover the entire site, then the assumption of independence requires that a new, independent sample of areas be selected each year.

Expressions are derived for the variance of the estimated trend, $Var(e^b)$. The standard error of the estimated trend is the square root of $Var(e^b)$.

General formulas for the variance of the trend and the estimated variance

The variance of the estimated trend is derived by applying the Taylor series expansion twice and then deriving expressions for the resulting variances and covariances using standard results from sampling theory.

unit. Cochran considers the case of a single mean and simple random sampling at both stages but many of the results hold equally well for the covariance of two means and for any sampling method at the second stage.

Selection of the $n_{j1,j2}$ sites

1. Simple random sample of sites

If the n_{j_1,j_2} sites are selected by simple random sampling then the estimated means per year will probably be the simple means of the survey results from sites surveyed in both years,

$$\bar{y}_{j1} = \frac{1}{n_{j1,j2}} \sum_{i}^{n_{j1,j2}} \bar{y}_{i,j1}, \quad \bar{y}_{j2} = \frac{1}{n_{j1,j2}} \sum_{i}^{n_{j1,j2}} \bar{y}_{i,j2} \quad , \tag{A3.8}$$

in which case the covariance (assuming m_{ij}/M small) is

$$Cov(\bar{y}_{j1}, \bar{y}_{j2}) = \frac{1}{n_{j1,j2}} \left[(1-f_1)Cov_B(\bar{Y}_{i,j1}, \bar{Y}_{i,j2}) + \overline{Cov}_W(\bar{y}_{i,j1}, \bar{y}_{i,j2})\right] \tag{A3.9}$$

where $f_1 = n_{j_1,j_2}/N$ is the "finite population correction" (fpc) and

$$Cov_B(\bar{Y}_{i,j1}, \bar{Y}_{i,j2}) = \frac{\sum_{i}^{N}(\bar{Y}_{i,j1} - \bar{Y}_{j1})(\bar{Y}_{i,j2} - \bar{Y}_{j2})}{N-1} \tag{A3.10}$$

with

$$\overline{Cov}_W(\bar{y}_{i,j1}, \bar{y}_{i,j2}) = \frac{1}{N}\sum_{i}^{N} Cov_{Wi}(\bar{y}_{i,j1}, \bar{y}_{i,j2}) = \frac{1}{N}\sum_{i}^{N} E[\bar{y}_{i,j1} - E(\bar{y}_{i,j1})][\bar{y}_{i,j2} - E(\bar{y}_{i,j2})]. \tag{A3.11}$$

An unbiased estimate of $Cov(\bar{y}_{j1}, \bar{y}_{j2})$ is provided by

$$C\hat{o}v(\bar{y}_{j1}, \bar{y}_{j2}) = \frac{(1-f_1)\,\mathrm{cov}_B(\bar{y}_{i,j1}, \bar{y}_{i,j2})}{n_{j1,j2}} + \frac{f_1}{n_{j1,j2}} \sum_{i}^{n_{j1,j2}} C\hat{o}v_{Wi}(\bar{y}_{i,j1}, \bar{y}_{i,j2}) \tag{A3.12}$$

where

$$\mathrm{cov}_B(\bar{y}_{i,j1}, \bar{y}_{i,j2}) = \frac{\sum_{i}^{n_{j1,j2}}[\bar{y}_{i,j1} - \hat{E}(\bar{y}_{j1})][\bar{y}_{i,j2} - \hat{E}(\bar{y}_{j2})]}{n_{j1,j2} - 1}, \tag{A3.13}$$

where $\hat{E}(\bar{y}_{i,j1})$ and $\hat{E}(\bar{y}_{i,j1})$ are unbiased estimates of $E(\bar{y}_{i,j1})$ and $E(\bar{y}_{i,j1})$, and $\hat{Cov}_{Wi}(\bar{y}_{i,j1}, \bar{y}_{i,j2})$ is an unbiased estimate of $Cov_{Wi}(\bar{y}_{i,j1}, \bar{y}_{i,j2})$ as defined in (A3.11). Formulas for the quantities in (A3.11-13) depend on the procedures followed within sites as discussed below (pages 7-10).

When the sites are selected using simple random selection, then the denominator in formula (A3.7) may be calculated using all sites surveyed in each year or only the $n_{j_1 j_2}$ sites surveyed in both years $j1$ and $j2$ (and used to calculate the numerator). This issue may warrant further consideration. I followed the latter approach.

2. Simple random sample of sites; N large

If the population is large relative to the sample size (e.g., $f_1 = n_{j1,j2}/N < 0.1$) then the right-most term in (A3.12) contributes little to the covariance and hence may be ignored. This case has important implications for estimation because the $Cov(\bar{y}_{j1}, \bar{y}_{j2})$ can then be estimated without estimating the within-site covariances.

3. Stratified sample of sites

If the sites are selected by stratified sampling then general formulas for the estimated means and their covariances (modified from Cochran 1977, pp. 91-92), with ST for "stratified", are

$$\bar{y}_{ST,j1} = \sum_h^H \frac{N_h}{N}\left(\frac{1}{n_{h,j1}}\sum_i^{n_{h,j1}} \bar{y}_{h,i,j1}\right), \quad \bar{y}_{ST,j2} = \sum_h^H \frac{N_h}{N}\left(\frac{1}{n_{h,j2}}\sum_i^{n_{h,j2}} \bar{y}_{h,i,j2}\right) \tag{A3.14}$$

and

$$Cov_{ST}(\bar{y}_{j1}, \bar{y}_{j2}) = \sum_h^H \left(\frac{N_h}{N}\right)^2 Cov_h(\bar{y}_{h,j1}, \bar{y}_{h,j2}). \tag{A3.15}$$

where the subscript h indicates stratum number and H = the number of strata. The procedure is thus (1) make estimates for each stratum calculated as though the sites in the stratum comprised the entire population, and then (2) combine the estimates using the weights (N_h/N) for the means and $(N_h/N)^2$ for the covariances. Note that the N_H must be know to use these formulas.

4. Some sites selected non-randomly

In any shorebird monitoring program, many of the sites will be selected non-randomly. One approach, during analysis, is to ignore this fact and proceed as though the sites had been selected randomly from a larger population of sites. This procedure is common in wildlife

studies. For example, we may select the first n individuals of a species that we encounter, but then proceed as though they were a simple random sample. One way to justify such a procedure is by asserting that the items in the sample presumably represent *some* population of interest, even though we may not be able to define the population exactly. This rationale might be satisfactory for some shorebird sites. For example, if a set of prairie pothole ponds along roads are surveyed, we might not be too uncomfortable asserting that they may be treated as a simple random (or perhaps cluster) sample from ponds in the study area. In other cases, however, this rationale may not seem reasonable at all. For example, if a region has 10 outstanding shorebird concentration sites, and surveys are conducted at all of them, it may make little sense to regard them as having been selected from a larger population of sites.

If asserting that the selected sites are a random sample from some larger population does not seem reasonable then a preferable alternative is to assign all the non-randomly selected sites to one stratum and use the formulas described in case 3 above. In the stratum with non-randomly selected sties $n_h = N_h$, $1\text{-}f_{h,1} = 0$, and the $\hat{Cov}_h(\bar{y}_{h,j1}, \bar{y}_{h,j2})$ thus depend only on the covariances within sites as indicated in formula (A3.12).

Estimates within sites

Estimates, $\bar{y}_{i,j1}$ and $\bar{y}_{i,j2}$, of the true within-site means, $\bar{Y}_{i,j1}$ and $\bar{Y}_{i,j2}$, must always be made. As noted in Case 2 above, estimates of the within-site covariances only need to be made if the first-stage fpc, f_1 (or $f_{h,1}$ if stratified sampling is used) are substantial (e.g., > 0.1). The procedures depend on how times for surveys are selected and on whether surveys cover all, or just part of, the site. A given set of surveys may also be analyzed using either parametric (model-based) or non-parametric methods. A few of the cases most likely to apply to shorebird monitoring are discussed below. I assume that each survey covers the entire site except as noted otherwise.

1. Non-parametric methods

The phrase "non-parametric" in this case means that no assumptions about the population are made in estimating the means or their covariances. In *using* the results to carry out statistical tests or build confidence intervals, one must assume that the distribution of the estimates is sufficiently close to a t-distribution that any errors resulting from lack of fit may be ignored. This assumption tends to hold quite well for estimators that are the sums or means of many subsidiary estimators as is the case in estimating trends. I have conducted many simulations to investigate the distributional properties of trend estimates and have seldom (if ever) found a case in which the standard error was small enough that the estimate was useful and yet the lack of fit was large enough to be of concern. Thus, I do not believe we need to worry about this issue with shorebird monitoring.

1a. Times for the surveys are selected using simple random sampling

This case is not of practical importance but is discussed to lay the foundation for discussing more practical approaches. If the survey times are a simple random sample from the times at which surveys might be conducted then the sample means,

$$\bar{y}_{i,j1} = \frac{1}{m_{i,j1}} \sum_{k}^{m_{i,j1}} y_{i,j1,k} \;, \quad \bar{y}_{i,j2} = \frac{1}{m_{i,j2}} \sum_{k}^{m_{i,j2}} y_{i,j2,k} \;,$$

(A3.16)

are unbiased estimates of $E(\bar{y}_{j1})$ and $E(\bar{y}_{j2})$ and may be used as the estimators for these terms, as explained under formula (A3.13), which is thus

$$\mathrm{cov}_B(\bar{y}_{i,j1}, \bar{y}_{i,j2}) = \frac{\sum_{i}^{n_{j1,j2}} (\bar{y}_{i,j1} - \bar{y}_{j1})(\bar{y}_{i,j2} - \bar{y}_{j2})}{n_{j1,j2} - 1} .$$

(A3.17)

The within-site covariances need only be estimated if a substantial fraction of the sites in the population was surveyed (i.e., if $f_1 > 0.1$). Even if this is true, the covariance is 0.0 for $j1 \neq j2$ due to the assumption of independent selection of survey times in different years. For $j1 = j2$ $Cov_{Wi}(\bar{y}_{i,j1}, \bar{y}_{i,j2}) = Var_{Wi}(\bar{y}_{ij})$ which is the variance of the mean of a simple random sample. An unbiased estimate of $Var_{Wi}(\bar{y}_{ij})$ is

$$\hat{Var}_{Wi}(\bar{y}_{i,j}) = (1 - f_{2i})\left(\frac{var(y_{i,j,k})}{m_{i,j}}\right) = \frac{1 - f_{2i}}{m_{i,j}} \left(\frac{\sum_{k}^{m_{i,j}} (y_{i,j,k} - \bar{y}_{i,j})^2}{m_{i,j} - 1} \right)$$

(A3.18)

where f_{2i} = the fraction of the available survey times included in the sample. It is included here to show the relation to standard sampling theory but in the case of shorebird sampling the set of times, M, at which surveys might be collected is indefinitely large so the 1 - f_{2i} may be ignored.

1b. Times for the surveys are selected using systematic sampling

In shorebird surveys, selection of times for the surveys by simple random sampling is neither practical nor desirable. Instead, some sort of systematic sampling is used. If the selection of survey times is carried out in such a way that each potential survey time has an equal chance of entering the sample, then the sample means are still unbiased estimates of their expected values, as with simple random sampling, and thus can be used in (A3.17) to estimate the covariance of the true means/site.

As noted above, if f_1 is small, then there is no need to estimate the within-site variances

which is fortunate because no unbiased way is known of doing so with systematic sampling (Cochran 1977, p. 223-224, 279). If f_1 is appreciable and thus should not be ignored, then the usual way of estimating the within-site variances is by using the formula for simple random sampling (A3.18). This approach yields estimates that, in general, are biased. If the numbers of birds counted on surveys close together tend to be more similar to each other than the numbers on widely spaced surveys (the usual case) then this approach tends to over-estimate the actual within-site variance, sometimes by substantial amounts (e.g., relative bias >50%). Parametric approaches may offer some improvement (see next section).

1c. Surveys do not cover the entire site

If surveys do not cover the entire site, then one approach is to replace y_{ijk} in formulas (A3.16-18) above with estimates,

$$\hat{y}_{ijk} = A_{ijk} y^*_{ijk}$$

where $\hat{y}_{ijk}$ is the estimate of y_{ijk}, y^*_{ijk} is the number of birds recorded on the survey, and A_{ijk} is an adjustment factor, for example (1/proportion of the site covered). The $\hat{y}_{ijk}$ may be used in the formulas above (pages 5-9). If the areas covered on each survey are selected independently on each survey and $E(\hat{y}_{ijk}) = y_{ijk}$, then all results above remain valid. If the same areas are covered on each survey within years or $E(\hat{y}_{ijk}) \neq y_{ijk}$ then care must be exercised in determining the form and properties of the estimators.

2. Parametric estimators

As noted above, survey times will generally be selected in a more or less systematic manner and, if within-site variances need to be estimated, no completely unbiased general method is known for making the estimates. When a model can be specified describing the distribution of the potential survey results, then estimators for the within-site variance may be available with substantially less bias than the simple random sampling estimator. Furthermore, if such models use additional external variables to calculate the estimated mean/site, then the true variances may be reduced. Two general classes of estimator are discussed below.

2a. Polynomial regression

If shorebird numbers tend to increase and then decrease smoothly rather than in a highly erratic manner, then polynomial regression (using time as the independent variable) may be a reasonable approach. The model assumptions will never be fully met so the estimators, including the within-site variance, will be somewhat biased but the bias may be substantially smaller than if the formula for simple random sampling is used. Furthermore, if the times are not selected under a well-defined plan and are concentrated in one portion of the study period then the simple mean may not be a very satisfactory estimator and the estimated mean produced by the regression model may be preferable.

2b. Models using weather and habitat variables

Much opportunity exists for building models, perhaps site-specific ones, to predict shorebird numbers as functions of weather and/or habitat variables. The opportunity is probably greatest in cases where the number of birds fluctuates radically between surveys (within or between years) but the reasons are fairly obvious such as the appearance of following winds or water levels that produce either favorable or unfavorable conditions. A large data set exists that could be used to build and test such models. The results would also help us better understand shorebird movements. I hope to develop a sample of such models in the later stages of this project.

Power calculations

Expression (A3.7), with the appropriate formulas for the estimators, provides a suitable way to estimate the standard error for a given data set. It does not provide a suitable method for carrying out power calculations, however, because it has too many terms (among other reasons). For power calculations we need a simpler formula with only a few variables that can then be manipulated to show the influence of each in determining the standard error of the trend. In deriving the needed formula for the true variance, (A3.5), it is helpful to separate terms in the sum where $j1=j2$ from those in which $j1 \neq j2$. From (A3.5), this yields

$$Var(e^b) \cong (e^\beta)^2 \left[\sum_j^L C_j^2 \frac{Var(\bar{y}_j)}{[E(\bar{y}_j)]^2} + \sum_{j1\neq}^L \sum_{j2}^L \frac{C_{j1} C_{j2} Cov(\bar{y}_{j1}, \bar{y}_{j2})}{E(\bar{y}_{j1}) E(\bar{y}_{j2})} \right].$$

(A3.19)

As noted in the previous sections, formulas for the estimators depend on the sampling plan and analytic methods. In this section, I develop a formula for simple random sampling of sites, but if stratified sampling or some other method were used the appropriate power formulas could be derived fairly easily following the same approach as used below. I also assume that $\bar{y}_{j1}$ and $\bar{y}_{j2}$ are unbiased estimates of $E(\bar{y}_{j1})$ and $E(\bar{y}_{j2})$ as would be true (or at least nearly true) with any standard sample selection plan and non-parametric estimation (but not necessarily with parametric estimation). The needed formulas are given on p. 5 (A3.8-11) and p. 8 (A3.17-18). When $j_1=j_2$ (A3.9) becomes

$$Cov(\bar{y}_{j1}, \bar{y}_{j2}) = Var(\bar{y}_j) = \frac{1}{n_j} \left[(1-f_1) Var_B(\bar{Y}_{i,j}) + (1-f_2) \overline{Var}_W(\bar{y}_{i,j}) \right)$$

(A3.20)

where the Var_B and $\overline{Var}_W$ are given by (A3.10) and (A3.11), with $j_1=j_2$, whereas for $j_1 \neq j_2$, (A3.9) remains the same,

$$Cov(\bar{y}_{j1},\bar{y}_{j2}) \;=\; \frac{1}{n_{j1,j2}}\Big[(1-f_1)Cov_B(\bar{Y}_{i,j1},\bar{Y}_{i,j2}) \;+\; \overline{Cov}_W(\bar{y}_{i,j1},\bar{y}_{i,j2})\Big] \;.$$

(A3.21)

In estimating the variance from a given sample, it was pointed out above that the variance within sites must only be estimated if the first-stage fpc is appreciable. In power estimation, however, one goal is to determine how effort should be allocated to achieving more visits per site vs. more sites. We thus need a formula that explicitly recognizes the role of variation and procedures within sites. We therefore present estimators for both components of the variance.

The sample analogue of Var_B, as in (A3.17), with j_1=j_2, tends to over-estimate Var_B. An unbiased estimator is

$$V\hat{a}r_B(\bar{Y}_{i,j}) = var_B(\bar{y}_{i,j}) - \overline{V\hat{a}r}_W(\bar{y}_{i,j})$$

(A3.22)

where

$$var_B(\bar{y}_{i,j}) \;=\; \frac{\sum_i^{n_j}(\bar{y}_{i,j}-\bar{y}_j)^2}{n_j-1}$$

(A3.23)

and

$$\overline{V\hat{a}r}_W(\bar{y}_{i,j}) = \frac{1}{n_j}\sum_i^{n_j} V\hat{a}r_{Wi}(\bar{y}_{i,j})$$

where $V\hat{a}r_{Wi}(\bar{y}_{i,j})$ is an unbiased estimate of the variance of $\bar{y}_{i,j}$, $E[\bar{y}_{ij}-E(\bar{y}_{ij})]^2$. As noted above (p. 8), with systematic sampling at the second stage no general method is known for estimating $Var_{Wi}(\bar{y}_{i,j})$, and the usual approach is to use the formula for simple random sampling as an alternative although this can result in substantial bias. That estimator is given in (A3.18).

The same form as (A3.22) holds in general for the $C\hat{o}v(\bar{Y}_{i,j1},\bar{Y}_{i,j2})$ but in our case the true covariances within sites are 0.0 due to independent sampling between years. The sample analogue, (A3.17), for the covariance of the true means thus gives an unbiased estimator of $Cov(\bar{y}_{j1},\bar{y}_{j2})$.

The basic estimators have now been presented. The formulas can be consolidated by replacing the sums in (A3.19) by the number of terms in the sum times their average value .

$$Var(e^b) \cong (e^{\beta})^2\left[\overline{LC_j^2}\left[\overline{Var(\bar{y}_j)/[E(\bar{y}_j)]^2}\right] + \overline{L(L-1)C_{j1}C_{j2}[Cov(\bar{y}_{j1},\bar{y}_{j2})/E(\bar{y}_{j1})E(\bar{y}_{j2})}\right.$$

(A3.24)

It seems reasonable to assume that there would be no temporal trend between the constants and the relative variances or relative covariances. In this case, we may express the variance of the trend as

$$Var\left(e^b\right) \cong \left(e^{\beta}\right)^2\left[\left(\overline{LC_j^2}\right)\left(\overline{Var(\bar{y}_j)/[E(\bar{y}_j)]^2}\right) + \left(\overline{L(L-1)C_{j1}C_{j2}}\right)\left(\overline{Cov(\bar{y}_{j1},\bar{y}_{j2})/E(\bar{y}_{j1})E(\bar{y}_{j2})}\right)\right.$$

(A3.25)

In addition, e^{β}, the true trend, will almost always be close to 1.0 and can therefore be ignored in the power calculations. Also, with sequential years and no missing data,

$$\overline{LC_j^2} = (-1)\overline{L(L-1)C_{j1}C_{j2}}\ .$$

(A3.26)

With these approximations, we may write (A3.19) as

$$Var(e^b) \cong \left(\overline{LC_j^2}\right)\left(\overline{Var(\bar{y}_j)/[E(\bar{y}_j)]^2} - \overline{Cov(\bar{y}_{j1},\bar{y}_{j2})/E(\bar{y}_{j1})E(\bar{y}_{j2})}\right).$$

(A3.27)

As a practical matter, we also assume that $n_j = n_{j_1 j_2}$ = n (otherwise all terms in the arrays n_j and $n_{j_1 j_2}$ must be specified). Substituting the estimators and re-arranging terms yields,

$$var(e^b) \cong \frac{\overline{LC_j^2}}{n}\left[\left(\overline{\hat{Var}_W(\bar{y}_{i,j})/\bar{y}_j^2}\right) + (1-f_1)\left(\overline{\hat{Var}_B(\bar{Y}_{i,j})/\bar{y}_j^2} - \overline{\hat{Cov}_B(\bar{Y}_{i,j1},\bar{Y}_{i,j2})/\bar{y}_{j1}\bar{y}_{j2}}\right)\right.$$

(A3.28)

where the estimators for the $\overline{\hat{Var}_W}$ (assuming simple random selection of survey times), $\hat{Var}_B$, and $\hat{Cov}_B$ are given by (A3.18), (A3.22), and (A3.17) respectively.

Note that (A3.28) has the form

$$var(e^b) \cong \frac{c_1}{n}\left[c_2 + (1-f_1)c_3\right]$$

(A3.34)

where c_1 depends only on the number of years (assumed to be sequential) in the study, c_2 depends only on precision of the within-site estimates, and c_3 depends only on the variation between true site means. To investigate the effect of changing the number of visits per site, c_2 would have to be expressed as a function of within-site variability and sample size, c_2^*/m for example where c_2^* = survey-to-survey variation and m is the number of visits per site, as in (A3.18).

One of the major results of this investigation has been to reveal the effect of sites not remaining in the program. This effect was described (Table 2) by estimating the increase in precision that would result if all sites were surveyed each year. This change would only affect c_1

in (A1.34). Since there is no need, for this analysis, to estimate c_2 and c_3 separately their sum can be estimated directly as

$$c_2 + c_3 = \overline{C\hat{o}v(\bar{y}_{j1}, \bar{y}_{j2}) / \bar{y}_{j1}\bar{y}_{j2}} \tag{A3.35}$$

where the formula for $C\hat{o}v(\bar{y}_{j1}, \bar{y}_{j2})$ was given in (A3.12) and for the analysis reported in Table 2, I assumed $f_1 = 0$.

Appendix Four

Means/year for each species (see p. 1-2 for methods)

Species	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98
BBPL	114	90	76	88	70	65	57	85	68	72	75	84	99	66	65	72	53	22	66	87	97	39		
LGPL	5.2	4.3	2.2	2.5	3.6	2.2	1.9	5.2	4.7	6.1	2.8	2.9	4.2	3.4	1.9	1.7	2.5	1.2	1.7	2.5	6.8	4.3		
SNPL	.24	.45	.35	.71	.59	1	.12	.51	.69	1.4	.17	.96	1	2.7	2.4	6.7	8.5	8.9	9.7	3.1	3.1	1.7		
SEPL	54	43	29	44	21	29	27	24	25	30	23	22	18	16	18	26	34	22	40	35	44	43	65	
PIPL	3	1	.74	2	.88	1.9	1.9	1.6	1.3	.64	0.6	.74	.66	.54	0.5	.61	.96	1.1	1.5	1.5	1.2	1.7	6.2	
KILL	4.9	2.7	9.9	6.4	25	11	7.8	11	10	41	12	9.4	29	9.9	6.5	7.2	5.2	4.7	3.2	13	5.5	4.9	27	
AMOY	.61	.56	.63	0.4	.16	.34	.47	.45	.54	.73	1.9	1.9	.99	.81	.87	0.8	0.8	.26	.56	.39	.11	2.2	5.2	
BNST	.01	.01	0	0	.03	.01	.01	.01	.12	.04	.06	1.5	.92	1.2	.43	2.8	11	19	65	64	253	846	1.3	
AMAV	.61	1.1	5.4	5.2	9.9	15	5.1	9.5	6.5	21	23	4.7	5.7	.92	2.5	15	37	50	157	101	253	474	.45	
LEYE	3.8	3.6	3.3	3.7	2.3	2.2	2.4	4.5	3.4	3.7	3.3	2.9	3.9	3	3.1	3.6	3.9	3.9	3.1	2.7	2.5	10	9.4	
GRYE	.07	.08	.04	.03	.02	.08	.25	.06	.03	.44	.08	.07	.86	.07	.24	.44	.37	1.2	.05	.13	0.1	.35	.08	.05
SOSA	.06	0.1	.17	.19	.21	.25	.23	.14	.06	.23	.21	.06	.23	.19	.07	.04	.15	.05	.04	.03	.06	.07	.31	.01
WILL	1.7	1.1	.86	.93	1.2	1.1	1.1	2	1.9	3.5	3	2.4	1.1	.79	2.1	1.9	.59	2.2	2.2	2.3	.54	1	1.9	0
SPSA	.32	.51	0.5	.37	.33	.54	.38	.39	.62	.59	.55	.43	0.5	.32	.32	.31	.24	.29	.33	.29	.34	.14	.88	
UPSA	0	0	0	0	0	.03	0	0	.03	.01	.24	.05	.07	.08	.01	.01	.01	.06	.04	.01	0	0	.02	
WHIM	.43	.33	.35	.29	0.1	.26	.24	.19	.23	.25	.32	.32	.44	0.1	.14	.32	.37	0.4	.39	.08	.09	.29	.67	
LBCU	0	0	0	0	0	0	0	0	.09	0	0	.01	.01	.01	.01	0	.05	.09	.06	.02	.03	.05	.01	
HUGO	.68		.35	.67	.24	.24	.23	.25	.27	.19	.25	.16	0.2	.15	.11	2.9	3.2	.81	2.3	.86	8.6	.17	.79	
MAGO	.07		.03	.04	.01	.04	.01	.18	.19	.23	.11	.25	.03	.01	3.3	1.5	2.3	8.4	25	15	25	147	.05	
RUTU	31	20	17	19	13	15	11	19	22	80	29	23	28	9.3	15	14	15	13	15	18	20	13		
REKN	54	45	39	101	65	67	69	65	111	81	93	40	20	23	21	23	21	3.6	18	62	68	29	14	
SAND	141	98	70	103	40	60	50	51	68	83	88	48	34	21	24	65	128	104	108	73	112	292	152	
SESA	234	182	144	121	100	83	158	128	119	127	106	85	63	51	45	90	92	50	64	96	99	100	100	
WESA	12	36	67	21	18	23	19	72	93	91	43	23	16	4.1	8.3	27	43	24	22	26	10	48	21	
LESA	8.9	44	36	28	14	23	24	53	26	177	15	22	17	5.5	13	28	20	19	13	24	5.7	17	37	
WRSA	.14	.38	.21	.37	.12	.17	.32	.42	.23	1.1	.26	.24	.32	.08	.21	.67	.45	.19	.64	.26	1.6	0.5	4.9	
BASA	2	13	4.3	5.3	7.6	11	.27	1.7	.75	11	.13	.26	2.3	.92	1.9	1.2	1.3	1.7	.79	.52	1	2.9	.61	
PESA	.92	1.4	4.1	6	8.2	6.5	15	16	2.1	24	2.2	3.3	8.2	4.1	2	3.2	6.7	5.7	4.1	11	2.2	.65	21	
DUNL	.77	.32	1.6	.32	.79	.37	.61	7.5	8.5	4.8	3.5	4.3	.27	0.3	33	35	.12	17	18	17	.56	.05	0.1	
STSA	.65	17	16	6.8	1	13	12	34	14	15	2.1	5.1	2.6	.92	1.9	8.6	24	6.6	3.2	2.4	.56	.98	0.2	
BBSA	.02	0.1	0.1	.06	.01	.21	.06	0.2	.14	.25	.11	.21	0.1	.19	.07	.05	.16	.05	.03	.03	.03	.01	0	
SBDO	6.8	3.6	6.7	11	5.9	8.4	6	9.3	9.9	16	12	9.8	6.7	3.2	4.6	5.7	9.1	4.7	4.8	4	2.1	6.1	9.5	
LBDO	.05	7.9	6.2	6.2	11	8.1	22	33	11	38	6.4	10	12	.19	2	19	5.9	27	3.5	9.7	1	.66	1.1	
COSN	.06	.08	.02	.03	.03	0.1	.35	0.4	.02	.09	.05	0	.06	.25	.09	.11	.14	.05	.05	0.2	.26	.12	.02	
WIPH	.03	.07	0.1	.09	.42	.31	.22	.18	1.2	6.6	1	1.5	3.7	.49	.95	5.5	47	43	7.9	2.9	26	13	.98	
RNPH	.06	.02	.01	0	.01	.01	.05	.11	.01	.02	.01	.07	.24	.72	.59	5.7	4.6	5.1	.57	.85	.96	.25	.09	1.3