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A COMPUTER PROGRAM FOR THE ANALYSIS OF MACROINVERTEBRATE DATA F--ETC(U)
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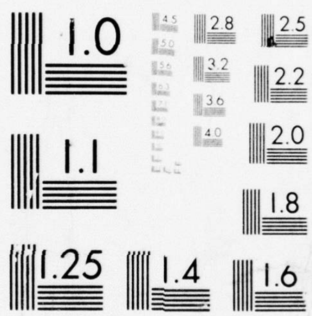

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TECHNICAL REPORT ARCSL-TR-77035

(EO-TR-76102)

A COMPUTER PROGRAM FOR THE ANALYSIS OF MACROINVERTEBRATE DATA FROM WATER QUALITY SURVEYS

by

Patricia A. Cimba, SP4
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Environmental Technology Division

May 1977

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Chemical Systems Laboratory
Aberdeen Proving Ground, Maryland 21010

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Data analysis	Species diversity
DICALC	Water quality surveys

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

An original DICALC program has been revised to calculate species diversity (using three methods) and relative abundance, absolute abundance, and density of each species collected at a sampling station. The new program has greater flexibility and utility for examining differences between aquatic community samples than the original DICALC. The procedures and options for DICALC are explained and the program is given in the appendix.

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PREFACE

The work described in this report was authorized under Task 2, Subproject 3 of PAA 5764114, Development of Methods to Minimize Environmental Contamination, Ecological Surveys of Environmental Conditions at USAMC Installations.

The use of trade names in this report does not constitute an official endorsement or approval of the use of such commercial hardware or software. This report may not be cited for purposes of advertisement.

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SUMMARY

In the course of analysis of macroinvertebrate data obtained during ecological surveys conducted during the project, a scheme of data analysis was developed. The following report describes a computer program developed to perform a portion of this data analysis.

CONTENTS

LIST OF FIGURES

A COMPUTER PROGRAM FOR THE ANALYSIS OF MACROINVERTEBRATE DATA FROM WATER QUALITY SURVEYS

I. INTRODUCTION.

The structure and organization of biological communities are of great interest to scientists involved in the study of these communities. Community analysis has long been a part of the field of pollution biology because one of the basic assumptions of community analysis is that polluted communities have different species occurrences and abundances than nonpolluted communities. Species diversity and density measurements are routinely made by pollution biologists during pollution surveys. The following is a description of a computer program that calculates some of these parameters.

II. SPECIES DIVERSITY MEASURES.

A. Shannon Diversity Index.

The Shannon diversity index is derived from information theory[1-3] as

$$\bar{d} = -\sum_{i=1}^{k} \frac{n_i}{n} \log_2 \frac{n_i}{n} \tag{1}$$

where n is the total number of individuals in k species, and n_i is the number of individuals in the ith species. The relative maximum of $\bar{d}$ is assumed when the $n_i (i = 1, \ldots, k)$ are uniformly distributed within the community, hence

$$\bar{d}_{\max} = \log_2 k \tag{2}$$

The relative minimum is calculated according to

$$\bar{d}_{\min} = \log_2 n - \left(1 - \frac{k+1}{n}\right) \log_2 (n - k + 1) \tag{3}$$

The relative efficiency, synonymous with the normed version of $\bar{d}$, or evenness,[4] is the measure of the ratio of the sample distribution of n_i to the theoretical uniform distribution of n_i in n:

$$\hat{\bar{d}} = \frac{1}{\log_2 k} \sum_{i=1}^{k} \frac{n_i}{n} \log_2 \frac{n_i}{n} \tag{4}$$

The redundancy is the complement of the efficiency:

$$\hat{\bar{d}}_r = 1 - \hat{\bar{d}} \tag{5}$$

B. Simpson Diversity Index.

The Simpson diversity index is defined as[5]

$$S = 1 - \sum_{i=1}^{k} \frac{n_i(n_i - 1)}{n(n-1)} \tag{6}$$

where

$$n > 1$$

and

$$\sum_{i=1}^{k} n_i = n$$

The relative maximum and minimum are calculated according to the following equations:

$$S_{max} = \frac{n(k-1)}{k(n-1)} \tag{7}$$

$$S_{min} = \left(2 - \frac{k}{n}\right)\left(\frac{k-1}{n-1}\right) \tag{8}$$

The normed version of equation 6 is

$$\hat{S} = \frac{1}{n(1 - 1/k)} \left[(n-1) - \sum_{i=1}^{k} \frac{n_i}{n} (n_i - 1) \right] \tag{9}$$

and the redundancy is again the complement of the normed version of the diversity index,

$$\hat{S}_r = 1 - \hat{S}$$

C. McIntosh Diversity Index.

The McIntosh diversity index assumes samples are taken from an infinite population, where each sample contains n individuals in k different species present, n_i individuals in the ith species, and

$$\sum_{i=1}^{k} n_i = n$$

The Euclidean measure is

$$\Delta = \left(\sum_{i=1}^{k} p_i^2 \right)^{1/2} \tag{10}$$

where p_i is the proportion of individuals that belong to the ith species,

$$\sum_{i=1}^{k} p_i = 1$$

and where $1/k \leqslant \Delta \leqslant 1$.

The McIntosh measure of species diversity is then defined to be

$$U = 1 - \Delta \tag{11}$$

As each $p_i \rightarrow 1/k$, U attains its relative maximum,

$$U_{max} = 1 - \frac{1}{\sqrt{k}} \tag{12}$$

The relative minimum is attained according to the least uniformly distributed combination of the $n_i (i = 1, 2, \ldots, k)$ in n:

$$U_{min} = \frac{k - 1 + \sqrt{k - 1}}{n} \tag{13}$$

The ratio of the calculated species diversity U to its relative maximum U_{max} is the normed version of U:

$$\hat{U} = \frac{1}{1 - 1/\sqrt{k}} \left[1 - \left(\sum_{i=1}^{k} p_i^2 \right)^{1/2} \right] \tag{14}$$

The redundancy (the measure of the deviation of sample distribution with respect to the true uniform distribution) is again the complement of the normed version:

$$\hat{U}_r = 1 - \hat{U} \tag{15}$$

III. DESCRIPTION OF DICALC PROGRAM.

The FORTRAN V program DICALC (see appendix) was developed for analysis of biological data and comparison of population and ecological studies.[7] DICALC originally included complete calculations of species occurrence, relative abundance at a sample station, and measures of species diversity for analysis of the sample distribution. In addition to these listings, the new version of DICALC includes the computations for the approximate density of the species at each station and for the relative and absolute abundance of each of the species. DICALC also calculates the grand total for all of the stations, determines the overall species diversity, the relative and absolute abundances, and the approximate density of each species in the sampling area.

DICALC can accommodate a maximum of 150 samples and 60 different species. If greater numbers of either are necessary, the program may be easily modified by use of the parameters NSIZE and MSPEC, the maximum number of samples and the maximum number of species, respectively. By changing the value of either or both parameters, the amount of storage is changed without further modifications to the program.

The following is a list of FORTRAN variables used in this version of DICALC listed in the order entered for input and in the order printed for output:

Variable name	Description	Type
Input		
NS	Number of different species present	I5
NSS	Number of stations	I5
ISS(J)	Number of substations for each station	16I5
TITLE	Site location	12A6
PROG	Data to be considered	A6
METHOD	Type of sampling method	A6
AREA	Numerical surface area of sampler	F10.6
STAT	Station names	5A6
SPEC	Species names	5A6
JM	Species numbers	I2
FMT	Format by which to read data	13A6, A2
Output		
X(I,J)	Data matrix	See FMT
NPA	Number of individuals per unit area for each station	F10.2
TNPA	Total number of individuals per unit area	F10.2
AA	Absolute abundance	F10.2
XN	Number of individuals for each station	F10.0
XP	Relative abundance	F10.2
XS	Number of species present at each station	F10.0
H	Shannon diversity index (designated $\bar{d}$ in section II.A)	F10.4
HM	Relative maximum	F10.4
HMI	Relative minimum	F10.4
HE	Relative efficiency (normed index)	F10.4
HRR	Redundancy	F10.4
SL	Simpson lambda	F10.4
S	Simpson diversity index	F10.4
SM	Relative maximum	F10.4
SMI	Relative minimum	F10.4

Variable name	Description	Type
SE	Relative efficiency (normed index)	F10.4
SRR	Redundancy	F10.4
UD	McIntosh delta	F10.4
U	McIntosh diversity index	F10.4
UM	Relative maximum	F10.4
UMI	Relative minimum	F10.4
UE	Relative efficiency (normed index)	F10.4
URR	Redundancy	F10.4

IV. DESCRIPTION OF PROGRAM OPTIONS.

A. Sampling Methods.

Three frequently used methods of collecting macroinvertebrates are programmed into DICALC. One of these methods may be selected for the calculations of the number of individuals per unit area. If, however, none of these three standard sampling methods is used, the numerical value of the surface area of the sampler may be read in as a variable.

The following options may be selected for the METHOD variable:

1. EKMAN–This option is for the use of any 6- by 6-inch grab method. The total area of the grab is 0.02323 m^2.

2. SURBER–This option is for the use of any 12- by 12-inch bottom-sampling method. The area of the sampler is 0.09290 m^2.

3. DENDY–This option is for the Hester-Dendy multiplate samplers. This method uses eight 7.75- by 7.75-cm plates, each 0.3 cm apart, and seven 2.60- by 2.60-cm spacers. The surface area is 0.08664 m^2.

4. OTHER–This is for any collection method in which the total sampling area is known and given.

B. Data To Be Considered.

The following options may be selected for the PROG variable:

1. TOTALS–With the "TOTALS" option, the program calculates the number of individuals per unit area, the relative abundance, the absolute abundance, and the different diversity measures for the station totals.

2. SUBTOT–With the "SUBTOT" option, the program calculates the number of individuals per unit area, the relative abundance, the absolute abundance, the different diversity measures for each replicate in the sampling station, and the overall station total.

3. CSR1—The "CSR1" option calls the subroutine CSR, which calculates the cumulative sums of the replicates for each station. The program then uses these cumulative sums to calculate the cumulative number of individuals per unit area, the relative abundance, and the different diversity measures. With the addition of each replicate, the change in diversity and the number of species present can be seen. This option is also useful in determining the number of replicates that adequately sample the biological community.

V. DESCRIPTION OF DATA CARDS.

A. Title Card.

The title card shown in figure 1 includes location, sample station, date, and method of sampling in format 12A6.

B. Program Option Cards.

If using EKMAN, DENDY, or SURBER method of sampling, the card shown in figure 2 is used. If, however, the numerical value for the surface area is to be read in, then the card shown in figure 3 is used.

C. Number of Substations in Each Station.

The number of replicates at each station must be supplied in the card format shown in figure 4.

There must be the same number of entries as there are stations (ISS(J) where J = 1, . . ., NSS). Use as many cards as necessary to include all substations.

D. Station or Substation Name Cards.

The number of these cards must equal the number of stations if PROG equals TOTALS, must equal the number of substations if PROG equals CSR1, and must equal the number of sub-

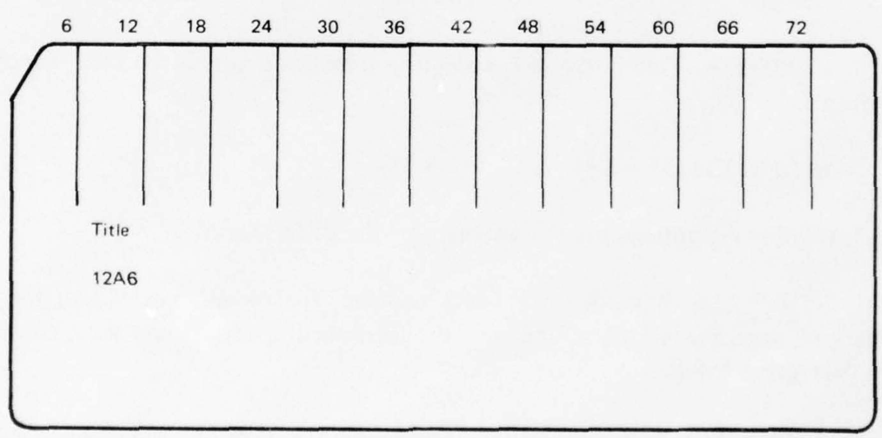

Figure 1. Title Card

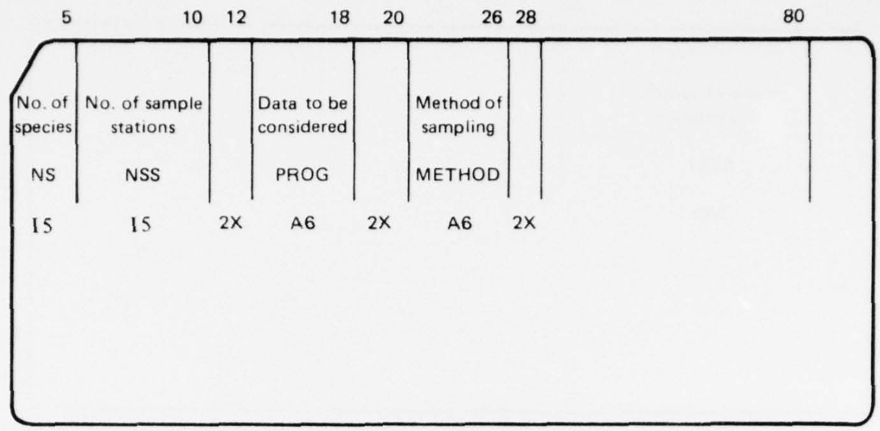

Figure 2. Program Option Card

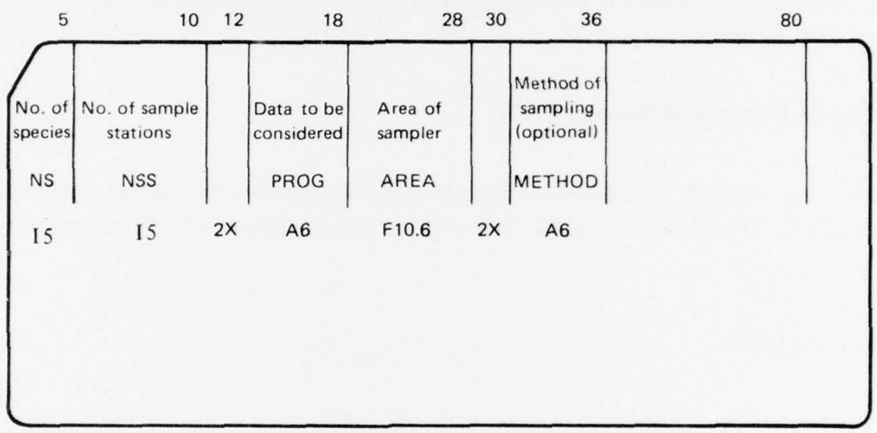

Figure 3. Alternative Sampling Method Option Card

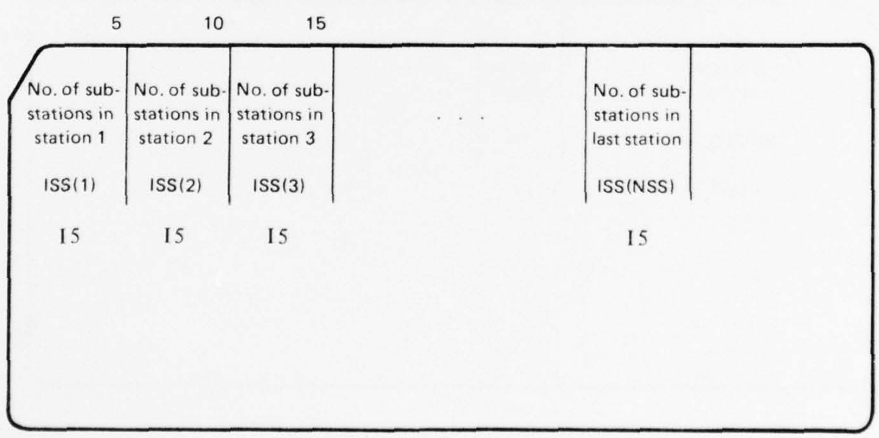

Figure 4. Substation Number Card

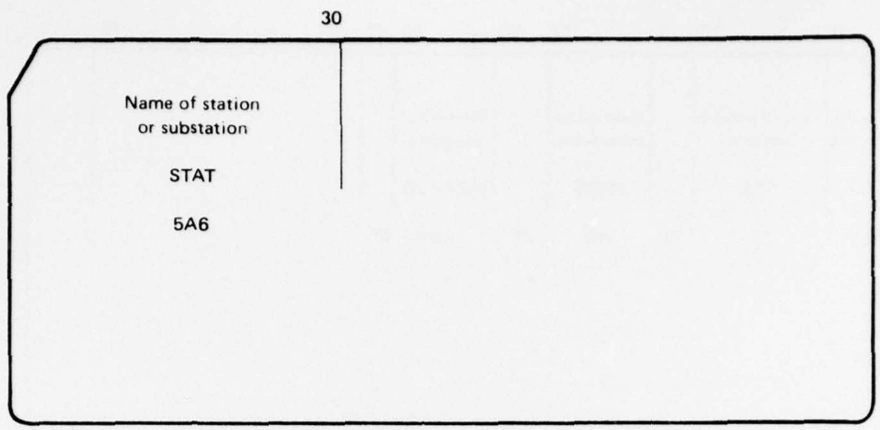

Figure 5. Station/Substation Name Card

stations plus the number of stations if PROG equals SUBTOT. The appearance of station/substation name cards is shown in figure 5.

E. Species Names and Number Cards.

For each species, a card appearing as in figure 6 provides the species name and a 2-digit number as identifiers. The number of these cards must equal the number of different species present (NS).

F. Format Cards.

The format by which data are to be read in is determined from the format card (figure 7). Two format cards must be included in the card set even if the format instructions only use one.

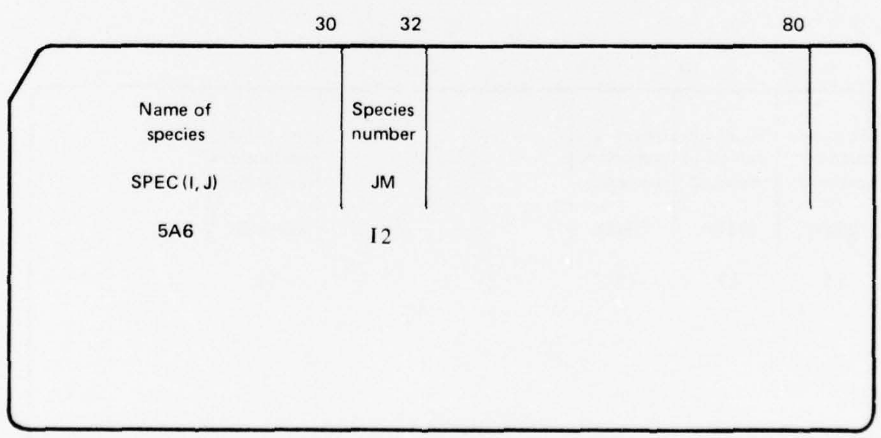

Figure 6. Species Name/Number Card

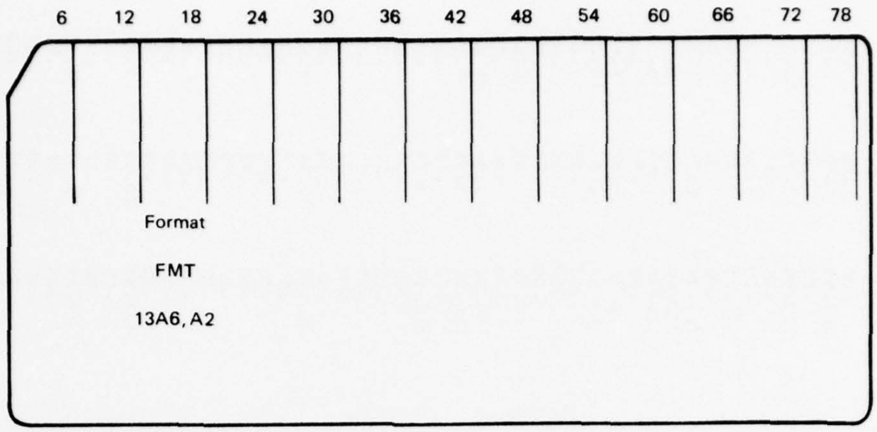

Figure 7. Format Card

G. Data Cards.

Data are read into a data matrix according to the format cards described in the preceding section. There must be at least as many data cards as there are species name cards; i.e., there must be at least one individual present for each species named.

VI. ARRANGEMENT OF DICALC PROGRAM.

The order in which program card sets appear in the card deck is as follows:

Card set	Description
1	Job control cards
2	DICALC–main program deck
3	Control card(s)
4	CSR subroutine
5	Title card
6	Option card
7	Substation card
8	Station/substation name card
9	Species name
10	Format cards
11	Data cards
Final	End of file control card

VII. SAMPLE OUTPUT.

A sample of the output from DICALC is shown in figure 8.

SAAP JUNE 75 MODIFIED SURBER

	SPECIES NAME	SPOON CREEK 1-I NO.	NO. INDIVIDUALS	RA	AA	SPOON CREEK 1-II NO.	NO. INDIVIDUALS	RA	AA
1	CHIRONOMUS SP	0.	.00	.00	.00	0.	.00	.00	.00
2	CRICOTOPUS SP	10.	107.64	2.49	13.51	17.	182.99	8.06	22.97
3	CRYPTOCHIRONOMUS SP	0.	.00	.00	.00	0.	.00	.00	.00
4	DICROTENDIPES SP	2.	21.53	.50	6.25	10.	107.64	4.74	31.25
5	EUKIEFFERIELLA SP	0.	.00	.00	.00	0.	.00	.00	.00
6	GLYPTOTENDIPES SP	0.	.00	.00	.00	0.	.00	.00	.00
7	MICROTENDIPES SP	2.	21.53	.50	1.27	3.	32.29	1.42	1.91
8	PARACHIRONOMUS SP	0.	.00	.00	.00	0.	.00	.00	.00
9	PENTANEURA SP	8.	86.11	2.00	4.52	14.	150.70	6.64	7.91
10	POLYPEDILUM SP	50.	538.21	12.47	15.58	31.	333.69	14.69	9.66
11	PROCLADIUS SP	4.	43.06	1.00	26.67	1.	10.76	.47	6.67
12	PSECTROCLADIUS SP	0.	.00	.00	.00	0.	.00	.00	.00
13	PSEUDOCHIRONOMUS SP	2.	21.53	.50	7.14	1.	10.76	.47	3.57
14	RHEOTANYTARSUS SP	5.	53.82	1.25	13.51	6.	64.59	2.84	16.22
15	STRICTOCHIRONOMUS SP	3.	32.29	.75	11.54	2.	21.53	.95	7.69
16	TANYTARSUS SP	0.	.00	.00	.00	0.	.00	.00	.00
17	CORYNEURA SP	0.	.00	.00	.00	0.	.00	.00	.00
18	CERATOPOGONIDAE	0.	.00	.00	.00	1.	10.76	.47	16.67
19	CHAOBORUS SP	7.	75.35	1.75	29.17	0.	.00	.00	.00
20	CHRYSOPS SP	0.	.00	.00	.00	4.	43.06	1.90	21.05
21	SIMULIUM SP	84.	904.20	20.95	21.37	21.	226.05	9.95	5.34
22	ANTHIPSODES SP	0.	.00	.00	.00	0.	.00	.00	.00
23	CHEUMATOPSYCHE SP	128.	1377.83	31.92	4.26	29.	312.16	13.74	.96
24	HYDROPTILA SP	0.	.00	.00	.00	0.	.00	.00	.00
25	NEOPERLA SP	0.	.00	.00	.00	0.	.00	.00	.00
26	PERLESTA PLACIDA	0.	.00	.00	.00	0.	.00	.00	.00
27	PLECOPTERA UNK	0.	.00	.00	.00	0.	.00	.00	.00
28	BAETIS SP	2.	21.53	.50	1.68	0.	.00	.00	.00
29	CAENIS SP	1.	10.76	.25	1.23	6.	64.59	2.84	7.41
30	ISONYCHIA SP	0.	.00	.00	.00	0.	.00	.00	.00
31	STENONEMA SP	0.	.00	.00	.00	0.	.00	.00	.00
32	TRICORYTHODES SP	0.	.00	.00	.00	0.	.00	.00	.00
33	CORYDALUS SP	0.	.00	.00	.00	0.	.00	.00	.00
34	CORIXIDAE	0.	.00	.00	.00	0.	.00	.00	.00
35	HEMIPTERA UNK	0.	.00	.00	.00	0.	.00	.00	.00
36	DUBIRAPHIA SP	0.	.00	.00	.00	0.	.00	.00	.00
37	HYDROPHILUS SP	0.	.00	.00	.00	0.	.00	.00	.00
38	STENELMIS SP	55.	592.03	13.72	2.38	43.	462.86	20.38	1.86
39	ASTACIDAE	1.	10.76	.25	3.33	0.	.00	.00	.00
40	HYALLELA AZTECA	0.	.00	.00	.00	0.	.00	.00	.00
41	LICERUS SP	0.	.00	.00	.00	3.	32.29	1.42	33.33
42	HIRUDINEA UNK	1.	10.76	.25	4.55	0.	.00	.00	.00
43	SPHAERIUM SP	0.	.00	.00	.00	0.	.00	.00	.00
44	FERRISSIA KIRKLANDI	0.	.00	.00	.00	0.	.00	.00	.00
45	LYMNAEA SP	0.	.00	.00	.00	0.	.00	.00	.00
46	PHYSA HAWNII	18.	193.76	4.49	20.45	7.	75.35	3.32	7.95
47	BRANCHIURA SOWERBYI	0.	.00	.00	.00	0.	.00	.00	.00
48	OLIGOCHAETE SP	17.	182.99	4.24	7.42	12.	129.17	5.69	5.24

Figure 8. Sample Output From DICALC Program

49 ATHERIX SP	1.	10.76	.25	14.29	0.	.00	.00	.00
50 COLLEMBOLA SP	0.	.00	.00	.00	0.	.00	.00	.00
51 PERICOMA SP	0.	.00	.00	.00	0.	.00	.00	.00
52 ARGIA MOESTA	0.	.00	.00	.00	0.	.00	.00	.00
53 ISCHNURA SP	0.	.00	.00	.00	0.	.00	.00	.00
TOTAL INDIVIDUALS	401.	4316.47			211.	2271.26		
TOTAL ABSOLUTE ABUNDANCE				210.13				207.67
SPECIES PRESENT	20.				18.			
SHANNON INDEX $\overline{d}$	2.9445				3.5067			
LOG(2) S	4.3219				4.1699			
RELATIVE MINIMUM	.4764				.7335			
EFFICIENCY	.6813				.8409			
REDUNDANCY	.3187				.1591			
SIMPSON INDEX S	.8163				.8923			
SIMPSON LAMDA	.1857				.1119			
RELATIVE MAXIMUM	.9524				.9489			
RELATIVE MINIMUM	.0926				.1550			
EFFICIENCY	.8572				.9403			
REDUNDANCY	.1428				.0597			
VARIANCE(N<25)	.000000				.000000			
VARIANCE(N>25)	.000334				.000260			
MCINTOSH INDEX U	.5691				.6654			
MCINTOSH DELTA	.4309				.3346			
RELATIVE MAXIMUM	.7764				.7643			
RELATIVE MINIMUM	.0583				.1001			
EFFICIENCY	.7330				.8707			
REDUNDANCY	.2670				.1293			

Figure 8 (Concluded). Sample Output From DICALC Program

VIII. CONCLUSION.

Macroinvertebrate communities are commonly analyzed by calculating species diversity and relative abundance. With the modifications presented here, DICALC, using these widely accepted methods, permits the user to swiftly calculate species diversity and relative abundance. In addition, data can be expressed in standard density units (number of individuals per square meter). The additional calculations of relative efficiency, redundancy, and relative maximum and minimum help the user to identify peculiarities about the distribution of individuals in each sample. Absolute abundance shows the proportion of individuals of a particular species collected in one of the samples during a study. This information permits the user to evaluate the numerical significance of any species in any sample. DICALC is a versatile program that is very helpful in investigating differences in community structure between sampling sites. When these data are correlated with environmental factors such as water quality, cause-and-effect relationships can be determined.

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APPENDIX

DICALC PROGRAM LISTING

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00100   C      DICALC PROGRAM FOR THE ANALYSIS OF MACROINVERTIBRATES FROM WATER      000000
00100   C      QUALITY SURVEYS.                                                      000000
00100   C                                                                            000000
00101          COMPILER (DIAG=3), (XM=1)                                             000000
00103          PARAMETER NSIZE=150                                                   000024
00105          PARAMETER MSPEC=60                                                    000024
00106          DIMENSION TITLE(12),FMT(28),SPEC(5,MSPEC),X(MSPEC,NSIZE),XP(MSPEC,    000024
00106         1NSIZE),XN(NSIZE),XS(NSIZE),H(NSIZE),HM(NSIZE),HE(NSIZE),HRR(NSIZE)    000024
00106         2,HMI(NSIZE),XHM(NSIZE),S(NSIZE),SL(NSIZE),SM(NSIZE),SMI(NSIZE),       000024
00106         3SE(NSIZE),SRR(NSIZE),U(NSIZE),UD(NSIZE),UE(NSIZE),UM(NSIZE),          000024
00106         4UMI(NSIZE),URR(NSIZE),STAT(5,NSIZE),TNPA(NSIZE)                       000024
00107          COMMON NPA(MSPEC,NSIZE),AA(MSPEC,NSIZE),ISS(NSIZE)                    000024
00110          REAL NPA                                                              000024
00110   C                                                                            000024
00110   C      READ TITLE AND PROGRAM OPTIONS CARD                                   000024
00110   C                                                                            000024
00111          READ (5,73) TITLE                                                     000024
00114          WRITE (6,77) (TITLE(L),L=1,12)                                        000034
00117          READ (5,74) NS,NSS,PROG,METHOD                                        000044
00117   C                                                                            000044
00117   C      IF USING THE ECKMAN METHOD, AREA=.02323 SQUARE METERS                 000044
00117   C                                                                            000044
00125          IF (METHOD.EQ.'ECKMAN') GO TO 4                                       000055
00125   C                                                                            000055
00125   C      DENDY METHOD USING 8 PLATES 7.75 X 7.75 SQUARE CENTIMETERS,           000055
00125   C      SPACERS 2.60 X 2.60 SQUARE CENTIMETERS                                000055
00125   C      SPACE BETWEEN PLATES IS .3 CENTIMETERS                                000055
00125   C      AREA=.08664 SQUARE METERS                                             000055
00125   C                                                                            000055
00127          IF (METHOD.EQ.'DENDY ') GO TO 3                                       000060
00127   C                                                                            000060
00127   C      IF USING THE SURBER METHOD, AREA=.09290 SQUARE METERS                 000060
00127   C                                                                            000060
00131          IF (METHOD.EQ.'SURBER') GO TO 2                                       000063
00133          READ (30,96,ERR=1) NS,NSS,PROG,AREA,METHOD                            000066
00142          GO TO 5                                                               000101
00143   1      WRITE (6,117)                                                         000103
00145          GO TO 71                                                              000107
00146   2      AREA=.09290                                                           000111
00147          GO TO 5                                                               000112
00150   3      AREA=.08664                                                           000114
00151          GO TO 5                                                               000115
00152   4      AREA=.02323                                                           000117
00153          GO TO 5                                                               000120
00154   5      CONTINUE                                                              000122
00155          READ (5,102) (ISS(J),J=1,NSS)                                         000122
00163          NSS3=NSS                                                              000137
00164          NSS2=0                                                                000141
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00165                DO 6 J=1,NSS                              000146
00170                NSS2=ISS(J)+NSS2                          000146
00171        6       CONTINUE                                  000151
00173             IF (PROG.EQ.'TOTALS') GO TO 9                000151
00175             IF (PROG.EQ.'SUBTOT') GO TO 7                000154
00177             IF (PROG.EQ.'CSR1  ') GO TO 8                000157
00201             WRITE (6,103)                                000162
00203             WRITE (6,72) PROG                            000167
00206             GO TO 71                                     000175
00207        7    CONTINUE                                     000177
00210             NSS=NSS2+NSS                                 000177
00211             GO TO 9                                      000201
00212        8    CONTINUE                                     000203
00213             NSS=NSS2                                     000203
00214        9    CONTINUE                                     000205
00214        C                                                 000205
00214        C    READ IN THE STATION NAMES                    000205
00214        C                                                 000205
00215                DO 10 I=1,NSS                             000205
00220                READ (5,111) (STAT(L,I),L=1,5)            000221
00226        10      CONTINUE                                  000235
00226        C                                                 000235
00226        C    READ IN TAXA                                 000235
00226        C                                                 000235
00230                DO 11 I=1,NS                              000235
00233                READ (5,75) (SPEC(L,I),L=1,5),JM          000235
00242        11      CONTINUE                                  000250
00242        C                                                 000250
00242        C    READ IN DATA FORMAT CARD                     000250
00242        C                                                 000250
00244             READ (5,76) FMT                              000250
00244        C                                                 000250
00244        C    READ IN DATA MATRIX                          000250
00244        C                                                 000250
00247                DO 12 I=1,NS                              000263
00252                READ (5,FMT) (X(I,J),J=1,NS^'             000263
00260        12      CONTINUE                                  000277
00260        C                                                 000277
00260        C    WRITE THE DATA MATRIX                        000277
00260        C                                                 000277
00262             IS=0                                         000277
00263             ICOUNT=0                                     000300
00264             ICOL=0                                       000301
00265             NUMP=NSS/25+1                                000302
00266             ISTART=1                                     000307
00267                DO 16 K=1,NUMP                            000314
00272                ICOUNT=NSS-ICOL                           000314
00273                ICHECK=MINO(25,ICOUNT)                    000316
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00274     97*            IF (ICHECK.EQ.ICOUNT) GO TO 13                                   97    000323
00276     98*            ICHECK=ICOL+25                                                   98    000325
00277     99*            GO TO 14                                                         99    000330
00300    100*     13     ICHECK=ICOL+ICOUNT                                              100    000332
00301    101*     14        DO 15 I=1,NS                                                 101    000335
00304    102*               WRITE (6,98) (X(I,J),J=ISTART,ICHECK)                        102    000352
00312    103*     15        CONTINUE                                                     103    000366
00314    104*            ISTART=ISTART+25                                                104    000366
00315    105*            ICOL=ICOL+25                                                    105    000371
00316    106*     16     CONTINUE                                                        106    000375
00320    107*         IF (PROG.EQ.'TOTALS') GO TO 25                                     107    000375
00322    108*         IF (PROG.EQ.'SUBTOT') GO TO 17                                     108    000400
00324    109*         IF (PROG.EQ.'CSR1  ') GO TO 21                                     109    000403
00326    110*     17  CONTINUE                                                           110    000407
00326    111*     C                                                                     111    000407
00326    112*     C   DETERMINE THE NO. OF INDIVIDUALS PER UNIT AREA FOR THE SUBSTATIONS 112    000407
00326    113*     C   AND TOTALS                                                         113    000407
00326    114*     C                                                                     114    000407
00327    115*            DO 20 J=1,NS                                                    115    000407
00332    116*            N=1                                                             116    000416
00333    117*            MM=ISS(1)                                                       117    000420
00334    118*               DO 19 I=1,NSS3                                               118    000430
00337    119*                  DO 18 K=N,MM                                              119    000456
00342    120*                  NPA(J,K)=X(J,K)/AREA                                      120    000456
00343    121*     18           CONTINUE                                                  121    000461
00345    122*               NPA(J,MM+1)=X(J,MM+1)/(AREA*ISS(I))                          122    000461
00346    123*               N=MM+2                                                       123    000472
00347    124*               MM=MM+ISS(I+1)+1                                             124    000475
00350    125*     19        CONTINUE                                                     125    000504
00352    126*     20     CONTINUE                                                        126    000504
00354    127*         GO TO 28                                                           127    000504
00355    128*     21  CONTINUE                                                           128    000506
00356    129*         CALL CSR (ISS,NSS3,X,NSIZE,NS,MSPEC)                               129    000506
00356    130*     C                                                                     130    000506
00356    131*     C   DETERMINE THE NO. OF INDIVIDUALS PER UNIT AREA FOR THE CUMULATIVE  131    000506
00356    132*     C   SUMS OF REPLICATES                                                 132    000506
00356    133*     C                                                                     133    000506
00357    134*            DO 24 J=1,NS                                                    134    000515
00362    135*            N=1                                                             135    000525
00363    136*            MM=ISS(1)                                                       136    000527
00364    137*               DO 23 I=1,NSS3                                               137    000535
00367    138*               II=1                                                         138    000545
00370    139*                  DO 22 K=N,MM                                              139    000555
00373    140*                  NPA(J,K)=X(J,K)/(AREA*II)                                 140    000555
00374    141*                  II=II+1                                                   141    000563
00375    142*     22           CONTINUE                                                  142    000567
00377    143*               N=MM+1                                                       143    000567
00400    144*               MM=MM+ISS(I+1)                                               144    000572
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00401   23          CONTINUE                                                000600
00403   24       CONTINUE                                                   000600
00405         GO TO 28                                                      000600
00405   C                                                                   000600
00405   C       DETERMINE THE NO. OF INDIVIDUALS PER UNIT AR=A FOR THE TOTALS 000600
00405   C     ONLY                                                          000600
00405   C                                                                   000600
00406   25       DO 27 J=1,NS                                               000602
00411               DO 26 K=1,NSS                                           000622
00414               NPA(J,K)=X(J,K)/(AREA*ISS(K))                           000622
00415   26          CONTINUE                                                000641
00417   27       CONTINUE                                                   000641
00421   28    CONTINUE                                                      000641
00422         NSS1=NSS                                                      000641
00423         NSS=NSS+1                                                     000642
00424         ISS(NSS)=0                                                    000644
00425            DO 29 J=1,NSS1                                             000706
00430            ISS(NSS)=ISS(J)+ISS(NSS)                                   000706
00431   29       CONTINUE                                                   000711
00431   C                                                                   000711
00431   C     CALCULATE THE TOTAL NUMBER OF INDIVIDUALS PER TAXA            000711
00431   C                                                                   000711
00433         IF (PROG.EQ.'CSR1  ') GO TO 36                                000711
00435            DO 30 J=1,NS                                               000714
00440            X(J,NSS)=0.                                                000726
00441   30       CONTINUE                                                   000735
00441   C                                                                   000735
00443            DO 32 K=1,NS                                               000735
00446               DO 31 J=1,NSS1                                          000735
00451               X(K,NSS)=X(K,J)+X(K,NSS)                                000735
00452   31          CONTINUE                                                000740
00454            IF (PROG.EQ.'SUBTOT') X(K,NSS)=X(K,NSS)/2                  000740
00456   32       CONTINUE                                                   000761
00456   C                                                                   000761
00460            DO 33 J=1,NS .                                             000761
00463            NPA(J,NSS)=X(J,NSS)/(AREA*NSS2)                            000761
00464   33       CONTINUE                                                   000764
00466         IF (PROG.EQ.'CSR1  ') GO TO 39                                000764
00466   C                                                                   000764
00466   C     CALCULATE THE ABSOLUTE ABUNDANCE                              000764
00466   C                                                                   000764
00470            DO 35 J=1,NS                                               000776
00473               DO 34 K=1,NSS                                           000776
00476               AA(J,K)=X(J,K)/X(J,NSS)*100.                            000776
00477   34          CONTINUE                                                001012
00501   35       CONTINUE                                                   001012
00503         GO TO 39                                                      001012
00504   36    CONTINUE                                                      001014
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00505     193*              DO 38 K=1,NS                                                      193    001014
00510     194*              X(K,NSS)=0                                                        194    001044
00511     195*              ISS(NSS3+1)=0                                                     195    001045
00512     196*              IP=ISS(1)                                                         196    001046
00513     197*                 DO 37 I=1,NSS3                                                 197    001054
00516     198*                 X(K,NSS)=X(K,IP)+X(K,NSS)                                      198    001056
00517     199*                 IP=IP+ISS(I+1)                                                 199    001061
00520     200*      37         CONTINUE                                                       200    001065
00522     201*              NPA(K,NSS)=X(K,NSS)/(AREA*NSS2)                                   201    001065
00523     202*      38      CONTINUE                                                          202    001074
00525     203*      39   CONTINUE                                                             203    001074
00525     204*      C                                                                         204    001074
00525     205*      C    CALCULATE THE TOTAL OF THE NUMBER OF INDIVIDUALS PER UNIT AREA       205    001074
00525     206*      C    FOR EACH STATION                                                     206    001074
00525     207*      C                                                                         207    001074
00526     208*           TNPA(1)=0                                                            208    001074
00527     209*              DO 41 J=1,NSS                                                     209    001123
00532     210*                 DO 40 I=1,NS                                                   210    001123
00535     211*                 TNPA(J)=TNPA(J)+NPA(I,J)                                       211    001123
00536     212*      40         CONTINUE                                                       212    001140
00540     213*      41      CONTINUE                                                          213    001140
00540     214*      C                                                                         214    001140
00542     215*              DO 43 I=1,NSS                                                     215    001140
00545     216*                 DO 42 J=1,NS                                                   216    001140
00550     217*                 IF (X(J,I).EG.0.) GO TO 42                                     217    001140
00552     218*                 XS(I)=XS(I)+1.0                                                218    001141
00553     219*      42         CONTINUE                                                       219    001156
00555     220*      43      CONTINUE                                                          220    001156
00555     221*      C                                                                         221    001156
00555     222*      C    CALCULATE TOTAL NUMBER OF INDIVIDUALS PER STATION                    222    001156
00555     223*      C                                                                         223    001156
00557     224*              DO 45 K=1,NSS                                                     224    001156
00562     225*                 DO 44 J=1,NS                                                   225    001156
00565     226*                 XN(K)=XN(K)+X(J,K)                                             226    001156
00566     227*      44         CONTINUE                                                       227    001173
00570     228*      45      CONTINUE                                                          228    001173
00570     229*      C                                                                         229    001173
00570     230*      C    CALCULATE PROBABILITY OF OCCURANCE FOR INDIVIDUALS                   230    001173
00570     231*      C                                                                         231    001173
00572     232*              DO 47 K=1,NSS                                                     232    001173
00575     233*                 DO 46 J=1,NS                                                   233    001173
00600     234*                 XP(J,K)=X(J,K)/XN(K)                                           234    001173
00601     235*      46         CONTINUE                                                       235    001211
00603     236*      47      CONTINUE                                                          236    001211
00603     237*      C                                                                         237    001211
00603     238*      C    CALCULATE INFORMATION THEORY INDICIES                                238    001211
00603     239*      C                                                                         239    001211
00605     240*              DO 49 K=1,NSS                                                     240    001211
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00610                DO 48 J=1,NS                                                001211
00613                IF (XP(J,K).LE.0.) GO TO 48                                 001211
00615                H(K)=H(K)+(XP(J,K)*(ALOG10(XP(J,K))/ALOG10(2.0)))          001213
00616        48      CONTINUE                                                    001226
00620             H(K)=-H(K)                                                     001226
00621        49   CONTINUE                                                       001236
00621        C                                                                   001236
00623             DO 50 K=1,NSS                                                  001236
00626             HM(K)=ALOG10(XS(K))/ALOG10(2.0)                                001236
00627             XHM(K)=XN(K)-XS(K)+1.                                          001244
00630             HMI(K)=(ALOG10(XN(K))/ALOG10(2.))-(XHM(K)/XN(K))*(ALOG10(XHM(K)  001250
00630           1 )/ALOG10(2.))                                                  001250
00631             HE(K)=H(K)/HM(K)                                               001272
00632             HRR(K)=1.-HE(K)                                                001275
00633        50   CONTINUE                                                       001306
00633        C                                                                   001306
00633        C    CALCULATE SIMPSON INDEX                                        001306
00633        C                                                                   001306
00635             DO 53 K=1,NSS                                                  001306
00640                DO 51 J=1,NS                                                001315
00643                SL(K)=SL(K)+(XP(J,K)*XP(J,K))                               001315
00644        51      CONTINUE                                                    001323
00644        C                                                                   001323
00646                DO 52 J=1,NS                                                001323
00651                S(K)=S(K)+(X(J,K)*(X(J,K)-1.))                              001323
00652        52      CONTINUE                                                    001330
00654             S(K)=1.-S(K)/(XN(K)*(XN(K)-1.))                                001330
00655             SM(K)=(XN(K)*(XS(K)-1.))/(XS(K)*(XN(K)-1.))                    001336
00656             SMI(K)=(2.-(XS(K)/XN(K)))*((XS(K)-1.)/(XN(K)-1.))              001344
00657             SE(K)=S(K)/SM(K)                                               001353
00660             SRR(K)=1.-SE(K)                                                001355
00661        53   CONTINUE                                                       001374
00661        C                                                                   001374
00661        C    CALCULATE MCINTOSH INDEX                                       001374
00661        C                                                                   001374
00663             DO 55 K=1,NSS                                                  001374
00666                DO 54 J=1,NS                                                001400
00671                UD(K)=UD(K)+(XP(J,K)*XP(J,K))                               001400
00672        54      CONTINUE                                                    001404
00674             UD(K)=SQRT(UD(K))                                              001404
00675             U(K)=1.-UD(K)                                                  001412
00676             UM(K)=1.-(1./SQRT(XS(K)))                                      001414
00677             UMI(K)=((XS(K)-1.)+SQRT(XS(K)-1.))/XN(K)                       001425
00700             UE(K)=U(K)/UM(K)                                               001433
00701             URR(K)=1.-UE(K)                                                001436
00702        55   CONTINUE                                                       001451
00702        C                                                                   001451
00702        C    WRITE DATA,PROBABILITIES,AND CALCULATIONS                      001451
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C
          DO 57 J=1,NS
            DO 56 K=1,NSS
            XP(J,K)=XP(J,K)*100.
   56       CONTINUE
   57     CONTINUE
        N=1
   58   NSK=N+1
        WRITE (6,77) (TITLE(L),L=1,12)
        IF (PROG.EQ.'TOTALS') WRITE (6,105) METHOD,AREA
        IF (PROG.EQ.'SUBTOT') WRITE (6,106) METHOD,AREA
        IF (PROG.EQ.'CSR1  ') WRITE (6,107) METHOD,AREA
        IF (N.EQ.NSS1) GO TO 62
        IF (N.EQ.NSS) GO TO 63
        WRITE (6,78) (STAT(L,N),L=1,5),(STAT(L,NSK),L=1,5)
        IF (PROG.EQ.'CSR1  ') GO TO 66
        WRITE (6,95)
        WRITE (6,93)
   59   WRITE (6,79)
          DO 60 J=1,NS
          WRITE (6,80) J,(SPEC(L,J),L=1,5),(X(J,K),NPA(J,K),XP(J,K),AA(J,
       1  K),K=N,NSK)
   60     CONTINUE
        WRITE (6,81) (XN(K),TNPA(K),K=N,NSK)
   61   CONTINUE
        WRITE (6,82) (XS(K),K=N,NSK)
        WRITE (6,83) (H(K),K=N,NSK)
        WRITE (6,84) (HM(K),K=N,NSK)
        WRITE (6,85) (HMI(K),K=N,NSK)
        WRITE (6,86) (HE(K),K=N,NSK)
        WRITE (6,87) (HRR(K),K=N,NSK)
        WRITE (6,88) (S(K),K=N,NSK)
        WRITE (6,89) (SL(K),K=N,NSK)
        WRITE (6,90) (SM(K),K=N,NSK)
        WRITE (6,85) (SMI(K),K=N,NSK)
        WRITE (6,85) (SE(K),K=N,NSK)
        WRITE (6,87) (SRR(K),K=N,NSK)
        WRITE (6,91) (U(K),K=N,NSK)
        WRITE (6,92) (UD(K),K=N,NSK)
        WRITE (6,90) (UM(K),K=N,NSK)
        WRITE (6,85) (UMI(K),K=N,NSK)
        WRITE (6,86) (UE(K),K=N,NSK)
        WRITE (6,87) (URR(K),K=N,NSK)
C
        IF (IS.EQ.1) GO TO 71
        IF (NSK.EQ.N) GO TO 63
        N=N+2
        GO TO 58
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01206   337*   62   WRITE (6,113) (STAT(L,N),L=1,5)                                          337   002241
01214   338*        IF (PROG.EQ.'CSR1  ') WRITE (6,115)                                      338   002256
01217   339*        IF (PROG.NE.'CSR1  ') WRITE (6,114)                                      339   002266
01222   340*        WRITE (6,116)                                                            340   002276
01224   341*        NSK=N                                                                    341   002303
01225   342*        IF (PROG.EQ.'CSR1  ') GO TO 67                                           342   002305
01227   343*        GO TO 59                                                                 343   002310
01230   344*   63   CONTINUE                                                                 344   002312
01231   345*        NSK=N                                                                    345   002312
01232   346*        IS=1                                                                     346   002313
01233   347*        IF (NSK.EQ.NSS) GO TO 64                                                 347   002315
01235   348*        WRITE (6,77) (TITLE(L),L=1,12)                                           348   002317
01240   349*        IF (PROG.EQ.'CSR1  ') WRITE (6,107) METHOD,AREA                          349   002327
01245   350*        IF (PROG.EQ.'CSR1  ') GO TO 69                                           350   002341
01247   351*        IF (PROG.EQ.'TOTALS') WRITE (6,105) METHOD,AREA                          351   002344
01254   352*        IF (PROG.EQ.'SUBTOT') WRITE (6,106) METHOD,AREA                          352   002356
01261   353*   64   CONTINUE                                                                 353   002371
01262   354*        IF (PROG.EQ.'CSR1  ') GO TO 69                                           354   002371
01264   355*        WRITE (6,94)                                                             355   002403
01266   356*        WRITE (6,99)                                                             356   002412
01270   357*        WRITE (6,79)                                                             357   002417
01272   358*           DO 65 J=1,NS                                                          358   002434
01275   359*           WRITE (6,100) J,(SPEC(L,J),L=1,5),X(J,NSS),NPA(J,NSS),XP(J,NSS)       359   002434
01307   360*   65      CONTINUE                                                              360   002454
01311   361*        WRITE (6,101) XN(NSS),TNPA(NSS)                                          361   002454
01315   362*        NSK=NSS                                                                        002463
01316   363*        N=NSS                                                                          002465
01317   364*        GO TO 61                                                                 362   002466
01320   365*   66   CONTINUE                                                                 363   002470
01321   366*        WRITE (6,108)                                                            364   002470
01323   367*        WRITE (6,93)                                                             365   002474
01325   368*        WRITE (6,79)                                                             366   002501
01327   369*   67   CONTINUE                                                                 367   002507
01330   370*           DO 68 J=1,NS                                                          368   002507
01333   371*           WRITE (6,104) J,(SPEC(L,J),L=1,5),(X(J,K),NPA(J,K),XP(J,K),K=N,       369   002534
01333   372*       1   NSK)                                                                  370   002534
01350   373*   68      CONTINUE                                                              371   002564
01352   374*        WRITE (6,110) (XN(K),TNPA(K),K=N,NSK)                                    372   002564
01361   375*        GO TO 61                                                                 373   002600
01362   376*   69   CONTINUE                                                                 374   002602
01363   377*        WRITE (6,109)                                                            375   002602
01365   378*        WRITE (6,99)                                                             376   002606
01367   379*        WRITE (6,79)                                                             377   002613
01371   380*           DO 70 J=1,NS                                                          378   002620
01374   381*           WRITE (6,112) J,(SPEC(L,J),L=1,5),X(J,NSS),NPA(J,NSS),XP(J,NSS)       379   002637
01406   382*   70      CONTINUE                                                              380   002657
01410   383*         NSK=NSS                                                                       002657
01411   384*        N=NSS                                                                          002661
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01412         WRITE (6,101) (XN(K),INPA(K),K=N,NSK)                         002662
01421         GO TO 61                                                       002700
01422   71    WRITE (6,97)                                                   002702
01424         STOP                                                           002706
01424   C                                                                    002706
01424   C     FORMAT STATEMENTS                                              002706
01424   C                                                                    002706
01424   C                    *****FORMAT STATEMENTS*****                     002706
01424   C                                                                    002706
01425   72    FORMAT (' ','PROG=',2X,A6)                                     002712
01426   73    FORMAT (12A6)                                                  002712
01427   74    FORMAT (2I5,2X,A6,2X,A6)                                       002712
01430   75    FORMAT (5A6,I2)                                                002712
01431   76    FORMAT (13A6,A2)                                               002712
01432   77    FORMAT ('1',T28,12A6)                                          002712
01433   78    FORMAT ('0',//35X,5A6,29X,5A6)                                 002712
01434   79    FORMAT (1X,/)                                                  002712
01435   80    FORMAT (' ',I3,2X,5A6,F7.0,5X,3F10.2,5X,F10.0,5X,3F10.2)       002712
01436   81    FORMAT ('0TOTAL INDIVIDUALS',15X,F10.0,5X,F10.2,25X,F10.0,5X,  002712
01436        1F10.2)                                                         002712
01437   82    FORMAT ('0TAXA PRESENT',T34,F10.0,T84,F10.0)                   002712
01440   83    FORMAT ('0SHANNON INDEX d ',T38,F10.4,T88,F10.4)               002712
01441   84    FORMAT (' RELATIVE MAXIMUM',T38,F10.4,T88,F10.4)               002712
01442   85    FORMAT (' RELATIVE MINIMUM',T38,F10.4,T88,F10.4)               002712
01443   86    FORMAT (' EFFICIENCY',T38,F10.4,T88,F10.4)                     002712
01444   87    FORMAT (' REDUNDANCY',T38,F10.4,T88,F10.4)                     002712
01445   88    FORMAT ('0SIMPSON INDEX S',T38,F10.4,T88,F10.4)                002712
01446   89    FORMAT (' SIMPSON LAMDA',T38,F10.4,T88,F10.4)                  002712
01447   90    FORMAT (' RELATIVE MAXIMUM',T38,F10.4,T88,F10.4)               002712
01450   91    FORMAT ('0MCINTOSH INDEX U',T38,F10.4,T88,F10.4)               002712
01451   92    FORMAT (' MCINTOSH DELTA',T38,F10.4,T88,F10.4)                 002712
01452   93    FORMAT (' ',31X,'INDIVIDUALS',3X,'PER SQUARE METER',23X,       002712
01452        1'INDIVIDUALS',3X,'PER SQUARE METER')                           002712
01453   94    FORMAT ('0',//47X,'TOTAL OF ALL STATIONS',/'0      TAXA    ',T33,  002712
01453        1'  TOTAL NO.',9X,'NO. INDIVIDUALS',4X,'RA')                    002712
01454   95    FORMAT ('0      TAXA    ',25X,'NO.',6X,'NO. INDIVIDUALS',3X,'RA',8X,  002712
01454        1'AA',13X,'NO.',6X,'NO. INDIVIDUALS',3X,'RA',6X,'AA')           002712
01455   96    FORMAT (2I5,2X,A6,F10.6,2X,A6)                                 002712
01456   97    FORMAT ('1')                                                   002712
01457   98    FORMAT ('0',25F5.0)                                            002712
01460   99    FORMAT (' ',32X,'OF INDIVIDUALS',5X,'PER SQUARE METER')        002712
01461   100   FORMAT (' ',I3,2X,5A6,F7.0,12X,2F10.2)                         002712
01462   101   FORMAT ('0TOTAL INDIVIDUALS',15X,F10.0,12X,F10.2)              002712
01463   102   FORMAT (16I5)                                                  002712
01464   103   FORMAT ('1ERROR: PROG NOT READ IN CORRECTLY')                  002712
01465   104   FORMAT (' ',I3,2X,5A6,F7.0,5X,2F10.2,T87,F7.0,7X,2F10.2)       002712
01466   105   FORMAT (' ',36X,'TOTALS',15X,A6,5X,'AREA=',F10.5,1X,'SQUARE METERS  002712
01466        1')                                                             002712
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01467    433*    106   FORMAT (' ',29X,'SUBTOTALS AND TOTALS',7X,A6,5X,'AREA=',F10.6,1X,      429    002712
01467    434*          1' SQUARE METERS')                                                        430    002712
01470    435*    107   FORMAT (' ',21X,'CUMULATIVE SUMS OF REPLICATES',6X,A6,5X,'AREA=',        431    002712
01470    436*          1F10.6,1X,'SQUARE METERS')                                                432    002712
01471    437*    108   FORMAT ('0     TAXA    ',24X,'NO.',6X,'NO. INDIVIDUALS',5X,'RA',        433    002712
01471    438*          1T88,'NO.',9X,'NO. INDIVIDUALS',3X,'RA')                                  434    002712
01472    439*    109   FORMAT ('0',//47X,'TOTAL OF ALL STATIONS',/'0     TAXA    ',23X,        435    002712
01472    440*          1'TOTAL NO.',10X,'NO. INDIVIDUALS',9X,'RA')                               436    002712
01473    441*    110   FORMAT ('0CUMULATIVE SUMS OF REPLICATES',3X,F10.0,5X,F10.2,T84,         437    002712
01473    442*          1F10.0,7X,F10.2)                                                          438    002712
01474    443*    111   FORMAT (5A6)                                                              439    002712
01475    444*    112   FORMAT (' ',I3,2X,5A6,F7.0,12X,F10.2,7X,F10.2)                            440    002712
01476    445*    113   FORMAT ('0',//35X,5A6)                                                    441    002712
01477    446*    114   FORMAT ('0     TAXA    ',25X,'NO.',6X,'NO. INDIVIDUALS',3X,'RA',8X,      442    002712
01477    447*          1'AA')                                                                    443    002712
01500    448*    115   FORMAT ('0     TAXA    ',24X,'NO.',6X,'NO. INDIVIDUALS',5X,'RA')        444    002712
01501    449*    116   FORMAT (' ',31X,'INDIVIDUALS',3X,'PER SQUARE METER')                      445    002712
01502    450*    117   FORMAT ('0DATA CARD NOT READ IN CORRECTLY.  CHECK THE CARD TO READ        446    002712
01502    451*          1NS,NSS,PROG,METHOD')                                                     447    002712
01502    452*    C                                                                               448    002712
01503    453*          END                                                                       449-   002712
END FOR

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