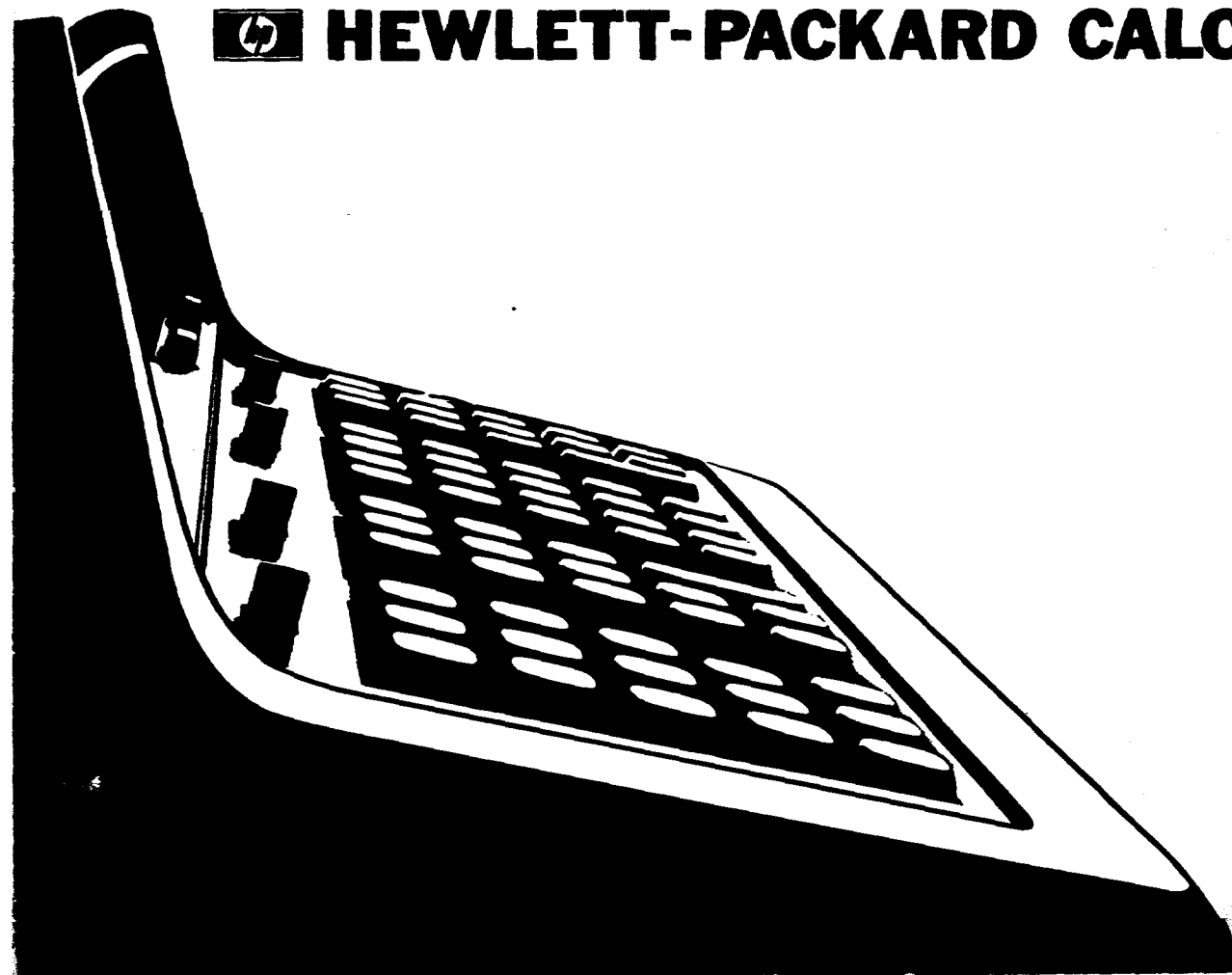


ANIMAL
ECOLOGY

 **HEWLETT-PACKARD CALCULATOR**



INTER-OFFICE CORRESPONDENCE

FROM: Pat Welch

DATE:

TO: CALCULATOR SALESMEN

SUBJECT: Animal Ecology

The enclosed programs are some examples of how Dr. J. D. Weintraub at California State College in Fullerton, California has employed the 9100 in teaching and research in the field of Animal Ecology.

In addition to these examples, Animal Ecologists use general statistics, so, the STAT-PAC should be useful to them.

If you have any inputs regarding other general purpose programs or specific examples of how the 9100 is being used in this field, let us know.

Go get 'em!!!!

Regards,

PW/bd

Pat

ANIMAL ECOLOGY PROGRAM LISTING

- 1 -- "K" Value of the Negative Binomial-Trial and Error
- 2 -- Expected Values for Negative Binomial Distribution
- 3 -- Logistic Versus Exponential Curves for Population Growth
- 4 -- Species Diversity Index Based on Information Theory
- 5 -- Expected Number from a Poisson Series
- 6 -- Mann-Whitney Ranking Statistic
- 7 -- Population Estimate and Confidence Limits of a Simple
Capture - Recapture Index
- 8 -- Population Estimate and Confidence Limits of Removal
Trapping

"K" VALUE OF THE NEGATIVE
BINOMIAL-TRIAL AND ERROR

If the distribution of animals or plants in space or time does not fit a Poisson series, then the negative binomial may be compared with the observed data. This program calculates an index of aggregation, k , by a trial and error method.

The equation used in this calculation is:

$$\text{Log}_{10} \left(\frac{N}{N_0} \right) = K \text{Log}_{10} \left(\frac{1 + M}{K} \right)$$

N = Total number of sample quadrants
 N_0 = Number having 0 items
 M = Mean

This is good for means below 10.

EXAMPLE

With 100 quadrants sampled, of which 15 had no animals, and a mean for the entire sample of 4.25 animals per quadrant?
What is the K value?

ANSWER: 1.58

Reference: Ecological Methods,
by T. R. E. Southwood, 1961,
Methuen and Company, Ltd.

ANIMAL
ECOLOGY
Program 1

X X X

X

X

5

1. PRESS: END
2. ENTER PROGRAM
3. PRESS: CONTINUE
4. ENTER DATA
5. PRESS: CONTINUE
6. ENTER estimated K Value
7. PRESS: CONTINUE
8. If $Z = Y$, K is correct
If $Z \neq Y$
9. PRESS: CONTINUE
Reestimate K
Return to Step 6

1	0	0
M	N_0	N
2	0	0
K	0	0
0	$\text{Log}(\frac{N}{N_0})$	K

EXAMPLE

N
N₀
M

Estimated K
Log $\left(\frac{N}{N_0}\right)$
K Log $10\left(\frac{1+M}{K}\right)$

A

100.
15.
4.25

0.
0.
1.4
.80364
.82391
0.

0.
0.
1.5
.81610
.82391
0.

0.
0.
1.58
.82397
.82391
0.

ANIMAL ECOLOGY -- 1

00	CLR	20
01	1	01
02	STP	41
03	PNT	45
04	PNT	45
05	XTO	23
06	a	13
07	RDN	31
08	DIV	35
09	DN	25
0a	LOG	75
0b	XTO	23
0c	b	14
0d	CLR	20

10	2	02
11	STP	41
12	PNT	45
13	RDN	31
14	a	13
15	XEY	30
16	1	01
17	+	33
18	DN	25
19	XEY	30
1a	DIV	35
1b	XEY	30
1c	LOG	75
1d	RUP	22

20	X	36
21	b	14
22	RUP	22
23	CLX	37
24	STP	41
25	PNT	45
26	PNT	45
27	CLX	37
28	GTO	44
29	0	00
2a	d	17
2b	END	46

EXPECTED VALUES FOR NEGATIVE BINOMIAL DISTRIBUTION

Knowing the value of 'k' from Program 1, this program calculates expected values of the negative binomial. One application is to find the number of quadrants containing 0, 1, 2 ... n animals in a sampling area.

The equation used in this calculation is:

$$N \cdot f(x_i) = N \left[\frac{\gamma (K + x_i)}{x_i! \gamma (K)} \right] \cdot \left[\frac{M}{M + K} \right]^{x_i} \cdot \left[\frac{K}{K + M} \right]^K$$

N = Number of quadrants

K = Aggregation index

x_i = Number of items per quadrant

γ and T = Constants

M = Mean

EXAMPLE

Given a 'k' value of 1.58, a mean of 4.25, and 100 quadrants sampled, calculate the expected number of quadrants containing 0, 1, 2 ... n number of animals using the negative binomial distribution.

$\gamma K = .891$

$T(K + x_i)$	$x_i!$	x_i
$T(K + 0) = .891$	$x_0! = 1$	0
$T(K + 1) = 1.408$	$x_1! = 1$	1
$T(K + 2) = 3.634$	$x_2! = 2$	2
$T(K + 3) = 13.009$	$x_3! = 6$	3
$T(K + 4) = 59.581$	$x_4! = 24$	4
$T(K + 5) = 332.462$	$x_5! = 120$	5

Answers:

x	values of the negative binomial
0	12.71
1	14.64
2	13.77
3	11.98
4	10.00
5	8.14

ANIMAL
ECOLOGY
Program 2

X X X

X

X

5

1. PRESS: END
2. ENTER PROGRAM
3. PRESS: CONTINUE
4. ENTER DATA
5. PRESS: CONTINUE
6. ENTER DATA
7. PRESS: CONTINUE
8. ENTER DATA
9. PRESS: CONTINUE
10. PRESS: CONTINUE (Recycle to Step 8)

For new data

PRESS: END

PRESS: CONTINUE

1	0	0
M	K	
2	0	0
$\gamma (K)$	N	
3	0	0
x_i	x_i	$T(K+x_i)$
x_i	0	$N \cdot f(x_i)$

EXAMPLE

K	0.
Mean	1.58
	4.25
Quadrants	0.
γK	100.
	.891
$T(K + 0)$	.891
$x_0!$	1.
x_0	0.
Negative Binomial	12.70931
	0.
	0.
$T(K + 1)$	1.408
$x_1!$	1.
x_1	1.
Negative Binomial	14.64088
	0.
	1.
	3.634
	2.
	2.
	13.77336
	0.
	2.
	13.009
	6.
	3.
	11.98114
	0.
	3.

ANIMAL ECOLOGY -- 2

00 CLR 20
01 1 01
02 STP 41
03 PNT 45
04 PNT 45
05 AC+ 60
06 + 33
07 XEY 30
08 DIV 35
09 XEY 30
0a LN 65
0b XTO 23
0c a 13
0d RCL 61

10 XEY 30
11 + 33
12 UP 27
13 RUP 22
14 DIV 35
15 RDN 31
16 LN 65
17 X 36
18 XEY 30
19 EXP 74
1a XTO 23
1b b 14
1c CLR 20
1d 2 02

20 STP 41
21 PNT 45
22 PNT 45
23 XTO 23
24 c 16
25 YTO 40
26 d 17
27 CLR 20
28 3 03
29 STP 41
2a PNT 45
2b PNT 45
2c AC+ 60
2d c 16

30 X 36
31 RDN 31
32 DIV 35
33 d 17
34 X 36
35 b 14
36 X 36
37 RUP 22
38 f 15
39 XEY 30
3a a 13
3b X 36
3c XEY 30
3d EXP 74

40 RUP 22
41 X 36
42 CLX 37
43 RUP 22
44 f 15
45 PNT 45
46 PNT 45
47 GTO 44
48 2 02
49 7 07
4a END 46

LOGISTIC VERSUS EXPONENTIAL CURVES
FOR POPULATION GROWTH

Population increase of yeast, protozoa, etc., will not continue indefinitely, but will reach a plateau. The first part of the growth curve may resemble the exponential curve, while the overall growth pattern will be more closely related to the logistic curve. This program calculates both curves, mainly for teaching comparison.

The equations used in these calculations are:

(1) Exponential $N_t = N_0 e^{rt}$

N_t = Population at time t

N_0 = Population at time 0

(2) Logistic $N_t = \frac{K}{1 + e^{a - rt}}$

K = Upper limit of population

r = Innate rate of increase

a = Constant of integration defining position
of the curve related to the origin

Reference: Laboratory Manual of General Ecology
by George W. Cox

EXAMPLE

Given an innate rate of increase (r) of 1.022 individuals per day, a population ceiling (K) of 450 individuals per .5 ml. and an 'a' value of 5.041, compare the logistics and exponentials curve of population growth that starts with 2 individuals per .5 ml.

ANSWER:

Time (t)	Exponential ($N_0 e^{rt}$)	Logistics $\frac{K}{1 + e^{a-rt}}$
0	2	2.9
1	5.6	7.9
2	15.4	21.4
3	42.9	54.8
4	119.2	125.2
5	331.3	232.8
6	920.7	336.9
7	2558.4	401.5
8	7109.2	431.2
9	19754.7	443.1
10	54893.3	447.5

ANIMAL
ECOLOGY
Program 3

X X X

X

X

5

1. PRESS: END
2. ENTER PROGRAM
3. PRESS: CONTINUE
4. ENTER DATA
5. PRESS: CONTINUE
6. ENTER DATA
7. PRESS: CONTINUE
8. ENTER: t
9. PRESS: CONTINUE
10. PRESS: CONTINUE (return to step 7)
11. PRESS: END, CONTINUE for new data set (return to step 3)

0 1 0

r N₀ 1

0 2 0

a K 2

3 0 0

t 0 0

t N₀e^{rt} $\frac{K}{1+e^{a-rt}}$

ANIMAL
ECOLOGY
Program 3

EXAMPLE

Data Entry	1.
N ₀	2.
R	1.022
Data Entry	2.
K	450.
a	5.041
$\frac{K}{1+e^{-rt}}$	2.89157
N ₀ ert	2.00000
t	0.
	7.94415
	5.55749
	1.
	21.40271
	15.44287
	2.
	54.83378
	42.91181
	3.
	125.22685
	119.24106
	4.
	232.75942
	331.34071
	5.
	336.85649
	920.71190
	6.

ANIMAL ECOLOGY -- 3

00	CLR	20	40	GTO	44
01	1	01	41	1	01
02	XEY	30	42	6	06
03	STP	41	43	END	46
04	PNT	45			
05	PNT	45			
06	XTO	23			
07	a	13			
08	YTO	40			
09	b	14			
0a	CLR	20			
0b	2	02			
0c	XEY	30			
0d	STP	41			
10	PNT	45			
11	PNT	45			
12	XTO	23			
13	c	16			
14	YTO	40			
15	d	17			
16	CLR	20			
17	3	03			
18	STP	41			
19	UP	27			
1a	a	13			
1b	XEY	30			
1c	X	36			
1d	XTO	23			
20	9	11			
21	AC+	60			
22	b	14			
23	LN	65			
24	+	33			
25	XEY	30			
26	EXP	74			
27	XTO	23			
28	f	15			
29	c	16			
2a	XEY	30			
2b	e	12			
2c	-	34			
2d	XEY	30			
30	EXP	74			
31	UP	27			
32	1	01			
33	+	33			
34	d	17			
35	XEY	30			
36	DIV	35			
37	f	15			
38	UP	27			
39	YE	24			
3a	9	11			
3b	XEY	30			
3c	PNT	45			
3d	PNT	45			

SPECIES DIVERSITY INDEX
BASED ON INFORMATION THEORY

This program calculates the expected species diversity in a given area.
The equation used in this calculation is:

$$H \sim 3.3219 \left[\log_{10} N - \frac{1}{N} (\sum N_i \log_{10} N_i) \right]$$

N = Total number of species
 N_i = Number of individuals of i^{th} species
H = Species diversity index

EXAMPLE

A collection of invertebrates yielded the following number of individuals:

Species A = 300
Species B = 150
Species C = 10
Species D = 5
Species E = 2
Species F = 1

What is the species diversity?

Answer:

Diversity = 1.1785

Number of individuals = 468

Number of species = 6

Reference: Ecological Methods

by T. R. F. Southwood,
1966, Methuen & Company, Ltd.

ANIMAL
ECOLOGY
Program 4

X

X

X X

5

1. PRESS: END
2. ENTER PROGRAM
3. PRESS: CONTINUE
4. ENTER DATA
5. PRESS: CONTINUE
6. PRESS: SET FLAG (after last data point)
7. PRESS: CONTINUE
8. PRESS: CONTINUE (ready for new data)

0 1

N_i

N i

H 0

ANIMAL
ECOLOGY
Program 4

i
N_i

1.
300.

2.
150.

3.
10.

4.
5.

5.
2.

6.
1.

N
i

469.
6.

H

0.
1.17848

ANIMAL ECOLOGY -- 4

00	CLR	20	40	RUP	22
01	XTO	23	41	PNT	45
02	d	17	42	PNT	45
03	1	01	43	END	46
04	XEY	30			
05	STP	41			
06	IFG	43			
07	2	02			
08	3	03			
09	PNT	45			
0a	PNT	45			
0b	YTO	40			
0c	d	17			
0d	UP	27			
10	UP	27			
11	LOG	75			
12	X	36			
13	RDN	31			
14	AC+	60			
15	CLX	37			
16	RDN	31			
17	d	17			
18	UP	27			
19	1	01			
1a	+	33			
1b	0	00			
1c	UP	27			
1d	RDN	31			
20	GTO	44			
21	0	00			
22	5	05			
23	e	12			
24	UP	27			
25	LOG	75			
26	RDN	31			
27	XEY	30			
28	1	01			
29	XEY	30			
2a	DIV	35			
2b	f	15			
2c	X	36			
2d	RDN	31			
30	-	34			
31	3	03			
32	.	21			
33	3	03			
34	2	02			
35	1	01			
36	9	11			
37	X	36			
38	e	12			
39	RUP	22			
3a	d	17			
3b	PNT	45			
3c	PNT	45			
3d	CLX	37			

EXPECTED NUMBER FROM A POISSON SERIES

This program checks randomness of distribution of individual animals of a class in a sampling area. For ecological work, the Poisson series is used to check this assumption. Calculated values can be compared to measured values using a χ^2 goodness of fit test.

The equation used in this calculation is:

$$f(N; \lambda) = \frac{\lambda^N e^{-\lambda}}{N!}$$

EXAMPLE

If the mean number of beetles in $\textcircled{N}$ 100 sampling areas is $\textcircled{\lambda}$ 5.43, what is the expected areas that have 0, 1, 2 ... x beetles?

$\textcircled{0}$	N_i	$f(N_i; \lambda)$	$N(N_i)$
	1	.0238	2.38
	2	.0646	6.46
	3	.1170	11.70
	4	.1588	15.88
	5	.1724	17.24
	6	.1560	15.60
	7	.1210	12.10
	8	.0821	8.22

$\textcircled{0}$ Example Entry

ANIMAL
ECOLOGY
Program 5

X

X

X X X

5

1. PRESS: END

2. ENTER PROGRAM

3. PRESS: CONTINUE

4. ENTER DATA:

5. PRESS: CONTINUE

DISPLAY

6. PRESS: CONTINUE

DISPLAY

etc.

7. To reset, PRESS: END

PRESS: CONTINUE (return to step 4)

0 0 0
 $\lambda(\text{mean})$ N_i N

N_i $f(N_i; \lambda)$ $N(N_i)$

$N_i + 1$ $f(N_i + 1; \lambda)$ $N(N_i + 1)$

EXAMPLE

N	100.
N_i	1.
λ	5.43
$N(N_i)$	2.38002
$f(N_i; \lambda)$	.02380
N_i	1.
	6.46176
	.06462
	2.
	11.69578
	.11696
	3.
	15.87702
	.15877
	4.
	17.24245
	.17242
	5.
	15.60441
	.15604
	6.
	12.10457
	.12105
	7.
	8.21597
	.08216
	8.

ANIMAL ECOLOGY -- 5

00 CLR 20
 01 STP 41
 02 PNT 45
 03 PNT 45
 04 XTO 23
 05 c 16
 06 YTO 40
 07 b 14
 08 RUP 22
 09 XTO 23
 0a d 17
 0b XEY 30
 0c CHS 32
 0d EXP 74

10 UP 27
 11 c 16
 12 LN 65
 13 UP 27
 14 b 14
 15 X 36
 16 XEY 30
 17 EXP 74
 18 RUP 22
 19 X 36
 1a YTO 40
 1b a 13
 1c b 14
 1d UP 27

20 UP 27
 21 1 01
 22 - 34
 23 X>Y 53
 24 2 02
 25 c 16
 26 RDN 31
 27 X 36
 28 RUP 22
 29 GTO 44
 2a 2 02
 2b 2 02
 2c a 13
 2d RUP 22

30 UP 27
 31 0 00
 32 XEY 30
 33 X=Y 50
 34 CNT 47
 35 1 01
 36 XEY 30
 37 DN 25
 38 DIV 35
 39 d 17
 3a XEY 30
 3b X 36
 3c RUP 22
 3d b 14

40 STP 41
 41 PNT 45
 42 PNT 45
 43 CLR 20
 44 b 14
 45 UP 27
 46 1 01
 47 + 33
 48 YTO 40
 49 b 14
 4a c 16
 4b GTO 44
 4c 0 00
 4d c 16

50 END 46

MANN-WHITNEY RANKING STATISTIC

This program is a significance test for differences in the medians of two samples, x and y. The distribution need not be normal. A rank is given to each x and y item, and the statistics U_1 and U_2 calculated. The values can be compared with the lowest U value in a suitable table to determine significance of the differences between medians.

The equations used in these calculations are:

$$U_1 = N_1 N_2 + 1/2 N_2 (N_2 + 1) - R_2$$

$$U_2 = N_1 N_2 + 1/2 N_1 (N_1 + 1) - R_1$$

$$U_2 = N_1 N_2 - U_1$$

$$R_1 = \text{Sum of ranks of x}$$

$$R_2 = \text{Sum of ranks of y}$$

EXAMPLE

Two species of insects were caught at a blacklight. Species x appeared at 1, 5, 8, 11, 20, 30, 35, and 40 minutes after 6:00 p.m. (each time represents one individual), and species y appeared at 3, 7, 9, 12, 13, 15, 18, and 22 minutes after 6:00 p.m. What is the U statistic?

x values	1	5	8	11	20	30	35	40
y values	3	7	9	12	13	15	18	22
Rank								
x rank	1	3	5	7	12	14	15	16
y rank	2	4	6	8	9	10	11	13

Answers:

$$U_x = 37 \quad U_y = 27 \quad N_x = 8 \quad N_y = 8$$

Reference: Statistics for Biologists
by R. C. Campbell
1967, Cambridge University Press

ANIMAL
ECOLOGY
Program 6

X

X

X X

5

- | | | | | |
|-----|---|-------|----|---|
| 1. | PRESS: END | | | |
| 2. | ENTER PROGRAM | | | |
| 3. | PRESS: CONTINUE | 0 | 1 | 0 |
| 4. | ENTER DATA (Rank of x) | x_i | i | 0 |
| 5. | PRESS: CONTINUE (Repeat for each x value) | | | |
| 6. | PRESS: SET FLAG after last data point | | | |
| 7. | PRESS: CONTINUE | 0 | 1 | 0 |
| 8. | ENTER DATA (Rank of y) | y_i | i | 0 |
| 9. | PRESS: CONTINUE (Repeat for each y value) | | | |
| 10. | PRESS: SET FLAG after last entry | | | |
| 11. | PRESS: CONTINUE | Ux | Uy | 0 |
| 12. | PRESS: CONTINUE (Return to Step 4) | Nx | Ny | |

EXAMPLE

X_i	1.
i	1.
.	2.
.	3.
.	3.
.	5.
.	4.
.	7.
.	5.
.	12.
.	6.
.	14.
.	7.
.	15.
.	8.
.	16.
Y_i	1.
i	2.
.	2.
.	4.
.	3.
.	6.
.	4.
.	8.
.	5.
.	9.
.	6.
.	10.
.	7.
.	11.
.	8.
.	13.
U_x	37.0
U_y	27.0
N_x	8.
N_y	8.

ANIMAL ECOLOGY -- 6

00 CLR 20
 01 XTO 23
 02 d 17
 03 1 01
 04 XEY 30
 05 STP 41
 06 IFG 43
 07 1 01
 08 b 14
 09 PNT 45
 0a PNT 45
 0b YTO 40
 0c d 17
 0d XEY 30

10 CLX 37
 11 XEY 30
 12 AC+ 60
 13 d 17
 14 UP 27
 15 1 01
 16 + 33
 17 CLX 37
 18 GTO 44
 19 0 00
 1a 5 05
 1b f 15
 1c XTO 23
 1d c 16

20 CLR 20
 21 1 01
 22 XEY 30
 23 STP 41
 24 IFG 43
 25 3 03
 26 9 11
 27 PNT 45
 28 PNT 45
 29 YTO 40
 2a b 14
 2b XEY 30
 2c CLX 37
 2d XEY 30

30 AC+ 60
 31 b 14
 32 UP 27
 33 1 01
 34 + 33
 35 CLX 37
 36 GTO 44
 37 2 02
 38 3 03
 39 b 14
 3a UP 27
 3b d 17
 3c X 36
 3d CLX 37

40 AC+ 60
 41 f 15
 42 - 34
 43 RUP 22
 44 b 14
 45 XEY 30
 46 1 01
 47 + 33
 48 b 14
 49 X 36
 4a . 21
 4b 5 05
 4c X 36
 4d RDN 31

50 + 33
 51 XEY 30
 52 YE 24
 53 e 12
 54 - 34
 55 XEY 30
 56 UP 27
 57 CLX 37
 58 RDN 31
 59 PNT 45
 5a PNT 45
 5b d 17
 5c XEY 30
 5d b 14

60 PNT 45
 61 PNT 45
 62 END 46

POPULATION ESTIMATE AND CONFIDENCE LIMITS OF A SIMPLE CAPTURE - RECAPTURE INDEX

This program calculates the simple Lincoln Index estimate of population, with input data supplied by capture-recapture procedures. It also calculates limits of the estimate for a 95% confidence level.

The equations used in these calculations are:

$$\begin{aligned} \text{Population estimate} &= \frac{a n}{r} \\ \text{Standard error} &= \frac{\left[\frac{a^2 n (n-r)}{r^3} \right]^{1/2}}{r^3} \end{aligned}$$

a = number marked initially
n = number captured on 2nd
occasion
r = number of marked animals
recaptured

EXAMPLE

335 animals are marked and released on day 1. 150 are recaptured on day 2, of which 30 are marked. What is the estimated population on day 1 ?

Answer:

Population Estimate = 1675

95% Confident Limits = 1139 - 2211

Reference: Ecological Methods

by T. R. E. Southwood, 1966,
Methuen and Company, Ltd.

ANIMAL
ECOLOGY
Program 7

X

X

X X X

5

1. PRESS: END
2. ENTER PROGRAM
3. PRESS: CONTINUE
4. ENTER DATA
5. PRESS: CONTINUE
6. PRESS: CONTINUE for new set of data, return to Step 4.

1 0 0

$$\frac{r}{a} \frac{n}{r} - 1.96 \sqrt{\frac{a}{r}} + 1.96 \sqrt{\frac{a}{r}}$$

EXAMPLE

	Data	
	a	335.
	n	150.
	r	30.
Answer:	Upper Limit	2211.11166
	Lower Limit	1138.88834
	Probable Error	1675.00000

ANIMAL ECOLOGY -- 7

00	CLR	20
01	1	01
02	STP	41
03	PNT	45
04	AC+	60
05	RDN	31
06	YTO	40
07	a	13
08	X	36
09	f	15
0a	DIV	35
0b	YTO	40
0c	b	14
0d	a	13

10	UP	27
11	X	36
12	e	12
13	X	36
14	RUP	22
15	f	15
16	-	34
17	RDN	31
18	X	36
19	DN	25
1a	RDN	31
1b	X	36
1c	X	36
1d	RDN	31

20	DIV	35
21	RDN	31
22	√	76
23	UP	27
24	1	01
25	.	21
26	9	11
27	6	06
28	X	36
29	RDN	31
2a	UP	27
2b	RUP	22
2c	b	14
2d	+	33

30	RUP	22
31	-	34
32	b	14
33	PNT	45
34	PNT	45
35	END	46

POPULATION ESTIMATE AND CONFIDENCE LIMITS
OF REMOVAL TRAPPING

Animals are trapped and removed on a series of occasions, and it is expected that the number caught on subsequent occasions, (and it is expected that the number caught on subsequent occasions) will diminish in a predictable manner. This program uses data from this procedure to predict initial total population and limits for a 95% confidence level.

The equations used in these calculations are:

(1)

$$T = n_1 + n_2 + \dots + n_k = \sum_{i=1}^k n_i$$

T = total catch

n_i = number caught on i^{th} occasion

(2)

$$\sum_{i=1}^k (i-1) y_i = (1-1)n_1 + (2-1)n_2 + \dots + (k-1)n_k$$

k = number of occasions

y_i = the catch on the i^{th} occasion

(3)

$$R = \frac{\sum_{i=1}^k (i-1) y_i}{T}$$

(4)

$$R = \frac{q}{p} - \frac{kq^k}{(1-q^k)}$$

p = probability of capture
on a single occasion

$q = 1 - p$

(5)

$$P = \frac{T}{(1-q^k)}$$

P = total population

(6)

$$\text{S.E. of } P = \sqrt{\frac{P(P-T)T}{T^2 - P(P-T) [(kp^2)/(1-p)]}}$$

S.E. = standard error of population

EXAMPLE

In a laboratory experiment, 2,000 beetles were placed in a wheat medium and a removal trapping method was started. At ten minute intervals, for fifty minutes, beetles were removed from the wheat. The number of beetles removed in order of time were:

322, 241, 250, 214, 142

How many beetles were there initially in the box, calculated by the removal method?

$q = .8457$ (calculated by trial and error)

Estimated population: 2,060

Confidence limits (95%) 1727 to 2394

Reference: Ecological Methods by T.R.E. Southwood, 1966 Methuen and Company Ltd.

ANIMAL
ECOLOGY
Program 8

	X		X		X		5
1.	PRESS: END						
2.	ENTER PROGRAM						
3.	PRESS: CONTINUE			1	0	0	
4.	ENTER DATA			N_i			
5.	PRESS: CONTINUE (Return to step 4.)						
6.	PRESS: SET FLAG (after last data point)						
7.	PRESS: CONTINUE						
	DISPLAY			2	0	0	
8.	PRESS: Y, Z on printer						
9.	ENTER DATA (estimate of less than 1)						
10.	PRESS: CONTINUE						
	DISPLAY			0	R data	R q est	
11.	If $y \neq z$, PRESS: CONTINUE and re-estimate q						
12.	If $y = z$, PRESS: SET FLAG						
13.	PRESS: CONTINUE						
	DISPLAY			0	0	P est	
14.	PRESS: END						
15.	ENTER PROGRAM B						
16.	PRESS: CONTINUE						
	DISPLAY			P est	P-1.96SE	P+1.96SE	

EXAMPLE

Input Data	(	322.
		241.
		250.
		214.
		142.
(i + 1)		6.
		0.
		0.
q _{est}		.8457
R _{data}		1.66883
R _{calc}		1.66895
		0.
P _{est}		2060.25735
		0.
		0.
95% Confidence Limits	(	2393.60034
		1726.91437
P _{est}		2060.25735

00 CLR 20
 01 1 01
 02 XTO 23
 03 d 17
 04 STP 41
 05 PNT 45
 06 IFG 43
 07 2 02
 08 4 04
 09 AC+ 60
 0a RDN 31
 0b d 17
 0c XEY 30
 0d 1 01

10 - 34
 11 RDN 31
 12 X 36
 13 CLX 37
 14 AC+ 60
 15 CLX 37
 16 RDN 31
 17 d 17
 18 XEY 30
 19 1 01
 1a + 33
 1b YTO 40
 1c d 17
 1d CLX 37

20 XEY 30
 21 GTO 44
 22 0 00
 23 4 04
 24 d 17
 25 UP 27
 26 1 01
 27 - 34
 28 YTO 40
 29 d 17
 2a RCL 61
 2b DIV 35
 2c XTO 23
 2d a 13

30 YTO 40
 31 b 14
 32 CLR 20
 33 2 02
 34 STP 41
 35 PNT 45
 36 PNT 45
 37 AC+ 60
 38 LN 65
 39 UP 27
 3a d 17
 3b X 36
 3c XEY 30
 3d UP 27

40 RUP 22
 41 LN 65
 42 + 33
 43 RDN 31
 44 EXP 74
 45 XEY 30
 46 EXP 74
 47 UP 27
 48 1 01
 49 XEY 30
 4a - 34
 4b YTO 40
 4c c 16
 4d RDN 31

50 DIV 35
 51 RUP 22
 52 1 01
 53 XEY 30
 54 f 15
 55 - 34
 56 f 15
 57 XEY 30
 58 DIV 35
 59 RDN 31
 5a XEY 30
 5b - 34
 5c b 14
 5d UP 27

60 CLX 37
 61 STP 41
 62 PNT 45
 63 PNT 45
 64 IFG 43
 65 6 06
 66 b 14
 67 CLR 20
 68 GTO 44
 69 3 03
 6a 4 04
 6b a 13
 6c UP 27
 6d c 16

70 DIV 35
 71 CLX 37
 72 UP 27
 73 PNT 45
 74 PNT 45
 75 END 46

00	RDN	31
01	AC+	60
02	a	13
03	-	34
04	X	36
05	e	12
06	X	36
07	YTO	40
08	b	14
09	1	01
0a	UP	27
0b	f	15
0c	-	34
0d	d	17

10	X	36
11	RDN	31
12	UP	27
13	X	36
14	f	15
15	DIV	35
16	RUP	22
17	XEY	30
18	a	13
19	DIV	35
1a	RDN	31
1b	X	36
1c	DN	25
1d	RDN	31

20	X	36
21	RDN	31
22	XEY	30
23	-	34
24	b	14
25	XEY	30
26	DIV	35
27	RDN	31
28	√	76
29	UP	27
2a	1	01
2b	.	21
2c	9	11
2d	6	06

30	X	36
31	RUP	22
32	DN	25
33	e	12
34	+	33
35	RUP	22
36	-	34
37	e	12
38	PNT	45
39	END	46

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