A new method for counting animals in small populations of recognizable individuals

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The problem of estimating the number of animals in a population is one which has attracted much attention and generated a large literature. Despite increasingly sophisticated mathematical analyses it remains true that the reliablity of any estimate rests ultimately on the rigor with which the field data were gathered. If an estimate of population size is not the main aim of an investigation the collection of appropriate data may be practically impossible or incompatible with requirements that e.g. study animals remain undisturbed. We present here a method of evaluating animal numbers for which trapping, marking, transect sampling, removal of animals or constant sampling effort are uneccesary. It requires only that individuals be seen and recognised — a requirement which is easily satisfied during studies of e.g. behaviour.

It is not our intention here to explore the mathematical properties of the expressions we present nor to compare the new method with the multitude of others which have been developed. It is our aim to bring the method to the attention of field workers who have the opportunity to test it, and those who may wish to refine its mathematics.

If the animals in a closed population are observed at random and animals which have been seen at least once can be recognized as such the probability that the i th observation is of a previously unseen animal depends on the size of the population and the number of animals already seen:

$$P_i = \frac{N - Ti\text{-}1}{N} \quad \text{..... (1)}$$

Where:

P_i = probability that the i th observation is of a previously unseen animal
N = number of animals in the population
T_{i-1} = number of animals which have already been seen

In the ideal case, where animals are observed at random and are recognized with complete certainty, the ideal value of T for any value of i is the sum of the probabilities of S=1 to S=i that each animal seen is a new one:

$$T = \Sigma^i_1 \, Pi \quad \text{...... (2)}$$

$$T = \frac{N}{N} + \frac{N - \frac{N}{N}}{N} + \frac{N - \frac{N}{N} - \left(\frac{N - \frac{N}{N}}{N}\right)}{N} + \text{....... (3)}$$

Where:

S = total number of sightings already made

T = number of new observations made during S sightings

In order to find the population size (N) it is recognized that, since N is the only unknown in equation 3, a unique theoretical curve of total new sightings (T) against the number of observations (S) exists for each value of N. The population size may be taken as that value of N which generates the curve with the best fit to census data. Due to the very large number of terms in equation 3 the necessary calculations and data handling are carried out by the computer programme LAPCOUNTER which is available from the authors.

LAPCOUNTER generates a set of ideal curves of T against S for a series of values of N. The value of N for which the ideal curve provides the closest least squares fit to census data is taken as the size of the population.

LAPCOUNTER was tested on simulated, ideal populations with perfectly random search and complete certainty of recognition, by searching for members of the series 1, 2, 3, ... N with a series of random integers between 1 and N. The first occurrence of a member of the first series in the second was regarded as a new sighting, subsequent occurrences of that member were treated as repeat observations (Figure 1).

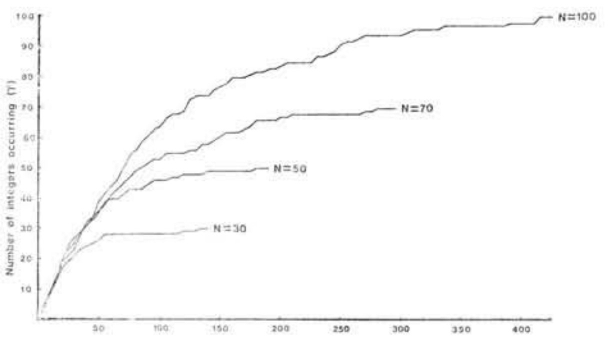

FIGURE 1. Plots of cumulative totals of members of the series of integers 1, 2, 3, . . . N occurring in a random series of integers between 1 and N.

TABLE 1: Population estimates generated by LAP COUNTER (N_{LAP}) from results of non-exhaustive, random searches for ideal populations of diffent sizes. D % is the percentage error of the LAP COUNTER estimate.

	True population							
	100		70		50		30	
Number found	N_{LAP}	D %	N_{LAP}	D %	N_{LAP}	D %	N_{LAP}	D %
100	99	1,0						
90	96	4,0						
80	95	5,0						
70	96	4,0	68	2,9				
60	103	3,0	65	7,1				
50	124	24,0	61	12,9	50	0,0		
40	112	12,0	61	12,9	55	10,0		
30	125	25,0	55	21,4	53	6,0	29	3,3
25							27	10,0
20	∞		66	5,7	46	8,0	26	13,3
15							24	20,0
10	∞		46	34,3	32	36,0	21	30,0

Data from these simulated searches were entered into LAPCOUNTER in order to test its accuracy (Table 1).

Having established that LAPCOUNTER produced accurate estimates under ideal conditions the tests were repeated using real field data from censusses of cats *(Felis catus)* on Dassen Island (Apps 1981, 1983, 1987) (Figure 2). LAPCOUNTER population sizes were compared with those based on exhaustive counts (Table 2). It is readily apparent that LAPCOUNTER yielded accurate population sizes from the results of exhaustive searches.

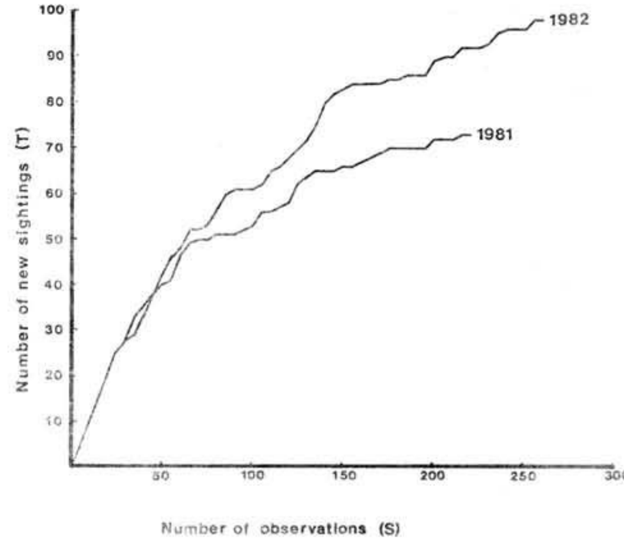

FIGURE 2. Plots of cumulative totals of new cats sighted against number of observations of cats during censussing on Dassan island in March 1981 and March 1982 (definite recognitions only).

TABLE 2. Population estimates generated by LAP COUNTER (N_{LAP}) from field data for censuses of cats on Dassen Island compared to estimates based on exhaustive counts of recognised cats (N_{Count}).

Year	N_{Count}	N_{LAP}	Percent Difference
1981	75	77	2,6
1982	107	105	1,9

The tests were repeated under conditions which allowed the searching programme to find only successively smaller fractions of the simulated populations. Under these conditions LAPCOUNTER must generate a value for N from a progressively shorter section of the T against S curve (Table 1). The LAPCOUNTER programme was effective for data from sightings of as few as 60% of the total population so long as searching and recognition were respectively random and completely reliable. Since neither of these conditions are likely to be rigorously satisfied under field conditions the above tests was repeated with the two sets of real data (Table 3). LAPCOUNTER yielded accurate population sizes from the real data even when the number of observations was only 50% of that required for an exhaustive count.

TABLE 3: Population estimates generated by LAP COUNTER (N_{LAP}) from results of non-exhaustive searches by S observations of field data for censuses of cats on Dassen Island. T is the number of cats found. D % is the percentage difference between N_{LAP} and an estimate of cat numbers based on exhaustive counts.

	March 1981 (75 cats)			March 1982 (107 cats)		
S	T	N_{LAP}	D %	T	N_{LAP}	D %
260				98	105	1,9
250				96	105	1,9
240				96	104	2,8
230	73	77	2,6	93	104	2,8
220	73	77	2,6	92	104	2,8
210	71	77	2,6	90	104	2,8
200	71	77	2,6	89	104	2,8
190	70	77	2,6	86	104	2,8
180	70	77	2,6	85	104	2,8
170	70	77	2,6	84	104	2,8
160	68	77	2,6	84	104	2,8
150	66	77	2,6	83	103	3,7
140	65	77	2,6	80	100	6,5
130	64	76	1,3	72	98	8,4
120	58	76	1,3	68	99	7,5
110	56	78	4,0	65	101	5,6
100	53	81	8,0	61	107	0,0
90	51	87	16,0	61	112	4,7
80	51	97	29,3	56	117	9,3
70	50	107	42,7	52	125	16,8
60	46	112	49,3	48	131	22,4
50	40	142	89,3	42	127	18,7
40	35	256	241,3	33	124	15,9
30				28	583	444,9

DISCUSSION

The close agreement between LAPCOUNTER and the exhaustive counts in the value given for the number of cats on Dassen Island indicates that, for the Dassen Island cats at least, the method is a valid one. Whether this extends to other situations can only be shown by further testing.

The LAPCOUNTER method requires that animals be individually recognizable. Although recognition marking of animals is an established procedure (Stonehouse 1978) the effort involved is considerable and more often than not it involves capture and/or immobilisation of the animal, the avoidance of which is one of the main advantages of the present method. Thus the recognition method offers the greatest advantages when applied to animals which may be recognised without the need for marking. This includes an interesting and important range of species among which are lions *(Panthera leo)* (Pennycuick and Rudnai 1970), giraffe *(Giraffa camelopardalis)* (Petersen 1972), black rhino *(Diceros bicornis)* (Mukinya 1973), elephants *(Loxodonta africana)* (Douglas-Hamilton and Douglas-Hamilton 1975), zebra (Equus burchelli) (Petersen 1972) and large primates (Schaller 1963, van Lawick Goodall 1968).

The need for recognition places an additional constraint on the application of the LAPCOUNTER method, in the form of an upper limit to the size of the population to which it may be directly applied, determined by the observer's ability to recognise large numbers of animals. What the upper limits are will depend on the abilities of the observer, the observability of the animals and the extent of differences among them (Bateson 1977, Pennycuick 1978, Scott, 1978). It seems that the direct application of the method will be limited to populations of less than a few hundred.

At this stage no means of fixing confidence limits for population sizes has been developed. We feel that field testing of the technique on populations of known size will be initially more useful than mathematical sophistication.

CONCLUSIONS

Application of the LAPCOUNTER program to counts of recognisable individuals is a potentially valuable method of measuring the sizes of small, isolated populations in circumstances unsuitable for the application of conventional population estimation methods.

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