

A CRITICISM ON SOME EXAMPLES OFFERING A KILL-EFFICIENCY BY THE MARK-AND-RELEASE CENSUS OF PRE- AND POST-POISONING VOLE POPULATIONS

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The efficiency of poisoned baits can be tested by comparing the population of animals before and after treatment, and the mark-and-release method is suitable for the censuses. But, when the success is so great that only a few survive the poisoning, the method is scarcely useful for the post-poisoning census because of deficiency in data for the calculation.

The census method should, in general, be undertaken in due allowance for heterogeneous response to live traps of individuals. Various kinds of differential trap-attitude have been disclosed by several mammalogists⁽¹⁾⁽²⁾⁽³⁾⁽⁹⁾⁽¹²⁾, and we are cautioned against a thoughtless use of the Lincoln Index to the census. Differential innate traits of trap reaction, even if the evidence is difficult to demonstrate, would be borne by different individuals; some may be more vulnerable to trapping than others wary of traps before they have been captured at all. Another differential trappability may be pointed out either in different sex (house mouse)⁽¹²⁾ or in different body size (rat)⁽²⁾.

However, it is certainly conceivable from accumulated data of our study that the heterogeneity induced after an initial experience of capture will give the most important effect to the mark-and-release sampling, the same conception being manifested by Chitty et al.⁽¹⁾ The last authors, moreover, afforded evidence in support of the maintenance by marked voles of the intensified trappability after 1-2 month intervals during which there were no traps on the study area. We cannot, therefore, ignore the effect of the career of animals through the pre-poisoning process upon the marked survivors in the post-poisoning one, and a simple formula for the direct calculation of survival rates from post-poisoning data has been proposed,⁽⁷⁾ the effect being taken into consideration.⁽¹¹⁾

Recently, Udagawa et al.⁽¹¹⁾ executed expensive work for the comparison of efficiency of some poisons in vole populations, but their analysis of the data seems to me not always satisfactory, and the reanalysis of them has⁽⁵⁾ provided us with important informations. A similar study is published by Jameson,⁽⁵⁾ and yet no capture records are available for us to make an exact criticism on it.

Calculation method of the kill efficiency

When marking and releasing is done after poisoning under the same trapping design as before, the probability of capture π for marked and p for unmarked, estimated before, is to be expected to still remain unchanged in the post-poisoning process. Let the pre-poisoning population estimated be N_1 , the survival rate r for marked and r' for unmarked can be given from the post-poisoning capture records (X_1, X_2, \dots, X_n for marked,

Y_1, Y_2, \dots, Y_n for unmarked) during n days by the subsequent formulae;⁽⁷⁾

$$r = \frac{\sum X - \{(n-1)Y_1 + (n-2)Y_2 + \dots + Y_{n-1}\}\pi}{nM\pi} \dots\dots\dots (1)$$

$$r' = \frac{\sum Y + \{(n-1)Y_1 + (n-2)Y_2 + \dots + Y_{n-1}\}p}{n(N_1 - M)p} \dots\dots\dots (2)$$

Then the kill efficiency in the whole population is

$$1 - \frac{(N_1 - M)r' + Mr}{N_1} \dots\dots\dots (3)$$

where M is the total number handled, existing at the end of the initial census.

If the same probability of capture is not to be expected before and after treatment under circumstances, such as a long interval between the initial and the poisoning and/or post-poisoning census, or a notable difference in the trapping design made between the pre- and post-poisoning censuses, new values of π and p need estimating from the post-poisoning data. In this case, on the base of the same principle underlying the above formulae, putting $Mr \equiv M'$, $(N_1 - M)r' \equiv L'$, the following formulae are available;⁽⁸⁾

$$E(X_{n+1}) = \{M' + (Y_1 + Y_2 + \dots + Y_n)\}\pi \dots\dots\dots (4)$$

$$E(Y_{n+1}) = \{L' - (Y_1 + Y_2 + \dots + Y_n)\}p \dots\dots\dots (5)$$

These are expected to show a straight line, running upward (4) or downward (5) on the increasing abscissa. The kill efficiency is counted by (3) from the values of M' and L' besides π and p estimated by these formulae, which may be in brief expressed in the common form $E(Y) = (N \pm x)p$.

Reanalysis of the trap records

The census work by Udagawa et al.⁽¹¹⁾ was carried on in a woodland at an elevation of 1250 m in the Kiso mountain-range, Nagano Prefecture. An initial census was operated by the mark-and-release method, in succession to which a poisoning and a second census were done, and yet, to my regret, a removal method by snap traps was employed for the second. Each of the study plots, 1 hectare in area, was surrounded with sheet-zinc to utterly prevent any member of the enclosed population from immigration and emigration. The measures seem very pertinent to a kill-efficiency test. Out of 4 plots treated by them, the records on plots No. 1 and No. 4 are taken up (Table 1).

From the pre-poisoning data in Table 1, the population parameters are produced by the maximum likelihood method⁽⁷⁾ as follows (Figure 1);

	$\hat{\pi}$	\hat{p}	\hat{N}
Plot 1	0.20 ± 0.070	0.064 ± 0.0072	224 ± 4.9
" 4	0.23 ± 0.033	0.086 ± 0.0135	109 ± 3.6

The populations, however, were estimated by the original authors at 133 (Plot 1) and

Table 1. Trap records of the field vole (*Microtus montebelli*) in the pre- and post-poisoning censuses (from Udagawa et al.⁽¹¹⁾)

Method	Date (1956)	Plot 1		Plot 4	
		Number of captures		Number of captures	
		Unmarked	Marked	Unmarked	Marked
Mark and-release (by cage trap)	Nov. 14	13 (1)	0	—	—
	15	16	1	9	0
	16	9	6 (1)	8	1 (1)
	17	12 (2)	5	8 (1)	6
	18	12 (1)	12	8	6
	19	14	17	7	9 (1)
	20	9	15	7	5
	21	7	11	4	10
	Total	92		51	
Poisoning with		1080 soaked in corn		zinc phosphide in unbaked biscuits	
Removal (by snap trap)	Nov. 25	0	5	6	7
	26	5	4	9	5
	27	1	1	3	2
	28	1	1	5	0
	29	1	0	0	1
	30	—	—	1	0
	Total	8	11	24	15

The figure in parenthesis is number of animals dead in the group.

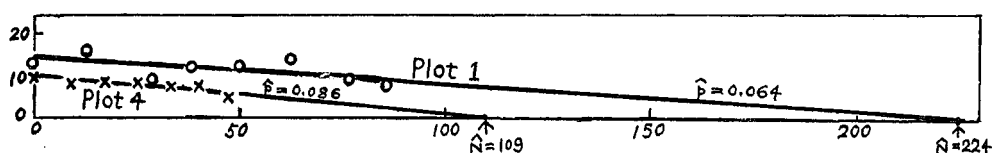


Figure 1. Straight lines expressing $E(Y) = (N-x)p$, determined by the maximum likelihood method from the data in Table 1 and actual plotted points

82 (Plot 4), which are clearly underestimates, originating from inappropriate application of the linear function $E(Y) = (N-x)p$ relying on a graphic method. Such a fault due to the graphic method is liable to occur especially when p is as small as in this case (Figure 1). The unusually small value of p is postulated as mainly referable to too low density of traps (trap spacing 15 m) in proportion to the population size.

Our evidence in favour of the postulation will briefly be adduced. We are studying how the exposed population \hat{N}' , estimated by our method, is dependent on trap densities (number of traps set per unit area); the dependency has been theoretically proved by Sugiyama, one of our collaborators, to follow the principle that the ratio of $E(\hat{N}')$ to the whole trappable population * N approximates 0.95 or 1.00 when $\rho \equiv r/d$ is 1 or more (r : radius of average home ranges, d : trap spacing in a grid-pattern trap system),

* That is all members, having any possibility of capture in traps, of the population exclusive of young in the sucking and weaning periods.

therefore $\rho \geq 1$ is required to reach N . To our best knowledge, the size of the genuine home range is, from the standpoint of methodology, difficult to estimate at present. Then, to test the validity of the theory, a field work was executed last autumn in the peat-bog grassland in Hokkaido under the design shown in Figure 2.

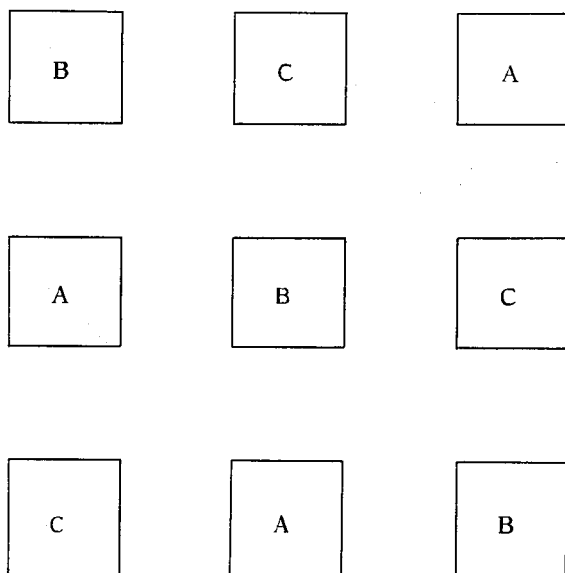


Figure 2. Trapping design by the Latin square method; each plot $40\text{ m} \times 40\text{ m}$, plot spacing 40 m , trap spacing 5 m (A), 8 m (B), 10 m (C.).

From the capture records in 6 days, it has proved that the majority of the overall population consists of the Bedford's vole (*Clethrionomys rufocanus*) and that each subpopulation on a plot is nearly discrete, since only few intermigrations between them were realized.

Under the plan of work, the combined subpopulations on the same trap-spacing plots (3 A, 3 B, 3 C) are most likely to be equal to one another in size. The population parameters of the vole estimated by the same method as employed above are;

	$\hat{\pi}$	\hat{p}	\hat{N}
A	0.73	0.34	64
B	0.73	0.21	55
C	0.625	0.31	50

These fail to show any significant difference between A, B and C, but there is a general tendency for π , p and N each to be enlarged with increasing trap-density. On referring to 20 m of the radius r of the average trap-revealed home range, obtained by me⁽⁶⁾ in 1952 on the same grassland, ρ for the present case might be over 1, and yet we cannot help suspecting that the whole trappable population might be near 64 rather than 50. It necessitates a further research.

At any rate, the profoundly small values of π and p in *Microtus* may be traced to low trap-density, so even the population recalculated by myself would be some underestimate, viewed from the whole trappable population.

The population surviving poisoning, N_2 , can be assessed from the data in Table 1, which should be applied to the formula (5) either for unmarked or for marked. Thus, even with maximum likelihood, the following estimates are gained;

	$\hat{\pi}$	\hat{N}_2		\hat{p}	\hat{N}_2	
Plot 1	0.55	11	} for marked	0.36	8	} for unmarked
" 4	0.54	15		0.41	24	

The values of probability of capture are much larger than those before poisoning; that is easily comprehensible from the fact that snap traps, instead of live traps, the former being threefold as many as the latter, were used after poisoning. The original authors seem to have applied formula (1) to the data for marked, this treatment being explicitly unsound.

The kill efficiency can be calculated from N_1 , M , number dead and N_2 as follows*;

Plot 1	0.87	} for marked	0.94	} for unmarked	0.91	} combined
" 4	0.69		0.59		0.63	

It is worth noting that the death rate or survival rate may be fairly different between marked and unmarked animals.

If the mark-and-release method had been adopted also after poisoning, how many captures would have been gained? These numbers may be expected on the presumption that the probability of capture experienced before poisoning is kept over the poisoning period. The expected number in Plot 4 is shown in Table 2.

Table 2. Expected number of captures in the mark-and-release process after poisoning in Plot 4 when the animals handled before poisoning are assumed as "marked" (I) or as "unmarked" (II)

	Day	Number of captures expected			Total number of previous survivors	
		Unmarked	Marked	Total	Unmarked	Marked
I	1	2	3	5	24	15
	2	2	4	6	22	17
	3	2	4	6	20	19
	4	2	5	7	18	21
	5	1	5	6	16	23
	6	1	6	7	15	24
	7	1	6	7	14	25
	Total	11	33			
II	1	5	0	5	39	0
	2	5	1	6	34	5
	3	4	2	6	29	10
	4	4	3	7	25	14
	5	2	4	6	21	18
	6	2	5	7	19	20
	7	2	5	7	17	22
	Total	24	20			

* Actual figures used in the calculation are ;

	M	No. unmarked among N_1	r	r'
Plot 1	91-5 (number dead)=87	224-97=132	11/87	8/132
" 4	51-3 (" ")=48	109-51= 58	15/48	24/58

The substitution of the values in Table 2 (I) and known values of π , p , N_1 and M into formulae (1), (2) and (3) results in death rates 0.69 for marked and 0.59 for unmarked, which are the same with those gained above, while the use of (5) only will suffice to treat the data in Table 2 (II). In either case, whether procedure I or II, referred to in the table, is followed, the same result can be reached, but I is simpler and preferable.

The census in the study of Jameson⁽⁵⁾ is performed exclusively by the modification of the Lincoln Index proposed by Hayne, but the probability of capture for the vole (*Microtus californicus*) would be so high, since trap spacing is calculated to be 6.7 m in average from his data. The census method is very unreliable in so far as no assurance for $\pi=p$ is made. I dare to doubt that the vole may be always homogeneous in trap response before and after initial capture.

An extreme underestimate of populations resulting from the use of Hayne's formula ($y=x/P$) is exemplified by utilizing the data reanalysed here. On analysis according to this formula, N_1 is estimated at 107 for Plot 1 and 62 for Plot 4, which are only about half of the right values, and the comparison of 62 with 28, estimated in the same way for N_2 from Table 2 (I), gives rise to 0.55 as a kill efficiency on Plot 4, it being quite unreliable, although both N_1 and N_2 may be underestimated in parallel.

The original author, furthermore, calculated the amount of invasion into a plot during an interval between the initial and second censuses on the supposition of $r=r'$ in terms of our symbols, but the supposition is considered unpractical by reference to our foregoing results.

Conclusion and summary

A criticism on two papers aiming at a kill efficiency by the census of pre- and post-poisoning populations in field voles was attempted, the methods, so far proposed by us, for the calculation of the death rate being collectively arranged. The reanalysis of some trap records by Udagawa et al. (1958) has provided us with evidence suggesting various important informations about the methodology.

(1) The unusually small value in probability of capture seems mainly due to too low density of traps in proportion to the population size. This is supported by the unpublished results of our study which attempts to know how a trap density affects an estimated size of the exposed population.

(2) The population, if estimated according to the Lincoln Index, would be strikingly underestimated, hence a kill efficiency, resulted, would be also very unreliable.

(3) The survival rate may be fairly distinct between marked and unmarked animals.

(4) The same death-rate can be reached by two different procedures, in post-poisoning mark-and-release, whether animals handled in the initial census are assumed as "marked" or "unmarked", but the former will be much simpler.

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