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The choice of round numbers in catch-depletion method

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ABSTRACT *The estimation of the population size of animals has long been a difficult work. The catch-depletion method, a method based on the catch effort and the catch numbers, has been widely used, especially in estimating the fish density in streams. Limited by the investment of time and labor, most field measures use two-catch or three-catch method, which may lead to the inaccurate measurement. Here we investigated how the number of catching rounds and the capture probability influence the accuracy of the estimates of catch-depletion method. We found that …*

KEYWORDS : -population size, maximum likelihood, catch-depletion method

INTRODUCTION

Measuring the precise estimates of animal abundance has long been a central and challenge topic for ecologists (Lockwood & Schneider 2000). The methods could be divided into two categories: mark-recapture experiments and catch-depletion method (Seber & Le Cren 1967). The former one is suitable for the terrestrial animals like mice and moose, which can be relatively easy to be marked. The latter method has been widely used in estimating fish density in streams, small rivers or ponds (Peterson *et al.* 2004), where capture by electricity is easy.

The catch-depletion method estimates the fish density by analyzing the catch effort, i.e. the number of caught fish. Fish is caught by electric equipment in net-enclosed water body (Bacon & Youngson 2007). Restricted by the investment of time and labor, usually two or three rounds are used. However, this might causes the inaccuracy of estimates (Peterson *et al.* 2004). Here we calculated the fish abundance estimates of catch-depletion method with different number of rounds under different capture probability. The aim is to investigate the influence of the round numbers and the capture probability on the accuracy of the catch-depletion method.

MATERIALS AND METHODS

Likelihood function

Define N as the number of individuals before fishing, Z_i as the catch effort by round i, and p as the probability that any one fish is caught. The probability that the catch in first round is exactly Z_i is given by

$$P(Z_1) = C_N^{Z_1} p^{Z_1}(1-p)^{N-Z_1} = \frac{N!}{Z_1!(N-Z_1)!} p^{Z_1}(1-p)^{N-Z_1} \quad (1)$$

For two-catch method, the joint probability of Z_1 and Z_2 is given by

$$P(Z_1, Z_2) = \frac{N!}{Z_1!Z_2!(N-Z_1-Z_2)!} p^{Z_1+Z_2}(1-p)^{N-Z_1+N-Z_1-Z_2} \quad (2)$$

Then for all the n rounds, the joint probability distribution of Z_1, Z_2, ..., and Z_m is given by

$$P(Z_1, Z_2, \ldots, Z_n) = \frac{N!}{\prod_{i=1}^{n} Z_i!(N-\sum_{i=1}^{n} Z_i)!} p^{\sum_{i=1}^{n} Z_i}(1-p)^{\sum_{i=1}^{n}(N-\sum_{j=1}^{i} Z_j)} \quad (3)$$

$$+\sum_{i=1}^{n}(N-\sum_{j=1}^{i} Z_j)\log(1-p) \quad (4)$$

In this function, N and p are unknown parameters, so we can write this function as

$$\log L_n = f(N, p) \quad (5)$$

Artificial data and Maximum Likelihood Estimate (MLE)

We assumed the total number (N) of fish in enclosed water body is 1,000. Under different capture probability (p), we calculated the supposed number for each round of catch (see Table 1). For each round under each capture probability, we calculated the MLE of the fish number (N^*) and capture probability (p^*). Then, we fixed p^* and calculated the log-likelihood values for different fish number, and got the 95% confidence intervals (95%CI) of fish number using likelihood-ratio test (LRT).

Table 1 Artificial data which show the fish number for each round of catch under different capture probability.

Index of the round (*i*)	Assumed Capture probability (p)								
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
1	100	200	300	400	500	600	700	800	900
2	90	160	210	240	250	240	210	160	90
3	81	128	147	144	125	96	63	32	9
4	73	102	103	86	63	38	19	6	1
5	66	82	72	52	31	15	6	1	0

RESULTS AND DISCUSSION

We demonstrated an illustration of the likelihood-ratio test (Fig. 1), which showed that increasing the number of catch round from 2 to 5 could decrease the 95%CI dramatically from [965, 1036] to [990, 1011], which indicated the increasing accuracy of the estimates. Surprisingly increasing n rarely altered the MLE of fish number.

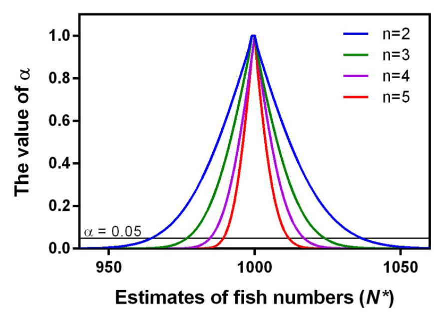

Figure 1 Illustration of the likelihood-ratio test for the artificial data when assumed p is 0.5. Different colors indicate different nu mber of rounds. The horizontal line indicates the 95% range of the estimates.

The extended
analyses for all the artificial data showed similar pattern (Table 2), i.e. increasing the number of rounds would shorten the 95%CI, especially when the capture probability was small. Additionally, we also found the MLE of fish number might be underestimated when both round number and capture probability were small.

Table 2 The maximum likelihood estimate (MLE) and the 95% lower boundary (LB) and upper boundary (UB) of the fish numbers.

Number of rounds (*n*)	Bounds and estimates	Assumed Capture probability (P)								
		0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
2	LB	801	882	917	955	965	974	981	988	994
	MLE	842	957	973	999	1000	999	1000	1000	1000
	UB	952	1038	1033	1047	1036	1027	1019	1012	1006
3	LB	830	938	957	968	977	985	990	995	999
	MLE	918	999	999	999	1000	999	1000	1000	1000
	UB	1013	1064	1045	1033	1023	1016	1010	1005	1002
4	LB	918	949	966	976	985	990	995	998	1000
	MLE	1000	999	1000	999	1000	999	1000	999	1000
	UB	1088	1051	1035	1023	1016	1009	1005	1002	1000
5	LB	929	958	973	983	990	994	998	999	1000
	MLE	1001	999	1000	999	1000	999	1000	999	1000
	UB	1077	1043	1028	1017	1011	1005	1003	1000	1000

Increasing the capture probability would also decrease the standard error of the MLE (Fig. 2). If *p* varied from 0.1 to 0.9, the standard error could change from about 40 to around 5. This indicates the importance of increasing the capture probability.

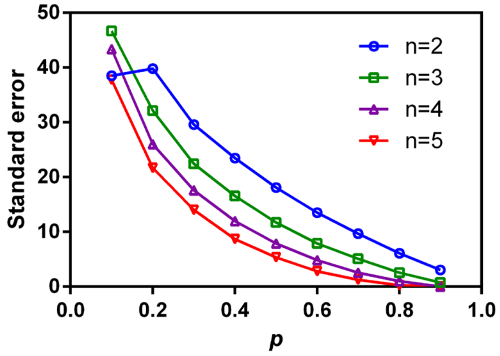

Figure 2 The relationship between the standard error of MLE and the captured probability. Different colors indicate different number of rounds.

CONCLUSION
Our findings demonstrated that two or more rounds of catch with capture probability higher than 0.4 could make sure an accurate estimate of fish number. More rounds of catch or higher capture probability indeed shortened the confidence interval of the estimates, i.e. decreased the standard error.

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