



doi: <http://dx.doi.org/10.19240/njpas.2016.A24>

## CAPTURE – RECAPTURE METHOD TO FISH CATCHMENT FOR ESTIMATING THE SIZE OF A CLOSED POPULATION USING OTIS SCHEME

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### ABSTRACT

Capture-recapture method was used to estimate fish abundance at Remto Farms, Eyenkorin Lasoju Ilorin, kwara state, Nigeria using Otis scheme. The fieldwork was aimed at estimating the fish abundance in ponds 1 and 2 based on varying probability affecting them. The models considered in this study are: Lincoln-Peterson model, Equal catchability model, the Heterogeneity model, Trap Response model, Heterogeneity and Trap response Model, the Schnabel and other time Dependent models. R-capture package was used to obtain the estimate of each of the models considered and to determine the best model. We observed that the Trap Response and the Schnabel-Heterogeneity models that vary with time gives the best models for the fieldwork.

**Keywords:** capture-recapture, animal abundance, pond, fishes, model

### INTRODUCTION

When investigating dynamics of an animal population, it is naturally desirable to have estimates of abundance or population size. In addition, it is desirable to have estimates of fundamental demographic variables that affect population size, i.e., reproductive or birth rate, immigration rate, mortality rate, and emigration rate. Capture-recapture method can be used to estimate population size, mortality + emigration rate, and birth + immigration rate (although not all models permit estimation of all 3 quantities). Capture-recapture method have a long history of use in ecology (Le Cren, 1965), and a very large literature on statistics of capture-

recapture sampling models exists with important reviews given by Anderson, (1995); Baumgartner, (2006); Chapman, (1951); Cormack, (1968); Cormack, (1979); Dauwalter and Fisher, (2007); Nicholas, (1981); Odenkirk and Smith, (2005); Peterson and Otto, (1983); Seber, (1982); Seber, (1986); Snyder, (2003) and White, (2008). In capture-recapture experiments, we typically sample the population under study  $k$  times where  $k$  is usually  $\geq 2$ . Each time, every unmarked animal caught is uniquely marked, previously marked animals have their captures recorded, and all animals are released back into the population (Otis *et al.*, 1978).

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Closed population models are simpler for the statistician to study and have received much attention. Otis *et al.* (1978) presented an excellent study of these models suitable for biologists. Within the closed population framework, the assumption of equal probability of capture has been relaxed in a variety of ways. A major disadvantage of closed population models is that their use is limited to short-term studies where births and deaths can be ignored. Unfortunately, even then they may not be applicable if there is significant migration in and out of the study area (Otis *et al.*, 1978).

The intent of this fieldwork are to; estimate the abundance of fish in ponds 1 and 2, fit and select the best model, and compare the estimate of the abundance of fish obtained in these two ponds.

**MATERIALS AND METHOD**

**Method of data collection**

Data were collected on cat fishes at Remto Farm located at Eye korin, Lasaju Ilorin, Kwara State Nigeria from 4<sup>th</sup> to 6<sup>th</sup> of August 2015. A live trapping of fishes were sampled from a fish pond of area 20ft x 40ft using dragnet. A systematic scooping was done the following day to collect a sample of fishes from the pond using different methods. The same method was repeated for the two ponds respectively.

**Otis Method**

The various capture-recapture models considered by Otis *et al.* (1978) and adopted in this fieldwork are as shown in Table 1 below:

**Table 1: Capture-recapture models for closed populations that allow for unequal capture probabilities**

Source of variation in capture probability				
Model	Heterogeneity	Trap response	Time	Estimator available
$M_o$				Yes
$M_hX^b$				Yes
$M_b$		X		Yes
$M_{bh}$	X	X		Yes
$M_t$			X	Yes
$M_{th}$	X		X	No
$M_{tb}$		X	X	No
$M_{tbh}$	X	XX		No

This set of 8 models comes from Otis et al (1978)  
 X's denote the sources of variation in capture probability incorporated in the models

- $M_o$  represents the equal catchability model
- $M_h$  represents the heterogeneity model
- $M_b$  represents the trap response model
- $M_{bh}$  represent the heterogeneity and trap response model
- $M_t$  represents the Schnabel model
- $M_{th}$  represents the Schnabel and heterogeneity model
- $M_{tb}$  represents the Schnabel and trap response model
- $M_{tbh}$  represents the Schnabel and trap response model varying with time.

These models were first considered as a set by Pollock, (1974) and more fully developed by Otis *et al.* (1978). These models differ in the manner in which capture probability is modeled. Different models considered three sources of variation in capture probability (i) heterogeneity, (ii) trap response, and (iii) temporal variation or variation among sampling periods (e.g. capture probability for day *i* differs from that of day *j*).

Here, closed population models assume that no births, deaths, or migration in or out of the population occur between sampling periods.

The standard error and the Akaike Information Criterion (AIC) of each model are compared to see which model will give a precise estimate of the abundance ( $M_0, M_t, M_b, M_h, M_{tb}, M_{th}, M_{bh}, M_{tbb}$ ) and check the least AIC to determine the best model and then the chosen model is compared with Lincoln – Peterson (LP) estimator. AIC is a measure of the relative quality of statistical models for a given set of data.

**EXPERIMENTAL PROCEDURES**

The experiment is as follows: A live trapping of fishes were sampled from a fish pond of area 20ft x 40ft using dragnet. Captured were marked by cutting their left fin and released back into the pond (known as first occasion). A systematic scooping was done the following day to collect sample of fishes from the pond using different method. The marked fishes were then observed from the harvested fishes (i.e. the number of marked fishes that were harvested in the second occasion). The first trapping is known as first occasion and the second known as second occasion.

**First and Second trapping (First and Second occasion) for POND 1:**

A sample of 98 fishes were live-trapped using dragnet in the fish pond. The fishes were marked by cutting their left fin and released back to the pond. In the second occasion, 78 were trapped out of which 8 were marked as shown in Table 2 below:

**Table 2: Captured and recaptured Fishes**

OCCASION (J)		
	First Occasion	Second Occasion
<b>FISHES CAUGHT N (J)</b>	98	76
<b>FISHES MARKED M (J)</b>	98	8

**Estimation of fishes abundance for pond I using Lincoln – Peterson (LP) method**

Let,

$n_1$  = the total number of fishes capture on the first occasion (marked and released).

$n_2$  = the total number of fishes capture on the second occasion (marked and unmarked).

$m_2$  = the total number of recapture (marked)

Then,

$$\hat{N} = \frac{n_1 n_2}{m_2}$$

where,  $n_1 = 98, n_2 = 76, m_2 = 8, \hat{P}_1 = n_1 / \hat{N} = 98/846 = 0.116$  and

$$\hat{P}_2 = n_2 / \hat{N} = 76/846 = 0.090$$

$$\hat{N} = \frac{n_1 n_2}{m_2} \approx 931$$

Chapman (1951) modified version with less bias =  $\hat{N} = \frac{(n_1 + 1)(n_2 + 1)}{(m_2 + 1)} - 1 = 846$

The approximately unbiased estimate of its variance given by

$$Var(\hat{N}) = \frac{(n_1 + 1)(n_2 + 1)(m_2 - 1)(m_2 - 1)}{(m_2 + 1)^2 (m_2 + 2)} \approx 57,596$$

$$S.E. (\hat{N}) = 239.99$$

The 95% confidence interval  $\hat{N}$  is (376, 1317)

Hence, we have a confidence interval ranging from 376 up to 1317 fishes, which is rather wide. The precision of the experiment could

have increased if the scooping systematic trapping method had re-captured more fishes.

**Table 3: Expected frequency for each encounter history**

ENCOUNTER HISTORY	OBSERVED FREQUENCY	EXPECTED FREQUENCY	PROBABILITY
<b>11</b>	8	9	$\hat{N} \hat{P}_1 \hat{P}_2 = 846 \times (0.116)(0.090)$
<b>10</b>	22	89	$\hat{N} \hat{P}_1 (1 - \hat{P}_2) = 846 \times (0.116)(0.91)$
<b>01</b>	68	67	$\hat{N} (1 - \hat{P}_1) \hat{P}_2 = 846 \times (0.884)(0.090)$
<b>00 (Not capture)</b>	748	681	$\hat{N} (1 - \hat{P}_1)(1 - \hat{P}_2) = 846 \times (0.884)(0.91)$
<b>Total (<math>\hat{N}</math>)</b>	846	846	

Population estimate, Standard error, Deviance, and AIC included are estimated (based on trapping data) for each model in R-capture package for which solution exist, the model

chosen by R-capture that fit the data best and the Lincoln- Petersen estimate (based on trapping and harvest data) are as shown in Table 4 below:

**Table 4: Model Estimates (Abundance, S.E and AIC)**

Model	Abundance	S.E	AIC
<b>M<sub>o</sub></b>	946.1	303.7	123.411
<b>M<sub>h</sub></b>	946.1	303.7	123.411
<b>M<sub>b</sub></b>	920.1	295.4	<b>020.388</b>
<b>M<sub>t</sub></b>	931.0	298.4	022.388
<b>M<sub>th</sub></b>	931	298.4	022.388

Model Chosen= M<sub>b</sub>

Petersen  $\hat{N} = 846$  S.E= 239.99

**Estimation of fish abundance for pond 2 using Lincoln – Peterson (LP) method**

$$n_1 = 102, n_2 = 101, m_2 = 12, \hat{P}_1 = 0.1262 \text{ and } \hat{P}_2 = 0.125$$

$$\hat{N} \approx 859$$

Chapman (1951) modified version ( $\hat{N}$ )  $\approx 808$

$$\text{Var}(\hat{N}) = 35,567.6500$$

$$\text{S.E}(\hat{N}) = 188.59$$

An approximately 95% confidence interval is (439, 1178). The interval ranges from 439 to 1178 fishes, which is narrower than that in Pond 1

**Table 5: Expected frequency for each encounter history**

ENCOUNTER HISTORY	OBSERVED FREQUENCY	EXPECTED FREQUENCY	PROBABILITY
11	12	13	$\hat{N}\hat{P}_1\hat{P}_2 = 808 \times 0.1262 \times 0.125$
10	1	89	$\hat{N}\hat{P}_1(1-\hat{P}_2) = 808 \times 0.1262 \times 0.875$
01	89	88	$\hat{N}(1-\hat{P}_1)\hat{P}_2 = 808 \times 0.8738 \times 0.125$
00 (Not capture)	706	618	$\hat{N}(1-\hat{P}_1)(1-\hat{P}_2) = 808 \times 0.8738 \times 0.875$
<b>Total (<math>\hat{N}</math>)</b>	808	808	

**Table 6: Model Estimates (Abundance, S.E and AIC)**

Model	Abundance	S.E	AIC
M <sub>o</sub>	858.5	218.5	121.010
M <sub>h</sub>	858.5	218.5	121.01
M <sub>b</sub>	847.3	219.4	023.005
M <sub>t</sub>	858.5	218.5	023.005
M <sub>th</sub>	858.5	218.5	<b>021.005</b>

Model Chosen = M<sub>th</sub>  
 Petersen  $\hat{N} = 808$  S.E = 188.59

From the estimates obtained, it is observed that the precision of the experiment will increase if more fishes is recapture on the occasion based on the result obtained from the 95% confidence estimate of the two ponds (i.e. The more recapture of marked fishes on the second occasion, the more narrower the confidence interval will be).

The fitted estimates from R-capture package are considerably lower than the LP estimate which is an indication of negative bias which suggested that the Lincoln Petersen assumption of equal catchability of animals on all occasion does not hold.

The chosen model from pond 1 is M<sub>b</sub> which indicate that every unmarked fishes in the pond has the same probability of capture (p) for all samples and every marked fishes has the same probability of recapture (c) for all samples after it has been captured once.

The chosen model from pond 2 is M<sub>th</sub> which indicate that each fish has its own unique pair of potential capture probabilities (p<sub>j</sub>c<sub>j</sub>, j=1...N) with p<sub>j</sub> and c<sub>j</sub> referring to whether the animal is unmarked or marked respectively which is assumed to remain constant over all sampling times.

## CONCLUSION

In conclusion, our findings are: (i). the abundance of fish in ponds 1 and 2 are 931 and 859 while Chapman, (1951) estimates are 846 and 808 respectively, (ii).having considered the performance of each model, Trap Response ( $M_b$ ) and the Schnabel-Heterogeneity ( $M_{th}$ ) models are the best, and (iii). There are more abundance of fish in pond 1 than pond 2.

## ACKNOWLEDGEMENT

We are grateful to the management of Remto Farms, Eyenkorin Lasaju Ilorin, Kwara state, Nigeria for giving us the opportunity to conduct this fieldwork on their fish ponds and also the reviewer for improving the quality of the original version of this research work.

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