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Estimation of the Population Size of Crocodile *Crocodylus palustris* (Lesson, 1831) from Two Incomplete Survey Methods-Daylight Ground Counts and Night Counts

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Abstract:*The population count of crocodiles was undertaken from the Warana basin of Maharashtra, India for successive two years 2013-14 and 2014-15. Two main survey methods Daylight Ground count and Night Count were used to access the population. As the Crocodile is a shy animal and the study area is so big it was impossible to locate every crocodile from the study area as well as to cover the whole study area. Hence population statistics was applied to calculate the population size of the Crocodile. The statistical approach explained by W. E. Magnusson (1978) was used for the present work. The calculation of probabilities for two survey methods estimated that the study area has about 182. It has an approximate variance of 806 and hence a standard error of ±28.39.*

Keywords:Crocodile, Warana basin, Daylight Ground count, Night count, Incomplete counts, Population size, Probability, Variance, etc.

I. INTRODUCTION

The Crocodiles as known to human beings are the largest reptiles present on the earth. They are known in the remote past. The Indian mythology represents crocodiles as a ride of Maa Ganga (the Ganga River goddess). Also, it is said that the god of rain – Varuna rides on the monster of Makara. Still, the world represents only 22 species of Crocodiles, out of which only 3 are found in India. These are – the Gharial- *Gavialis gangeticus*, the mugger- *Crocodylus palustris,* and the salt-water crocodile- *Crocodylus porosus*.

In India, Madras crocodile bank Trust, Chennai, TN is the private trust involved in the protection and conservation of crocodiles along with the crocodile conservation project of Govt. of India. H. R. Bustard – a consultant from the Food and Agricultural Organization (FAO) of the United Nations Development Programme (UNDP) was invited to look at the crocodile situation by Govt. of India in 1974. Before the launching of a crocodile conservation project by Govt. of India, Biswas and Whitaker paid attention to the status of crocodiles in the early 1970s.

Currently, Gharial is found only in restricted parts of the Ganga basin, like areas nearby Lucknow in UP, Patna in Bihar, and parts of Mahanadi at Bhubaneshwar, Orissa. In the past, they were abundant all over in Ganga, Brahmaputra, and Mahanadi basins of North-East India. The mugger was pre-dominant all over central and south India from Rajasthan, UP, WB to the Tamilnadu, but presently they are restricted to very limited parts of the same region. In Maharashtra, they were present all over the state, but presently they are observed only in the Krishna basin of western Maharashtra and at the boundary of MP in northern Maharashtra. The salt-water crocodiles were dominant all along the east coast of India and Kerala coast, but presently it is found only on the West Bengal and Orissa coast.

In recent eight to ten years, crocodile *Crocodylus palustris* (Lesson, 1831) was reported from the Warana basin by people from various fields like farmers, newspaper reporters, and biology teachers (Patil et. al. 2012, Atigre et. al 2015,

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Atigre 2018). Hence author has tried to estimate its population size by incomplete counts of Daylight Ground count and Night Count and applying a statistical approach as explained by W. E. Magnusson (1978).

II. Review of Literature

Many workers have used the daylight ground counts method for crocodile surveys. According to Graham (1968) daylight, ground surveys of crocodilians generally reveal only a small percentage of the population. Chapman (1970) estimated that percentage as 20-50% for *Crocodylus niloticus*. Modha (1967) used daylight ground counts for *Crocodylus niloticus* and found them together on a few beaches of Lake Rudolf. Pooley (1969) observed that all mature crocodiles of Lake St. Lucia (45 miles long) are coming together on a 1 ½ miles nesting beach. Night Counts is the best method ever used for crocodilians survey. Chabreak (1976) used this method to monitor the hunted population. Graham (1968), Campbell (1972), Parker and Watson (1970) and Pernetta and Burgin (1980) have used this method for the survey of the status of crocodiles. Messel reported about 60-70 % of the population in tidal rivers of northern Australia with this method. Woodward and Marion (1979) evaluated the factors affecting night counts of Alligator Mississippiensis in lakes in Florida U.S.A.All of them found that this method is a superior one than others as the results are more accurate for different workers in the same area.

Eltringham (1972) and Magnusson (1978, 2008) have used a statistical approach to estimate the population size from incomplete counts of elephants (Loxodonta africana) and crocodiles (Crocodylus porosus) respectively. Magnusson (1978, 2008) has used the probability and variance to the data of incomplete nest counts from swamps of the Liverpool River System, Northern Australia

III. Study Area

The river Warana is a major tributary of the river Krishna. It begins its course close to the western crest of Sahyadri at a height of about 987 m. above MSL at Patherpunj in Patan Taluka of Satara District. River Warana runs north to south direction on the hilltop (Sada) in the Sahyadri ranges. Further, it takes an eastward turn and runs about 148 km between 16^0 33' and 17^0 16' North latitudes and 73^0 33' and 74^0 41' East longitudes on the famous Deccan plateau in Maharashtra, just east of the Western Ghats till it joins the river, Krishna, at Haripur near Sangli city of Maharashtra. The major tributaries of the river Warana on the left bank are Zolambi and Morana and on its right bank are Tanali, Kansa & Kadavi. Rivers Zolambi & Tanali merges in river Warana behind this dam in the Vasantsagar water reservoir.

Study Regions: The study was carried out by dividing the entire study area into four different study regions. The study regions were made by considering ecological conditions, topographical settings of river Warana and previous information about crocodiles sighting in the study area. The study regions made, are as follows.

1. Study Region A -CHANDOLI DAM TO SAGAON WITH RIVER - This is the first and uppermost study region with the first part of river Warana and river Kanasa. The length of this study region of river Warana is 48 km while that of river Kanasa is 14 km.
2. Study Region B - RIVER KADAVI - River Kadavi is a major tributary of the river Warana. It begins its course in the Sahyadri ranges at the border of Kolhapur and Sangli district and merges in River Warana near village Thergaon. The total length of river Kadavi is about 46 km and the covered study area from a dam up to where it merwiths in river Warana is about 40.8 km.
3. Study Region C -SAGAON TO SHIGAON WITH RIVER MORANA - This part of river Warana runs in the east direction on the famous Deccan plateau and it includes part of river Warana and river Morana. The length of this study region of river Warana is 46 km while that of river Morana is 14 km.
4. Study Region D -SHIGAON TO HARIPUR. - This is the last study region. The length of this study region of river Warana is 36 km.

IV. Methodology

The survey methods that are used in the present study on the nesting biology of crocodiles are described below.

1. **Daylight Ground Counts:** Ground counts on foot or by boat in a river or by a vehicle along the river in daylight is a more effective method. When the crocodiles come out of the water for basking or for any other purpose they can be sighted easily. This method is easy during breeding season as all adults congregate in a

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small area. But it is not a suitable method as one can cover a small area for the survey. The author has tried to cover the maximum study area in a day and collected maximum data.

2. **Night Counts:** Counting at night, usually from a boat, with the aid of a spotlight is the most widely used method of counting crocodiles. For this method, a spotlight of 400,000 candlepower Q-beam and 12-volt headlights are used. This spotlight causes the shining eyes of crocodiles. The tapetum of eyes glows red in the spotlight and can be seen from a considerable distance. Usually, the spotlight is used by poachers for hunting at the night. The method may be biased as the younger animals avoid the spotlight at the night. All crocodiles sighted were classified by total length (TL) as hatchlings (TL < 30 cm), juveniles (TL = 30-90 cm), subadults (TL = 90-180 cm), or adults (TL > 180 cm). Crocodiles that submerged before TL could be determined were classified as 'eyeshine only' (EO). Encounter rates were calculated as the number of crocodiles observed per kilometer of survey route (Platt & Thorbjarnarson, 2000a)

Statistical Approach: Eltringham (1972) and Magnusson (1978, 2008) have used a statistical approach to estimate the population size from incomplete counts of elephants (*Loxodonta africana*) and crocodiles (*Crocodylus porosus*) respectively. Magnusson (1978, 2008) has used the probability and variance to the data of incomplete nest counts from swamps of the Liverpool River System, Northern Australia.

The data about the crocodile population obtained by two methods from the Warana basin is used statistically in the following way.

Let us assume,

Number of crocodiles, seen by both surveys - B,

Number of crocodiles, seen by survey 1 but not by survey 2 – S_1,And Number of crocodiles, seen by survey 2 but not by survey 1 – S_2.

If M is the unknown number missed by both surveys and N is the total number of crocodiles, also unknown, then the exhaustive frequencies and the probabilities associated with them are

$B + S_1 + S_2 + M = N$

$P_1P_2 + P_1 (1-P_2) + P_2 (1-P_1) + (1-P_1) (1-P_2) = 1$

P_1 is the probability of crocodiles being seen by the first survey and P_2 is the probability of crocodiles beingseen by the second. Hence the unknown parameters can be estimated from the known frequencies B, S_1, and S_2, by

$P_1 = B / (B + S_2)$

$P_2 = B / (B + S_1)$

$M = S_1S_2 / B$

$N = (B + S_1) (B + S_2) / B$ ---------- eq. 1

The model is logically equivalent to that of the Petersen estimate. On the first survey, a sample is mapped (marked), the sample of the second survey comprises some entities previously mapped (recaptures), others unmapped. The difference lies in the symmetry of the present model: the first and second surveys are interchangeable. Nonetheless, the well-explored mathematics of the Petersen estimate can be adapted easily to this model. Chapman (1951) has given a correction for the Petersen estimate. Applying this to equation 1 our estimate becomes

$$N = \frac{(S_1 + B + 1)(S_2 + B + 1)}{(B + 1)} - 1 \quad \text{----------eq. 2}$$

This is, in contrast to the estimate of eqn. (1), exactly unbiased when

$$S_1 + S_2 + 2B \geq N$$

Its variance can be estimated by a translation of Seber's (1973:60) formula which is also exactly unbiased when

$$\text{Var}(N) = \frac{S_1 S_2 (S_1 + B + 1)(S_2 + B + 1)}{(B + 1)^2 (B + 2)} \quad \text{----------eq. 3}$$

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The use of this method assumes that the counts of the 2 surveys are independent and that there is a constant probability of seeing each crocodile by a given method of survey.

V. Observation And Results

The number of Crocodiles counted by two survey methods Daylight Ground Counts and Night Counts in different study regions is summarized in Table1 and Table 2 respectively and a comparative chart for both survey methods is given in Table 3.

Figure 1: Eyeshine of the Crocodile observed during night count in study region B

Figure 2: Two Crocodiles observed in water during daylight ground count in study region D

Figure 3: One Crocodile on the bank of River Warana during daylight ground count in study region C

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Table 1: Summary of Daylight ground counts for *Crocodylus palustris* performed in Warana basin during 2014-15

Sr. No.	Study Region	Hatchlings	Juveniles	Sub-adults	Adults	Total
1	Study Region A	0	0	0	0	0
2	Study Region B	2	0	0	1	3
3	Study Region C	5	3	0	3	11
4	Study Region D	6	3	2	4	15

Table 2: Summary of Night counts for *Crocodylus palustris* performed in Warana basin in 2014-15

Sr. No.	Study Region	Eyeshine	Sub-adult	Adult	Total
1	Study Region A	0	0	0	0
2	Study Region B	7	0	2	9
3	Study Region C	14	2	3	19
4	Study Region D	18	3	3	24

Table 3: Observations of crocodile population from Warana basin with two survey methods

Sr. No.	Survey Methods	Study Region A	Study Region B	Study Region C	Study Region D	Total
1	Daylight Ground Counts	0	3	11	15	29
2	Night Counts	0	9	19	24	52
3	Both surveys	0	2	5	10	17

VI. DISCUSSION

By applying the probability and variance to the data following population size estimate is obtained. The total number of crocodiles observed along the river Warana and Kadavi by the first survey method – daylight ground counts are 29 (S_1 = 29), crocodiles observed by second survey method – night counts are 52 (S_2 = 52) and crocodiles observed by both surveys are 17 (B = 17). Hence the probability of seeing a crocodile by daylight ground count is estimated as P_1 = 17 / (17 + 52) = 0.25, and from the night count is estimated as P_2= 17 / (17 + 29) = 0.37. The number missed by both surveys is estimated as M = 29 x 52 / 17 = 88.71 i. e. 89 and the total number, both counted and uncounted, is estimated by eqn. (2) as N = 181.78 i. e. 182. It has an approximate variance (eqn. 3) of 805.93 i. e. 806 and hence a standard error of √806 = ± 28.39.

Above statistics about crocodile population size from Warana basin by two survey methods Daylight Ground Counts and Night Counts for all study regions and total study area is summarized in Table 4.

Table 4: Summary of probability and variance of observations about crocodiles by two survey methods from the Warana basin.

Sr. No.	Study Region	S1	S2	B	P1	P2	M	N	Variance	Standard Error
1	A	0	0	0	0	0	0	0	0	0
2	B	3	9	2	0.8	0.4	14	23	54	±7.35
3	C	11	19	5	0.21	0.31	42	71	353	±18.79
4	D	15	24	10	0.4	0.29	36	83	226	±15.03
5	Total	29	52	17	0.25	0.37	89	182	806	±28.39

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Where,

S_1	- Daylight ground counts survey
S_2	- Night counts survey method
B	- Observations by both surveys
P_1	- Probability of the first survey
P_2	- Probability of the second survey
M	- Crocodiles missed by both surveys
N	- Total number of crocodiles

The use of this method assumes that the counts of the 2 surveys are independent and that there is a constant probability of seeing each crocodile by a given method of survey. The first assumption is critical. The second assumption is not critical. The pairs of surveys have been simulated in which the probability of seeing a crocodile, rather than being a constant for a survey, was a random draw from a beta distribution of fixed mean and variance, with different distributions being used for the 2 surveys. These produced estimates similar to those of control simulations in which probabilities were set at the means of the beta distributions.

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