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THE EMBRYO AND HATCHLING MORTALITY OF THE GREEN TURTLE (*CHELONIA MYDAS*) AND OLIVE RIDLEY (*LEPIDOCHELYS OLIVACEA*) IN RELATION TO CLUTCH SIZE

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This study was carried out at the Kosgoda Victor Hasselblad Turtle hatchery in Sri Lanka, between December 1988 and November 1989. A total of 64 nests of *Chelonia mydas* and 32 nests of *Lepidochelys olivacea* were examined after the emergence of hatchlings. The percentage late mortality (late embryonic stages and early hatchlings) of *C. mydas* and *L. olivacea* showed a positive relationship with the increasing number of eggs in a clutch. There was no significant relationship between the percentage early embryonic mortality and the clutch size. The percentage of live hatchlings of both species showed a negative relationship with the increasing clutch size. Dividing and transplanting *C. mydas* clutches with more than 120 eggs and *L. olivacea* clutches with more than 110 eggs may result in higher percentages of live hatchlings. Investigations on the incubation temperature of small egg clutches need to be made in order to find the effect on the sex ratio of hatchlings.

INTRODUCTION

Five species of marine turtles nest on the beaches of Sri Lanka. They are the green turtle (*Chelonia mydas*), olive ridley (*Lepidochelys olivacea*), leatherback (*Dermochelys coriacea*), hawksbill (*Erythmochelys imbricata*), and the loggerhead (*Caretta caretta*). Artificial hatchery programs are implemented as a means of conserving turtles. Unlike in other countries there are no trained personnel to collect eggs. Instead eggs are collected by villagers and are brought to the hatcheries. It was observed that the mortality of hatchlings in large egg clutches of *L. olivacea* in hatcheries was high. The objective of this study was to find whether there is a relationship between hatchling mortality and clutch size of marine turtles in hatcheries.

METHODS

The standard practice in hatcheries is to transplant egg clutches of all five species of turtles within the same enclosure. Each clutch is transplanted in a separate nest in the same sequence as they are brought to the hatchery. The dimensions of the transplanted nests are similar to those of the natural nests, and the spacing between nests is 50 cm. This study was carried out with such transplanted nests of *C. mydas* (n=64) and *L. olivacea* (n=32) at the Kosgoda, Victor Hasselblad turtle hatchery from December 1988 to November 1989. Nests of the other three species of marine turtles were rare.

In order to examine the contents, the transplanted nests were excavated 4-6 days after the emergence of hatchlings (*C. mydas* nests about 52 days and *L. olivacea* about 58 days after burying). The contents at the bottom of some of the nests were found lumped together (especially those of *L. olivacea* during the rainy season) at the time of excavation. This made it difficult to distinguish the individuals that had died at various stages of the hatching process (i.e. individuals that were completely out of the shell, those that were half-way out, and those that had pipped the egg shell). Under these circumstances, the contents of the excavated nests were categorized as follows:

(1) *Infertile eggs.* Eggs without embryos and without evidence of development visible to the naked eye. Spoilt eggs (blackened eggs, eggs infested with maggots, eggs in which the yolk and the albumin were mixed in a liquid consistency or like a solid yellow mass) were also included in this category.

(2) *Early embryonic mortality (Early mortality).* Eggs with evidence of development such as blood vessels and pre-carapace stage embryos.

(3) *Late embryonic and early hatchling mortality (Late mortality).* Dead embryos with carapaces, dead hatchlings that had pipped the egg, those that were halfway out of the shell and those that had completely come out of the shell.

(4) *Total mortality.* Early mortality and late mortality together was considered as the total mortality.

(5) *Live hatchlings.* Live hatchlings that were assisted out of the nest at the time of excavation were categorized together with the hatchlings that had already emerged.

RESULTS

The categories 2, 3, 4 and 5 were presented as percentages of the total number of eggs in a clutch (known prior to transplanting) and also as percentages of fertile eggs in a clutch (fertile eggs = total number of eggs – infertile eggs). The mean percentages of these categories are given in Table 1.

Correlation analysis revealed (Table 2, Figs. 1 & 2) that there is a positive relationship between the total number of eggs (clutch size) and the percentage late mortality of *C. mydas* and *L. olivacea*. A similar rela-

		%Live Hat.	%Early M.	%Late M.	%Total M.
C. mydas					
	Mean	71.97	7.29	11.03	18.32
		(79.03)	(8.25)	(12.52)	(20.77)
	SD	17.02	7.05	10.43	12.10
		(14.63)	(10.39)	(12.74)	(14.82)
	n	64	64	64	64
L. olivacea					
	Mean	61.82	11.66	14.09	25.75
		(69.74)	(14.35)	(15.91)	(30.26)
	SD	23.16	12.22	18.13	17.19
		(19.33)	(15.26)	(19.78)	(19.33)
	n	32	32	32	32

TABLE 1. Live hatchlings, early, late, and total mortalities of *C. mydas* and *L. olivacea* as a percentage of the total number of eggs and as a percentage of fertile eggs (figures given in parentheses) in a clutch. *n* = number of clutches, Hat. = hatchlings, M. = mortality.

		Total no. of eggs *vs* %Live Hat.	Total no. of eggs *vs* %Early M.	Total no. of eggs *vs* %Late M.	Total no. of eggs *vs* %Total M.
C. mydas					
	n	64	64	64	64
	r	-0.32	0.1	0.33	0.36
	P	<0.05	NS	<0.01	<0.01
	df	62	62	62	62
L. olivacea					
	n	32	32	32	32
	r	-0.58	0.14	0.58	0.52
	P	<0.01	NS	<0.01	<0.01
	df	30	30	30	30

TABLE 2. Correlation coefficients for the total number of eggs and live hatchlings, early, late and total mortalities of *C. mydas* and *L. olivacea*. NS= not significant, Hat. = hatchling, M. = mortality.

		No. fertile eggs *vs* %Live Hat.	No. fertile eggs *vs* %Early M.	No. fertile eggs *vs* %Late M.	No. fertile eggs *vs* %Total M.
C. mydas					
	n	64	64	64	64
	r	-0.36	0.1	0.35	0.37
	P	<0.01	NS	<0.01	<0.01
	df	62	62	62	62
L. olivacea					
	n	32	32	32	32
	r	-0.57	0.06	0.61	0.57
	P	<0.01	NS	<0.01	<0.01
	df	30	30	30	30

TABLE 3. Correlation coefficients for the number of fertile eggs and live hatchlings, early, late and total mortalities of *C. mydas* and *L. olivacea*. NS= not significant, Hat. = hatchling, M. = mortality.

	No. eggs	df	Correlation coefficient %Live Hat.	%Late M.	%Total M.
C. mydas					
	<170	62	-0.32*	0.33**	0.36**
	<160	61	-0.24NS	0.36**	0.28*
	<130	54	0.24NS	0.30*	0.24NS
	<120	43	0.36*	0.40**	0.28NS
	<110	27	-0.20NS	0.30NS	0.22NS
	<100	16	-0.14NS	0.00	0.00
L. olivacea					
	<150	30	-0.58**	0.58**	0.51**
	<130	27	-0.45*	0.37NS	0.24NS
	<120	25	-0.49*	0.39*	0.26NS
	<110	23	0.40*	0.00	0.00
	<100	20	-0.37NS	0.00	0.00
	<90	15	0.1NS	0.00	0.00

TABLE 4. Significant cut off points in the total number of eggs that reduce the percentage live hatchlings of *C. mydas* and *L. olivacea*. (* $P < 0.05$; ** $P < 0.01$). Hat. = hatchling, M. = mortality.

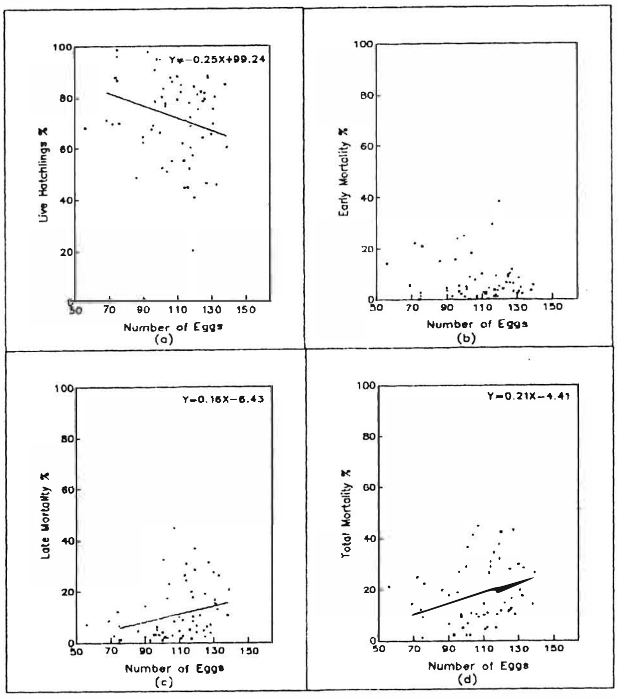

FIG. 1. Relationship between the total number of *C. mydas* eggs and (a) live hatchings (b) early mortality (c) late mortality (d) total mortality.

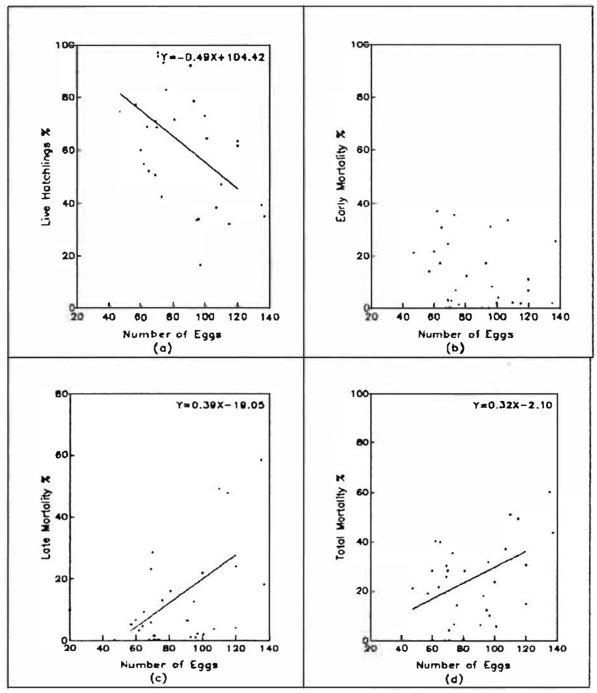

FIG. 2. Relationship between the total number of *L. olivacea* eggs and (a) live hatchlings (b) early mortality (c) late mortality (d) total mortality.

tionship existed between the clutch size and the percentage total mortality for both species, while there was no significant relationship between the clutch size and the percentage early mortality. The percentage of live hatchlings of both species showed a negative relationship with the increasing clutch size.

Similar relationships were found when only the fertile eggs in a clutch were considered (Table 3).

The following method was adapted to find the maximum number of eggs in a nest that will not reduce the percentage of live hatchlings. The clutches with a total number of eggs above a certain value were progressively reduced and the correlation analyses were repeated on these reduced samples (Table 4). The results indicated a significant reduction in the percentage of live hatchlings of *C. mydas* and *L. olivacea* when the total number of eggs are around or more than 120 and 110, respectively.

DISCUSSION

It was not possible to find out the percentage hatching success because of the difficulty in distinguishing the individuals that had died at different stages of the hatching process. Percentage hatching success is generally defined as follows:

$$\textit{Percentage hatching success} = \frac{\textit{Total no. of hatched individuals (dead and alive)}}{\textit{Total no. of eggs buried (clutch size)}} \times 100$$

Therefore, it is not possible to conclude in this study whether the hatching success is affected by the increase in the number of eggs in a clutch. However, Fowler (1979) observed high hatching success rates (70-80%) in some of the smallest green turtle clutches (natural) in Tortuguero, Costa Rica. Similar studies on natural nests in Sri Lanka have not been carried out.

As mentioned earlier, eggs that are transplanted in Sri Lankan hatcheries are not collected by trained people. Therefore, these eggs may have been subjected to rough handling by the villagers, who sell them to the hatcheries. In spite of this, a mean of 71.98% live hatchlings of *C. mydas* and 61.82% live hatchlings of *L. olivacea* is impressive.

Signs of very early embryonic death are difficult to detect when the nest is excavated at the end of the incubation period. Therefore, it is likely that such eggs were mistaken for infertile eggs. There is also the possibility that the spoilt eggs that were categorized as infertile eggs, contained early embryonic stages. As a result, the calculated percentage early mortality stages would be underestimated.

However, if all the spoilt eggs in the nests were considered to be infertile (*C. mydas* 9.70%; *L. olivacea* 12.16%) the fertility rates of *C. mydas* and *L. olivacea* would be 90.3% and 87.8%, respectively. According to Ehrhart (1982), fertility rates of the loggerhead, leatherback and the green turtle vary between 80-90% but these could be higher. The fertility rates obtained in this study are within this range.

The percentage of live hatchlings, early, late and total mortalities showed similar relationships with the total number of eggs in a clutch as well as with the number of fertile eggs. This may be due to the fact that the fertility of the eggs was high.

Increase in the late mortality, which includes the late embryonic and early hatchling stages, may be due to several factors. A possible cause would be due to the reduced gas exchange within the nests. According to Ackerman (1980), mortality increases in environments in which gas exchange is reduced below "naturally occurring levels". The oxygen consumption of turtle eggs appears to increase "sigmoidally" throughout incubation becoming relatively constant just prior to hatching (Ackerman 1980). This probably results in reducing the available oxygen within the nests of large egg clutches during the late stages of development.

Carr & Ogren (1960), observed that during emergence, hatchlings show periodic bursts of activity. Prange & Ackerman (1974), suggested that periodicity of activity in a clutch of hatchlings is related to the demand and supply of oxygen in the active nest. During sustained activity the hatchlings exhaust the supply of oxygen in the nest and build up an oxygen debt which halts their efforts. Hatchlings resume their digging efforts after recovering from the oxygen debt following the diffusion of oxygen into the nest. In an artificial hatchery where a number of clutches are buried, the diffusion of oxygen may be slow and may even be insufficient. It is possible that this causes the death of emerging hatchlings and embryos within the nest.

The results of this study suggest that the percentage of live hatchlings in large egg clutches of *C. mydas* and *L. olivacea* are less than those with small ones. Thus dividing and transplanting *C. mydas* clutches with more than 120 eggs (in this study maximum was 164) and *L. olivacea* clutches with more than 110 eggs (in this study maximum was 140) into two batches, may result in higher percentages of live hatchlings.

However, it has been found that the sex ratio of hatchlings is dependent on the incubation temperature (Mrosovsky, 1982). It is possible that the reduced clutch size will have an effect on the incubation temperature which will in turn affect the sex ratio of hatchlings. Investigations should be made on the incubation temperature of small clutches in order to find out the effect on sex ratios.

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