

**The Green sea turtle (*Chelonia mydas*):  
further observations on breeding in captivity**

GLENN F. ULRICH\* AND ALAN S. PARKES\*\*

*Mariculture Ltd., † Grand Cayman, BWI*

(Accepted 11 October 1977)

(With 4 figures in the text)

Mating, nesting and hatching of the Green sea turtle on Mariculture Ltd's farm on Grand Cayman Island, BWI in 1973 were recorded in a previous paper. The results described were the first of their kind, so that events in the farm breeding colony in the following year were awaited with much interest, especially as to hatchability of the eggs. The observations made in 1974, which extended and mainly confirmed those made in 1973, are described below.

**Contents**

	Page
Introduction .. .. .	238
Methods .. .. .	238
Husbandry .. .. .	238
Recording .. .. .	238
Identification .. .. .	239
Handling of eggs .. .. .	239
The 1974 breeding stock .. .. .	239
Results .. .. .	240
Mating patterns .. .. .	240
Time between mating and first nesting .. .. .	241
The 1974 nesting season .. .. .	241
Secular changes during the season .. .. .	242
Number, size and sequence of clutches .. .. .	243
Weight of eggs .. .. .	244
Laying in successive years .. .. .	246
Laying without observed mating .. .. .	246
Hatching on the beach .. .. .	247
Discussion .. .. .	247
Difference between the 1973 and 1974 results .. .. .	247
Events between mating and nesting .. .. .	248
Laying without mating .. .. .	248
Sperm storage in female <i>Chelonia</i> .. .. .	249
Annual layers .. .. .	249
Self-sufficiency .. .. .	250
Summary .. .. .	250
References .. .. .	251

\*Present address: South Carolina Wildlife & Marine Resources Department, Finfish Management Unit, Marine Resources Division, Post Office Box 12559, Charleston, South Carolina 29412, U.S.A.

\*\*Present address and for offprint requests: 1, The Bramleys, Shepreth, Royston, Herts., England.

†Now Cayman Turtle Farm Ltd.

### Introduction

In 1973 at the Mariculture Ltd (MCL) farm, 19 females laid 11,268 eggs in 92 clutches, an average of 593 eggs per laying female and of 122 eggs per clutch (Simon, Ulrich & Parkes, 1975). Both these indices are well within the range reported for the Green sea turtle in the wild. Hatchability however was low at 42% viable hatchlings. This rate may well be similar to that found in the wild (for which overall figures are not easy to obtain) but it was low compared with the rate of nearly 80% for the 97,312 eggs collected from wild rookeries and hatched under the same conditions in the same hatchery, though at different times, in the same year (Simon, 1975). Of the 58% of farm laid eggs not giving rise to viable hatchling, an appreciable number contained advanced dead-in-shell embryos or produced non-viable or malformed hatchling, but the great majority were categorized from external appearance as "infertile", a category which could include both lack of fertilization (UF) and early embryonic death (EED). Superficial examination of the contents of the "infertile" eggs showed that EED was not uncommon, and in the absence of any evidence of parthenogenesis or gynogenesis it must be assumed that such eggs had been fertilized. The importance of developing a simple method of distinguishing between UF and EED was emphasized in the previous paper.

A summary of the 1975 and 1976 results is given by Wood & Wood (1978).

### Methods

#### *Husbandry*

The main features of the breeding pool on the MCL farm, size, water-flow etc., were as previously described, but in 1974 there were two important changes in the management of the breeding stock. First, the growing stock reserved for the breeding colony, comprising the best of the animals from the first three batches of young hatched and reared on the farm from ex-wild eggs, had been housed in the breeding pool during the 1973 season but, with the exception of a few of the more developed ones, were housed elsewhere when the breeding stock for 1974 was assembled. The pool was thus reserved for animals which it was hoped might breed in the 1974 season, so that the population of the pool in 1974 never exceeded 73 females and 14 males, compared with the 300 mainly immatures removed from the pool at the end of 1973.

Second, during 1971-73 adult males and females had been kept continuously together without result and the onset of mating in 1973 appeared to be sparked off by the introduction of two unfamiliar males straight from Surinam. In a memorandum presented to MCL early in 1973, Professor J. R. Hendrickson suggested that males should be segregated from females except during the mating season, a technique which had proved effective in breeding the Giant tortoise of the Galapagos. This idea seemed to be confirmed by the events in the pool and accordingly, in November 1973, the breeding pool was emptied and the males separated from the females.

Feeding was as previously described except that there was some shortage of the dry cubed food in June 1974 and supplementation by turtle grass was increased.

#### *Recording*

So far as possible the following records relating to breeding performance were kept: date(s) of mating and nesting, number of eggs per clutch, total weight of clutch and date of hatching, together with number of "infertile" eggs, embryos dead before or after hatching and viable hatchlings to water. "Hatch rate" in the present paper means the percentage of eggs giving rise to viable hatchlings. Observation of activity in the pool and on the beach, especially at night,

was not easy and it is understandable that four animals laid without having been observed to mate and that at least six nests and probably more were missed at the time of laying (see p. 248).

#### *Identification*

The history of the ex-wild animals in the breeding pool when mating began in April 1973 has been given by Simon, Ulrich & Parkes (1975). When the pool was emptied in November 1973, only two of the 64 females introduced between September 1969 and May 1971 could be positively identified as to origin and date of introduction (see above). Worse still, of the 19 females known to have nested earlier in the year and tagged at the time, often double tagged, only 12 could be identified.

In view of the unreliability of tagging, a notching system was introduced when the breeding stock for 1974 was assembled. This system was based on the five rear marginal scutes on each side, numbered 1-10 from left to right (the front marginals do not overhang sufficiently to permit effective matching). Up to three notches can be made in the rear marginals of adults and one, two or more scutes can be used at a time, so that the system is capable of virtually indefinite extension. Deep notches appear to last almost indefinitely, and in any case can be re-cut. Thus, they provide a permanent system of identification on close inspection. They give little help, however, in identifying turtles in the pool, especially mating couples. For the 1974 season, therefore, large blue tags were added to the rear flippers. Additionally, as a temporary aid to identification at a distance, the males had their numbers given in white marine paint in large figures on each side of the carapace. In 1975 a further system of identification was introduced by fixing a numbered plastic plate to each side of the carapace. Unfortunately the plate numbers did not correspond with the 1974 tag numbers. For future reference to the present paper, the 1975 plate numbers are given with the prefix P in addition to the 1974 tag number, indicated by the letter B.

#### *Handling of eggs*

As in 1973, the eggs were dug up either as soon as the female had finished nesting or on the following morning and incubated as previously described (Simon, 1975). An intermediate treatment was, however, introduced. Because of the uncertainty as to the desirability of washing the eggs before incubation to remove adhering sand a large scale experiment was carried out in 1974. Almost all clutches of sufficient size were divided as nearly as possible into two equal parts, one half being dipped into water sterilized by boiling before being packed into Styrofoam boxes for incubation. Other clutches were allotted alternately to the washed and unwashed groups. In all, 9666 eggs were incubated, 4135 of them after washing. From the unwashed and washed groups, the viable hatch rates were 45.3% and 44.2% respectively. This difference, is not significant and in any case is in favour of the untreated groups, so that the technique of washing in water was not used again. The results considered below relate to the combined unwashed eggs and washed eggs, the overall hatch rate given by the 4332 viable hatchlings from the 9666 eggs being 44.8%.

#### **The 1974 breeding stock**

In February 1974, 72 of the best-looking female turtles were selected, notched and tagged, and returned to the breeding pool. Fourteen of these were identified as Costa Ricans introduced in September 1973 and at the time they constituted the only large group of ex-wild females of known origin. Almost all of the remaining 58 females were ex-wild from the original introductions, but positive identification was possible only for two, both from the Guyanan group brought to the farm in May 1970 [Tags 6005/B79,

P35, notch (3-3) (1-1); and tags I188/B100, P61, notch (3-2)(5-1)]. At least one and possibly more of the 58 were farm reared—one "female" put into the pool (not included in the figures above) proved to have been an immature male when the population of the pool was surveyed in December 1974. In June, three more females were put into the pool, two ex-wild and one thought to be farm-reared, making 73 females in all after one death and one autopsy.

In April, 13 males were put into the breeding pool two or three at a time, these included the two Surinam males flown to Cayman in 1973. The Ascension male introduced in 1972 was returned to the breeding pool in June 1974, making 14 males in all.

## Results

### *Mating patterns*

In 1974 mating activity was not observed until 7 May, three weeks later than in the previous year, but within a couple of weeks several males were actively copulating. Mating activity was not seen after 21 June.

In all, seven males, on the farm for between 1 and 3½ years, and 10 females, on the farm for between 3 and 4½ years were observed to mate, but even among this small number of females, the patterns of sexual behaviour were very different. In general, sexual receptivity may be said to have waxed and waned in any particular female, but the time scale and intensity varied greatly. Thus female B84 (P24) mated three times in two days with two different males for a total of more than 7 hours; she produced 897 eggs in eight clutches with a hatch rate of 79.8%. Female B115 (P38) mated five times in four days with three different males for a total of more than 17 hours; she laid 934 eggs in eight clutches with a hatch rate of 77.2%. Female B110 (P34) was recorded as mating for 52 hours and then after a one day interval for 19 hours with a different male and finally for a short period on the following day with the first male; she laid 823 eggs in five large clutches with a poor hatch rate (34.9%). Another female (B8, P82) was observed to be mounted three times by three different males on one day for a total of a little over two hours; she laid 614 eggs in six clutches, which had a hatch rate of 83.9%. Another one, female B100 (P61) a 1973 layer, was observed to mate 28 times in 12 days with six different males for periods between one and 13 hours, and showed a waxing and waning of sexual activity over the 12 days, the peak being reached when four matings occurred on each of days 3 and 4 after the start. This female laid 994 eggs in seven clutches, the first of which contained 141 eggs, including 12 sausage-shaped multiple-yolked eggs weighing 4 lbs 8 ozs. Excluding the multi-yolked eggs, none of which developed, the hatch rate was poor at 21.1%, in spite of the very active matings.

The 1974 season provided a curious example of the importance of the social environment in sexual behaviour. A pair of ex-wild turtles (Male B301, P109, female B116, P57) both of which had been sexually active in 1973, were isolated in a large tank from February to June 1974. In this situation they showed no sexual activity. They were then transferred to the large breeding pool, where the male, apparently stimulated by competition, quickly mounted the female, as afterwards did two pool males. Total mountings occupied more than six hours. In spite of being rather late in the season this female laid six clutches containing 907 eggs, but the hatch rate was only 16.3%.

None of the 14 identified Costa Rican animals, introduced from the wild in September 1973 was observed to mate or nest in 1974.

All these records must be considered in the light of two facts (a) that under the conditions of observation some matings may have been missed, and (b) when the male mounts it is extremely difficult to know whether intromission and ejaculation occurs, especially during a brief mounting or when the couple is harassed by other males. Two females were recorded as each having been mounted on one occasion but were not observed to nest.

TABLE I  
*Hatch rate in relation to the mating-nesting interval*

M-N interval (days)	No. of ♀s	Total clutches	Total eggs	Viable hatchling	Viable hatch (%)
21-22	2	11	1721	476	27.6
30-34	4	28	3228	2240	69.4
37-39	2	14	1536	412	26.8
68-95	2	7	753	0	0.0

TABLE II  
*Comparison of breeding results, 1973 and 1974*

	1973	1974
No. of ♀s	19	14
No. of clutches	92	80
Av. clutches for ♀	4.8	5.7
No. of eggs	11268	9752
Av. eggs for ♀	593	697
Av. eggs for clutch	122	122
Hatch rate (%)	42.3	44.8

*Time between mating and first nesting*

The time between mating and first nesting and its relation to the viable hatch rate for the 10 females observed to mate is shown in Table I. The conclusion seems to be unequivocal. The most frequent interval was in the 30-34 days range and was associated with a hatch rate much above the average; intervals shorter and longer were associated with below average hatch rates. The longest intervals were associated with nil hatches. The physiological significance of the mating-nesting interval and its importance in turtle husbandry make it urgent to confirm or modify this result (see p. 248 for discussion).

*The 1974 nesting season*

Nesting was first observed on the night of 12-13 June 1976, when 124 eggs were laid by female B84 (P24), which had been on the farm for at least three years and had not, so far as is known, previously mated or nested there. The last observed nest was made on the night of 25-26 October, by which time 14 females had laid 9752 eggs in 80 clutches. The average number of eggs per laying female was 697, considerably higher than in 1973, as was the number of clutches per female (Table II). Average clutch size was 122, the same as that in the previous year. The smallest clutch recorded contained 48 and the largest

187 eggs, hatch rates being 31.3 and 61.3% respectively. The highest average clutch size for any one female was 151 and the lowest 78, hatch rates for these two females being 37.8 and 16.3%. The inter-nesting interval was essentially similar to that found in 1973 in that almost all of the 66 intervals were of 9–12 days, with the mode at 10 days (29 intervals). There were five intervals of 20–23 days, which were almost certainly double intervals during each of which a nest had been missed (see p. 247). Abnormal intervals of 35–40 days could have been multiple intervals due to two or three consecutive nests having been missed late in the season or may merely have resulted from the waning of reproductive activity.

*Secular changes during the season*

The secular distribution of nests is shown in Fig. 1, and, for comparison, with that of number of eggs, clutch size, hatch rate and incubation time, in Table III. Peak nesting activity occurred in the last half of August, nearly a month later than in 1973, as shown both by number of clutches and number of eggs. Clutch size showed no consistent change during the season, but, as in 1973, incubation time increased steadily as the season advanced. During the main season, hatch rates showed no obvious correlation with the time at which the animals started to lay, but animals which did not start to lay until

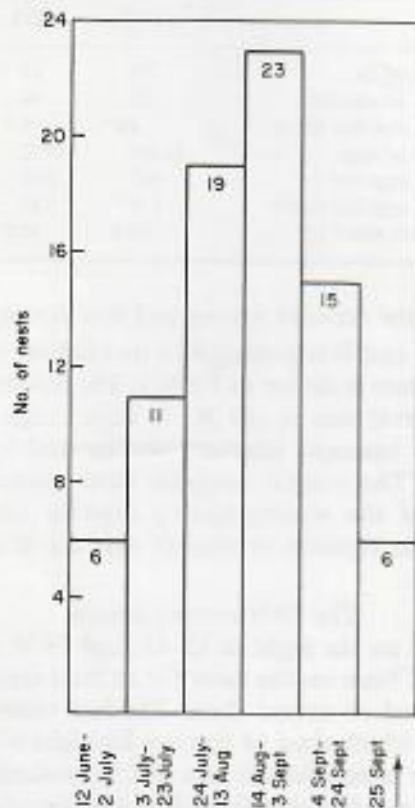


FIG. 1. The 1974 breeding season: number of nests by three-week periods.

August or September laid only three or four clutches and only one produced fertile eggs. Two of these, however, had not been seen to mate.

*Number, size and sequence of clutches*

The distribution of the 80 clutches of eggs among the 14 females is shown in Table IV. It appears from these figures that females laying only three or four clutches had hatch rates far below the average, but otherwise it is difficult to detect any relation between hatch rate and number of clutches laid.

TABLE III  
*Changes during the breeding season, 1974*

Period	No. of nests (clutches)	No. of eggs set	Av. clutch size	Incubation time (days)	Viable hatch (%)
12 June-2 July	6	684	114	56	74.8
3 July-23 July	11	1541	140	57	43.2
24 July-18 Aug.	19	2395	126	58	48.4
14 Aug.-3 Sept.	23	2771	120	63	49.3
4 Sept.-24 Sept.	15	1580	105	66	32.0
25 Sept.	6	695	116	83	17.7
Total	80	9666	122	—	44.8

TABLE IV  
*Hatch rate in relation to number of clutches laid by a female*

No. of clutches	No. of ♀s	Eggs set	Viable hatchlings	Viable hatch (%)
3	1	261	0	0.0
4	3	1356	174	12.8
5	2	1415	729	51.5
6	3	2295	970	42.2
7	3	2508	1022	40.7
8	2	1831	1437	76.5
—	14	9666	4332	44.8

The distribution of size of clutch by 20 eggs intervals is shown in Fig. 2. As in 1973, the largest number of clutches occurred in the 121-140 egg range and the distribution was slightly skew. The overall spread was also as in 1973. The hatch rate followed the same general pattern; the 23 clutches containing 121-140 eggs had by far the best rate, well above average. As in 1973, there was a general relationship between body weight of the female and the average number of eggs in her clutch.

Hatch rate in relation to clutch sequence is shown in Table V. The overall figures suggest that hatchability rises steadily up to the fifth clutch, but this apparent result could be affected by the low hatchability where only three or four clutches were laid. The overall figures were therefore broken down by number of clutches laid. This analysis showed that, in 1974, hatchability rose on the average up to about the middle of the clutch sequence.

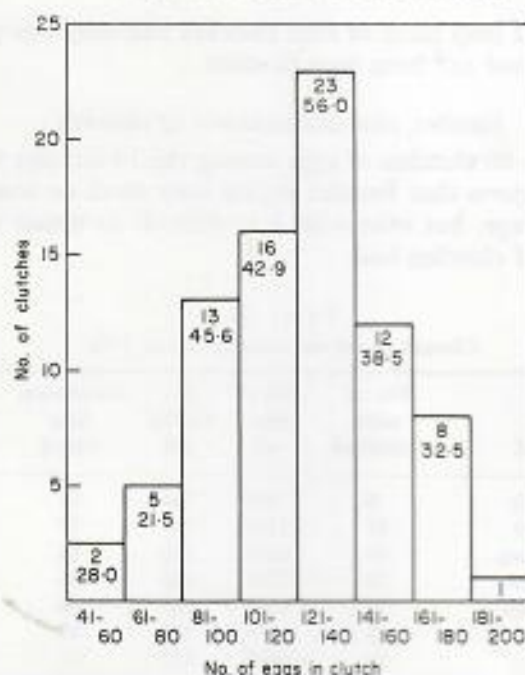


FIG. 2. Number of clutches (upper figure in column) and hatch rate (lower figure) according to size of clutch.

#### Weight of eggs

The average weight of the clutches laid by the 14 females varied from 9 lb 11 oz for a female weighing 260 lb to 18 lb 11 oz for a female weighing 500 lb. Within this bracket there was a general tendency for clutch weight to increase with body weight, associated no doubt with the tendency noted above for the number of eggs in a clutch to increase with body weight. The material is too small for detailed analysis, but an impression of body weight and clutch weight is given in Fig. 3.

Average egg weight per female varied from 1.67 oz for a female weighing 440 lb, to 2.04 oz for a female weighing 430 lb, plotting the values gave no suggestion of a correlation between body weight and average egg weight. There was, however, a clear negative

TABLE V  
Hatch rate and clutch sequence (all females)

Clutch sequence	No. of clutches	No. of eggs	No. eggs per clutch	Viable hatchlings	Viable hatch (%)
1st	14	1585	113	559	35.2
2nd	14	1798	128	770	42.8
3rd	14	1814	129	824	45.4
4th	13	1530	118	728	47.6
5th	10	1234	123	629	50.9
6th	8	978	122	470	48.0
7th	5	543	109	253	46.5
8th	2	182	91	97	53.2



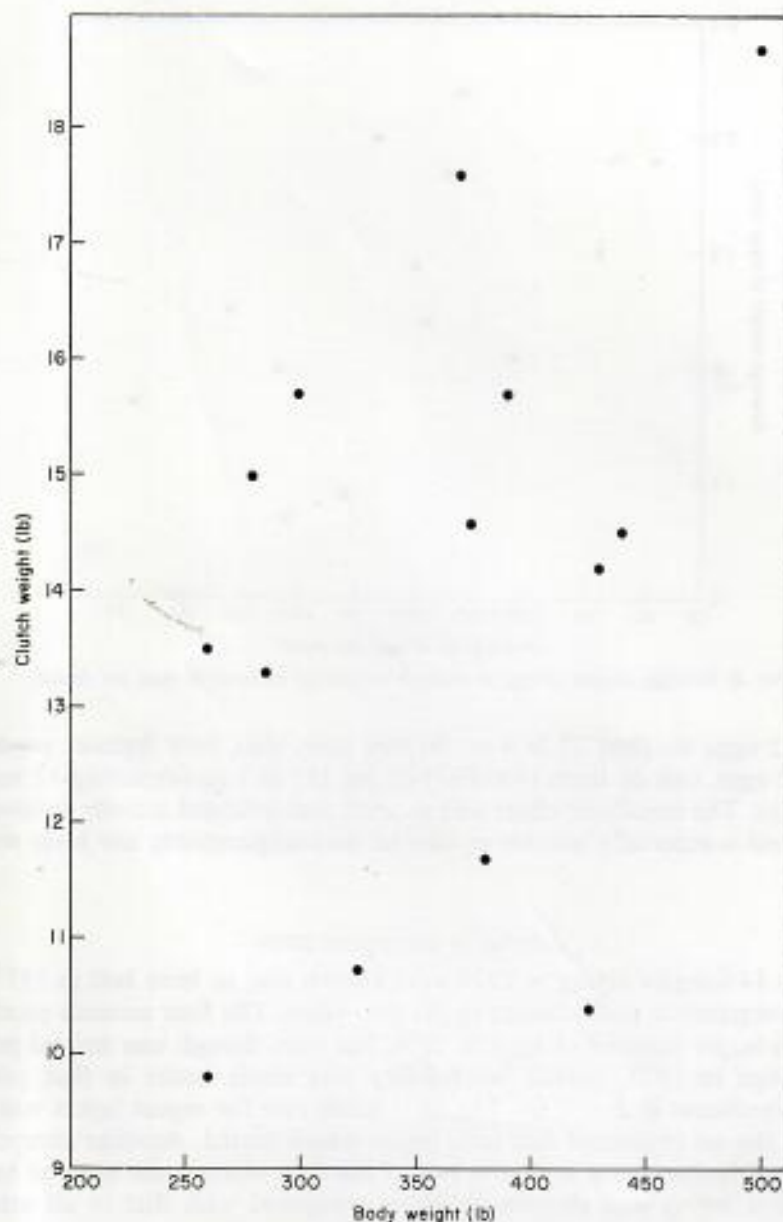


FIG. 3. Clutch weight in relation to body weight.

correlation between the number of eggs in a clutch and average egg size, approximating to a decrease of 0.1 oz for every 20 additional eggs in the clutch (Fig. 4).

Evidently, much more detail of the correlates of egg weight remains to be filled in by future observation, and especially by recording of a less heterogeneous breeding colony, but lack of detail does not obscure the remarkable egg production of the female turtle even in captivity. In 1974, four clutches each weighed more than 20 lb, the heaviest

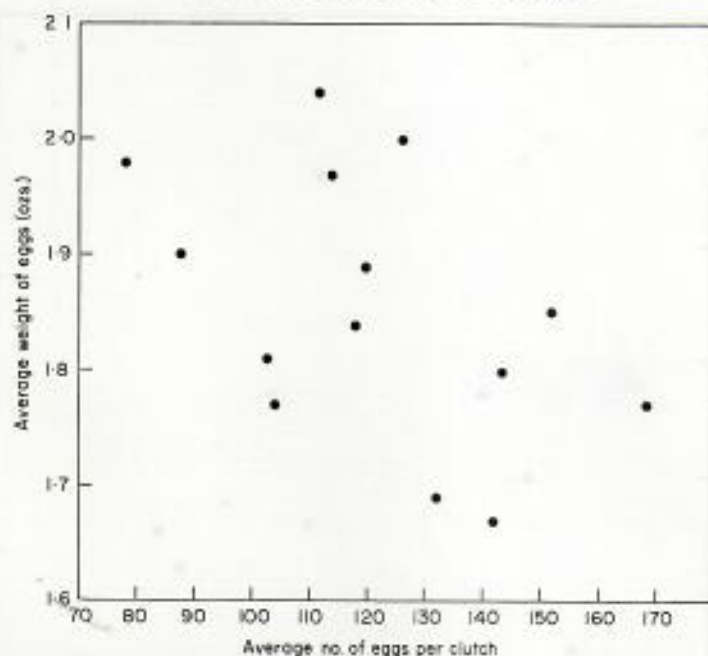


FIG. 4. Average weight of egg in relation to average number of eggs per clutch.

containing 162 eggs weighed 21 lb 4 oz. In this year, also, four females produced more than 100 lb of eggs, one of them (100/P61) laying 115 lb 9 oz (including 12 multi-yolked ones) in 66 days. The metabolic effort and ovarian and oviducal activity involved must be tremendous, and is especially notable in view of the comparatively low body temperature, about 28°C.

#### *Laying in successive years*

Four of the 14 females laying in 1974 were known also to have laid in 1973. Table VI shows their comparative performance in the two years. The four animals produced more clutches and a larger number of eggs in 1974, but even though one animal produced no viable hatchlings in 1973, overall hatchability was much better in that year and the difference is significant at  $P = 0.01$ . The 1974 hatch rate for repeat layers was also much below that of the six presumed first time layers which mated. Another exceptional thing about the repeat laying group is that in two of the four animals the interval between first mating and first laying was abnormally short compared with that in all other animals which mated.

#### *Laying without observed mating*

Four females laid without having been observed to mate. The laying and hatching data are given in Table VII. All of the four animals laid numbers of eggs within the normal range. Had the eighth nest of female B37 been found, she would have been the top layer of the year. Inter-nesting interval and incubation time, allowing for a probable missed nest in B37 and seasonal increase in the I.T., were also within the normal range and

TABLE VI  
Comparison of 1973 and 1974 for the four turtles laying in both years

No. of ♀	No. of clutches	1973		No. of clutches	1974	
		No. of eggs	Viable hatch (%)		No. of eggs	Viable hatch (%)
B100/P61	7	1052	66.1	7	999	32.6
B110/P34	2	370	0.0	5	833	34.9
B116/P57	7	958	67.7	6	907	13.1
B158/P46	5	641	41.8	6	784	36.6
Total	21	3021	53.7	24	3523	28.2

TABLE VII  
Hatch rate of eggs laid by females not observed to mate in 1974

No. of ♀	Date first nest	No. of clutches	No. of eggs	Viable hatchlings	Viable hatch (%)
B114/P29	July 16	5	597	430	72.0
B37/P27	July 31	7	984	610	62.0
B63/64/P75	Aug. 19	4	445	174	39.1
B111/P81	Aug. 23	4	419	0	0.0

are not shown. In three of the females, hatchability was also within the normal range; for the possible significance of the nil hatch of the fourth see Discussion, p. 248.

#### *Hatching on the beach*

Hatchlings appeared in the pool on six occasions between September 1 and November 30 and 446 in all were recovered. For the second consecutive year, therefore, more than 10,000 eggs were laid by the females of the Cayman breeding colony. Only one of the six nests known to have been made on the beach was discovered after hatching compared with four out of five in 1973 and this contained 89 hatched eggs and five with dead embryos, a viable hatch rate of 94.7%. Three of the beach hatches corresponded to the middle of "double" inter-nesting intervals in the records of individual females and could confidently be assigned to Nos. 84, 158 and 116 but are not included in the records. Nests hatching on 1 and 3 September did not correspond to any recorded double inter-nesting intervals and from the dates were probably first nests of females 100 and 114, missed in the early days of the night watch. The sixth batch of hatchlings could not be assigned with certainty, but was probably from a seventh nest of female 158.

#### **Discussion**

##### *Differences between the 1973 and 1974 results*

In 1974, mating started nearly a month later than in 1973. The reason is uncertain. It was generally agreed that the cooler winter weather persisted longer in the second season but no records of comparative water temperature are available. Another possible factor was that in 1974 there was a great deal of unnecessary disturbance round the pool

in April when mating was expected to begin, but no definite cause can be assigned for the late start in 1974.

Of more detailed results, two suggestions from the 1973 records have not been confirmed. First, in 1973 it seemed that later clutches laid by a female might have a lower hatch rate than earlier ones; in 1974, the hatch rate increased in the first three to five clutches laid (Table V). The suggestion from 1973 however was based on five females each laying six clutches (the largest homogeneous group available) whereas the present conclusion is based on all the material available. Second, in 1973 it appeared from carapace length and egg diameter that larger females laid larger clutches of larger eggs. In 1974, it appeared that the larger females laid larger and heavier clutches, but lighter eggs. Here again, the figures are not strictly comparable and a definite answer to the inter-relation between body, clutch and egg sizes must await further material.

#### *Events between mating and nesting*

Experience with the Cayman farm turtles shows that oviposition without recent mating, even if it occurs, is unusual, so that mating presumably has two functions, as in certain mammals: to inseminate the female with spermatozoa and to trigger a neuroendocrine mechanism leading to ovulation. In the turtle, however, unlike, for instance, the rabbit and ferret, mating appears to initiate a series of ovulations so that successive clutches of eggs are laid without further mating. And here there is a problem. The optimal period between mating and first nesting seems to be four to five weeks, but the usual interval between two successive clutches is only about 10 days. Unless, therefore, successive batches of eggs co-exist in the oviduct, as they do during development in the ovary, which is unlikely on mechanical if no other grounds\*, the usual time between ovulation and oviposition is not more than about 10 days. If the same time relation exists between the first ovulation following mating and the first oviposition, then the first three weeks or so of the mating-nesting interval is presumably accounted for by the time taken to activate the ovulation-producing mechanism. But this is supposition and hard information about the time relations of mating, ovulation, fertilization and oviposition is much needed.

One other point is relevant. Assuming a dual function of copulation in the turtle, the two functions could get separated. A sterile but fully potent male would activate the neuroendocrine mechanism of ovulation, without inseminating spermatozoa; or a fertile male, for some reason, could fail to trigger the ovulation-producing mechanism. The results, respectively, would be unfertilized eggs and, presumably, mating without nesting.

#### *Laying without mating*

Of the four turtles which laid in 1974 without having been observed to mate, three laid fertile eggs, two of them with an above average hatch rate. This could imply the carry over of viable sperm from a previous season, but no sexual or nesting activity by these three females had been observed during their three years in the pool and in all the circumstances (see p. 238) it is likely that these three females though not observed to do so did in fact mate in 1974. The fourth female which laid without observed mating in 1974 and produced 419 eggs in four clutches is open to the same interpretation, but the fact that she produced no viable hatchlings and that none of the eggs showed obvious

\*A single clutch of 160 eggs, each occupying say  $1\frac{1}{2}$  ins requires 20 ft of oviduct, 10 ft each side.

signs of development, raises the question of whether female *Chelonia* can lay without previous mating. There are two possibilities. Some animals which normally ovulate only after mating, e.g. rabbit, pigeon, may sometimes do so as the result of sexual excitement induced by the proximity of other excited individuals. The result is the atypical production of eggs, necessarily infertile, without mating. Or a species originally characterized by courtship- or coitus-induced ovulation may under domestication or for other reasons become a spontaneous ovulator, so that large numbers of infertile eggs can be produced in the complete absence of males. This situation is of course found in domestic fowl. It remains to be seen whether the Cayman farm turtles will come to show a similar effect of domestication and, if so, whether it is already appearing. Proof or disproof of this possibility would require the isolation of virgin females for long periods.

#### *Sperm storage in female Chelonia*

In 1974, as in 1973, no female was observed to mate again after having made her first nest, yet many succeeding clutches showed high fertility. The eighth clutch of female B84, for instance, laid 85 days after the first one and 110 days after last mating, had a hatch rate of 85.0%. Moreover, taking all females together (Table V) there was no clear decline in hatch rate in successive clutches. Either, therefore, the pre-nesting mating results in the immediate fertilization of all the eggs required for successive clutches, which would imply fertilization of ovarian eggs, or else sperm from the pre-nesting mating are stored and are available for the fertilization of successive clutches of eggs when they leave the ovary. For various reasons, fertilization of ovarian eggs is not likely. Probably sperm are stored through at least one breeding season, as in certain vivifarious fish, such as *Lebistes*, which produces a series of batches of living young after removal of the male. The site of storage in *Chelonia* can only be surmized. There is no evidence of the existence of definite spermathecae, of the kind found in the Queen bee. Storage of sperm in crypts in the oviduct, as in certain snakes and domestic hens, is the most probable, though this would be rather remarkable in *Chelonia* in view of the tremendous activity of the oviduct during the laying season. Possibly, sperm storage in crypts in the ovary is involved, as in *Lebistes*. Whatever the site of storage, it must be assumed provisionally that sperm can survive in the female *Chelonia* for up to four months. The question of longer survival, for years rather than months, will be answered only by the prolonged isolation of previously mated females. In the meantime, there are no rational grounds for maintaining that the numerous matings observed on the farm, now over several years, have all been ineffective and that the tens of thousands of fertile eggs laid by the ex-wild females have been fertilized by spermatozoa stored from matings in the wild before capture. Even if sperm could survive for many years in the female tract in *Chelonia*, for which there is no current evidence, observations on fish indicate that in the presence of stored sperm, fresh sperm from a new insemination effect fertilization preferentially. In any case, the attempt to discredit the breeding of *Chelonia* in captivity by postulating indefinite storage of sperm carried over from the wild is being put to rest by the laying of fertile eggs by young farm reared females mated with farm reared males.

#### *Annual layers*

Of the 12 identified layers in 1973, four laid again in 1974. Such annual laying is not unknown in the wild, but it is rare. Increased frequency of laying on the farm could be

a very important asset provided the quantity and the quality of the eggs were not impaired. In the event, the four repeat layers laid more clutches and more eggs in 1974, but the hatch rate was only about one-half that of the eggs they produced in 1973. This decrease in the hatch rate of the eggs of repeat layers, when the overall hatch rate was slightly greater in 1974 than in 1973, could have various explanations. The most obvious one is that the intensive laying used up some nutritional factor essential for good hatchability faster than it was being replaced by the food. This explanation would imply that the low hatch rate was due to early embryonic death; other explanations, such as inadequate mating, might imply lack of fertilization of the egg. Here we have yet another example of the importance of distinguishing between these two causes of failure to hatch.

#### *Self-sufficiency*

The main interest of the 1974 breeding season on the Cayman turtle farm was the demonstration that the breeding in 1973 was not a chance event, and the confirmation that Green sea turtles, taken from the wild and allowed time to acclimatize, could mate and nest in captivity. The first biological question in establishing a farm has thus been answered.

The second question, as to whether the stock hatched from ex-wild eggs, reared on the farm and reserved for the breeding stock, now numbering several hundred animals, will also prove to be fertile, will be answered in the next year or two and, on present indications, answered in the positive. The final question, as to whether the reproductive cycle from farm laid egg to farm laid egg can be completed, is not likely to be answered before the early 1980s, when the stock hatched from eggs laid on the farm in 1973 should become sexually mature.

In the meantime, few observers can doubt that the farm is biologically viable and will not, biologically, need further importations of eggs or animals from the wild. Failure of the stock from inbreeding, for instance, is not likely; on the contrary, given adequate culling, the mixture of geographical races on the farm, from Ascension Island, Surinam/Guyana and Costa Rica, may well lead to hybrid vigour and the development of domesticated strains of high quality. There are many problems, of course, but they are essentially of the kind which can be solved, have been solved for other species and, given the opportunity, will be solved for the Green sea turtle.

#### **Summary**

In 1974, on the turtle farm on Grand Cayman Island, BWI, 14 females laid 9752 eggs in 80 clutches, an average of 5.7 clutches and 697 eggs per female. The average number of eggs per clutch was 122 and 44.8% of the 9666 eggs set produced viable hatchlings. These results are compared with the corresponding ones for 1973 (Table II).

The most frequent interval between mating and nesting was 30-34 days, at which the hatch rate of 3228 eggs was 69.4. Intervals shorter or longer gave much lower hatch rates (Table I).

Nesting extended from 12-13 June to 25-26 October, with the peak of nests, eggs and hatch rate in August, about a month later than in 1973 (Fig. 1 and Table III). The most frequent clutch size, however, was the same as in 1973, in the range 121-140 eggs, and the scatter was similar (Fig. 2).

Females laying only three or four clutches had a very low hatch rate (Table IV).

Contrary to the 1973 results, there seemed to be no correlation between clutch order and hatch rate (Table V).

The average clutch weight per female varied from 9 lb 11 oz for a 260 lb female to 18 lb 11 oz for one weighing 500 lb, but average egg weight showed no correlation with the female's body weight.

Four turtles laying in both years produced more clutches and more eggs in 1974, but the hatch rate was much lower (Table VI).

Four females laid without having been observed to mate and two of them had hatch rates above the average. The arrangements for surveillance, however, were inadequate and matings may well have been missed (Table VII).

#### REFERENCES

- Simon, Marlin H. (1975). The Green sea turtle (*Chelonia mydas*); collection, incubation and hatching of eggs from natural rookeries. *J. Zool., Lond.* **176**: 39-48.
- Simon, Marlin H., Ulrich, Glenn F. & Parkes, Alan S. (1975). The Green sea turtle (*Chelonia mydas*); mating, nesting and hatching on a farm. *J. Zool., Lond.* **177**: 411-423.
- Wood, James R. & Wood, Fern E. (1978). Captive breeding of the Green sea turtle (*Chelonia mydas*). *Proc. World Maricult. Soc.* **7**.