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LONG TERM STUDIES OF THE REPRODUCTION OF MALACLEMYS TERRAPIN CENTRATA

by

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The diamond-back terrapins have to be characterized as a highly evolved and specialized form of North American emydid turtles. All *Malaclemys* are recognized as one species (and there has been, to the best of my knowledge, no attempt to subdivide this any more, in contrast to the species of the closely related genus *Graptemys,* where the increase of nomina by the work of taxonomists is still in progress) with seven sub-species; but there is so much overlapping variation that the diagnosis can only be made with the inclusion of geographic origin. Also concerning the living conditions, there is little essential difference. For this purpose the author compared *Malaclemys terrapin centrata* with *M.t. macrospilota* during his observations. – R.C. WOOD (1977), a specialist in this field, considers the *Graptemys spp.* as evolutionary derivates of *Malaclemys spp.;* the hitherto opinion thought it just to be the opposite. – Most remarkable, the whole genus adapted or readapted itself to marine conditions – but by far not as the only freshwater turtle. It has to be added that most chelonians, at least cryptodirans, are eurohalinic i.e. they are able to tolerate a wide spectrum of salinities from fresh to brackish or even sea water. – But in *Malaclemys* there must be a dependence on at least some constituents of sea water. – Furthermore the Northern spp. of Malaclemys are a classical example of an animal threatened by extinction (because of being considered as a delicacy) and then rescued by strict legislation (Summarized by CARR, 1952).

The author received the specimens for his breeding stock in November 1967 from St. Catharine Island; the diagnosistic of the subspecies *Malaclemys terrapin centrata* could be made from the collecting site, since along with the efforts of an artificial propagation (see below) some subspecific populations have been partly mixed in the first decades of the century. The result is a heterogenous colour pattern still nowadays in closely related specimens. – The «breeding specimens» have been 2 males and 2 females out of these; their length, width and depth of carapace and weight are given in table 1.

TABLE 1

(l = light colour pattern; d = dark colour pattern)

	March 1971	*November 1972*	*December 1979*
♀ l	153 - 116 - 57 mm, 540 g	163 - 119 - 62 mm, 705 g	—
♀ d	140 - 106 - 52 mm, 415 g	161 - 119 - 63 mm, 650 g	163 - 127 - 65 mm, 745 g
♀ l	106 - 78 - 40 mm, 185 g	114 - 84 - 45 mm, 240 g	122 - 88 - 44 mm, 265 g
♀ d	106 - 83 - 43 mm, 200 g	113 - 88 - 43 mm, 235 g	116 - 91,5 - 52 mm, 225 g

So after regular reproduction had started in summer 1972, the females added very little growth, the males a bit more.

If one keeps in mind the habitat factors salinity, light, seasonal rhythm and nutrition, *Malaclemys terrapin centrata,* once acclimatized, is a robust animal for captive conditions. In contrast to *Graptemys, Malaclemys* soon will become very tame – very appropriate for experimental observations and for exhibitions.

There is already an extensive literature on captive propagation in a farm, the Beaufort Station – one of the examples of successful reproduction of an animal becoming endangered as long as it has been in demand for consumption; but this also faded in the 20-ies (HAY, 1904; COKER, 1906; BARNEY, 1922; HILDEBRAND, 1929, 1932, 1933; McCAULEY, 1945). On the other hand the natural history has been studied in the wild also (MONTEVECCHI and BURGER, 1975; SEIGEL, 1980a; WOOD, 1981), but there is still a lack of close observations in captivity, i.e. aquaria.

Fortunately the females readily accept artifical nesting sites in the form of sand boxes of about 40 × 40 × 17 cm, mounted inside the aquarium; thus here is no discussion concerning nest site selection (BURGER and MONTEVECCHI, 1975).

METHODS

The animals have always been kept in aquaria and plastic containers of more than 200 l content; for an arrangement the technique with hanging floors (SACHSSE, 1967) proved best for this potent swimmer. It combines all «niches» for the animals with observation possibilities. The design of the container is very important for chelonians (and captive animals in general), because as an example, specimens kept alone in water at a near optimum temperature without any arrangement refused learning experiments after a while. Especially for the stock of *Malaclemys*, the living conditions have been almost the same as those already described for *Chinemys reevesii*. For times both species have been kept together in brackish water (SACHSSE, 1975). The author started to keep *Malaclemys* in sea water of 1,028 specific gravity (made by a 3.6 % solution of «Neo-Tropicmarin» – in the same manner as for marine turtles), then slowly decreasing the concentration along with controls of the animals; after years it was found sufficient to add 0.3-0.5 % marine salt. The salt water terrapins also tolerate «pure» fresh water, if they are fed with a diet containing marine invertebrates. These have been included into a gelatine preparation rather well known in the meantime for such purposes, which is used here since 1966, originally due to a personal communication of E. THOMAS (for details see SACHSSE, 1974). CONANT also mentioned this technique (1971). The author's *Malaclemys* have been even imprinted to a certain degree by long use of such a mixture with special appearance and taste. For a part of the animals this food has been the only possible source for constituents of oceanic water over many years. – During summer the water contained mostly a flora of unicellular algae, which is favourable but not necessary (SACHSSE, 1970), (Fig. 1).

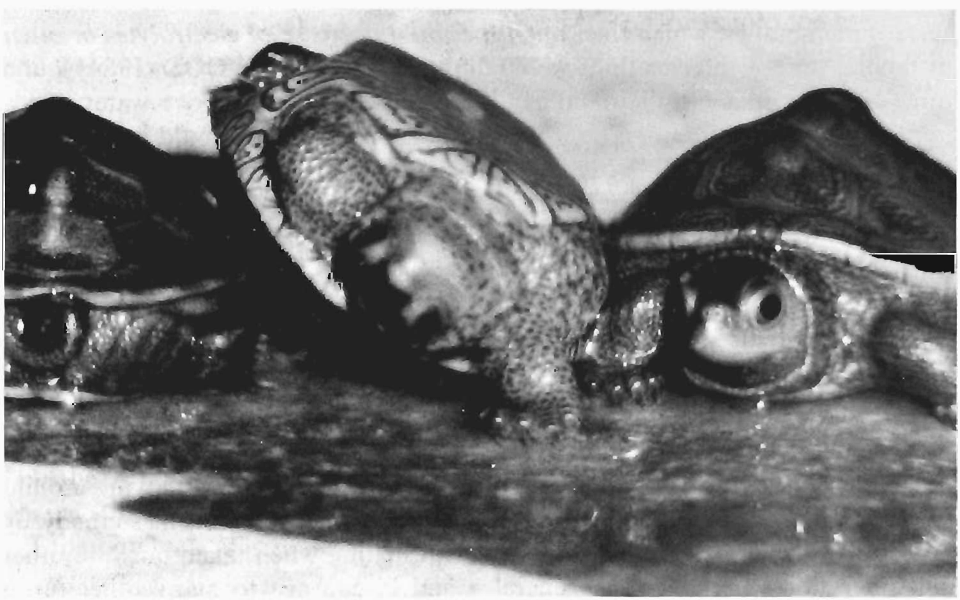

Fig. 1 – 3 newly hatched *Malaclemys*: note the egg caruncle, and the tail region of the «malformed female».

OBSERVATIONS

Since *Malaclemys* are rather sociable, specimens of very different size can be kept together. They are also rather resistant against cold. The lower limiting temperature for feeding is around 14° C. But still at far colder water temperature they will come out for basking, even when there is cloudy sunshine.

For a reptile in this special ecological niche a most important physiological aspect is hibernation, in this case from November to April, depending on the weather influencing the (at times protected) open air containers. If left there during the winter, the animals rest on the bottom with head and extremities half extended. At around 12° C they will become active again. In some years they have been taken into smaller containers into a cellar with more constant temperature, also for reasons of observation. But hibernation experiments analogous to those done with other terrapins produced better results: An optimum for overwintering have been deep, channel-like pits in the breeding terrain, protected against other animals and filled with wet wood cuttings – by scientific definition a moist chamber with very slowly changing temperatures between 0° and 7° C. The idea has been that a long period of metabolic inactivity might become dangerous, if a submersed animal will loose control over its surface membranes, which then might permit a decrease of electrolytes or other metabolic shifts – interrelations we do not understand yet. WOOD (1981) found three different sites of hibernation in the wild – below and above water – in a population of *Malaclemys t. terrapin,* but understandably he could not find out, which specimens would choose land and which water, depending on metabolic parameters. – Comparing the artificial hibernations here, among the imported animals as well as among the offspring, the water method always tended to have occasional deaths rather than the «moist chamber». If a specimen does not survive the hibernation, death occurs always in the first week after emergence. Most characteristic symptoms for that will be oedema and sluggishness – and the absence of other special symptoms. – In the hibernation pits the time could be extended up to 6 months.

One to three weeks after emergence mating occurs, which is difficult to observe, because during courtship and copulation the couple is moving around through the arranged container. Additionaly the water is oftentimes cloudy by unicellular algae. *Malaclemys* will stop with mating when taken out into other containers for observation. In general – and in contrast to many other turtle species – all mating activities are short, inconspicuous and only at this short time of the year. Also after the deposition of the first or second clutch no mating could be observed during all these years. The courtship consisted of some activities of sniffing, bobbing or touching head to head, occasionally also a true titillating by the claws of the forefeet, but only rudimentary in comparison to *Graptemys* and *Chrysemys.* After a few seconds already, the male swam around the female and tried to mount it. Also SEIGEL (1980) emphasized, how difficult it is to observe the courtship of *Malaclemys* in the wild. His results are very similar.

The distance from mating to the first clutch was around 6 weeks, from mid April to June, but the wheather and consequently feeding has been more important for the maturation of the eggs than the distance of time. The same was true for the following clutch. From 1971 to 1979 – the breeding project here to be recorded – there has been a tendency to deposit eggs earlier in spring, an effect of acclimatization. But the most impressive conclusions from table 1 is the fact that from 1971 to 1979 one of the 2 females has been sexually suppressed. From the distance of the clutches together with close observation of females it is evident that only 1 female, the alpha female, reproduced at all. Variation between the distances of egg depositions can be easily explained by the concomitant wheather, which has been documented all year round. On 5th of July 1976 – there was no clutch yet that year – the alpha female died and the post mortem examination showed that about 2 1/2 eggs had grown together to a mass that now was blocking the outlet of both the oviducts into the urodaeum. Accidents of this kind are not quite infrequent in chelonians. From 1977 on the hitherto «suppressed» beta female took over the reproduction, starting with 2 clutches of a health or appearance of the beta female. So another explanation would be that the males prefered only one of 2 very similar looking females. The author has observed such preferences in kinosternids (unpubl.). If we hypothetically postulate any invisible differences like behavioural or olfactorial ones, the origin again will be on the side of the 2 females. The well fitting size relations of the animals in question, the observation of large mating aggregations of *Malaclemys* in the wild (SEIGEL, 1980), and the sociable behaviour in general speak against such sexual preferences; there is also very little spatial limitation concerning the habitat for the populations of this species, if we designate the phenomenon as a reproductive restriction induced by captive conditions. – Further ethological observations are necessary to test these interesting findings, being still too limited from the side of the material. – The reproductive strategy of the dominating female as the only reproducing one is prevalent in the wolf, *Canis lupus.*

Since 1979 the reproduction ceased (also in *Chinemys reevesii* and other spp.) because fast growing trees together with rainy summers prevented all sunshine from the enclosures; in view of a general, pending move no improvements have been started any more. Beside that, it was difficult to find prospective customers for the offspring – a sign for the bad reputation of *Malaclemys* for captive maintenance and also for the mostly very limited market for wild animals bred in captivity (table 2; fig. 2).

Egg deposition has taken place always during the night; the construction of the nest was excellent in the biological sense: 12-16 cm deep, pearshaped and so well covered that the author had difficulty to find it in these small, artificial nesting arrangements. The eggs have parchment shells so soft that one feels slight identations while handling them. Incubation in a wet substrate caused a «growth» or swelling of the eggs about proportional to the humidity of the material, in case of exessive water resulting also in the death of the embryo (see also PACKARD et al., 1982). The kind of substrate (sand or other natural matter) is not so important as the developmental outfit of the eggs; an insufficient one will end in embryonic death also during an optimal incubation. During

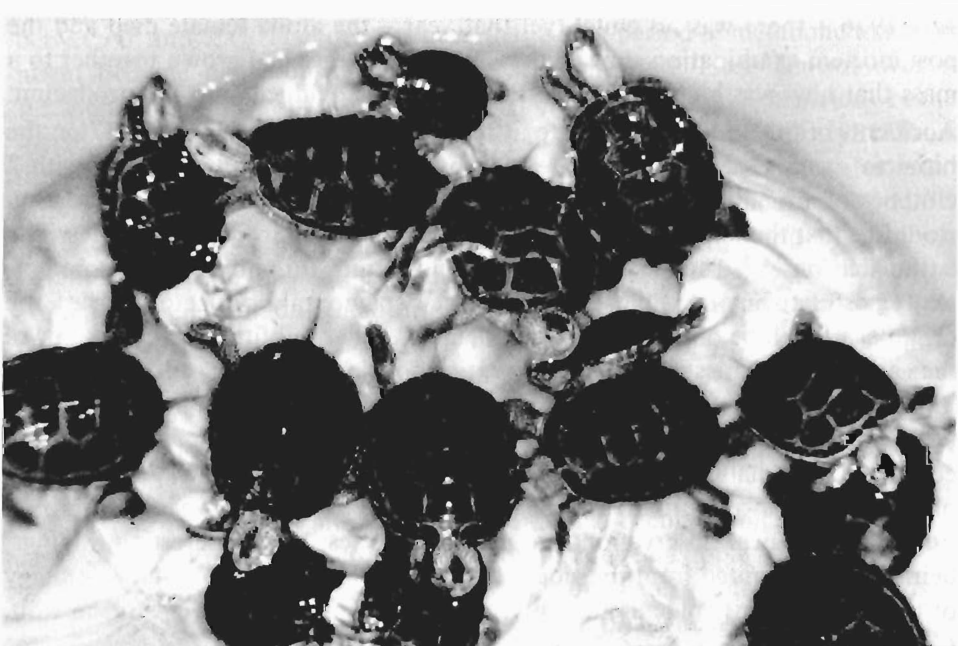

Fig. 2 – 15 young terrapins, the breeding result of one year, at the age of 3 and 4 months.

many breeding experiments with chelonians it became an impression of some likelihood that females with badly outfitted or may-be unfertile eggs are more inclined «to loose these into the water» from time to time and not to deposit them as a clutch into a nest. But this will be difficult to test because eggs submersed in water will be damaged within a short time. The most primitive case of such a bad outfit consists of a thickening of most or all components of the eggshell – a frequent condition in captivity, if females hesitate to deposit the eggs and keep them a too long time in their oviducts.

The knowledge of the possibility of inferior outfit of the eggs in general has been the reason, why the author applied only rather low incubation temperature in earlier years, 27° ± 2° C.

Only in the 70ies PIEAU reported the first findings of temperature dependent sex determination (TSD) in chelonians, but still with very limited experimental numbers. At scientific meetings almost all people contradicted with arguments well known from genetics and reproductive biology. At this time TSD was hard to imagine; almost simultaneously, the author found here in *Malaclemys* the impressive distortion of a sex ratio 52 males : 2 females (table 1). But until 1977 the hatching rate was only around 50 % and this has been – to my knowledge – the first laboratory breeding over a longer time, thus an experimental procedure in its beginnings, other explanations like differential mortality or deviations due to artifacts appeared more likely to me. But very soon observations in reptiles with high numbers of young, comparison of subspecies and of results in the field with those in the laboratory did not leave any doubt about TSD in many reptiles, especially turtles. Elevated incubation temperature around the first third of development will produce females, a lower one males. This is consistant with the results of the author in *Malaclemys* and also in *Chinemys reevesii.* But all I did has been skepticism. As already mentioned, from 1977 on numerous reports appeared on TSD; for a survey see BULL (1980), VOGT and BULL (1982) and BULL (1983). PIEAU (1975), investigated the details concerning the mechanisms during ontogenesis. A retrospective explanation of the 2 females among the offspring of the authors breeding stock is impossible : The first hatched in 1972, but parts of its external genital region, including cloaca and clitoris have been malformed in the direction to a rudiment. But it started to expel small eggs and on dissection the internal genital apparatus has been female.

The second female hatched in 1977 and is still immature at present. – There is little difficulty to rear the young. At hatching they have a very pointed egg caruncle, but they open their eggshel mostly by one or both forefeet. This takes hours or even one or two days, during which also the remaining yolk sac of about pea size is being drawn back into the abdominal cavity. The hatchlings will feed only after a few days and then only on living, moving food like *Daphnia* and *Culex* larvae. After a few days more they will accept the gelatine mixture. They may be kept together, but they need an arrangement with basking sites, natural light (as described) from the beginning (fig. 3).

Chromosome preparations have been done by M. SCHMIDT (1976) from developing eggs in this laboratory. Since there is no possibility so far to get dividing cells without killing the turtle, the use of an embryo is least harmful. Its tissues are highly mitotic, but other cytogenetical difficulties have to be mastered. Fig. 4 shows the karyotype of *Malaclemys terrapin centrata.* Precise chromosome preparations have been a hope for scientists working in evolution and systematics, but these new investigations have been rather unyielding in chelonians : As the oldest, still living order of terrestrial vertebrates they exhibit extreme conservativism not only in their morphology, but also in their genome, in other words, there are only few different patterns of the chromosome complement in 220 living species of turtles (fig. 4). Thus new genetical methods have to be worked out and applied to differentiate subspecies of closely related genera like *Graptemys* and *Malaclemys.*

Fig. 3 – Terrapins eating the gelatine mixture (equally possible under water) in a provisional (quarantine) container.

TABLE 2

Year	*Salinity*	*End of hibernation*	*Egg depositions*	*No.*	*«Lost eggs»*	*Incubation period in days*	*Hatch rate*	*Sex**	*Remarks*	*Hibernation*
1971	30	none	—	—	—	—	—			10.IX.
1972	10	18.III. α♀:	26.VI.	7		58	3/7	1 ♀	1 malform. (♀)	19.XI.
			13.-21.VIII.		2	—	—			
1973	5	11.-22.III.	4.VII.	7		80	5/7			13.XI
			26.VII.	4		75	3/4			
			16.VIII.	7		100	2/7			
1974	3	24.-28.III.	7.VI.	8		87	6/8			20.X.
			17.VI.	7		69-77**	6/7			
			31.VI.	7		75	3/7			
1975	3	25.-31.III.	22.V.	6		70	3/6			7.XI.
			8.VI.	7		90	3/7			(NZ : 7.XI.)+
			22.VI.	10	—	80	4/10			
1976	3	26.-29.III. (NZ : 2.V.)+	α♀ +	—					courtship malform. ♀	17.XI.
1977	3	11.IV.	β♀ : 28.V.	8		65	8/8	1 ♀		16.XI.
			27.VI.	9		55-78**	8/9			(NZ : 14.X.)
1978	3	28.IV. (NZ : 28.IV.)+	(VII.)	—	6	—	—		cold weather	18.XI.
1979	none	10.III.	11.VI.	8	too small eggs	—	0/8		enclosure	20.XII.
			13.VIII.	8		—	0/8		in shadow	

* all other young = ♂♂ ** different incubations + NZ = F1 animals

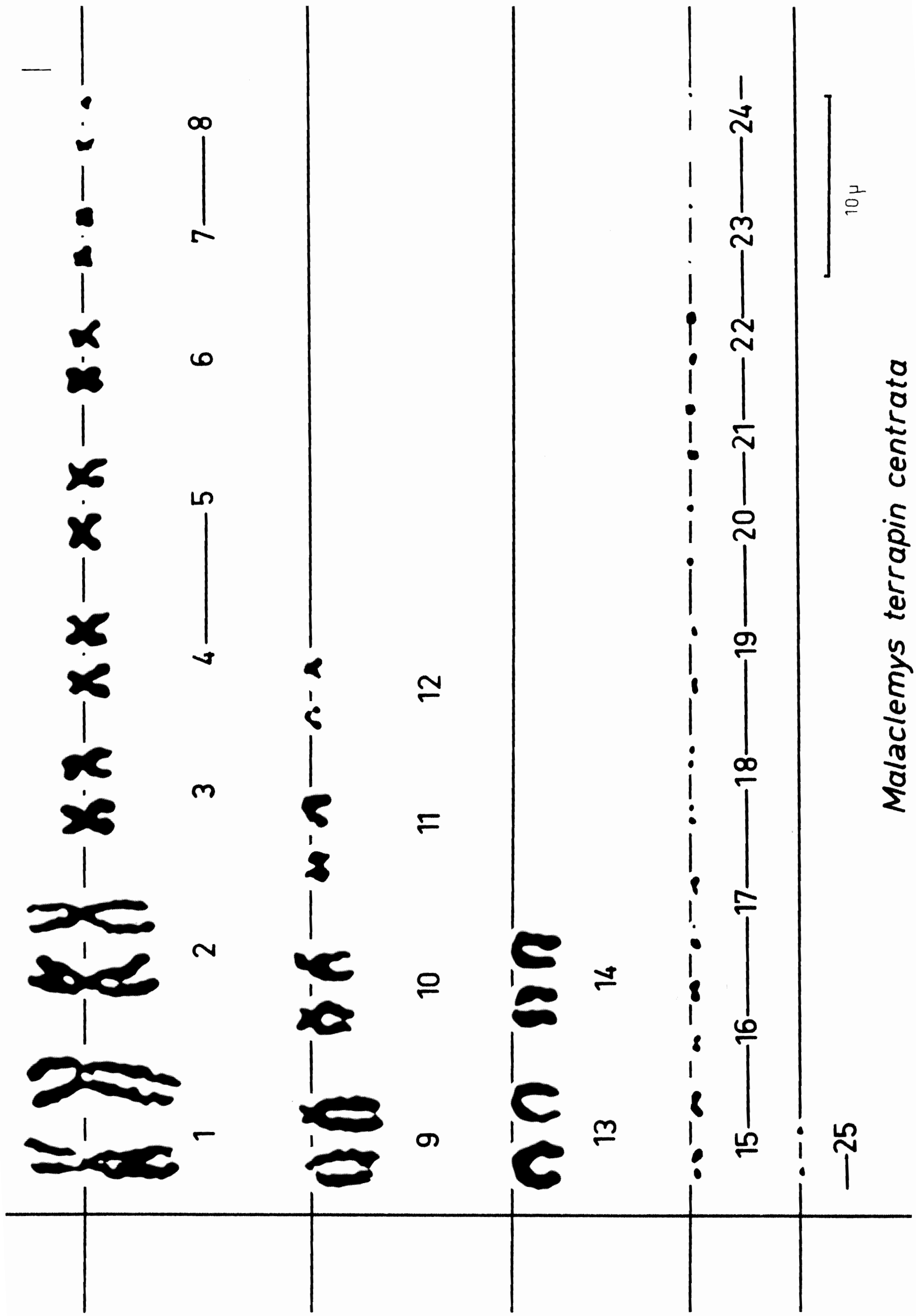

Fig. 4 – Karyotype of Malaclemys terrapin centrata; 2n = 50 chromosomes.

SUMMARY

There are reports considering the biology of *Malaclemys terrapin* in the wild and from large scale farms; here a third approach, a long term breeding program under aquariumlike conditions has been performed and now summarized. For maintenance the most important aspects are salinity, light, feeding, arrangement of containers, and hibernation. 2 males and 2 females were chosen and always kept together : Both males have been observed sexually active, but always only 1 female, alpha or beta, reproduced. This being discussed on the background of the observed reproductive behavior in total. From 1972 to 1977 52 young hatched and have been reared with a sex ratio of 50 males : 2 females; during these years skepticism still prevailed concerning temperature dependent sex determination, which is now the unequivocal retrospective explanation. – Chromosome analysis with cytogenetic evaluation has been done from embryonic tissues. – For the author *Malaclemys* has been – and still continues to be – an example of a turtle with rather well definable ecological conditions, kept as a colony in aquarium-like arrangements.

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