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OBSERVATIONS ON GUT FUNCTION IN *MAUREMYS CASPICA CASPICA* (GMELIN)

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ABSTRACT

Adult *Mauremys c. caspica* consume relatively small quantities of food (average 0.06% body wt day^{-1}; food in dry state). The large females eat more than the small males both absolutely and relatively. The oesophagus acts as a food storage organ for as much as 3-4 hours. The gut clearance time is of the order of 72 hours, but transport of food along the gut is considerably slowed by food deprivation. The absorption efficiency of *Mauremys c. caspica* during routine feeding was 46.4%.

INTRODUCTION

Observations on gut function in aquatic chelonians have so far been relatively sparse, although sea turtles have attracted some attention in recent years (Bjorndal, 1980; Hadjichristophorou and Grove, 1983; Davenport and Oxford, 1984; Birse and Davenport, 1987), particularly the green turtle *Chelonia mydas* L. which is herbivorous as an adult.

Mauremys c. caspica is a predominantly carnivorous, freshwater emydid turtle which features pronounced sexual dimorphism, at least in the Saudi Arabian population (age-for-age, females weigh about 5-6 times as much as males). The study reported here was designed to investigate appetite, gut transit time and absorption efficiency in adult *Mauremys*, with a view to comparing these parameters with those of sea turtles and other chelonians.

MATERIALS AND METHODS

COLLECTION AND MAINTENANCE

The specimens used in this study were collected in the late 1970s in Saudi Arabia. They have since formed a breeding colony at the University College of North Wales, but only seven adult males (mean weight 130g; range 101-173g) and four females (mean weight 815g; range 762-866g) were used in the investigation reported here. The turtles were held in enclosures (2 metres x 1 metre; half land; half water) supplied with running fresh water and kept at 25 ± 1°C. Routine feeding was *ad lib* with trout pellets (Omega: floating) which have previously been used in studies upon juvenile *Chelonia mydas* and *Caretta caretta*. Some of the female turtles laid eggs within a month of the end of the study.

APPETITE

Five turtles (2 male, 3 female) were individually fed every 24 hours for 5 days. In the case of each meal for each animal a quantity of dry trout pellets were weighed and the turtle fed 1 pellet at a time until it had refused 5 pellets in 10 minutes. Offered, but uneaten pellets were dried in an oven then weighed with the unoffered pellets to allow the determination of the amount of food consumed (as g dry weight).

GUT TRANSIT TIME

Two approaches were adopted to assess gut transit time. Firstly, two turtles (both male) were X-rayed and then fed a satiation meal of trout pellets labelled with barium sulphate (2% w/w; thoroughly mixed in by grinding together with pestle and mortar). The animals were X-rayed again at the following intervals after the meal: 1, 2, 3, 5, 8, 12, 15, 18, 24, 30, 36, 48, 54 and 72 hours. During this period the animals were fed daily on trout pellets, which they swallowed whole.

Secondly, two groups of turtles (A and B, each of 5 turtles) were each fed satiation meals of trout pellets labelled with chromic oxide (which is green in colour, non-toxic and not absorbed across the gut). As with barium sulphate, the chromium oxide was thoroughly mixed with the material of the pellets. Group A was subsequently fed daily upon normal trout pellets for 6 days. Group B was starved for 10 days. Each turtle was held in a separate aquarium fitted with a slatted floor which prevented breakup of faeces. The colour and quantity of faeces produced by each animal was recorded daily.

ABSORPTION EFFICIENCY

To estimate absorption efficiency, several turtles were fed a chromic oxide-labelled meal for several days until green faeces had been produced for at least 2 days. Samples of food and faeces were then collected and analysed for energy content by bomb calorimetry. Chromic oxide content was analysed spectrophotometrically.

RESULTS

Estimates of feeding rate are shown in Table 1. From this table it can be seen that feeding rate varies considerably from day to day in both sexes. On average

Turtle Wt (g)	Sex	Mean daily Satiation Ration (mg dry wt)	Satiation ration as % body weight per day					Mean daily Satiation Ration (% body weight)
			Day					
			1	2	3	4	5	
866	F	730	0.136	0.003	0.085	0.071	0.127	0.084
856	F	600	0.087	0.007	0.046	0.086	0.124	0.070
120	M	43	0.080	0.000	0.050	0.010	0.040	0.036
136	M	39	0.035	0.009	0.053	0.018	0.027	0.028
121	M	84	0.120	0.040	0.060	0.129	0.080	0.070

TABLE 1: Estimation of daily satiation meal size.

the turtles consumed food equivalent to about 0.06% body weight day^{-1}. Against expectation, the much larger females not only consumed far more food than males in absolute terms, but also ate rather more (mean 0.077% body weight day^{-1}) on a weight specific basis than males (mean 0.045% body weight day^{-1}).

GUT TRANSIT

X-radiographs illustrating the progress of a barium meal through the gut of a male turtle (154g) are shown in Fig. 1. Portions of the gut were identified by dissection of preserved specimens of *Mauremys* of similar size. Five minutes after a meal, *all* food was

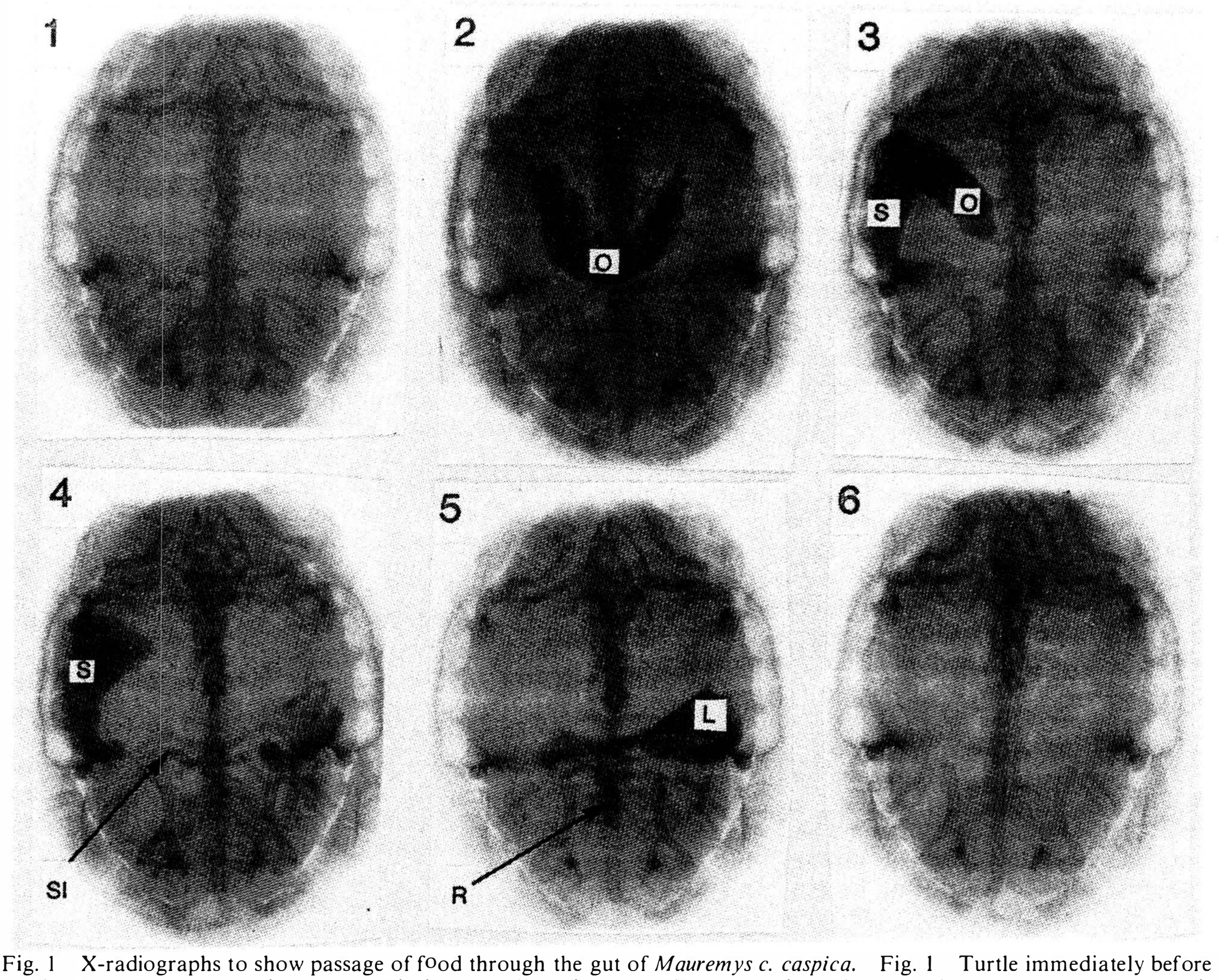

Fig. 1 X-radiographs to show passage of food through the gut of *Mauremys c. caspica*. Fig. 1 Turtle immediately before feeding. Note that the head is retracted within the shell. Fig. 2 5 minutes after ingestion of barium meal. The whole meal is within the oesophagus. Fig. 3 2 hours after the meal. Some food has moved to the stomach, but a considerable quantity remains in the oesophagus. Fig. 4 12 hours after the meal. Food may be seen in stomach, small intestine and large intestine. Fig. 5 36 hours after the meal. All material has now accumulated in large intestine; faeces can be seen in rectum. Fig. 6 72 hours after meal. No barium shadow remains.

Key: O = oesophagus, S = stomach, SI = small intestine, L = large intestine, R = rectum.

Group	Turtle No.	Sex	Days after labelled meal 1	2	3	4	5	6	7	8	9	10
A	1	F	—	—	—	G	G	B*				
	2	F	—	G	G	—	G	B				
	5	M	—	G	G	B/G	B	B				
	6	M	—	—	(G)	B	B	—				
	7	M	—	—	B/G	B	B	B				
B	3	F	—	—	B/G	—	G	(G)	G	G	—	G
	4	F	—	—	—	—	—	—	—	(G)	—	—
	8	M	—	—	—	—	B	(G)	—	(G)	—	—
	9	M	—	—	—	G	B/G	G	(G)	—	—	—
	10	M	—	—	G	G	G	(G)	—	(G)	(G)	—

Key: B = brown, G = green, B/g = brown and green, * copious faeces, ( ) = sparse faeces.

Table 2: Faecal colour in turtles fed a chromic oxide-labelled meal on Day 0.

found in the lower part of the oesophagus, which evidently acts as a food storage organ, since considerable quantities of food still remained in it when two hours had elapsed after the meal. Only after 3-4 hours had all food moved onwards into the stomach. Small quantities of food had entered the small intestine after 3 hours and some had reached the the large intestine by the time 12 hours had elapsed. Progessively the stomach emptied, no barium shadow being visible after 36 hours. The gut was completely clear of barium after 72 hours. Similar results were obtained with another turtle of slightly smaller size (121g).

Table 2 shows the results derived from the feeding of chromic oxide-labelled meals. Animals in group A which, which were fed normal meals after their chromic oxide meal produced green faeces between 2 and 5 days after the meal. Brown (i.e. chromic oxide-free) faeces appeared 4-5 days after the meal and all animals produced brown faeces on day 6. Group B animals, which were starved after the chromic oxide meal showed a very different pattern of faecal production. No green faeces were produced until 3 days had elapsed; small quantities of green faeces were still being produced after 9-10 days. Clearly, starvation slows and inhibits transport of material along the gut.

Absorption Efficiency

The energy content of dried faeces was measured for five individuals (one on two separate occasions) and 2 or 3 determinations were made on each sample (the number depending upon the amount of available material). The mean faecal energy content was $12.6 KJg^{-1}$ (SD = 1.0). The energy content of dry trout pellets (2 determinations) was $17.8 KJg^{-1}$. The chromic oxide content of faeces was $9.5 \mu mg$ dry weight^{-1} (n = 5; SD = 1.5); that of food was $7.2 \mu mg$ dry weight^{-1}.

The mean absorption efficiency (calories) was therefore:

$$\left(1 - \frac{7.2/17.8}{9.5/12.6}\right) \times 100\% = 46.4\%$$

DISCUSSION

The daily dry mass ration eaten by specimens of *Mauremys* (0.06% body weight day^{-1}) is considerably smaller than that recorded for young green and loggerhead sea turtles of similar size (*Chelonia mydas*, 2-3% body weight day^{-1} according to Hadjichristophorou and Grove (1983) and Davenport and Oxford (1984); *Caretta caretta*, <3.7% body weight day^{-1} (Birse and Davenport (In Press)) and of young painted turtles (*Chrysemys picta*) which ate 0.125-0.5% body weight day^{-1} according to Kepenis and McManus (1974). Obviously the energy requirements of rapidly growing juvenile animals are likely to be much greater than those of adult animals approaching their maximum size (though giant Aldabra tortoises of 25kg body weight eat 0.87% body weight day^{-1} according to Coe *et al* (1979)), but the feeding rates of *Mauremys* are remarkably low, presumably reflecting the species' low level of activity. Food intake can also be considered on an energetic basis. *Mauremys* takes in about $0.01 KJg$ body weight^{-1} day^{-1} and absorbs some $0.005 KJg$ body weight^{-1} day^{-1}. Corresponding mean values for *Chrysemys* (11-55g body weight) at 25°C were $0.10 KJg$ body weight^{-1} day^{-1} and $0.08 KJg$ body weight^{-1} day^{-1} (calculated from data of Kepenis and McManus, 1974), again indicating that *Mauremys* is a low activity, low energy demand emydid.

Despite a relatively low average feeding rate, specimens of *Mauremys* eat occasional large meals and appear to be adapted to take in large quantities of food quickly, since the oesophagus functions as a food store, holding food for more than two hours. Oesophageal food storage appears to be a not unusual feature of chelonians since we have now detected it in *Caretta caretta* (Birse and Davenport, 1987) and *Chelonia mydas* (Davenport *et al.*, In Press) as well. It may be suggested that oesophageal food holding was initially associated with head retraction in response to predator threat (swallowing is presumably difficult when the neck is contorted), with a storage function evolving later and persisting even in those chelonian groups which have subsequently abandoned head retraction.

The difference in absolute feeding rates between male and female *Mauremys* is considerable (females ate 12 times as much as males), and graphically illustrates the energetic cost of maintaining an animal of sufficient size to lay clutches of large eggs. Sexual size dimorphism is quite common in emydid turtles and *Mauremys* from Saudi Arabia appear to be an extreme example of this phenomenon, which may not be invariable throughout the species' range since Pritchard (1979), in his general description of the species, states that males achieve the same maximum length as females, while Meek (1987) has recently reported that females of the closely related *Mauremys c. leprosa* are rather larger than males, particularly in late adulthood.

A total gut clearance time (T.G.T.) in *Mauremys* of 72 hours was indicated by both barium and chromic oxide meal studies. This T.G.T. is much shorter than those reported for sea turtles of similar size, which range from 122 hours in *Caretta caretta* (Birse and Davenport, 1987) to 176 hours in *Chelonia mydas* (Hadjichristophorou and Grove, 1983), and of giant tortoises (*Geochelone gigantea* in which it is about 240 hours (Hamilton and Coe, 1982). However, it is similar to the values reported for other emydids (*Pseudemys scripta*, 61 hours; *Chrysemys picta*, 59 hours) by Parmenter (1981). The relatively short gut transit time may help to explain the low mean absorption efficiency (energy) recorded of around 50%, although assimilation efficiences of around 80% have been reported for *Chrysemys* which has even faster gut transit (Kepenis and McManus, 1974). For comparison, assimilation efficiencies of about 35% have been reported for herbivorous giant tortoises, while recent experiments (Davenport *et al.*, In Press) indicate that the absorption efficiency of omnivorous *Chelonia mydas* juveniles lies between 65 and 90%, being lower on a diet of sea grass than when the animals were fed fish.

The observation that food deprivation slows/inhibits movement of food along the gut in *Mauremys* is to be expected. The reasons for such slowing are likely to be complex. To a large extent such slowing may be adaptive, allowing prolongation of digestion to extract as much energy as possible from the food in the gut (see Sibley (1981) for review), but there may also be a mechanical component in that the absence of later meals prevents effective peristaltic propulsion of material along the gut. In this slowing of gut transit *Mauremys* is similar to the sea turtles.

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