AN ATTEMPT TO USE BARIUM MEALS AND X-RAY PHOTOGRAPHY TO DETERMINE GASTRIC EVACUATION RATE AND GUT RETENTION TIME IN JACKASS PENGUINS *SPHENISCUS DEMERSUS*

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INTRODUCTION

The Jackass Penguin *Spheniscus demersus* population in southern Africa is decreasing in size (Frost *et al.* 1976). One possible reason for this decrease is the changing nature of the penguins' food supply, brought about by changing fishing practices (Crawford & Shelton 1981). Current studies of Jackass Penguin diet involve techniques such as stomach pumping (Randall & Davidson 1981, Wilson in press) to obtain food samples. It would be useful to know how long it had taken the food sample retrieved to reach a particular stage of digestion. From this, and a knowledge of how fast a Jackass Penguin can swim, it should be possible to calculate a theoretical range for the species. If retention time in the stomach could be determined, this, coupled with the state of the retrieved sample, could give meal size. For example, if it were known that the sample was half digested, that is, half its original volume, it may be possible to estimate the original meal size.

This paper examines the feasibility of using barium meals and X-ray photography to determine the time taken for fish to be evacuated from the gut, and retained in the gut, of Jackass Penguins.

METHODS

In the first experiment an adult Jackass Penguin, weighing 3,5 kg, was taken into captivity before the experiment to allow it to become more used to being handled. The bird was starved for 36 h and then force fed five Horse Mackerel *Trachurus capensis* weighing a total of 126 g. Each fish contained a gelatin capsule filled with 'Microtrast' oesophageal cream 70% W/W barium sulphate, the 'barium meal'. Barium sulphate is opaque to X-rays and digestion will release it from the capsule causing fogging on the X-ray plate. The bird was restrained in a rubber jacket and first X-rayed 15 minutes after feeding. X-ray photographs were taken hourly until the gut became opaque. Between each X-ray photograph the bird was kept in an opaque container and was disturbed as little as possible.

In the second experiment two adult Jackass Penguins, each weighing about 2,5 to 3,5 kg, were taken into captivity a week before the experiment, again to allow them to become more used to being handled. After starving for 36 h each bird was fed on Pilchard *Sardinops ocellata* (Horse Mackerel was not available). One bird

was fed a Pilchard weighing 150 g containing a gelatin capsule containing 'Microtrast' barium sulphate powder. The other bird was fed a similar sized Pilchard without a capsule of barium sulphate in order to see if the progress of digestion could be followed simply by detecting the fish backbone and otoliths using X-ray photographs. The penguin which had been fed the Pilchard containing barium sulphate was X-rayed at half-hourly intervals until the gut became opaque. The other bird was X-rayed four times using different exposures until it became apparent that it was not going to be possible to detech the fish.

In a third experiment the birds were fed Pilchards of similar sizes and then induced to regurgitate using a stomach pump (Wilson in press), after two, three, four and five hours.

In a fourth experiment, two similar sized Pilchards had gelatin capsules containing barium sulphate powder placed in them and they were then X-rayed at half-hourly intervals to determine if there was any diffusion of the barium sulphate powder without the action of the penguins' digestive enzymes.

RESULTS

Immediately after feeding, the first penguin's barium meal could be seen as discrete units on the X-ray photograph. After one hour only three capsules could be seen and some of the barium meal had started diffusing through the gut. Two hours from first feeding only two capsules could still be seen. An hour later (three hours after first feeding) the two capsules could still be seen although they were not as distinct as in the previous photograph and more of the barium meal had dispersed through the gut. Four hours after first feeding most of the gut was opaque and after five hours the gut was totally opaque.

The results of the second experiment show that immediately after feeding the capsule containing the barium sulphate is seen as a discrete unit. Fifteen minutes after feeding the outline of the capsule was becoming less distinct. One hour after feeding barium sulphate was starting to diffuse through the gut. Two hours after feeding the gut had become totally opaque.

The attempt to detect fish inside the penguin without using barium sulphate was unsuccessful. Four exposures were tried but none was sufficiently penetrating to detect fish bones or otoliths.

In the third experiment the fish retrieved by stomach pumping were only partially digested and still recognizable as whole fish. However, they were sufficiently digested to allow the digestive enzymes of the bird to reach the barium sulphate capsule. The fish retrieved after three and four hours were progressively more digested until after five hours the fish were close to the well digested state in which they are usually retrieved when collecting samples in the field (pers. obs.).

In the fourth experiment, after 2½ hours the barium sulphate capsules in the four Pilchards remained intact.

DISCUSSION

The term gastric evacuation avoids any implication of absorption and includes passage of undigested material through the stomach (Elliot 1972). A more useful measurement for calculating meal sizes would be gut retention time. However, these experiments demonstrate that X-ray photography using a contrast medium, such as a barium meal, is unsuitable. Depending on how fast the digestive enzymes of the bird penetrate the fish and reach the barium sulphate, the gut can become opaque before digestion is anywhere near complete. Barium sulphate does not bind to the tissue of the fish. Consequently, once it has diffused out, it can be no longer used to record the passage of fish. The same problems apply to the use of this technique for measuring the rate of gastric evacuation.

Molnar *et al.* (1967) were able to follow the passage of fish eaten by predatory fish without using any contrast media, in species of fish where the stomach is definitely differentiated from the intestinal canal. This was unfortunately not possible with Jackass Penguins, probably because of the nature of the penguins' body wall.

X-ray studies were successfully used to study movements of the hen's intestine (Vonk & Postma 1948). However, in this study they required the gut to be opaque. Skadhauge *et al.* (1980) measured large intestinal passage time using X-ray photography in hydrated and dehydrated Dik-Dik Antelopes *Rhynchotragus kirkii* by measuring passage of clearly differentiated faecal pellets. However, E. Skadhauge (pers. comm.) found the technique unsatisfactory, because the gut became opaque before passage was complete.

Further investigations of the rate of gastric evacuation and gut retention time in the Jackass Penguin are to be made using dyes and radio-isotope techniques.

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