GASTRIC FUNCTION IN A CAPTIVE AMERICAN BITTERN

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THE American Bittern (*Botaurus lentiginosus*) is primarily carnivorous with a diet consisting mainly of frogs and small fish (Bent 1926: 78–79). Apparently the only previous studies of gastric function in such an aquatic, carnivorous ciconiiform dealt with pellet formation (Hibbert-Ware 1940) and with the pH of gastric ingesta (Mennega 1938, Herpol 1967c) in the Gray Heron (*Ardea cinerea*). The objectives of the present study were to determine for one American Bittern: (1) the average meal to pellet interval (MPI), (2) the proteolytic activity and pH of gastric secretions, (3) food consumption rate and the proportion of an ingested meal egested as a pellet, (4) the proportions of bone and hair in the pellet, and (5) the relationship of the pyloric stomach to pellet formation and to the gastroduodenal contraction sequence.

METHODS

A mature American Bittern with a broken leg but otherwise in excellent health was used in a 16-week study from May through August while the leg was mending and the bird was regaining full mobility. Hopefully, physiological changes caused by the annual cycle had little effect on the particular processes studied during this period. The bittern was housed in a 6 × 10 foot room, in which temperature and humidity varied between 18°–20°C and 60–90%, respectively.

Laboratory mice (*Mus musculus*) served as the diet during these experiments because we found that fewer pellets were formed from fish or frog diets. Also, mice have served as the standard diet in similar studies with raptors previously performed in this laboratory; and therefore mice were preferred for purposes of comparison. The bittern ate mice readily and appeared to maintain a healthy condition on that diet. The bird was usually fed as many mice as it wanted. During periods when MPI was being determined, the bird was fed four mice at 0800 h, uneaten mice were removed 4 h later, and records were kept on the number and weight of the mice eaten. The dry weight of the mice eaten was calculated by multiplying the wet weight of mice by 0.378, as this was determined to be the average proportion of dry matter per mouse (Duke et al. 1975). The amount of desiccation per unit of time of the uneaten mice in the room was determined and the weights of the uneaten mice were corrected accordingly. Water was available *ad libitum* except for 12 h preceding the collection of gastric juice. The bird was weighed frequently before and during the study to assure that it was maintaining a constant weight.

The room was checked frequently for fresh pellets to determine the time of pellet egestion accurately. Pellets were air-dried for a minimum of 48 h, and the weights were recorded. Following air drying, some pellets were oven-dried at 90°C for 24 h as it was found that pellets reach a constant dry weight with this procedure. A factor determined from the weight loss by oven drying was used to correct the air-dried pellet weight to an oven-dry weight. Six of the oven-dried pellets were selected randomly and used to determine the proportions of bone and hair therein. For this study, we separated bone and hair manually, then redried and weighed the bone fragments and calculated the proportion of bone in the original pellet.

Two methods were used separately or simultaneously to associate an egested pellet with the meal it represented. Black mice and white mice were fed alternately and the occurrence of black or white pellets could thus be related to the appropriate mouse meal. Plastic-coated wires of various shapes (e.g. rods and circles) were sewn into the abdominal cavity of mice fed to the bittern, and wires recovered subsequently in the pellets could be related to a particular meal.

The proteolytic activity of gastric juice was determined exactly as described by Duke et al. (1975). This technique involved the measurement of the amount of tyrosine released from hemoglobin substrate upon exposure of the substrate to gastric juice from the bittern. Gastric juice samples were obtained by inserting a tube orally and passing it into the gizzard. One sample was collected at 0900. At 1300, a meal of mice was given to the bittern, and a second gastric juice sample was collected 4 h after two of the mice were eaten. The bird usually ate at least two mice immediately.

Radiographic observations were made to determine the gastroduodenal contraction cycle and the relationship of the pyloric stomach to that cycle. The radiographic unit (Emperor 90/15 table, 6 inch image intensifier, 875 line, split TV, 35-mm ciné, jupiter 900 MA control and transformer) had components that allowed both closed-circuit television monitoring and recording on 35-mm film (double negative film, type 5222, DXN 718). Barium sulfate (Barosperse) was given as an aqueous suspension to outline the gastrointestinal tract. The contrast medium was injected orally via a tube and a syringe. The bird was observed primarily from the right dorsolateral oblique position.

RESULTS

The bittern always ate mice whole and swallowed them head first. Occasionally, it swallowed two or three mice in rapid succession. The average weight of the bittern during the study was 700 g and it ate an average of 23.9 g (dry weight) per day. The proportion of the ingested food that later appeared as a pellet was 7.4%. The average proportion of bone per pellet was 7.2%.

Dissection of intact pellets showed them to contain small, tightly packed, individual balls of fur. Bone fragments were found throughout the entire pellet both in and between the balls. The fur balls were held in a pellet shape by a matting of loose hair and hair projecting from the outer surface of the balls of fur. The pellet was coated with thick mucus that apparently acted as a cement to hold the matted pellet together and also as a lubricant to ease its passage up the esophagus. One pellet usually represented the undigestible material from only the previous meal, but occasionally, on the day after the bittern's diet was changed from black to white mice, a portion of a fresh pellet consisting predominantly of white hair also contained a bit of black hair. Commonly two or three small pellets were cast within an hour, and these were considered to be portions of the same pellet. On several occasions, the bittern cast a pellet within 5 min after the presentation of a fresh meal. The

TABLE 1

AVERAGE MPI FOR AN AMERICAN BITTERN EATING A DIET OF LABORATORY MICE

Dry matter (g) per meal	$\bar{x}$ MPI	n	Overall average MPI (hours)
6–10	24.0	1	
11–15	22.5	2	
16–20	24.0	2	
21–25	23.4	5	
26–30	18.0	2	
31–35	19.7	6	
36–40	24.0	1	22.23

average MPI was determined to be 22.23 h (Table 1). Hibbert-Ware (1940) reported that pellets of the Gray Heron also consisted of balls of fur.

Preprandial (basal) pH values were less than postprandial, viz. 1.65 and 1.86 respectively (Table 2). The postprandial pH increase in the stomach was believed to be due to dilution of the gastric juice by ingesta. The concentration of tyrosine liberated by exposure of the hemoglobin substrate to gastric juice was less postprandially than before eating, being 1.62 mg/ml and 5.2 mg/ml respectively (Table 2). Dilution of the gastric juice by ingesta was again believed to be the cause for the apparent decrease in proteolytic activity of the gastric juice.

The gastroduodenal contraction sequence was seen to begin with a peristaltic wave moving through the glandular stomach into the muscular stomach (Fig. 1A). The peristaltic ring continued through the muscular stomach, where the contractions proceeded across the greater curvature at a much faster rate than in the lesser curvature. This movement con-

TABLE 2

PREPRANDIAL AND POSTPRANDIAL PROTEOLYTIC ACTIVITY AND pH IN GASTRIC JUICE SAMPLES FROM AN AMERICAN BITTERN EATING LABORATORY MICE

	4 h preprandial			4 h postprandial		
		Lib. tyr.[1]	Total tyr.[2]		L b. tyr.	Total tyr.
	pH	(mg/ml)	(mg/ml)	pH	(mg/ml)	(mg/ml)
$\bar{x}$	1.65	5.19	5.82	1.86	1.62	2.73
s	0.11	1.34	1.42	0.14	0.48	0.42
n	5	5	5	5	5	5

[1] Lib. tyr. = liberated tyrosine (tyrosine released upon exposure of a gastric juice sample to a hemoglobin substrate).
[2] Total tyr. = total tyrosine (tyrosine present in gastric juice before adding substrate plus liberated tyrosine = total tyrosine).

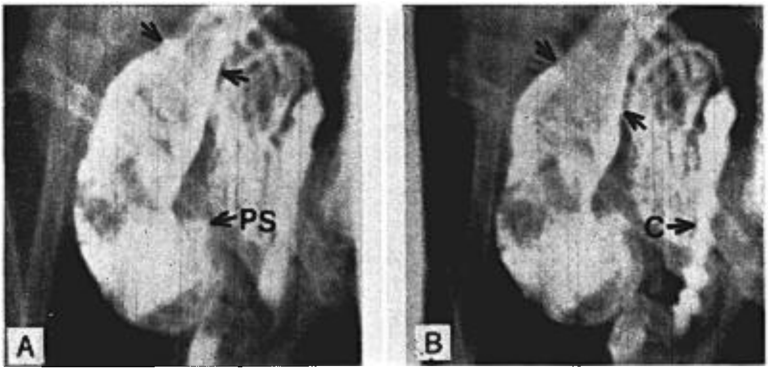

Fig. 1. A and B, sequential cineradiographic prints of the progression of the peristaltic wave during a typical gastroduodenal contraction sequence in an American Bittern. Arrows indicate a contraction; PS indicates the pyloric stomach. Note the rings of contraction characteristic of antiperistalsis in the colon (C) in B.

tracted the muscular stomach into a hook shape (Fig. 1B). As the hook-shaped stomach began to relax to its shape at the start of the cycle, contractions of the pyloric stomach and duodenum occurred and ingesta moved rapidly through the pyloric stomach and down the proximal duodenum. A new peristaltic wave could be seen to begin in the glandular stomach at about the time when the previous wave had begun to move across the greater curvature (Fig. 2). We could not determine the func-

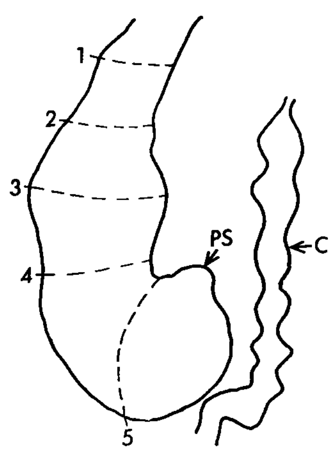

Fig. 2. Schematic drawing of the stomach and colon of an American Bittern. The numbers 1–5 illustrate the movement of a peristaltic wave during a gastric contraction cycle.

tion of the pyloric stomach or its role in pellet casting via radiography nor by any other observations or measurements made in this study.

Antiperistalsis was noted in the colon.

DISCUSSION

The inactivity of the bird, the conditions of the holding room, and the mouse diet were all unnatural for the American Bittern, but the physiological data obtained can be roughly extrapolated to natural conditions.

The proportion of the food the bittern ate that appeared as a pellet was comparable to this proportion in falconiforms, and this proportion was substantially less in both falconiforms and the bittern than in two strigiform species (Duke et al. 1975). The lower proportions indicate that more of the meal was digested. An analysis of the percentage of bone in pellets showed that the bittern and falconiforms had about one-sixth as much bone in their pellets as strigiforms. Therefore the lower proportion of the meal appearing in the pellets of falconiforms and the bittern may be accounted for by more thorough corrosion of bones during digestion.

Preprandial gastric proteolytic activity found herein for the bittern was nearly twice that found for hawks and owls, but was 25% less than the preprandial proteolytic activity determined for turkeys (Duke et al. 1975) and chickens (Burhol and Hirschowitz 1970). In contrast, Herpol (1964, 1967a), using fasted birds (i.e. preprandial), found that gastric proteolytic activity of carnivorous birds (*Falco tinnunculus tinnunculus*, *Buteo buteo buteo*, *Athene noctua vidalii*) was generally greater than that of omnivorous (*Larus ridibundus*, *Sturnus vulgaris*, *Gallinula chloropus*) and granivorous (*Columba livia domestica*, *Gallus domesticus*) birds. Probably these conflicting results are due to differences in methods of determining proteolytic activity. Herpol (1964, 1967a) determined proteolytic activity of homogenized extracts of GI tract organs. Burhol and Hirschowitz (1970) collected gastric secretions via a proventricular fistula.

Preprandial gastric pH of the bittern was approximately equal to that of falconiforms while that of strigiforms was higher (Duke et al. 1975). This lower pH probably accounts for the greater bone corrosion previously described for the bittern. Mennega (1938) determined that the postprandial gastric pH of *Ardea cinerea* ranged from 2.54 to 4.90 and van Dobben (1952) found the pH of the gastric juice of Great Cormorants (*Phalacrocorax carbo sinensis*) to range from 0.9 to 2.9 shortly after eating and to be 4.6 at 3 h after eating. The pH values presented in both the latter studies are considerably higher than values presented herein for the bittern, but the pH value reported by Herpol (1967c) for

Ardea cinerea was similar to those we found here. van Dobben also indicated that egested pellets of the cormorant were enveloped in the lining of the gizzard. This was not seen in the present study.

Preprandial gastric pH found in Turkeys (*Meleagris gallopavo*) (Duke et al. 1975) was higher than that found in the bittern in the present study; but gastric pH for pigeons and chickens, as determined by Herpol (1967b), was slightly lower than that found in the bittern. Gastric juice was collected by stomach tube in all these studies.

The egestion of several pellets from one meal within a brief period may result from the fact that the esophagus of the bittern is at least three times longer than that of a hawk or owl. Therefore it is possible that some pellets could be broken apart by esophageal activity associated with pellet egestion. The egestion of a pellet within 5 min of the presentation of a new meal may indicate that the sight of food reflexly stimulated egestion, or that the ability to induce pellet casting consciously to facilitate ingestion of the new meal occurred. Further studies of the regulation of pellet egestion should be made.

Although the order of contraction of the pyloric stomach in the gastroduodenal contraction sequence was determined in this study, the function of the pyloric stomach was not discerned. Because bitterns eat considerable quantities of undigestible material, the pyloric stomach may act as a filter to prevent undigestible materials from entering the duodenum as Farner (1960: 435) suggested. The gastroduodenal contraction sequence seen in the bittern was very similar to that reported in Great Horned Owls (*Bubo virginianus*), except that owls lack a pyloric stomach (Kostuch and Duke 1975). Colonic antiperistalsis, as observed here, has been described previously in domestic Turkeys (Dziuk and Duke 1972) and in chickens (Akester et al. 1967).

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Summary

Gastric function was studied in a captive adult American Bittern. The 700-g bird ate an average of about 24 g (dry weight) of mice per day. An average of 7.4% of its ingested food was returned as pellets, which contained about 7% bone. Meal to pellet intervals averaged 22.23 h. The pH of the gastric juice of the bittern averaged 1.65 and 1.86 respectively for preprandial and postprandial samples. The proteolytic activity of gastric juice samples, like their acidity, was also lower postprandially than preprandially due to dilution of the samples by

ingesta. In the gastroduodenal contraction sequence a peristaltic wave began in the glandular stomach and proceeded through the muscular stomach and pyloric stomach and into the duodenum. The function of the pyloric stomach could not be determined.

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