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NOTES

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An Evaluation of Stomach Flushing Techniques for Crocodilians

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Among the options available for obtaining dietary data, stomach flushing techniques have been widely used as alternatives to killing study organisms to obtain their stomach contents. These techniques are especially useful for dietary analyses of protected species, or for investigators who wish to obtain dietary information from marked populations or monitor diets of individuals. Flushing techniques have been used in crocodilian diet analyses (Taylor et al., 1978; Webb et al., 1982; Ayarzagüena, 1983), but have not been rigorously evaluated. If a stomach flushing technique is not 100% effective, measurement errors may be introduced into analyses of diet composition. Counts of prey items, prey size estimates, and estimated importance of prey categories could all be affected.

The spectacled caiman, *Caiman crocodilus*, is probably the most abundant crocodilian in the world (Groombridge, 1982), and in the Venezuelan llanos populations are managed as a renewable natural resource (Rivero-Blanco, 1985). The availability of both living and dead animals make it a good species to use for evaluating dietary techniques. Caimans are primarily fish eaters in the llanos, but also consume other vertebrates, insects, crabs, and snails. During a dietary study of caimans at Hato Piñero, a private ranch and biological research station in the state of Cojedes, Venezuela, I tested three stomach flushing methods for use on crocodilians: The scoop and pump method (Taylor et al., 1978), the garden hose method (Ayarzagüena, 1983), and a modification of Ayarzagüena's (1983) technique that employs the hose in combination with Heimlich maneuvers. The Heimlich maneuver is a first-aid technique used to dislodge obstructions in the air passageways of a choking person. Here I describe the hose with Heimlich maneuvers method and present the results of a comparison of the three techniques in terms of their effectiveness in removing stomach contents.

Between 4 November 1985 and 17 March 1986, 46 *C. crocodilus* ranging 135–1086 mm SVL were randomly subjected to one of the three methods and subsequently killed for verification of any remaining stomach contents. There was no significant difference in mean size among caimans subjected to the three methods (F-ratio = 0.050, df = 2,43, $P > 0.95$). Five individuals used to test the scoop and pump technique and six caimans flushed with the hose and Heimlich maneuvers method had stones and debris in their stomachs, but no food. One individual with a completely empty stomach was excluded from further analyses. Following preservation in 70% ethanol, the contents removed by flushing and any contents remaining in the subject's stomach were separately weighed to the nearest 0.1 g on a triple beam balance while still moist.

Dietary analyses usually include measures of prey size, number of prey categories, and which prey category or taxon was dominant in terms of volume or mass. To evaluate the biases of stomach flushing techniques on these determinations, I analyzed the stomach contents removed by flushing and then reanalyzed them using the data from both the flushed items and contents remaining in the stomachs. The effectiveness of each method was evaluated according to whether or not caimans were completely flushed, and if the number of prey categories, the number of prey items, the rank (by volume) of prey categories, or the prey size estimates changed after any remaining stomach contents were included.

The scoop and pump method, described by Taylor et al. (1978) and Webb et al. (1982), was tested on 16 caimans. This method employed a scoop for large items that was inserted into the animal's stomach while water was poured into the caiman until it was full. Items were then pulled out with the scoop. The pump is a plastic tube that also was inserted into the stomach. Water was poured into the tube and the crocodilian was squeezed until stomach contents entered the tube and could be poured out.

Five caimans were subjected to the method described by Ayarzagüena (1983). In this method an ordinary garden hose 18 mm in diameter was connected to a household tap and the smooth free end was inserted into the stomach. The subject regurgitated its stomach contents when the tap was turned on.

I flushed 25 caimans using Ayarzagüena's method with Heimlich maneuvers. The hose was carefully inserted down the esophagus into the stomach, where it could be felt by palpation of the caiman's left flank. Then, with one person in front of the caiman holding the hose and another alongside the animal with hands under the lower belly, the tap was turned on to full force (10 l/min) for a caiman >500 mm SVL. The caiman's stomach rapidly filled with water, and with the hose still in place and running, the person beside the caiman vigorously squeezed its belly up towards the spine and forward in a motion analogous to the Heimlich maneuver. A mixture of water and stomach contents was forced out and collected in a large washtub positioned below the caiman's head. The Heimlich maneuver was repeated three to four times as the stomach repeatedly filled. The entire procedure was repeated usually three times per animal until no more stomach contents appeared. For large caimans a total of 60–80 L of water were used with up to 12 Heimlich maneuvers. In a few cases, especially with caimans >900 mm SVL, the procedure had to be repeated five or six times.

Several additional steps facilitated handling the caimans and improved the efficiency of the garden hose with Heimlich maneuvers method. First, the caiman's mouth was opened and a cylinder was tied in place between the jaws. The technique worked best when the subject's mouth was opened very wide; for caimans >500 mm SVL we used a PVC pipe 10 cm in diameter and 14 cm long. For smaller caimans the mouth cylinder was a tin can 6 cm in diameter and 6 cm long wrapped with adhesive tape. Caimans >400 mm SVL were tied to a plank by the hindquarters, tail, and lower mandible to control thrashing, and the head end of the plank was declined about 20°. A trickle of water through the hose served as a lubricant to facilitate the passage of the hose down the esophagus. Touching the caiman's nostrils caused it to close the glottis on the floor of the mouth, a precaution necessary to prevent water from entering the respiratory system. After each bout of flushing, water remaining in the buccal cavity was drained and the caiman allowed to take some breaths. Caimans <350 mm SVL were flushed identically except a small clear plastic tube was used in place of the hose and the force of the water was reduced. An adult caiman could usually be processed in 20 min.

All the methods produced positive results in that a variety of food items plus stones and vegetation were flushed from the caimans' stomachs. But the methods were quite different in their absolute efficiency expressed as a percent of the total weight of stomach contents removed (Table 1). The hose with Heimlich maneuvers method removed all food items in 100% of the subjects, significantly more than the scoop and pump (Mann-Whitney $U = 124$, df = 1, $P = 0.021$). Four caimans retained some of their stones, the largest remaining in all but one. One of the six individuals that contained only non-food items was not completely flushed. The scoop and pump method was second most efficient at removing contents, removing all food items in 69% of the subjects and all contents in 50% of the subjects. When five individuals that contained only non-food items were excluded, all food was removed in 55% of the eleven remaining caimans. The proportion of stomach contents removed by the scoop and pump was not predictable. The largest piece of prey remained in the stomachs of four subjects, and part of the stone load remained in six individuals. One of the five stomachs that contained only non-food items was not completely flushed, retaining 37 out of 68 stones. The hose alone was ineffective, removing all food in only two trials. Two of three stomachs not completely flushed with the hose retained the largest pieces of prey. The small number of trials with the hose alone precluded statistical comparisons to the other two methods.

TABLE 1. Percent effectiveness of three crocodilian stomach flushing techniques.

	Hose with Heimlich maneuvers (N = 24)	Scoop and pump (N = 16)	Hose alone (N = 5)
All food removed	100%	69%	40%
All contents removed	83%	50%	40%
Difference in no. of prey categories	0%	25%	20%
Difference in no. of prey items	0%	31%	60%
Difference in prey rank (by volume)	0%	31%	20%
Difference in prey size estimate	0%	37%	20%

The hose with Heimlich maneuvers provided complete and significantly more accurate assessment of the dietary variables (Table 1). Diet composition and prey size estimates differed in at least 25% of the caimans flushed with the scoop and pump and in at least 20% of those flushed with the hose alone. *T*-statistics computed from arcsine transformations of the proportions in Table 1 (Sokal and Rohlf, 1969) revealed the hose with Heimlich maneuvers method was significantly better than the scoop and pump for all four variables ($t = 2.911$, $P < 0.01$ for the number of prey categories; $t = 3.769$, $P < 0.001$ for the number of prey items; $t = 3.679$, $P < 0.001$ for prey rank; $t = 4.082$, $P < 0.001$ for prey size estimates). The hose alone gave slightly better results than the scoop and pump for three dietary analysis variables, but that could be due to the small number of trials for that method and the few prey types in the examined stomachs. Prey size estimates improved when prey sizes that could not be reconstituted based on flushed pieces of prey could be better estimated once all the contents were available. The rank of prey categories differed when large items and unrepresented prey categories remained after flushing.

All of the methods caused minor irritation of the mucosa of the esophagus or stomach, but none of the caimans that were released showed ill effects. I used the hose with Heimlich maneuvers technique on more

than 290 caimans and routinely observed marked animals up to two months after they had been flushed. As part of a different experiment, eight hatchlings <200 mm SVL and eight adults 650–850 mm SVL were kept in captivity for six days after flushing and appeared normal.

There are advantages and disadvantages to both the scoop and pump technique and the hose with Heimlich maneuvers technique. The hose with Heimlich maneuvers method is significantly more reliable, but the scoop and pump are completely portable and crocodilians can be processed anywhere, even in a boat. The hose method requires water under pressure, thus users of the method are limited to facilities with running water. It is feasible, though, that a mechanical water pump or compressed air could be taken into the field to provide water pressure.

It is important to consider the stomach flushing method for a particular study according to what questions will be asked of the data. Qualitative studies aimed at providing lists of prey, for example, can be carried out using any method. The frequency of crocodilians in which stones occur probably can be reliably determined, but analyses depending on total representation of the stone load may be biased for fewer and smaller stones. Similarly, parasite load analyses should not be made using stomach flushed crocodilians because it is unlikely that any flushing technique would remove all stomach and esophageal parasites embedded in the gastrointestinal lining. Prey size determinations may be biased against large prey, thus large sample sizes should be obtained to insure that large as well as small prey are adequately represented. Detailed analyses of diet composition would be affected by the technique used; quantifying diet in crocodilians is most accurate using the hose with Heimlich maneuvers method.

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Extracranial Endolymphatic Sacs in *Eurydactylodes* (Reptilia: Gekkonidae), with Comments on Endolymphatic Function in Lizards

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The presence of enlarged endolymphatic sacs and associated calcium carbonate precipitates has been interpreted as a synapomorphy uniting the gekkonid subfamilies Gekkoninae and Sphaerodactylinae (=Gekkoninae sensu Kluge, 1987) (Kluge, 1967). Kluge (1967, 1987) knew of no occurrences of this condition among the Eublepharinae or the Diplodactylinae, nor among the closely related Pygopodidae. In preparing a morphological analysis of the diplodactyline tribe Carphodactylini, I examined radiographs of specimens representing all but three of the 44 constituent taxa (species examined listed in Appendix 1). Calcium carbonate deposits, which appear as dense x-ray opaque masses, were commonly found in the cranial vault in most species and were prominent in the embryos of the live bearing New Zealand taxa *Hoplodactylus* and *Naultinus* (sensu Bauer, 1986). In addition, extracranial endolymphatics were located in both species of the New Caledonian genus *Eurydactylodes*. Nine of thirteen animals (>50% of known museum specimens for the genus) possess moderate to extremely large sacs extending into the nuchal region (Fig. 1). In the most extreme case, the enlarged sacs occupy a volume equal to that of the skull, giving the specimen the appearance of a grossly inflated head (Fig. 2). Underwood (1954), on the basis of other criteria, considered this genus to belong to the Gekkoninae rather than the Diplodactylinae. *Eurydactylodes* has since been determined to lie nested well within the Tasman radiation of the Carphodactylini (Bauer, 1986), and the expansion of its endolymphatic sacs must be regarded as a derivation independent of that in the Gekkoninae.

The endolymphatic system of tetrapods consists of bilateral endolymphatic ducts which originate from the sacculus of the inner ear and terminate in expanded sacs which lie between the meninges (White-