

## DIGESTIBILITY OF THE SPONGE *CHONDRILLA NUCULA* IN THE GREEN TURTLE, *CHELONIA MYDAS*

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The green turtle, *Chelonia mydas*, is an herbivore that feeds primarily on sea-grasses and algae; animal tissue is not commonly ingested after the turtle shifts from pelagic to benthic habitats (Mortimer, 1982; Bjorndal, 1985). Sponges are often a major portion of the animal matter that is consumed. Stomachs from 243 Nicaraguan green turtles contained only 1.4% animal matter, two-thirds of which was sponge (Mortimer, 1981). Sponges were found in 4 of 94 green turtles from Brazil and were the third most common animal group (Ferreira, 1968). The only animal tissue found in digestive tracts from 14 green turtles from Antigua-Barbuda was a sponge in the order Haplosclerida in 1 of the turtles (Bjorndal and Bolten, unpubl. data). Balazs (1980) reported that sponges are occasionally included in the diet of Hawaiian green turtles. Sponge was the only animal tissue found in the stomachs of four green turtles in Honduras (Carr, 1952).

Feeding on sponges is not common in vertebrates. Spongivory is limited to a small number of fish species, sea turtles and four species of freshwater turtles (Meylan, 1988). In marine turtles other than the green turtle, sponges comprise the major part of the diet of the hawksbill, *Eretmochelys imbricata* (Meylan, 1988) and a small portion of the diet of the loggerhead, *Caretta caretta* (Dodd, 1988).

The extent to which sponge tissue is digested has apparently not been measured in a vertebrate. Sponges have a variety of chemical and structural components that protect them from predation and may lessen their digestibility. These characteristics include toxic compounds, silica spicules and spongin (Meglitsch, 1967; Green, 1977).

The possibility that the small amount of animal matter ingested by green turtles may make a major contribution to their nutrition has been discussed (Hirth et al., 1973; Bjorndal, 1985). To approach this question, and to investigate the nutritional yield of sponges to vertebrate spongivores, the digestibility of the chicken liver sponge, *Chondrilla nucula*, was measured in three size classes of green turtles in the southern Bahamas.

### METHODS

This study was conducted in a section of Union Creek, Great Inagua, Bahamas. Union Creek is a tidal bay (such areas are termed "creeks" in the Bahamas) that is a natural feeding area for green turtles. It was impounded to protect the turtles in the study area and is located in a wildlife sanctuary protected by the Bahamas National Trust.

Twice a month for 12 months, three green turtles in each of three size classes [8 kg (7-9 kg), 48 kg (46-50 kg) and 66 kg (64-68 kg)] were caught, fitted with a fecal collection bag and released back into the study area. After 24 h, the turtles were recaptured and the contents of the bags collected. Sponges passed through the digestive tract intact and were easily separated, with no apparent contamination, from the matrix of digested blades of *Thalassia testudinum*, the main diet of green turtles in the study area. Live sponges were collected each month, and both sponges and sponge tissue from feces were dried at 60°C and stored for later analysis. A more detailed description of the study area and the feces collection are in Bjorndal (1980).

Analyses for nutrient composition of diet and fecal samples were conducted to determine the composition of the diet and to calculate digestibilities. Dried samples were ground to pass through a 1-mm screen in a Wiley mill. A portion of each sample was dried at 105°C to determine percent dry

Table 1. Composition (mean  $\pm$  standard deviation) of *Chondrilla nucula* and *Thalassia testudinum*. All are expressed as percentage of dry matter except energy is  $\text{kJ}\cdot\text{g}^{-1}$  dry matter and spicule hydration is percentage of dry spicules. Values for *C. nucula* are corrected for spicule hydration. Data for *T. testudinum* (grazed plots) are from Bjorndal (1980)

|                   | <i>C. nucula</i> | <i>T. testudinum</i> |
|-------------------|------------------|----------------------|
| Organic matter    | 67.9 $\pm$ 4.6   | 74.1 $\pm$ 0.8       |
| Energy            | 15.9 $\pm$ 1.0   | 14.0 $\pm$ 0.2       |
| Nitrogen          | 8.1 $\pm$ 0.7    | 2.7 $\pm$ 0.1        |
| Silica            | 1.8 $\pm$ 0.2    | —                    |
| Spicule hydration | 5.4 $\pm$ 1.0    | —                    |

matter and then ashed in a muffle furnace for 3 h at 500°C to determine percent organic matter. Energy content was determined in a bomb calorimeter following standard procedure (Parr Instrument Co., 1960). Total (Kjeldahl) nitrogen was measured with a block digester (Gallaher et al., 1975) and an automated Technicon analyzer (Hambleton, 1977).

Silica content was determined by digesting a sample in concentrated nitric acid at room temperature overnight, after which the solution was boiled for 4 to 5 h, until it was a clear yellow color. The residue was recovered under vacuum on tared glass fiber filters (Reeve Angel 934AH, prewashed with nitric acid), washed with water followed by acetone, and dried at 105°C. The dried residue was ashed at 500°C for 3 h to determine the percent water of hydration of sponge spicules. Sponge spicules are hydrated, and the water of hydration is not lost when samples are dried at 105°C. If values for nutrient composition are not corrected for water of hydration, values will be under-estimated (Paine, 1964). All analytical values were corrected for water of hydration. Replicates for all analyses were accepted within 2% error.

Silica, corrected for water of hydration, was used as a dietary marker to calculate digestibility—the net loss of a nutrient from digesta as it moves through the digestive tract. Silica is often used as a dietary marker (Van Dyne, 1968) using the formula:

$$D/100 = 1 - [(M \text{ in food}/N \text{ in food}) \times (N \text{ in feces}/M \text{ in feces})]$$

where D is digestibility expressed as percent, M is the percent concentration of the marker (silica in this case), and N is the percent concentration of the nutrient.

Statistical analysis followed Zar (1984). Alpha was 0.05 for all tests. Data expressed as percentages were submitted to arcsine transformation before analysis.

## RESULTS AND DISCUSSION

Energy and nitrogen values of *C. nucula* are relatively low for animal tissue because of the high mineral content (=dry matter–organic matter) of the sponge (Table 1). The greatest difference in the nutrient composition of *C. nucula* and *T. testudinum* is the higher concentration of nitrogen in the sponge (Table 1).

Digestibilities of *C. nucula* (Table 2) did not vary significantly between warm (May to October) and cool (November to April) seasons for either the 8- or 48-kg size class (Mann-Whitney *U*-test). The 66-kg size class could not be tested for season effect due to small sample size. Water temperatures for warm and cool seasons are in Bjorndal (1980).

Body size did not have a significant effect on the digestibility of any component of *C. nucula* (Kruskal-Wallis). The only significant differences between digestibility values for *C. nucula* and *T. testudinum* are for organic matter and energy in the two larger size classes and for nitrogen in the 8-kg size class (Mann-Whitney *U*-test).

*Chondrilla nucula* would provide more nitrogen to green turtles than an equal amount of *T. testudinum* because *C. nucula* has higher nitrogen concentration (Table 1) and higher or equivalent nitrogen digestibility (Table 2). Protein quality of *C. nucula* is high; its amino acid composition is similar to that of dehulled soybean meal (Yacowitz and Zacccone, 1982). Bjorndal (1980) suggested that the

Table 2. Digestibilities (mean  $\pm$  standard deviation) for dry matter, organic matter, energy and nitrogen of *Chondrilla nucula* and *Thalassia testudinum* in three size classes of green turtles. Sample size is N. Data for *T. testudinum* are from Bjørndal (1980); dry matter digestibility was not calculated. Within each column, only those digestibility values with an asterisk are significantly different between diets for each nutrient (Mann-Whitney *U*-test,  $\alpha = 0.05$ )

|                             | Size class (kg)  |                 |                 |
|-----------------------------|------------------|-----------------|-----------------|
|                             | 8                | 48              | 66              |
| <i>Chondrilla nucula</i>    |                  |                 |                 |
| N                           | 5                | 7               | 3               |
| Dry matter                  | 48.8 $\pm$ 11.3  | 53.4 $\pm$ 7.3  | 50.6 $\pm$ 2.8  |
| Organic matter              | 41.1 $\pm$ 14.5  | *45.7 $\pm$ 9.0 | *43.9 $\pm$ 3.9 |
| Energy                      | 40.3 $\pm$ 14.9  | *43.4 $\pm$ 9.4 | *43.3 $\pm$ 2.9 |
| Nitrogen                    | *51.9 $\pm$ 11.2 | 54.6 $\pm$ 6.7  | 52.8 $\pm$ 3.2  |
| <i>Thalassia testudinum</i> |                  |                 |                 |
| N                           | 36               | 36              | 36              |
| Organic matter              | 44.7 $\pm$ 7.9   | *67.2 $\pm$ 2.5 | *64.6 $\pm$ 5.9 |
| Energy                      | 34.3 $\pm$ 8.5   | *62.0 $\pm$ 2.7 | *57.9 $\pm$ 7.2 |
| Nitrogen                    | *15.2 $\pm$ 1.1  | 45.3 $\pm$ 1.6  | 53.8 $\pm$ 4.0  |

low level of nitrogen available to small green turtles may limit growth. Therefore, it is surprising that green turtles ingested only very small quantities of *C. nucula*, although the sponges were always available.

Intake of sponges may be limited by irritation from silica spicules, although the concentration of spicules is low in *C. nucula* (Table 1), or by toxic compounds in the sponges. *Chondrilla nucula* has been reported to be toxic to fish when the fish is exposed to an extract of the sponge or is force-fed the sponge (Green, 1977). Chickens fed a diet containing only 4–8% *C. nucula* had reduced growth and developed pancreatic hypertrophy and hyperplasia (Yacowitz and Zaccone, 1982). However, *C. nucula* is the predominant sponge in the diet of the Caribbean hawksbill (Meylan, 1988).

Although some of the components in sponges are digested to a greater extent than those in *T. testudinum*, the digestibilities of all sponge components are low relative to expected values of over 80% for animal tissue (Bjørndal, 1985; Zimmerman and Tracy, 1989). Green turtles are capable of efficient nitrogen digestion; when fed artificial, pelleted diets containing 25–35% protein, green turtles (22–25 kg) digested 86–89% of the nitrogen (Wood and Wood, 1981).

Low digestibilities of *C. nucula* could be a result of the high concentration of collagen fibrils in *C. nucula*. The digestibility of collagen fibrils is not known (Meylan, in press), but may be low. Results in Table 2 suggest that the sponge collagen fibrils, which contain much of the organic matter, energy and nitrogen, have low digestibility in green turtles.

Low digestibilities of *C. nucula* could also result from associative effects between sponge and seagrass digesta. Interactions between the greater mass of *T. testudinum* in the digesta and *C. nucula* may affect digestion of the sponge. For example, sponges may be moved more rapidly through the small intestine or may be blocked from contact with proteolytic enzymes because of the presence of the seagrass. Because of potential associative effects, values presented here for sponge digestion may differ significantly from those that would be measured in green turtles feeding entirely on *C. nucula*.

The low intake and low digestibilities, at least of *C. nucula*, indicate that sponges do not have an important role in the nutrition of green turtles as sources of energy

or nitrogen, except perhaps as a source of nitrogen in small turtles. If digestion of animal tissue has a significant role in the nutrition of green turtles inhabiting benthic feeding grounds, it is more likely to involve trace mineral, vitamin or essential amino acid requirements, than nitrogen or energy requirements.

#### ACKNOWLEDGMENTS

This work was funded by the Caribbean Conservation Corporation and National Marine Fisheries Service. I thank A. Bolten and L. Ogren for their support and G. Foster for analytical assistance. The study would not have been possible without the assistance of S., J. and H. Nixon, and M. Lightbourn or the logistical support provided by the Bahamas National Trust and Morton Bahamas Limited. I am grateful for the cooperation of the Bahamas Ministry of Agriculture, Trade and Industry, especially C. Higgs.

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DATE ACCEPTED: September 19, 1989.

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