Marine Sponges, Other Animal Food, and Nonfood Items Found in Digestive Tracts of the Herbivorous Marine Turtle *Chelonia mydas* in Hawai'i[1]

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Abstract: Although the usual diet of *Chelonia mydas* comes from algae and sea grasses (plant material), animal material has been found in samples taken over the past 35 yr. The small black-brown protein sponge *Chondrosia chucalla* resembles the alga *Codium arabicum* in size, color, and texture, and both grow next to each other on the reefs. We hypothesize that turtles are actively seeking and eating these sponges and not mistaking them for *C. arabicum*. Both protein and silica sponges occur in the diet of *Chelonia*, but only 6.8% of the time are eaten in addition to their usual plant diet. Thirty different kinds of other animals were found in the samples, including Cnidaria, Mollusca, Crustacea, Insecta, Echinodermata, squid, fish, tumor flesh, and other animals but in low frequency (5%). Most of the miscellaneous nonfood debris items were terrestrial leaves, plastic, paper, string, fibers, hair, and paint chips but also in low frequency (<7%). Among animal food items known to have nutritional value, the protein sponge *C. chucalla* could be contributing an important nutritive factor, but this needs further research.

The diet of *Chelonia mydas* (L.) in Hawai'i usually consists of marine algae and sea grasses, but over the past 35 yr other items have been found in green turtle digestive tracts, especially the black sponge *Chondrosia chucalla*. Balazs (1980) reported that *C. mydas* juveniles and adults sometimes feed on invertebrates, such as small anthozoans, *Physalia*, *Velella*, and *Janthina* as well as *C. chucalla* and other sponges. Several other reports have also recorded animal food items, such as Porifera, Coelenterata, Mollusca, Bryozoa, Echinodermata, and Urochordata, in the *C. mydas* diet (Garnett et al. 1985, Meylan 1988, Bjorndal 1990, Fuentes et al. 2006, Arthur and Balazs 2008, Carrion-Cortez et al. 2010). However, Amorocho and Reina (2007) reported that turtles in their study had a bias toward tunicates in addition to algae. It is also well known that *C. mydas* hatchlings are chiefly carnivorous and the larger juveniles and adults are predominantly herbivorous (Thompson 1988, Hirth 1971, 1997). Perhaps some of the early juvenile carnivorous behavior remains in the adults as they eat seaweeds and also prey upon animal material, especially protein sponges that are living in the same reef habitats. In addition, turtles are ingesting other animal food items (Balazs 1985) and nonfood debris with which algae or sponges may be associated. Knowledge of all prey types and availability is essential for the full understanding of every stage of green turtle life history and survival (National Marine Fisheries Service and U.S. Fish and Wildlife Service 2007).

Until recently it was assumed that turtles inadvertently ate *C. chucalla* while foraging for *Codium arabicum*, which has an almost identical appearance and texture. *Codium arabicum* has thalli that are dark green 2–4 cm firm

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lumps growing on hard reef substrate in the same zones and often adjacent to *C. chucalla*. *Chondrosia chucalla* is a desmosponge that grows as 2–4 cm stiff black to dark black-brown lumps on the same coral rock in and among reef algae at shallow depths. Divers have observed both *C. mydas* and *Eretmochelys imbricata* actively seeking out and preying upon sponges in deeper cave areas in Hawai'i (Bennett et al. 2008).

Our objectives were to: (1) determine if *C. mydas* is selectively eating *C. chucalla* and not confusing it with *Codium arabicum* and (2) classify animal and the miscellaneous nonfood diet items.

MATERIALS AND METHODS

Diet samples were obtained from stranded turtle necropsies according to the methods described in Russell and Balazs (2009), by stomach lavage (Arthur and Balazs 2008), or directly out of the mouth of the turtle. The greater majority of samples were from the forestomach contents during necropsies (Work 2000). One 50 ml sample was taken from the forestomach of each necropsied turtle, preserved in 10% formalin/seawater, and analyzed microscopically (Russell and Balazs 2000). The algae were sorted to species, quantified, and converted into percentages, but the animal and debris contents were simply recorded as present/absent and some were measured for size. Correlation between *C. arabicum* and *C. chucalla* was done with the statistical package Minitab 16 (Minitab Inc., State College), where $r = \Sigma\ (X - \overline{X})\ (Y - \overline{Y}) / S_x - S_y$ (X = *Codium arabicum*; Y = *C. arabicum* occurring with *C. chucalla*). Fisher's Exact Test was used to compare percentage results between islands (Rao 1998).

RESULTS AND DISCUSSION

A total of 2,471 digestive tract samples taken from *Chelonia mydas* in the six main Hawaiian Islands (Kaua'i, O'ahu, Moloka'i, Maui, Lāna'i, Hawai'i) was examined between 1975 and 2010 (127 mouth, 43 esophagus lavage, 2,201 forestomach, 61 stomach, 39 intestines). The most accurate samples came from the forestomachs, because they gave the greatest amount of fresh and easily identifiable material. The least valuable samples came from fecal pellets, and those are not included in our study because their contents were difficult to identify and many times they were contaminated by feathers, flies, ants, and other things from the environment where they were found.

Chondrosia chucalla *and Silica Sponges*

Our original assumption that *C. mydas* was taking *C. chucalla* by mistake while eating *C. arabicum* was unfounded. The desmosponge *Chondrosia chucalla* was present in 85 of the 2,471 samples, which is an occurrence of about 3.4%. *Codium arabicum* was present in 376 of the samples, which is about 15% occurrence, and most of the samples were from O'ahu (Table 1). If the turtles were mistakenly taking *C. chucalla* while grazing on *C. arabicum* there should be a high correlation between these two species and *C. chucalla* should seldom be seen in samples without *C. arabicum*. However, the correlation between *C. arabicum* together with *C. chucalla* between the six islands is $r = 0.203$ and $P = .70$, hence not significant. In addition, *C. chucalla* was most often eaten when *C. arabicum* was not present in the same sample (Table 1). The turtles were not mistaking *C. chucalla* for *C. arabicum*, as was origially assumed, but rather they were eating the sponge on purpose.

Codium arabicum often grows with *Codium edule* and both contribute significantly to the diets of *Chelonia mydas* (Russell and Balazs 2009). When all of the sample results were examined for all of the Hawaiian Islands, including the Northwestern Hawaiian Islands (NWHI), 842 samples contained either *C. arabicum* and/or *C. edule*, and 255 samples (30%) contained both at the same time. Turtles graze on both of these common *Codium* species and could inadvertently graze on *C. chucalla* at the same time. But *C. arabicum* is distinctly different from *C. edule*, which is a prostrate branching species and does not at all resemble either *C. arabicum* or *C. chucalla* in size, shape, or texture.

Chondrosia chucalla was also found without *Codium arabicum* in 48 of the 85 samples that

TABLE 1

Codium arabicum, a Green Alga, and *Chondrosia chucalla*, a Protein Sponge, Found in Digestive Tracts of *Chelonia mydas* from Six Hawaiian Islands: Numbers of Times Each Was Found in Samples and Numbers of Times *C. arabicum* and *C. chucalla* Were Found in the Same Samples

Taxa	Kaua'i	O'ahu	Moloka'i	Maui	Lāna'i	Hawai'i	Totals
Codium arabicum[a]	3	348	4	4	7	10	376
C. arabicum with the sponge *C. chucalla*	0	36	0	0	1	0	37
Sponges alone are given below:							
Protein sponge *Chondrosia chucalla*	2	72	4	2	2	3	85
White silica sponge *Spongia oceania*	2	12	0	2	1	3	20
Yellow silica sponge[b]	1	4	0	0	0	1	5
Orange silica sponge (*Mycale armata*)	0	2	0	0	0	0	2
Silica sponge spicules[b]	3	44	0	4	0	10	61
Total samples with sponges	8	134	4	8	3	17	174
No. of samples examined	57	1,689	63	254	58	350%	2,471
% of samples with sponges	14%	8%	6%	3%	5%	5%	Avg 6.8%

Note: Silica sponges are included for comparison.
[a] Chlorophyta (green algae).
[b] Unable to identify these sponges to species.

contained the sponge. *Chondrosia chucalla*, with no *C. arabicum* present was also found in one sample each from unpublished data we gathered from Saipan, Florida, and Midway and has also been reported from green turtle stomach samples in earlier reports (Balazs 1980, Balazs et al. 1987, Hirth 1997). These additional data also support the hypothesis that *C. mydas* is not inadvertently taking *C. chucalla* along with *C. arabicum* but is actively seeking out and eating this protein sponge.

Glass or hexactinellid sponges contain a myriad of silica spicules that give the sponges a texture similar to fiberglass. Only 88 (3.6%) of the samples contained a few loose silica spicules, which is nearly the same number of times as *Chondrosia chucalla*. However, when the samples that have only spicules and no recognizable lumps of silica sponge were removed, the percentage of silica sponge appearance in samples dropped to 1%. Hexactinelid sponge species included *Spongia oceania* (20 samples), *Mycale armata* (two samples), and a yellow sponge (five samples) that could not be identified to species. Sponges were part of the turtle food ca. 6.8% of the time, and when sponge data were compared between islands the larger 14% value from Kaua'i and the 8% on O'ahu and the percentages at the other islands were not significantly different ($P = .189$). Therefore, statistically the same amount of sponge was being ingested by *C. mydas* on all of the islands.

Spongivory in *Chelonia mydas*, *Caretta caretta*, and *Eretmochelys imbricata* has been known for a long time (Meylan 1988, Bjorndal 1990) but appears to be of critical importance only in the latter species. *Chelonia mydas* is primarily an herbivore but consumes a small amount of sponge along with its vegetable diet. We also observed a totally different unidentified small protein sponge species attached to the lower branches of *Amansia glomerata* (Rhodophyta) in the forestomach samples. *Amansia glomerata* is a favorite food of *C. mydas* that grows in deeper shaded reef areas rather than on bright shallow reef flats, and this additional protein sponge material may also provide some protein to the turtle diet (Russell and Balazs 2009). Green turtles may also be forced to turn to sponges for food, especially if they cannot find enough algae to sustain themselves. One turtle, not used in our analysis, was artificially confined to a pond in Hawai'i, had no algae to eat, and had only silica sponge in its forestomach. We propose that silica sponges, such as *Mycale armata*, either are not as appealing as the protein sponge *Chondrosia chucalla* or are eaten when there is no plant material available.

Animal Food Items in Addition to Sponges

Other food found in *C. mydas* samples totaled 28 different kinds of animal items (Table 2), such as small Crustacea (including barnacles) assorted Cnidaria, Echinodermata, Mollusca, worms, invertebrate and fish flesh and bones, eggs, ciliates, insects, turtle skin, and turtle tumor flesh. Sample amounts for each item were low and the results did not lend themselves for accurate statistical analysis. However, 5.6% of the samples had some kind of animal material in them. Barnacles were found in five of the samples and may have been purposely eaten by the turtles. The Cnidaria (jellyfish and *Physalia*) were present as withered masses that look like wads of clear cellophane without the jelly but with an abundance of triggered cnidocytes. Balazs (1980) reported both juvenile and subadult green turtles at Midway and Kure (NWHI) "voraciously feeding on *Physalia* and *Velella*." Seminoff et al. (2002, 2006) and Heithaus et al. (2002) used real-time video-time-depth recorders attached to adult green turtles in Bahía de los Angeles, Mexico, that showed them feeding on Cnidaria (Scyphozoa medusa, *Ptilosarcus undulatus*, *Antipathes galapagensis*, and *Lytocarpus nuttini*) and Annelida, but no sponges were reported in their data. The use of video-time-depth recorders such as those used on green turtles would greatly enhance

TABLE 2

Other Animal Food Items Found in *Chelonia mydas* Mouth, Esophagus Flush, Forestomach, Stomach, and Intestine Samples

Type of Animal Material	Kaua'i	O'ahu	Moloka'i	Maui	Lāna'i	Hawai'i	Totals
Crustacea	0	7	1	1	1	13	23
Copepoda	0	0	0	0	1	1	2
Isopoda	0	0	0	0	0	2	2
Decapoda	0	0	0	2	0	0	2
Shrimp	0	0	0	1	0	3	4
Barnacles	0	4	0	0	0	1	5
Arachnida (black mites)	0	2	0	0	0	0	2
Insecta *Periplaneta americana*	0	1	0	0	0	0	1
Bryozoa	0	9	0	0	0	1	10
Hydrozoa	3	4	1	1	0	2	11
Cnidaria (jellyfish)	0	3	0	0	0	1	4
Anemones	0	1	0	0	0	0	1
Octocorals (soft corals)	0	2	0	1	0	3	6
Physalia sp.	0	1	0	0	0	0	1
Echinodermata (small sea cucumbers)	0	0	0	0	0	2	2
Fish flesh and bones	0	0	0	1	0	1	1
Flesh (animal muscle)	1	7	0	1	0	1	10
Mollusca	1	2	0	0	0	2	2
Brachidontes crebristiatus	0	2	0	0	0	0	2
Nudibranchs	0	1	0	0	0	1	2
Snails (micromollusks)	0	1	0	0	0	4	5
Snail eggs	7	0	1	0	0	0	1
Squid pens	0	1	0	0	0	0	1
Platyhelminthes (flukes)	0	5	1	0	0	0	6
Polychaete worms	0	1	0	0	0	1	2
Tube worms	0	5	0	0	0	2	7
Numerous 1 mm diam. eggs	0	1	0	0	0	1	2
Stalked ciliates	0	0	0	0	0	2	2
Turtle skin fragments	0	3	0	0	0	0	3
Turtle tumor flesh	1	5	0	0	1	0	7
Total animal food items	10	69	4	8	3	43	138
% of 2,471 samples	0.4%	2.8%	0.2%	0.3%	0.1%	1.7%	5.6%

the understanding of green turtle foraging behavior in Hawai'i (Heithaus et al. 2002, Seminoff et al. 2006).

The Mollusca were mostly small micromollusks that are also commonly found among the algae (the primary food source for *Chelonia mydas*). Most of the egg masses we found were in jelly and most likely from micromollusks. Animal flesh and squid pens were often found in the same samples, and the squid flesh was recognized by its different texture from fish flesh, which was usually accompanied by fish bones. Hirth (1997) also reported that captive hatchling green turtles would eat sea anemones, shrimp, and fish when it was given to them by their keepers. Turtle skin and tumor flesh were found in 10 forestomach samples and may have come from their own tumors, which can often be located in the mouth (Balazs and Pooley 1991) or from biting tumors off of other turtles.

Miscellaneous Nonfood Items

Most of the nonfood material found in turtles was terrestrial grass and general kinds of leaves (119 samples at a 9.6% frequency). *Casuarina equisetifolia* (ironwood) leaves were identified and occasionally *Scaevola sericea* (beach naupaka), but grasses were identifiable only to family, because the grass fragments were too deteriorated to allow determination to species. The shoreline where turtles feed is sometimes lined with *C. equisetifolia* trees and *S. sericea* shrubs (Balazs et al. 1987). It appears that terrestrial plant leaves and mangrove fruits are part of the usual diet items of green turtles in South America (Carrion-Cortez et al. 2010).

Plastic, paper, string, fibers, human hair, and paint chips were found but to a lesser extent (76 samples at a 3% frequency). The paint chips were most often blue, orange, or red and could have been ingested along with algae and other food items attached at the waterline of boats or buoys. One unusual sample from Mā'ili Point, O'ahu (13 December 1992), contained masses of American cockroach (*Periplaneta americana*) fragments, wings, legs, and eggs (Table 2). Perhaps the cockroaches were flushed out of a storm drain and eaten by the turtles as they floated on the surface. Most of the nonfood items were found in the O'ahu and Hawai'i samples and the least from Lāna'i (Table 3). Insects were considered to be a supplemental food item for posthatchling loggerhead turtles feeding in floating patches of *Sargassum* 93 km east of

TABLE 3

Miscellaneous Ingested Nonfood Items Found in *Chelonia mydas* Out of a Total of 2,471 Digestive Tract Samples

Nonfood Items	Kaua'i	O'ahu	Moloka'i	Maui	Lāna'i	Hawai'i	Totals
Terrestrial grass	2	29	1	2	0	5	39
Terrestrial leaves	0	31	0	0	0	19	50
Casuarina equisetifolia	1	26	0	2		1	30
Cloth	0	1	0	0	0	2	3
Cotton fibers	0	2	0	0	0	0	2
Monofilament line	0	6	0	0	0	1	7
Paper	0	3	0	0	0	0	3
String	0	6	0	0	0	0	6
Synthetic fibers	0	2	0	0	1	1	4
Plastic hard	1	2	0	0	0	0	3
Plastic film	0	4	1	1	0	0	6
Paint chips	0	2	0	1	0	0	3
Animal hair	1	5	0	0	0	0	6
Insect parts	0	1	0	0	0	0	1
Total nonfood items	5	120	2	6	1	29	163
% of 2,471 samples	0.2%	4.9%	0.08%	0.2%	0.04%	1.2%	6.6%
Total no. of samples examined	57	1,689	63	254	58	350	2,471

Florida (Richardson and McGillivary 2001) and for the Kemp's ridley turtle (Dobre 1996). Miscellaneous nonfood items do not appear often enough in the green turtle diet in Hawai'i for us to conclude that they are of any primary importance.

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