The Last Meal: Diet Analysis of Stranded Green Turtles (*Chelonia mydas*) on East Hawai‘i Island

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ABSTRACT

Green turtles, *Chelonia mydas*, in the Hawaiian Islands consume mainly marine algae and sea grasses. The quality and amount of the food that green turtles are consuming are important factors in growth rate, age of maturity, survivorship to adulthood, reproductive output and population growth (Balazs & Chaloupka 2004). In this study, the esophagus, crop and stomach contents of sixteen juvenile and subadult green turtles (*Chelonia mydas*) found stranded or dead on the east coast of Hawaiʻi Island were sorted and identified to the lowest possible taxonomic level, and the dry weights were measured. Macroalgae from phylum Rhodophyta was the most common and most abundant type of algae. Chlorophyta and Phaeophyta were also present in the samples. *Pterocladiella capillacea* was the most abundant diet item. Algae made up a majority of the diet of the sampled green turtles, but non-algal and non-food items were also found within the esophagus, crop, and stomach of these turtles. Some of these items include terrestrial grass, segmented worms, plastics, mollusks, sponges, barnacles, *Cricocephalus albus*, black hair, small shell pieces, and sand. The fill and conditions of the esophagus, crop and stomach varied between the turtles. Dietary studies of green turtles are important for the insurance of effective species and habitat management for green turtles as well as for their dietary items (Forbes 1999, Arthur & Balazs 2008).

1. INTRODUCTION

Dietary studies of green turtles are important for effective management for green turtles, their habitat, and their dietary items (Forbes 1999, Arthur & Balazs 2008). The quality and amount of food that green turtles are consuming are important factors in growth rate, age of maturity, survivorship to adulthood, reproductive output, and population growth (Balazs & Chaloupka 2004). Variability in interannual nesting numbers of marine turtles including green turtles was correlated with the forage material availability before breeding which is affected by environmental conditions (Broderick et al. 2001).

Throughout the world, green turtles have been found to eat primarily sea grass with small amounts of algae if both food items are present, but if sea grass is not present in large enough quantities to sustain grazing, green turtles will shift towards an algal-based diet (Bjorndal 1980). For example, green turtles in the Galapagos Islands, including subspecies *Chelonia mydas agassizii*, have an algal-based diet (Pritchard 1971). The main algae found within their stomachs was *Caulerpa* (Pritchard 1971). Other species of algae, mangrove leaves, and roots were also found within some of the turtles (Pritchard 1971).

Green turtles are omnivorous planktivores in their early pelagic stage of life, and they shift to more herbivorous diets after they recruit inshore at approximately 35 cm straight carapace length (SCL) (Balazs 1980, Zug et al. 2002, Bolten 2003). However, some studies have found that juvenile green turtles can exhibit omnivorous traits after coastal recruitment (Amorocho 2007, Jiménez et al. 2017). In northern Peru, juvenile green sea turtles consumed a variety of diet items, including "algae, cnidarians, mollusks, arthropods, chordates and garbage/anthropogenic debris" (Jiménez et al. 2017). Because of the quantities of the non-algal and non-plant diet items, these green turtles were considered omnivorous (Jiménez et al. 2017). East Pacific green turtles *Chelonia mydas agassizii* in the Colombian Pacific at Gorgona National Park were also determined to be omnivorous (Amorocho 2007). The five major diet components of these turtles in order of percent dry mass were: "tunicates (Salpidae and Doliolidae), red mangrove fruits (*Rhizophora mangle*), algae (Rhodophyta, Chlorophyta, Cyanophyta), small crustaceans (shrimp larvae) and leaves (*Ficus* spp.)" (Amorocho 2007). Non-food items found in these green turtles included "coral fragments, shells, and sand/pebbles" (Amorocho 2007).

Hawaiian green turtles are herbivorous and usually consume algae as their primary food source (Arthur & Balazs 2008). In Kāneʻohe Bay, Oʻahu, 135 species of marine vegetation were found to be eaten by turtles, including non-native algae: *Acanthophora spicifera, Hypnea musciformis, Gracilaria salicornia, Eucheuma denticulatum, Gracilaria tikvahiae, Kappaphycus striatum* and *Kappaphycus alvarezii* (Russell & Balazs 2015). This study showed that from 1985 to 2012 non-native algae composed an average of 64% of the food turtles in that area were consuming (Russell & Balazs 2015).

Red macroalgae in the phylum Rhodophyta have been observed to be the most common type of algae eaten by immature green sea turtles in Oʻahu, Molokaʻi, Lānaʻi, and Hawaiʻi Island and comprised an average of 78% of the dietary volume (Arthur & Balazs 2008). Phaeophyceae and Chlorophyta were common, but did not make up a large percentage of the dietary volume (Arthur & Balazs 2008). The species of algae that made up more than 50% of diet samples taken from Hawaiian green turtles included *Halophila* sp., *Acanthophora* sp., *Centroceras* sp., *Gelidiella* sp., *Gracilaria* sp., *Hypnea* sp., *Pterocladiella* sp., *Amansia glomerata*, *Cladophora* sp., *Codium* sp. and *Dictyosphaeria* sp. (Arthur & Balazs 2008). Sea grass was only consumed in select areas (Arthur & Balazs 2008). Cyanobacteria and animal matter including sponges, crustaceans, jellyfish, egg masses, gastropod shells and *Stylocheilus* sp. made up a very small percentage of dietary volume, but had relatively high frequency of occurrences (Arthur & Balazs 2008). These green turtles also consumed terrestrial material and plastics (Arthur & Balazs 2008).

While generally herbivorous, Hawaiian green turtles will also consume non-algal and non-food items (Russell et a. 2011). Green turtles found stranded in Kauaʻi, Oʻahu, Molokaʻi, Maui, Lānaʻi, and Hawaiʻi Island had eaten a variety of animal matter from Porifera, "Cnidaria, Mollusca, Crustacea, Insecta, Echinodermata, squid, fish, turtle tumor flesh, and other animals but in low frequency" (Russell et al. 2011). These turtles also consumed non-food items including "terrestrial leaves, plastic, paper, string, fibers, hair, and paint chips" (Russell et a. 2011). However, the diet of green turtles in east Hawaiʻi Island has not been the focus of study.

In the current study, the esophagus and crop contents of green turtles (*Chelonia mydas*) found stranded or dead on the east coast of Hawaiʻi Island were examined. The objective was to determine the dietary composition of green turtles in east Hawaiʻi Island including algal, non-algal, and non-food items.

2. METHODS

Sixteen green sea turtles that had stranded between 3/24/2020 and 6/27/2022 were the subject of this study. The turtles were found at nine different locations along the east coast of Hawaiʻi Island. One turtle was retrieved from Punaluʻu Beach Park. All other turtles were found at locations near Hilo, Hawaiʻi, including Richardson Ocean Park, Moku Ola (Coconut Island), Liliʻuokalai Park and Gardens, Reeds Bay, Wailoa River State Park, Onekahakaha Beach Park, Lalakea Shoreline Access, and Oceanview Drive (Fig. 1). The green turtles were either found dead upon arrival, or they were euthanized because of severe health conditions. Curved carapace lengths (CCL) were measured. The turtles were frozen at the University of Hawaiʻi at Hilo until they were shipped to the National Marine Fisheries Service in Honolulu, HI for necropsies. The esophagus, crop and stomach of each turtle were removed, frozen, and saved prior to this analysis.

Table 1. Stranding data for 16 green turtles on east Hawaiʻi Island

Case #	Location Description	Latitude (°N)	Longitude (°W)	Stranding Date	CCL (cm)
H-387	Moku Ola	19.73	-155.07	3/8/2022	49.5
H-386	Moku Ola	19.73	-155.07	3/2/2022	45.5
H-383	Richardson Ocean Park	19.74	-155.01	2/8/2022	68.25
H-375	Richardson Ocean Park	19.74	-155.01	12/10/2021	41
H-380	Reeds Bay	19.73	-155.06	12/12/2021	42
H-371	Onekahakaha Beach Park	19.74	-155.04	10/3/2021	56
H-374	Punaluʻu Beach Park	19.14	-155.50	12/2/2021	75
H-346	Onekahakaha Beach Park	19.74	-155.04	7/31/2020	78
H-361	Richardson Ocean Park	19.74	-155.01	4/21/2021	74
H-360	Richardson Ocean Park	19.74	-155.01	4/15/2021	78.5
H-354	Richardson Ocean Park	19.74	-155.01	2/2/2021	53.5
H-359	Liliʻuokalani Park/Moku Ola	19.73	-155.07	4/12/2021	45
H-343	Liliʻuokalani Park/Moku Ola	19.70	-155.08	5/18/2020	41
H-341	Liliʻuokalani Park	19.73	-155.07	4/16/2020	41
H-339	Reeds Bay	19.70	-155.08	3/24/2020	55.5
H-400	Wailoa River State Park	19.72	-155.08	06/27/2022	71

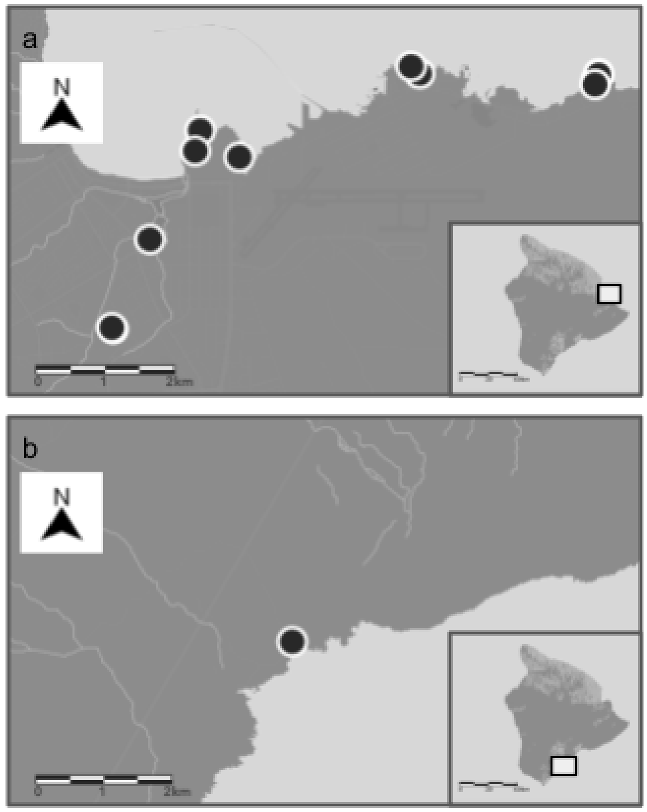


Fig. 1. Individual green turtle strandings near (a) Hilo, HI, U.S.A. and (b) Punaluʻu, HI, U.S.A. between 3/24/2020 and 6/27/2022. Inset maps show location on Hawaiʻi Island

The esophagus and crop contents of the 16 Hawaiian green sea turtles were analyzed. The weight of the entire sample (esophagus, crop, and stomach including contents) was measured. The esophagus and crop (esophagus + crop) were separated from the stomach based on the external and internal structures (presence of spines and texture [papillae] on the esophagus mucosa and the smooth stomach mucosa), and the weight of each section was measured. The contents of the two sections were analyzed separately. For both the esophagus + crop section and the stomach section, the organ lining was opened with a cut running from the anterior end to the posterior end. The contents of the organs were removed and separated into different visible types of diet items using a dissecting microscope (Olympus SZ51 and Lecia Zoom 2000). The individual diet items were dried at 55-60° Celsius for > 2 days to a constant weight. After drying, the dry weight of the diet items were measured. Small samples of each diet item were used to create permanent slides as diet item vouchers or stored in a 4% formalin-salt water solution for further analysis. Slides of cross-sectioned algae were created if applicable to the identification process. Examination of the slides under a compound microscope (Olympus CH30) was used to identify dietary items to the lowest possible taxonomic level in accordance with Abbott (1999), Russell and Balazs (2000), Abbott and Huisman (2004), and Huisman et al. (2007). The esophagus + crop contents for all 16 green turtles were sorted and analyzed. A portion of the stomach contents were analyzed while others have not been sorted yet due to time constraints.

Frequency of Occurrence (FO) was calculated to quantify the presence of individual dietary items using the following equation from Arthur and Balazs (2008): $FO = \frac{Number\ of\ samples\ with\ diet\ item\ present}{Total\ number\ of\ samples} * (100)$. Relative abundance (RA) was calculated for each diet item using the following equation: $RA = \frac{total\ dry\ weight\ of\ diet\ item\ in\ all\ samples}{total\ dry\ weight\ of\ all\ samples} * (100)$. Importance values (IV) were calculated using the following equation: $IV = FO + RA$. IV values were calculated to show an encompassing representation of diet item importance including abundance and presence. The Shannon-Wiener diversity index (H') was calculated for each turtle's esophagus + crop sample using the following equation: $H' = -\sum_{i=1}^{S} (p_i \ln p_i)$ where: $p_i = \frac{dry\ weight\ of\ diet\ item\ in\ sample}{total\ dry\ weight\ of\ sample}$ and $S = total\ number\ of\ diet\ items$.

A Kruskal-Wallis rank sum test was run to assess variability among diet item types. A Spearman's rank correlation model was used to assess the relationship between CCL and total esophagus + crop dry weight. A Wilcox rank sum test was run to identify the relationship between stranding causes (fishing line presence and tumor presence) and total esophagus + crop dry weight. Statistical tests were run using R studio.

3. RESULTS

According to Balazs (1980) Hawaiian green turtles with SCLs <65 cm are juveniles, and turtles with SCLs <81 cm are subadults. These size and maturity category limits were converted from SCL to CCL using the following equation from Chaloupka et al. (2008): $SCL = 1.245 + 0.913 * CCL$, to get categories to the nearest whole cm of <70 CCL for juvenile and <87 CCL for subadult Hawaiian green turtles. Eleven turtles had CCLs <70 cm and are considered to be juveniles, and five turtles had CCLs <87 cm and were assumed to be subadults (Balazs 1980) (Fig. 2). No turtles in this study were considered adults.

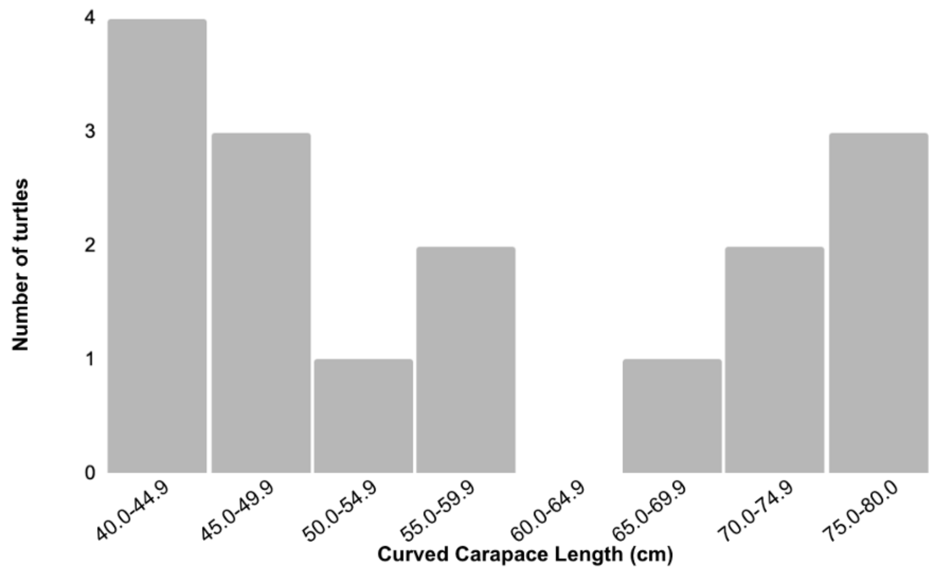


Fig. 2. Curved carapace length (cm) of green turtles stranded on east Hawai‘i Island between 3/24/2020 and 6/27/2022 and analyzed for diet contents (n=16).

A Spearman's rank correlation showed that there is no significant relationship between the CCL and the total dry weight of the esophagus + crop contents of each turtle (Fig. 3). The fill and conditions of the esophagus, crop, and stomach varied between the turtles. Some turtles had full guts. Others had nearly empty organs. The contents in some turtles were very well-preserved, while in others, the algae was discolored, partially digested, and unidentifiable. The contents were usually better preserved in the esophagus + crop samples than in the stomach samples, because only the stomach has enzymes and a low pH. Some organs had large amounts of mucus.

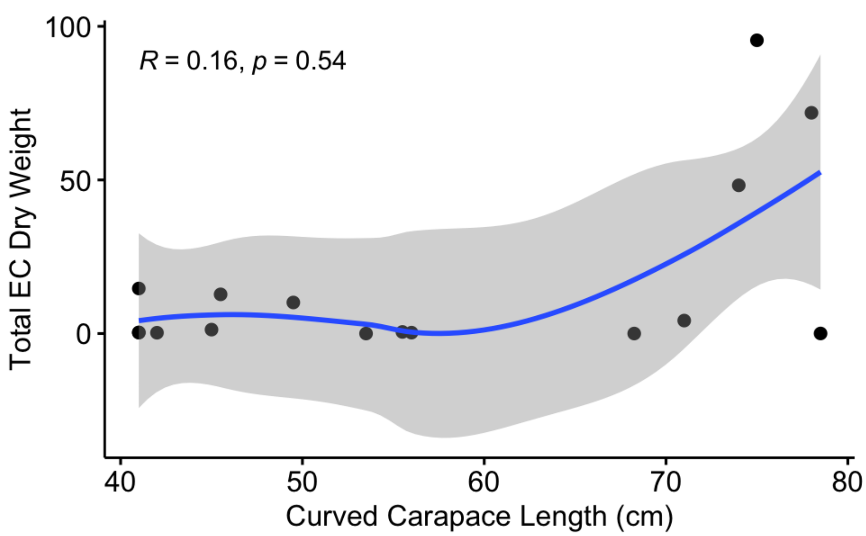


Fig. 3. Spearman's rank correlation between each turtle's total esophagus + crop contents dry weight (g) and curved carapace length (cm) (n=16). No significant correlation was found.

Seven diet item types were identified in the esophagus + crop contents of the turtles: Rhodophyta (red algae), Chlorophyta (green algae), Phaeophyceae (brown algae), terrestrial material, animal material, cyanobacteria, and non-food (or unknown) material. Macroalgae from phylum Rhodophyta have the highest total dry weight per esophagus + crop sample than any other diet item type (Fig. 4). The total esophagus + crop dry weights of the other diet item types did not significantly differ from each other except for green algae and non-food (or unknown) material, which were significantly different.

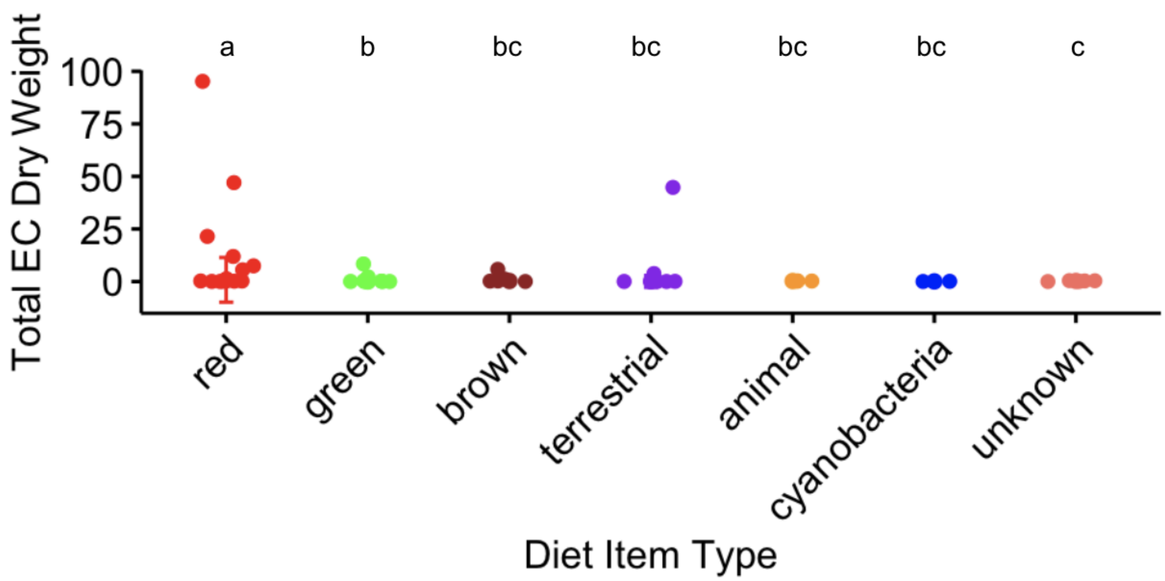


Fig. 4. Comparison among total esophagus + crop contents dry weights of seven diet item types. Kruskal-Wallis rank sum test showed differences among some of the diet types.

Juvenile and subadult green turtles on the east side of Hawai‘i Island have an algal-based diet. Among the three types of algae identified in the esophagus + crop contents, red algae were the most common with a FO of 87.5000% (Table). Red algae were also the most abundant algae type with a RA of 73.3959%. Green algae were the second most abundant and second most common algal type with a FO of 56.26% and a RA of 4.2755%. Brown algae were the least abundant and least common algal type with a FO of 31.25% and a RA of 2.8734%.

Non-algal and non-food items were found within the esophagus + crop contents of these turtles. Terrestrial material including terrestrial grass and leaves was abundant and common within the samples. Non-food items including plastics, fishing line, detritus conglomerate, hair and tumor flesh were common but not abundant. Animal material was also common but not abundant. Cyanobacteria were present but neither common nor abundant. Sand and coral skeleton fragments were present in a majority of the esophagus + crop samples but were not included in the measurements or calculations.

Table 2. Diet items present in 16 stranded turtles on east Hawai'i Island. Algal diet items present in measurable quantities (> 0.001 g) and all terrestrial material, non-food material, animal material, and cyanobacteria present in any quantity are shown.

Diet Item	RA (%)	FO (%)	IV
Algae			
Pterocladiella capillacea	54.5528	31.2500	85.8028
Amansia glomerata	2.6773	43.7500	46.4273
Gracilaria salicornia	13.1053	31.2500	44.3553
Gelidiopsis variabilis	2.5162	18.7500	21.2662
Gelidiopsis sp. (unidentified)	0.1170	6.2500	6.3670
Total *Gelidiopsis spp.*	2.6331	25.0000	27.6331
Ahnfeltiopsis concinna	0.0194	12.5000	12.5194
Hypnea spinella	0.0125	6.2500	6.2625
Hypnea sp.	0.0053	6.2500	6.2553
Total *Hypnea spp.*	0.0178	12.5000	12.5178
Bleached branched flat red (unidentified)	0.0068	12.5000	12.5068
Branched straplike bleached red	0.0904	6.2500	6.3404
Branched red	0.0694	6.2500	6.3194
Bleached branched red (unidentified)	0.0641	6.2500	6.3141
Branched red (purple color, bleached apices)	0.0321	6.2500	6.2821
Branched red (pointed apices, singular apical cell)	0.0282	6.2500	6.2782
Branched flat red (unidentified)	0.0234	6.2500	6.2734
Branched red	0.0164	6.2500	6.2664
Red (purple color, small medullary cells)	0.0154	6.2500	6.2654
Grateloupia sp. (possibly *G. phuquocensis*)	0.0133	6.2500	6.2633
Branched spiky red	0.0131	6.2500	6.2631
Branched thin cylindrical red (unidentified)	0.0084	6.2500	6.2584
Branched red (purple color, pointed apices)	0.0050	6.2500	6.2550
Branched flat red	0.0025	6.2500	6.2525
Branched flat red (unidentified)	0.0012	6.2500	6.2512
Gelidium pusillum	0.0007	6.2500	6.2507
Total Rhodophyta	73.3959	87.5000	160.8959
Ulva sp. (unidentified)	1.3078	6.2500	7.5578
Ulva sp. (unidentified)	0.3193	6.2500	6.5693
Ulva intestinalis	0.0753	6.2500	6.3253
Ulva sp. (film, unidentified)	0.0020	6.2500	6.2520
Ulva sp. (unidentified)	0.0015	6.2500	6.2515
Total *Ulva spp.*	1.7059	25.0000	26.7039

Rhizoclonium sp.	0.0698	12.5000	12.5698
Rhizoclonium grande	0.0421	6.2500	6.2921
Total *Rhizoclonium spp.*	0.1119	18.7500	18.8619
Chaetomorpha antennina	0.5507	12.5000	13.0507
Branched green (unidentified)	1.7874	6.2500	8.0374
Branched green (unidentified)	0.0529	6.2500	6.3029
Valonia aegagropila	0.0244	6.2500	6.2744
Bryopsis pennata	0.0142	6.2500	6.2642
Branched green (unidentified)	0.0105	6.2500	6.2605
Branched green (unidentified)	0.0060	6.2500	6.2560
Branched green (unidentified)	0.0034	6.2500	6.2534
Branched green (unidentified)	0.0032	6.2500	6.2532
Branched green (feathered, unidentified)	0.0027	6.2500	6.2527
Cladophoropsis membranacea	0.0018	6.2500	6.2518
Branched green (feathered, unidentified)	0.0006	6.2500	6.2506
Total Chlorophyta	4.2755	56.2500	60.5255
Sargassum echinocarpum	2.0174	12.5000	14.5174
Sargassum sp. (unidentified)	0.2971	6.2500	6.5471
Sargassum sp. (unidentified)	0.1158	6.2500	6.3658
Sargassum sp. (unidentified)	0.0479	6.2500	6.2979
Sargassum sp. (unidentified)	0.0075	6.2500	6.2575
Sargassum sp. (unidentified)	0.0057	6.2500	6.2557
Sargassum sp. (unidentified)	0.0044	6.2500	6.2544
Total *Sargassum spp.*	2.4957	25.0000	27.4957
Padina australis (*Vaughniella* phase)	0.3026	6.2500	6.5526
Branched flat brown (unidentified)	0.0750	6.2500	6.3250
Total Phaeophyceae	2.8734	31.2500	34.1234
Terrestrial material			
Unidentified terrestrial grass	0.7362	31.2500	31.9862
Segmented terrestrial grass	0.1624	12.5000	12.6624
Paspalum vaginatum	17.0416	6.2500	23.2916
Total terrestrial grass	17.9738	37.5000	55.4738
Wood	0.0456	31.2500	31.2956
Terrestrial leaves	-	6.2500	-
Terrestrial leaves (lattice veins)	0.6930	6.2500	6.9430
Dead terrestrial leaves (curly veins)	0.0188	6.2500	6.2688
Terrestrial leaves (thick and small)	-	6.2500	-
Terrestrial leaves (parallel veins)	-	6.2500	-
Total terrestrial leaves	0.7118	12.5000	13.2118
Unidentified grass or root	0.0336	6.2500	6.2836
Clear branching roots	-	6.2500	-

Total terrestrial material	18.7312	56.2500	74.9812
Non-food material			
Blue plastic fibers	-	37.5000	-
Clear plastic fibers	-	25.0000	-
Clear plastic film	-	18.7500	-
Black plastic fiber	-	12.5000	-
Blue plastic fragment	-	12.5000	-
Pink plastic fiber bundle	-	12.5000	-
Orange fiber bundle	-	6.2500	-
White fiber tuft	-	6.2500	-
Red plastic fiber	-	6.2500	-
Green plastic fibers	-	6.2500	-
Green plastic strip	-	6.2500	-
Blue-green plastic fiber bundle	-	6.2500	-
Black rope	-	6.2500	-
Total plastic (excluding fishing line)	-	50.0000	-
Clear monofilament fishing line	-	31.2500	-
Detritus conglomerate	0.3980	31.2500	31.6480
Hair (animal and human)	-	25.0000	-
Tumor	-	18.7500	-
Total non-food material	0.3980	62.5000	62.8980
Animal material			
Gastropod shells	-	18.7500	-
Shell-less gastropod	-	12.5000	-
Gastropod in shell	-	6.2500	-
Bivalve shells	-	6.2500	-
Crepidula sp. (slipper shell)	0.1240	6.2500	6.3740
Total Mollusca	0.1240	37.5000	37.6240
Porifera (sponges)	0.1109	31.2500	31.3609
White eggs	-	18.7500	-
Urchin spine	-	18.7500	-
Cricocephalus albus (flukes)	-	6.2500	-
Segmented worm	-	6.2500	-
Crustacean zooplankton	-	6.2500	-
Barnacle	0.0252	6.2500	6.2752
Unidentified Arthropod	-	6.2500	-
Animal flesh (with radula)	-	6.2500	-
Total animal material	0.2601	50.0000	50.2601
Cyanobacteria			
Oscillatoria sp.	-	6.2500	-
Symploca hydnoides	-	6.2500	-

Total cyanobacteria	-	12.5000	-

Eleven major diet items were identified based on abundance with total dry weights > 1g (Fig. 5). *Pterrocladiella capillacea* was the most abundant diet item followed by total terrestrial grass, *Gracilaria salicornia*, *Amansia glomerata*, *Gelidiopsis variabilis*, *Sargassum* spp., an unidentified branched green, *Ulva* spp., total terrestrial leaves, *Chaetomorpha antennina*, and a detritus conglomerate.

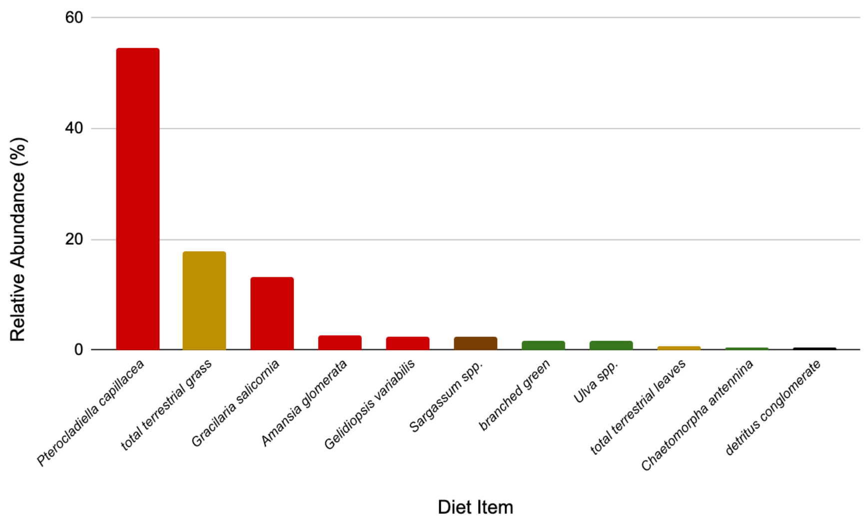


Fig. 5. Rank of abundance of 11 major diet items with total dry weights > 1 g.

The Shannon-Weiner diversity index was calculated to show the diversity of algae present in measurable amounts (> 0.001 g) within the esophagus + crop sample of each turtle. The values ranged from 0 (low algal diversity) to 1.41 (higher algal diversity). Some samples were composed of a majority of one species of algae with small amounts of other species, while the majority of other samples were composed of several species of algae. Turtle H-354 and Turtle H-383 had no measurable contents. Turtle H-360 had only one measurable diet item. The contents of Turtle H-374 were dominated by one species, *Pterocladiella capillacea* (95.1772 g dry weight), with other measurable species *Sargassum echinocarpum* (0.2502 g dry weight) and *Grateloupia* sp. (0.0346 g dry weight) having considerably lower abundance.

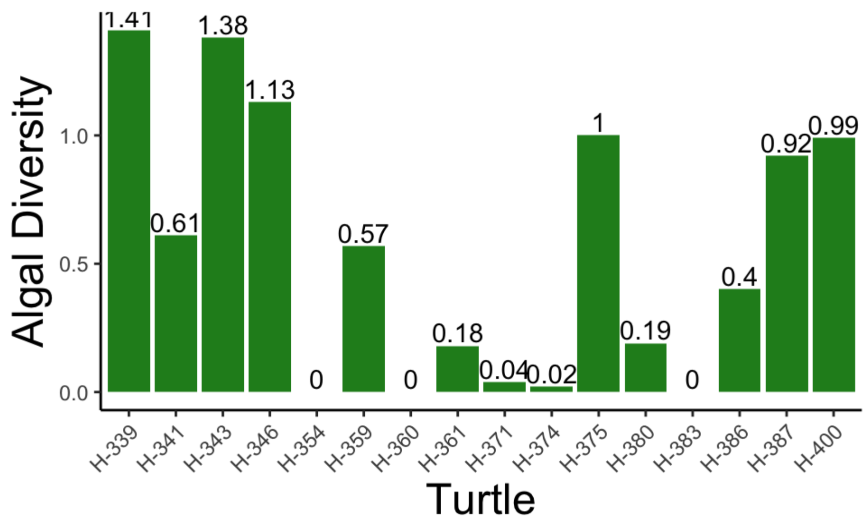
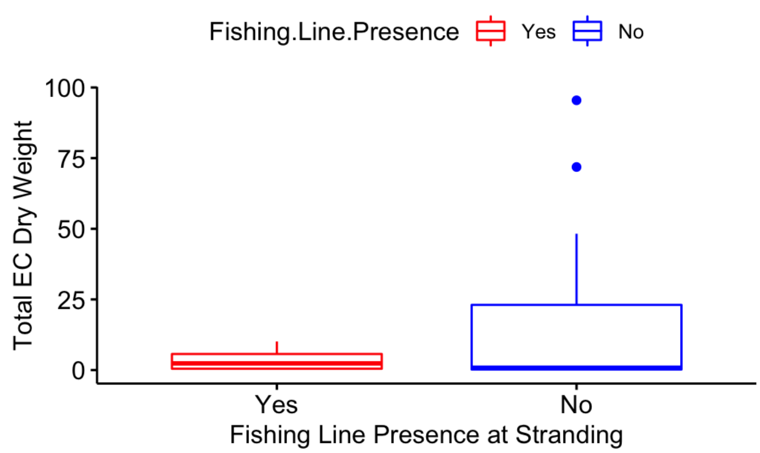
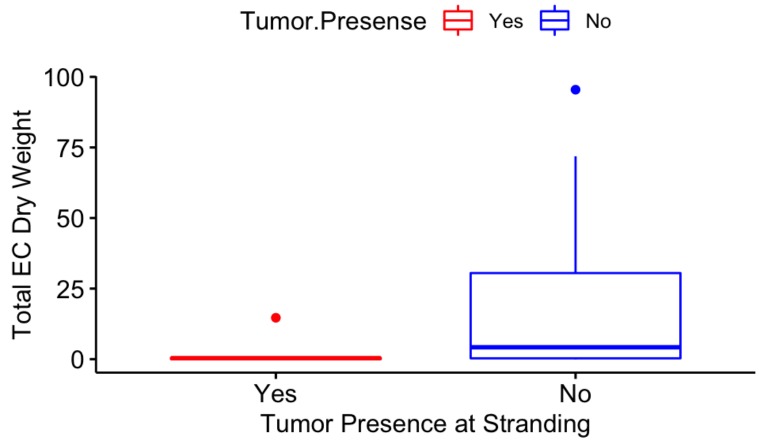


Fig. 6. Shannon-Weiner diversity index showing algal diversity of 16 esophagus + crop samples from turtles stranded on east Hawai‘i Island.

Stranding causes and total esophagus + crop dry weight of turtles were compared. There was no significant difference in the total esophagus + crop dry weight of turtles with fishing line present at their stranding compared to turtles without fishing line present at their stranding (Fig. 2). There was no significant difference in the total esophagus + crop dry weight of turtles with tumors present at their stranding compared to turtles without tumors present at their stranding (Fig. 2).



a.



b.

Fig. 7. Wilcox rank sum test showing no significant relationship between stranding causes (a. Fishing line presence at stranding, p = 0.9516; and b. Tumor presence at stranding, p = 0.2815).

4. DISCUSSION

The fill and condition of the esophagus and crop of the 16 juvenile and subadult green turtles on the east coast of Hawaiʻi Island varied greatly between turtles. The organ fill ranged from completely empty to large amounts of contents. There was no significant correlation between esophagus and crop fill (dry weight) and the size of the turtles (CCL). The fill of the esophagus and crop is more likely linked to the unique circumstances leading up to the individual turtles' stranding and death than the size of the turtle. This non-significant correlation does not represent the relationship of turtle size and amount of food consumed in the general green turtle population. Rather, it shows different diet characteristics of turtles that have stranded and died.

Red Macroalgae from phylum Rhodophyta are the most common and most abundant diet item type in the diets of 16 juvenile and subadult green turtles on the east coast of Hawaiʻi Island, specifically near Hilo and Punaluʻu Beach Park. This agrees with other studies done on green turtle diets in the Hawaiian Islands. Terrestrial material was the second most abundant diet item type and had the second highest IV. Green and brown algae were second and third most abundant respectively, but both had lower IV values than non-food items, and brown had a lower IV value than animal material. Non-algal and non-food diet items reflected what was found in other studies (Russell et al. 2011). This study showed that juvenile and subadult green turtles on east Hawaiʻi Island have a herbivorous diet with small amounts of animal matter being consumed. Animal matter, mainly consisting of sponges and mollusk shells, could have been consumed preferentially or accidentally eaten along with vegetative diet items. Plastics were commonly found in many of the esophagus + crop content samples. Plastic fibers present may have been attributed to contamination during sample analysis. Tumor flesh present in the esophagus + crop contents likely originated from that individual or other turtles. Two species of cyanobacteria were present, but not in measurable amounts, so no relative abundance or IV values were calculated for that diet item type. Sand was likely either accidentally eaten along with algae or other diet items, or it entered the turtles during stranding events.

Pterocladiella capillacea was identified as the most abundant diet item. This species was common and abundant in previous green turtle diet studies in the Main Hawaiian Islands (Arthur & Balazs 2008). *Pterocladiella capillacea* is a high protein and high energy food source (McDermid et al. 2007).Terrestrial grass was the second most abundant diet item. The majority of the total terrestrial grass dry weight was from *Paspalum vaginatum*, an invasive semi-aquatic grass. Green turtles have been observed eating this grass (McDermid et al. 2015). If turtles possess the proper microflora in their guts that is adapted to metabolize complex structural carbohydrates present in *Paspalum vaginatum*, this grass could provide more protein and energy per gram per bite than the commonly consumed *Pterocladiella capillacea* (McDermid et al. 2015). *Paspalum vaginatum* is a nutritional diet item for green turtles (McDermid et al. 2015). *Gracilaria salicornia* was the third most abundant diet item. This invasive red algae was introduced to the Hawaiian Islands in the 1970s (Smith et al. 2004). *Gracilaria salicornia* was common and abundant in other dietary studies in the Hawaiian Islands (Arthur & Balazs 2008). The presence of invasive species in the diets of green turtles shows that they are adaptable to changing forage presences. Other major diet items included *Amansia glomerata, Gelidiopsis variabilis, Sargassum* spp., a branched green species, *Ulva* spp., total terrestrial leaves, *Chaetomorpha antennina*, and a detritus conglomerate. The detritus conglomerate was dark in color and consisted of dead terrestrial matter and other materials stuck together. This conglomerate was likely ingested accidentally with other diet items. The major algae species composing the diets of the turtles in this study predominantly reflected the algae species found in previous studies in the Main Hawaiian Islands (Arthur & Balazs 2008).

The algal diversity within the esophagus + crop sample of each turtle was shown through the Shannon-Weiner diversity index. The algal diversities varied among the turtles. The lowest diversities (H'=0) were found in turtles with no esophagus + crop contents except sand (Turtle H-354 and Turtle H-383) and in turtles with only one measurable algal diet item (Turtle H-360). Low algal diversity in other turtles could represent diets that mainly consisted of one type of algae with few other algal species present in high abundance. High diversity values indicate diets with more uniform abundance and higher species richness. These values may indicate preference and selectivity of diet items by individual turtles or the diversity of the forage that is available to the turtles in their habitats.

Turtle H-374, the only turtle retrieved from Punaluʻu Beach Park, had a low algal diversity (H'=0.02). This turtle had the highest total EC dry weight, and its diet mainly consisted of one species, *Pterocladiella capillacea*. The dry weight of *Pterocladiella capillacea* in this turtle made up most of the dry weight and abundance for *Pterocladiella capillacea* in all of the samples. Turtle H-374 was previously tagged. The tag locations and numbers are: Left anterior: N-798; Left posterior: N-799; Right anterior: B-336; and Right posterior: R-93. This turtle has been measured in previous studies and growth rates were calculated. The turtle had a SCL of

40.9 cm in April 1991, 54.2 cm in April 1995, and a CCL of 75 cm in December 2021. Comparisons of size measurements through time and diet studies can help identify influences of the amount of food and of different species of diet items on turtle growth rates.

Fishing line was observed to cause serious negative effects on the internal organs of green turtles. Four turtles had fishing line present in their esophagus + crop samples. In two of these turtles several lines of fishing line ran through the esophagus, crop, stomach, and portions of the intestines. These lines caused bruising, gouging, and plaque build-up. They also caused an obstruction of passage in the digestive tract and entangled food items. The stomach and intestines of one turtle (H-400) were twisted and contorted around the fishing line. There was no significant relationship between total esophagus + crop fill and fishing line presence. Tumors caused by fibropapillomatosis are another known stranding cause. There was no significant relationship between total esophagus + crop fill and tumors present on the turtle on the date of stranding. Future research and larger sample sizes would be useful in further understanding the relationships between stranding cause and the amount of food consumed by green turtles.

This is the first in-depth analysis of east Hawaiʻi Island green turtle diet. Dietary studies are important for effective management of this Federally listed species, its habitat, and the macroalgae critical for green turtle survival. Further studies including comparison of diet amount and diet items with growth rates, stranding causes, and locations in east Hawaiʻi Island will benefit the understanding of green turtle diets in east Hawai'i Island.

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