Hungry Hungry *Honu*:
East Hawaiʻi Island green turtle (*Chelonia mydas*) diet determination utilizing stable isotopes ($\delta^{13}C$ and $\delta^{15}N$)

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Abstract:

Stable carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotopes are frequently utilized to determine the origin of nutrients in the diets of wildlife. The consumption of organic matter throughout an animal's life results in the deposition of isotopic signatures which can elucidate the prey and trophic level an animal feeds on. Adult green turtles (*Chelonia mydas*) are considered herbivorous animals that feed primarily on coastal seagrasses and macroalgae, but juveniles are opportunistic omnivores. Green turtles throughout their lives may feed on protein-rich items such as fish bait when the opportunity allows. Samples of skin were analyzed from 17 green turtles that had stranded between March 2020 to June 2022 from eight locations on the east coast of Hawaiʻi island. The turtles ranged in size from 36.1 - 78.5 cm curved carapace length (CCL) indicating size classes of juvenile to sub-adult. Mean $\delta^{13}C$ ‰ was - 15.9 ± 1.55 SD and mean $\delta^{15}N$ ‰ was 8.63 ± 1.41 SD. These values for east Hawaiʻi Island turtles are similar to those in previous studies on green turtles found at Palmyra Atoll, Fiji, and the Eastern Pacific. These values are consistent with a marine plant diet. The conservation of marine plant populations in the Hawaiian Islands is essential for the management of healthy green turtle populations.

Keywords - Feeding Ecology, Food Web, Diet Determination, Primary Consumer, Isotope Cycling

1. Introduction

Since the late 1970s, stable carbon and nitrogen isotopes have been utilized to determine the origin of nutrient resources in the diets of wildlife (DeNiro & Epstein 1978). The consumption of organic matter throughout an animal's life results in the deposition of isotopic profiles within the tissue (Seminoff et al. 2009). Carbon and nitrogen isotopes are deposited in tissue over time and can give information on longer term diet than other methods i.e. gut analysis, mouth sampling, crop lavages, and direct observation (DeNiro & Epstein 1981). Samples from multiple specimens within a population provide data on consumption patterns at a specific trophic level (Seminoff et al. 2009). For sea turtles, stable isotopes have been used to study migratory paths and to map feeding locations during their life history (Ceriani et al. 2012, Vander Zanden et al. 2015, Haywood et al. 2020).

The ratios of $\delta^{13}C$ (ratio of ^{13}C:^{12}C) and $\delta^{15}N$ (ratio of ^{15}N:^{14}N) are the two most frequently utilized isotopes to study dietary interactions (Post 2002). The $\delta^{13}C$ is used to identify the primary producers because this form of carbon remains unchanged throughout a food chain (Post 2002). However, nitrogen ratios are enriched in organisms higher in the food chain because ^{14}N isotopes are excreted preferentially, thus leaving higher ^{15}N levels within the organisms (DeNiro and Epstien 1989).

Epidermis tissue (subsequently referred to as 'skin') samples provide a recent history of feeding preferences; however, there have been no studies that directly determine the isotopic replenishment rate or turnover for adult sea turtle skin. However, adult freshwater pond sliders (*Trachemys scripta*) which are commonly used as a surrogate for sea turtles exhibit an estimated isotopic turnover rate in their skin of approximately four to six months (Seminoff et al. 2007, Seminoff et al. 2012). Based on tissue turnover rates in hatchlings and small juvenile sea turtles in captivity, isotope ratios are estimated to reflect habits at least four months prior to sampling (Reich et al. 2008, Seminoff et al. 2007, Reich et al. 2010, Ceriani et al. 2014)

After leaving their natal beach, green turtles spend the first period of their life in the open ocean. During these three to five years, the juvenile green turtles are opportunistic omnivorous feeders and consume a varied diet of pelagic planktonic items (Bolten 2003, Cardona et al. 2010). After their pelagic period, juvenile green turtles migrate to coastal environments where they transition to an herbivorous diet (Bjorndal 1980, Bjorndal and Bolten 1988, Bolten 2003, Balazs and Chaloupka 2004a, Reich et al. 2007, Arthur and Balasz 2008). According to previous stable isotope analysis studies (Godley et al. 1998, Hatase et al. 2006, Cardona et al. 2010) and gut content analysis (Limpus et al. 1994, Seminoff et al. 2002, Amorocho and Reina 2007), the exact time frame of diet change is variable among individuals when they make the switch. Turtles are thought to make this transition to nearshore environments when their straight carapace length (SCL) is around 35 cm in length (Zug et al. 2006). Adult green turtles migrate incredible distances between reproductive and feeding grounds (Hays and Hawkes 2018). Despite the distance, sea turtles are able to display high levels of site fidelity to specific feeding areas despite completing multiple migratory events within their life without issue (Shimada et al. 2020).

The switch to a herbivorous diet remains permanent throughout the remaining life of green turtles; this diet is the foundation of the common perception of sea turtles grazing on coastal macroalgae and seagrasses (Bjorndal 1980). The ecological impact of green turtles as megaherbivores in seagrass meadows is well documented (Frazier 1971, Hirt et al. 1973, Bjorndal 1980, Mortimer 1981, Bjorndal & Bolten 2003, McClenachan et al. 2006, Heithaus et al. 2008,Vander Zander et al. 2013, Heithaus et al. 2014). Seagrasses are the primary diet in populations of green turtles located on the coast of the Mediterranean (Margaritoulis & Teneketzis 2003, Cardona 2010), atolls in the Indian Ocean (Hasbún et al. 2000, Whiting et al. 2007), coastal areas of Australia (Arthur et al. 2009), and the Caribbean (Mortimer 1981).

In areas where seagrasses are sparse, turtles consume a diet either supplemented or primarily composed of macroalgae (Balazs 1976, Garnett et al. 1985, Limpus et. al 2005, Shimada et al. 2014, Whiting et al. 2014). Mangrove leaves and propagules are frequently found in diet analysis of green turtles found in some locations (Limpus & Limpus 2000, Arthur et al. 2009). In Hawaiʻi, coastal terrestrial grass, terrestrial leaves, and other items are occasnionally found within sea turtle stomachs (Russell et al. 2011) Other reports suggest adults may opportunistically feed on on invertebrates when available such as sponges, molluscs, fish, or macrozooplankton (Mortimer 1981, Bjorndal 1997, Burkholder et al. 2011, Russell et al. 2011, Fukuoka et al. 2016, Piovano et al. 2020). Preference for certain plant food items has been demonstrated in populations found in Australia (Brand-Gardner et al. 1999), but, diet selection is thought to be driven by availability of items (Forbes 1996)

In the main Hawaiian islands, green turtles primarily consume abundant red macroalgae (*Rhodophyta*) (Arthur & Balazs 2008). Green (*Chlorophyta*) and brown (*Phaeophyta*) macroalgae are also consumed by turtles when available (McDermid et al. 2007). Two seagrasses, *Halophila decipiens* and *H. hawaiiana* have also been reported to make up a substantial portion of turtle's diet, but only in areas that provide habitat for seagrass growth, e.g. near Oʻahu (Russell et al. 2003). In a study conducted with turtles taken from Pālāʻau, Molokaʻi, the red algaes *Acanthrophora spicifera, Amansia glomerata, Gracilaria salicornia, Hypnea* *cervicornis, Hypnea musciformis* and *Spyridia filamentosa* were commonly occurring species found to be consumed by turtles (Balazs et al. 1987, Russell & Balazs 2009).

The present study used stable isotope analysis of skin samples to investigate the diets of green turtles from the east coast of Hawaiʻi Island. The hypothesis was that the $\delta^{13}C$ and $\delta^{15}N$ values indicate a macroalgal diet and that the isotope ratios would not differ significantly from values reported from other green turtle populations.

2. Methods

Seventeen samples of *Chelonia mydas* skin were obtained from turtles that stranded between March 2020 and June 2022, from eight separate locations on the east coast of Hawaiʻi Island (Figure 1). Stranding reports contained data on date, location, curved carapace length (CCL), current condition, and tag number if present. CCL was utilized as a proxy for age; individuals with a CCL less than 70 cm were considered juveniles, individuals with a CCL of 70 to 86 cm were grouped as sub-adults, and individuals with a CCL of over 87 cm were recognized as adults (Balazs 1980).

Figure 1: Stranding locations of green turtles (*Chelonia mydas*) on the east coast of Hawaiʻi Island.

The deceased turtles were taken to the University of Hawaiʻi at Hilo and frozen for preservation until transport to National Marine Fisheries Service on Oʻahu on June 23, 2022 where necropsies were conducted on August 11, 2022. Skin samples were removed from the hind flippers close to the tail with a scalpel, and frozen in individual, labeled Whirlpak bags, and then transported back to the Marine Science Department at the University of Hawaiʻi at Hilo on August 18, 2022.

Skin samples were rinsed with deionized water, before being weighed on a Scout Pro Model SP 402 for wet weights. Samples were then diced with a scalpel and dried in aluminum weighing dishes at approximately 60°C for a minimum of 24 hours in a FisherSci model oven.

The skin samples were dried to a constant weight and dry weights were recorded. Samples were ground with a mortar and pestle by hand into a fine powder. Some samples were pulverized in a Wig-L-Bug Grinding Mill to improve grinding. Powdered samples were returned to weigh boats in the oven temporarily until they were loaded into sterilized tin capsules. Between processing steps, samples were kept stored in the oven to prevent rehydration. (Seminoff et al. 2006)

Prepared samples in tin capsules were analyzed by the Analytical Laboratory at the University of Hawaiʻi at Hilo. Nitrogen and carbon were assayed using a Thermo Delta V IRMS machine. Some samples were randomly picked and processed as duplicates to test for consistency of ratio values, but were not used during data analysis.

The abundance of stable isotopes were reported as δX with X representing either ^{13}C or ^{15}N. To represent the ratio of isotopes, the R_{sample} and $R_{standard}$ concept is used with respect to the heavy and light isotopes ($^{13}C/^{12}C$ and $^{15}N/^{14}N$). δX values past tense recorded as per mil (parts per thousand difference from international standard) and were calculated using the formula:

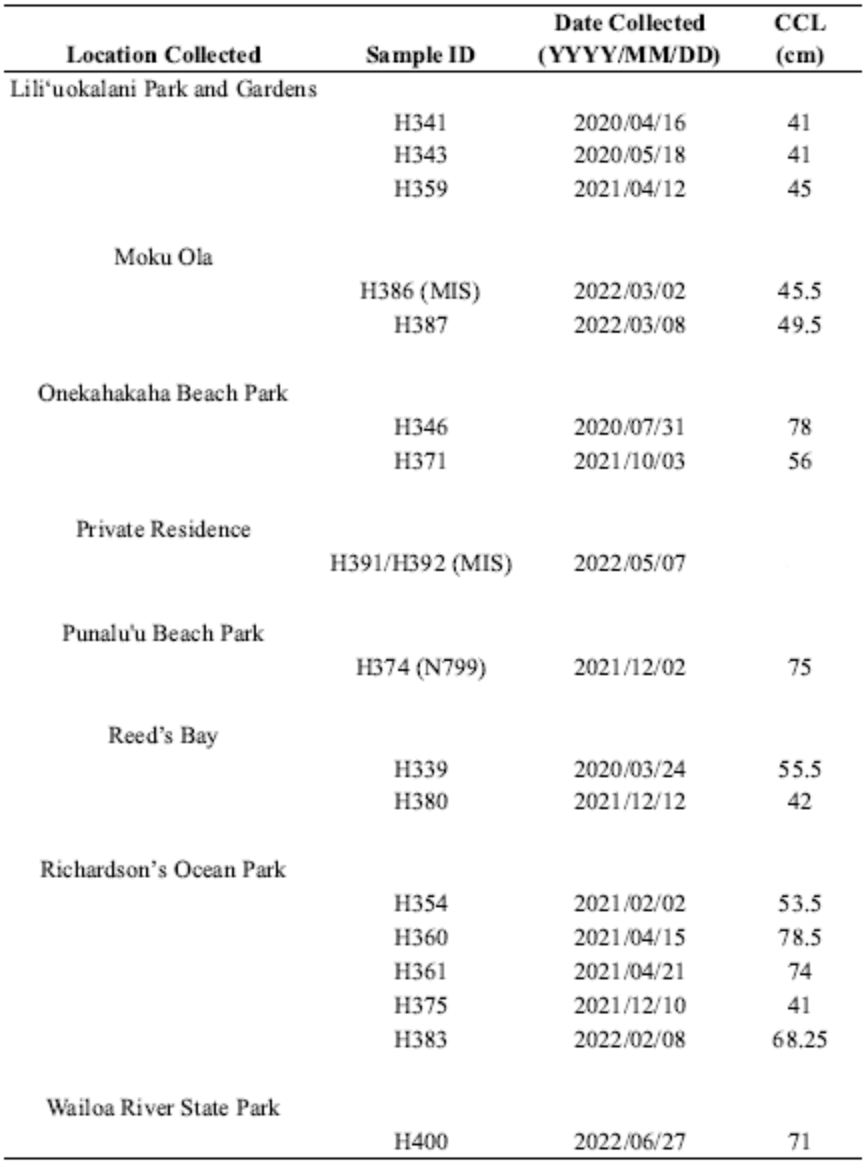
$$\delta X = 1000 \text{ x } ([(R_{sample} / R_{standard}] - 1)$$

Results of isotope ratios were compared to the standards set forth by the United States Geological Survey (USGS). The $R_{standard}$ for ^{13}C was Vienna PeeDee Belemnite (VPDB) [40 ($\delta^{13}C$ vs VPDB = -26.4) & USGS 41 $\delta^{13}C$ vs. VPDB = 37.6)], and $R_{standard}$ for ^{15}N was normalized to atmospheric nitrogen [USGS 40 ($\delta^{15}N$ vs. Air = -4.5) & USGS 41 ($\delta^{15}N$ vs Air = 47.6)]. Both $R_{standards}$ were accurate to 0.2‰. Two laboratory standards were run alongside the samples to verify the accuracy and precision of the spectrometer.

Results are reported as mean ± standard deviation (SD). Statistical analysis was performed using RStudio program version 1.4.1106 and GoogleSheets.

3. Results

Skin samples (n = 17) from turtles that were found stranded at eight different locations on the east coast of Hawaiʻi Island (Table 1) were analyzed. The wet weight of samples ranged from 0.07 g to 0.31 g, after drying samples weighed from less than one gram to 0.14 g. The curved carapace lengths (CCL) of 16 turtles ranged from 36.1 - 75 cm in length (mean ± SD = 57 ± 15 cm) (Figure 2). One turtle (H391/H392 (MIS)) was recorded with a straight plastron length. This choice in measurement method lacks a conversion method to curved carapace length (CCL), and has been omitted from size-related data as a result. Based on CCL measurements, juvenile turtles comprised of 65% (n = 11) used in this study of the stranded individuals, and the remaining 35% (n = 6) were classified as sub-adults (Table 2).



Location Collected	Sample ID	Date Collected (YYYY/MM/DD)	CCL (cm)
Lili‘uokalani Park and Gardens			
	H341	2020/04/16	41
	H343	2020/05/18	41
	H359	2021/04/12	45
Moku Ola			
	H386 (MIS)	2022/03/02	45.5
	H387	2022/03/08	49.5
Onekahakaha Beach Park			
	H346	2020/07/31	78
	H371	2021/10/03	56
Private Residence			
	H391/H392 (MIS)	2022/05/07	
Punalu'u Beach Park			
	H374 (N799)	2021/12/02	75
Reed’s Bay			
	H339	2020/03/24	55.5
	H380	2021/12/12	42
Richardson’s Ocean Park			
	H354	2021/02/02	53.5
	H360	2021/04/15	78.5
	H361	2021/04/21	74
	H375	2021/12/10	41
	H383	2022/02/08	68.25
Wailoa River State Park			
	H400	2022/06/27	71

Table 1: Stranded green turtles (*Chelonia mydas*) found along the east coast of Hawai‘i island between 2020 and 2022 categorized by the locations stranding occurred at. Curved carapce length (CCL) is given in centimeters.

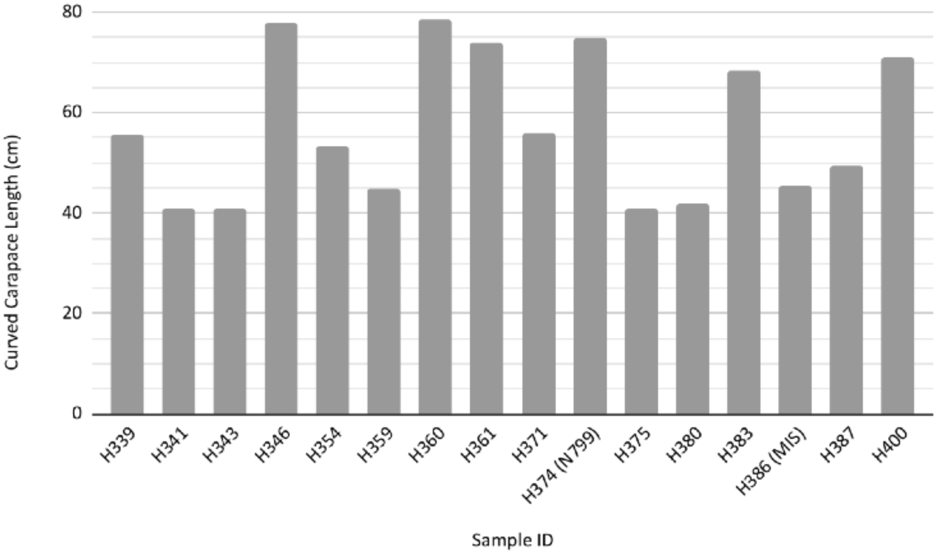
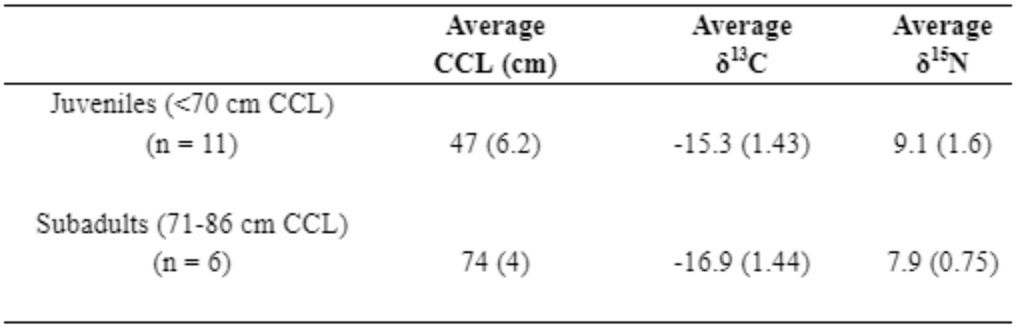


Figure 2: The curved carapace length (CCL) of stranded green turtles (*Chelonia mydas*) found along the east coast of Hawai‘i island between 2020 and 2022 that were utilized in this study as a proxy for age.



	Average CCL (cm)	**Average $\delta^{13}C$**	**Average $\delta^{15}N$**
Juveniles (<70 cm CCL) (n = 11)	47 (6.2)	-15.3 (1.43)	9.1 (1.6)
Subadults (71-86 cm CCL) (n = 6)	74 (4)	-16.9 (1.44)	7.9 (0.75)

Table 2: Mean curved carapace length (CCL) measurements (± SD) and mean skin tissue isotopic signatures (± SD) from age classes of stranded green turtles (*Chelonia mydas*) found along the east coast of Hawai‘i island between 2020 and 2022 Age classes were defined as juvenile (> 65 cm CCL) and sub-adult (65 - 83 cm CCL).

The average value of $\delta^{13}C$ found within the samples was -15.9 (± 1.55), with values ranging from -14.3 to -18.0 (Figure 3). The average value of $\delta^{15}N$ was 8.6 (± 1.41), with values ranging from 6.2 to 11.9 (Figure 4).

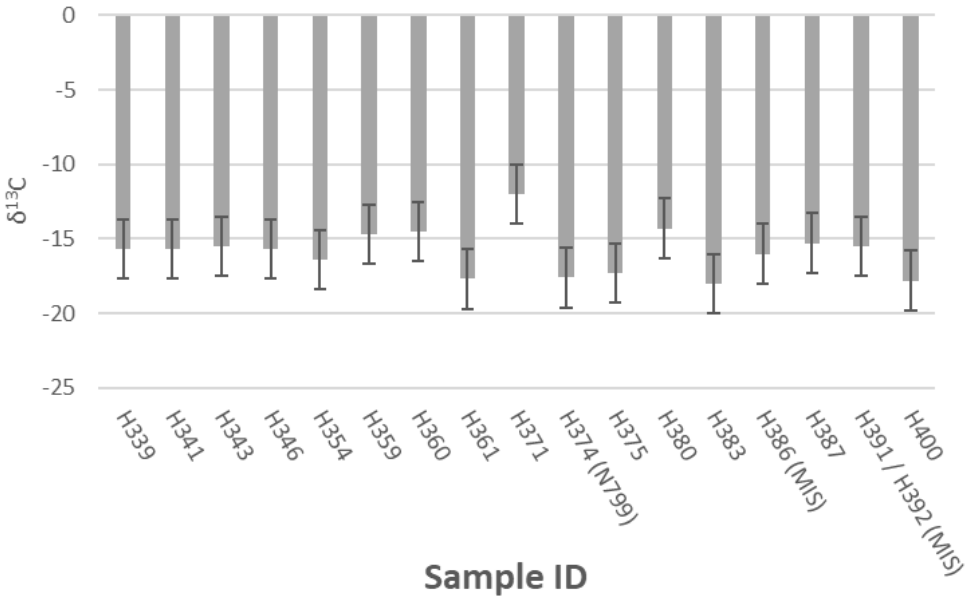


Figure 3: The composition of δ¹³C (± SD) in skin tissue samples from stranded green turtles (*Chelonia mydas*) found along the east coast of Hawai‘i island between 2020 and 2022

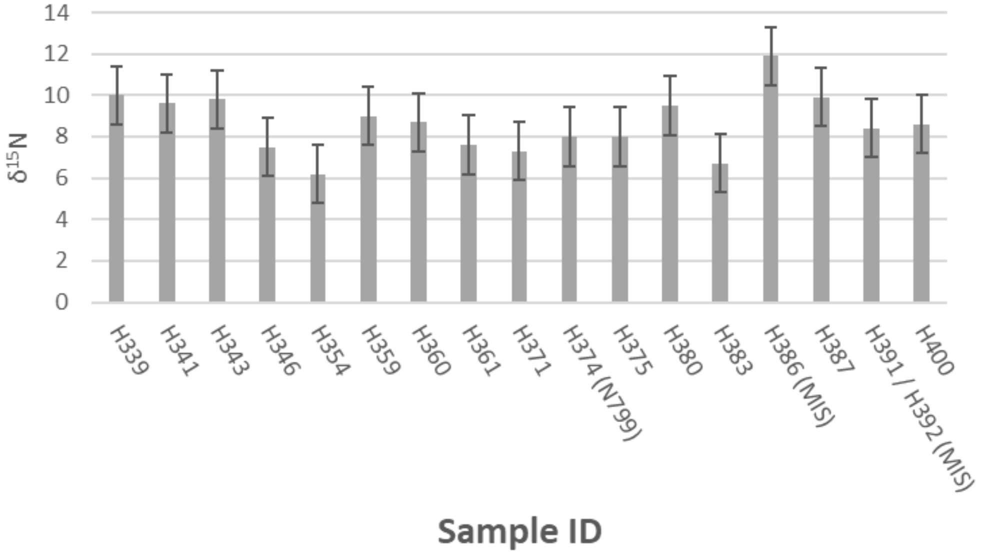


Figure 4: The composition of $\delta^{15}N$ (± SD) in skin tissue samples from stranded green turtles (*Chelonia mydas*) found along the east coast of Hawai‘i island between 2020 and 2022

Level recorded of $\delta^{15}N$ and $\delta^{13}C$ varied based on individuals. The turtle with the highest value of $\delta^{15}N$ was Turtle H371 (-12) (Figure 7), while Turtle H383 had the lowest value (-18)

(Figure 8). The turtle with the lowest value of $\delta^{13}C$ was Turtle H354 (6.2) (Figure 6) while Turtle H386 (MIS) had the highest value (11.9) recorded (Figure 8).

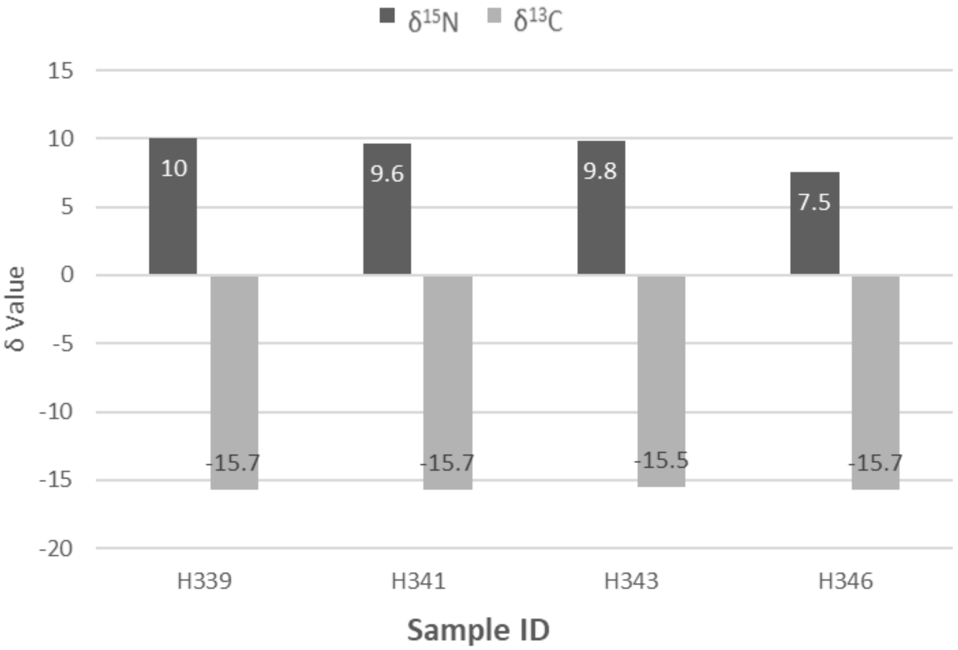


Figure 5: The composition of $\delta^{15}N$ and $\delta^{13}C$ in skin tissue samples taken from stranded turtles H339, H341, H343, and H346.

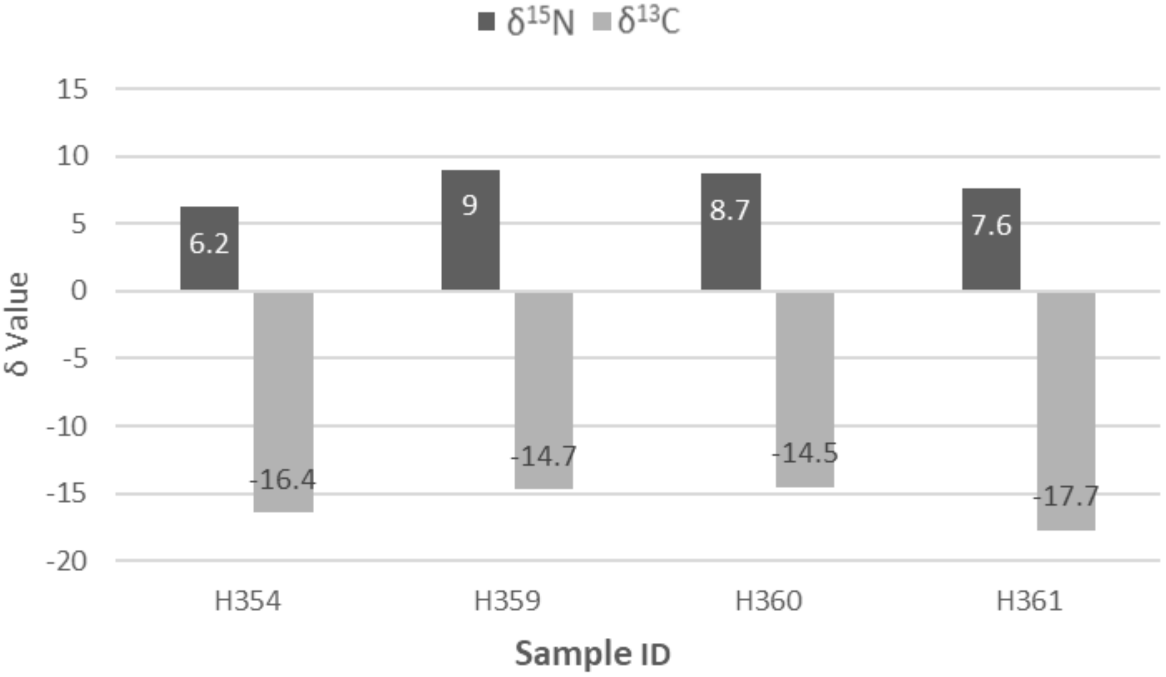


Figure 6: The composition of δ15N and δ13C in skin tissue samples taken from stranded turtles H354, H359, H360, and H361.

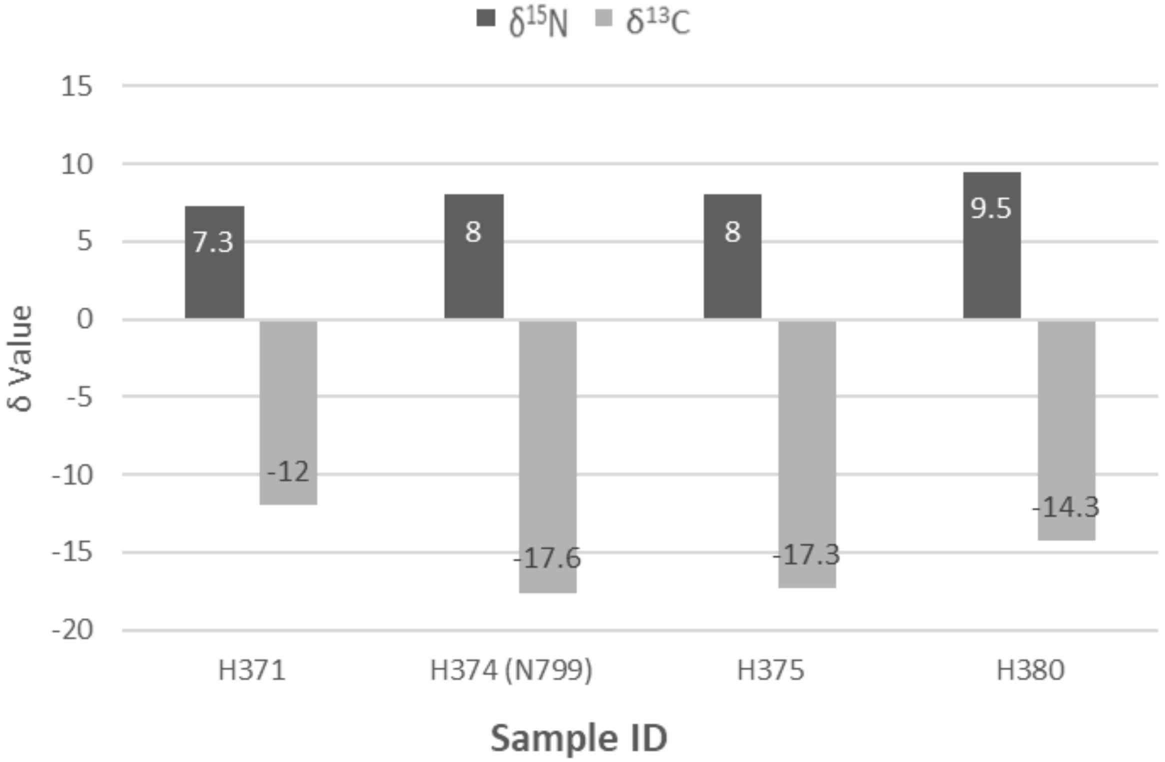


Figure 7: The composition of δ15N and δ13C in skin tissue samples taken from stranded turtles H371, H374 (N799), H375, H380.

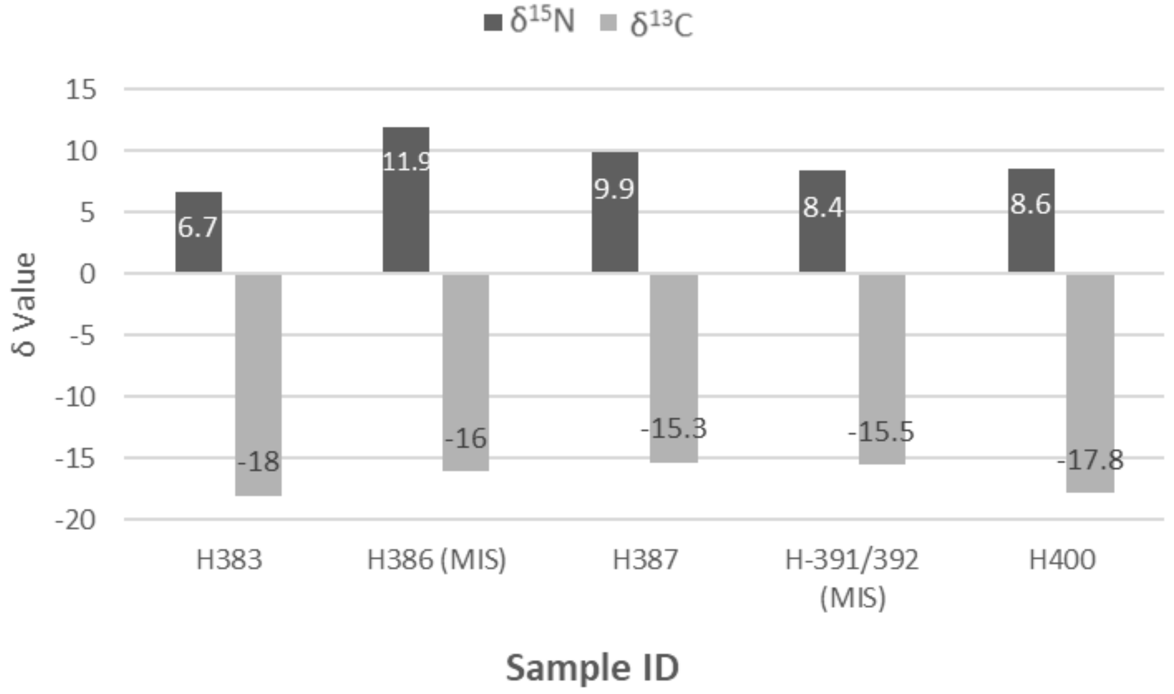


Figure 8: The composition of $\delta^{15}N$ and $\delta^{13}C$ in skin tissue samples taken from stranded turtles H383, H386 (MIS), H387, H-391/392 (MIS), and H400.

4. Discussion

The results of isotope levels are consistent with prior assumptions that after recruiting from the pelagic environment, sea turtles in Hawaiʻi primarily consume macroalgae. The lower nitrogen values that are present in subadults, and enriched in juveniles can be explained by this transition from animal to plant items in their diet. The existence of depleted values in juveniles or enriched subadults can be explained by either these individuals still consuming an omnivorous diet with a late dietary switch or a more recent transition to the neritic environment. East Hawaiʻi turtles may also supplement their diets with higher trophic level dietary items when opportunities are present.

The juvenile turtles presented with the most depleted carbon values. This can be indicative of a recent dietary shift from pelagic planktonic items to a coastal marine plant diet. However, the juvenile signatures were not significantly different from the sub-adult turtles which were slightly more enriched with carbon. Both the juvenile and subadult carbon values are indicative of a macroalgae diet. According to Arthur and Balazs (2008), macroalgae is a prey source that is considered to be further depleted in $\delta^{13}C$ when compared to seagrasses.

The subadult turtles possessed an overall depleted nitrogen value than the juvenile turtles. This suggests that the subadults were feeding on a higher trophic level than the juveniles prior to stranding (Arthur et al. 2009) The proteins in prey items are the main source for ^{15}N, while ^{13}C is able to be extracted from proteins, lipids, and carbohydrates. As a result, the turnover rate of epidermis layers, the dietary quantity of proteins in the individual turtle's diet, and turnover of protein consumption can affect the isotopic accumulation rate more frequently for nitrogen than carbon (Robbins et al. 2005, Robbins et al. 2010). In turtles, stable carbon ratios are reported to be enriched at levels approximately 0 - 1‰ higher than their prey (Seminoff et al. 2006) while nitrogen may be enriched at levels closer to 0.22 - 2.92‰ than prey (Seminoff et al. 2006).

As no prey samples were collected during the time frame of strandings for the turtles utilized in this study, no direct comparison of values could be made to showcase the variability in the diet. However, other studies conducted are able to indicate the values of carbon and nitrogen isotopes found with other populations which can be indicative of what can be expected from turtles who are consuming a diet of other items (Arthur et al. 2009, Kelly 2012) (Table 3).

Although isotopic signatures can not be directly compared across regions of feeding because of variables of baseline isotopic values by location or prey type, inferences of dietary preference indications can be made from literature analysis of generalized results of species' isotope levels. Showed turtles taken from Australia (Arthur et al. 2009) and Palmyra Atoll (Kelly 2012) all possessed enriched carbon values when compared to the individuals from east Hawaiʻi turtles. Hawai‘i turtles consume a diet of macroalgae, rather than seagrasses unlike Australian and Palmyra turtles (Arthur et al. 2009, Kelly 2012). Differences can be attributed to environmental conditions differing isotopic signatures within regions (Pajuelo et al. 2012), location of sampling, and preferential consumption differences.

Food Source Option (Prey)	$\delta^{13}C$ (‰) Mean	±SD	$\delta^{15}N$ (‰) Mean	±SD
Values taken from Literature				
Macroalgae	-15.0	7.05	6.55	2.28
Chlorophyta	-15.97	6.54	6.22	2.10
Phaeophyta	-11.52	4.89	7.14	3.00
Rhodophyta	-17.72	5.34	6.84	1.18
Invertebrates	-11.69	5.21	9.52	0.29
East Hawai‘i turtles				
Green Turtle (n = 17)	-15.9	1.55	8.6	1.41

Table 3: Mean isotopic values of prey items taken from the literature (Appendix A) to compare with east Hawai‘i turtles values. Prey groups include Macroalgae (green algae (*Chlorophyta*), brown algae (*Phaeophyta*), red algae (*Rhodophyta*)), Seagrasses, Mangroves, Zooplankton, and Invertebrates. Mean ± SD skin isotopes for sampled green turtles within the study from east Hawai‘i also included for visual comparison.

No significant differences were found in nitrogen and carbon values among species. Small sample sizes from locations or different prey availability could explain the lack of statistical significance with isotope values. Further research can be conducted to explore the values of nitrogen and carbon isotopes within local Hawai‘i macroalgal populations.

Hawai‘i Island turtles may face physiological factors affecting the processing of proteins or other molecules into tissues which would affect the levels of isotopes present within tissue (Seminoff et. al 2006). Differences in individuals’ growth, age, and dietary preferences and compositions may also exist between the populations referenced in the study (Seminoff et al. 2006, Arthur et al. 2008, Reich et al. 2008, Kelly 2012) which would affect the isotope values.

Prey groups in literature frequently overlap and are not considered to be significantly different in many cases which limits accuracy. Incorporation of more species or groups for comparison may be beneficial for future studies.

Understanding the importance of marine plants in the diet of green turtles is essential in managing turtles as an endangered species. Sea turtles play an important position in the coastal marine ecosystem as a herbivore, and it is critical to maintain suitable habitats for their feeding to occur. The body condition of turtles living within a region can also provide researchers with an idea of the overall health of an ecosystem, by judging the success of a primary consumer (Wabnitz et al. 2010). To regulate the threat of human activities to ecosystems, potential solutions include creating more Marine Protected Areas (MPAs) in critical habitat locations and implementing local beach restoration efforts. Proper resource management is needed to maintain the protection of these vulnerable areas to prevent habitat loss.

Acknowledgements. I would like to firstly say *mahalo* to my professors and advisors - Dr. Karla McDermid, George Balazs, and Dr. Jason Turner - who supervised my thesis and provided valuable assistance during the preparation and completion of my project. I would like to also acknowledge and thank Etta Karth, Erik Johnson, Jaz Panelo, Summer Martin, Brittany Clemans, Jen Sims and the UH Hilo MOP Sea Turtle Stranding Response Team who participated in different aspects with the preparation of materials, laboratory support, and the handling and process of *honu* following their stranding. Finally, to all my friends, family, co-workers, employers and mentors who can not all be listed individually: thank you for the time and support you have given to me, for believing in the successful completion of my thesis, and the constant flexibility with my busy schedule.

Prey Group	**Source**	**Species**	**Sampling Location**	δ^{13}C (‰)	**± SD**	δ^{15}N (‰)	**± SD**
Chlorophyta				-15.97	6.54	6.22	2.10
Avrainavillea	Kelly 2012		Palmyra Atoll	-19.92		8.03	
	Kelly 2012		Palmyra Atoll	-14.00		6.04	
Bryopsis	Kelly 2012		Palmyra Atoll	-16.34		6.74	
	Kelly 2012		Palmyra Atoll	-17.34		7.38	
Caulerpa	Kelly 2012		Palmyra Atoll	-12.27		5.30	
	Kelly 2012		Palmyra Atoll	-11.29		6.16	
	Kelly 2012		Palmyra Atoll	-13.90		5.38	
	Kelly 2012		Palmyra Atoll	-15.40		7.06	
	Kelly 2012		Palmyra Atoll	-14.17		5.31	
	Hyndes & Lavery 2005	*C. gemminata*	nearshore waters, SW Australia	-13.4		5.5	
	Hyndes & Lavery 2005	*C. flexilis*	nearshore waters, SW Australia	-12.6			

	Raven et al. 2002	*C. cactoides*	Coobowie Bay, SA, Australia	-21.35			
	Raven et al. 2002	*C. flexilis*	Coobowie Bay, SA, Australia	-32.98			
	Raven et al. 2002	*C. microphysa*	W Flower Garden, Gulf of Mexico (GoM)	-22.79			
	Raven et al. 2002	*C. microphysa*	W Flower Garden, GoM	-20.3			
	Raven et al. 2002	*C. microphysa*	Sonnier, GoM	-19.6			
	Raven et al. 2002	*C. microphysa*	Stetson, GoM	-19.94			
	Raven et al. 2002	*C. microphysa*	Stetson, GoM	-20.97			
	Raven et al. 2002	*C. microphysa*	E Flower Garden, GoM	-19.99			
	Raven et al. 2002	*C. obscura*	Stragglers, WA, Australia	-20.33			
	Raven et al. 2002	*C. obscura*	Carnac Island, WA, Australia	-30.18			

Prey Group	**Source**	**Species**	**Sampling Location**	δ13C (‰)	**± SD**	δ15N (‰)	**± SD**
	Raven et al. 2002	*C. obscura*	Carnac Island, WA, Australia	-29.59			
	Raven et al. 2002	*C. obscura*	Hamelin Bay, WA, Australia	-31.33			
	Raven et al. 2002	*C. obscura*	Mewstone, WA, Australia	-28.99			

	Raven et al. 2002	*C. obscura*	Mewstone, WA, Australia	-28.59	
	Raven et al. 2002	*C. obscura*	Stragglers, WA, Australia	-30.12	
	Raven et al. 2002	*C. obscura*	Stragglers, WA, Australia	-28.39	
	Raven et al. 2002	*C. obscura*	The Lumps,WA, Australia	-25.92	
	Raven et al. 2002	*C. obscura*	The Lumps, WA, Australia	-31.38	
Cladophora	Kelly 2012		Palmyra Atoll	-9.12	8.20
	Kelly 2012		Palmyra Atoll	-9.57	7.44
	Kelly 2012		Nursery	-15.14	6.64
	Dailer et al. 2010	*C. sericea*	NW Maui		0.2
	Vizzini & Mazzola 2003	*Cladophora sp.*	Lake of Sabaudia, Italy	-15.9	5.9
	Lepoint et al. 2000	*C. proliphera*	Gulf of Calvi, Corsica	-17.5	4
	McClelland et al. 1998	*C. vagabunda*	Pond/River, Mass., USA	-15.2	5.4
	Maberly et al. 1992	*C. sericea*	Tentsmuir Drift, East Coast Scotland	-19.35	
	Maberly et al. 1992	*C. rupestris*	Mid-Shore, East Coast Scotland	-16.66	
	Maberly et al. 1992	*C. rupestris*	Sheltered Rock Pool, , East Coast Scotland	-13.33	

Prey Group	Source	Species	Sampling Location	$\delta^{13}C$ (‰)	± SD	$\delta^{15}N$ (‰)	± SD
	Raven et al. 2002	*C. albida*	Filey, England	-10.83			
	Raven et al. 2002	*C. hutchinsonia*	Filey, England	-12.15			
	Raven et al. 2002	*C. rupestris*	Fifeness, England	-14.02			
	Raven et al. 2002	*C. rupestris*	Filey, England	-18.09			
	Raven et al. 2002	*C. rupestris*	East Sands, Scotland	-15			
	Raven et al. 2002	*C. rupestris*	East Sands, Scotland	-15.37			
	Raven et al. 2002	*C. rupestris*	Hemsdale, Scotland	-14.33			
	Raven et al. 2002	*Cladophora sp.*	Gran Canaria	-16.12			
Codium	Kelly 2012		T.H.	-9.82		7.47	
	Kang et al. 2008	*C. arabicum*	Samchoek Coast, Korea	-10.3		3.8	
	Lepoint et al. 2000	*C. bursa*	Gulf of Calvi, Corsica	-10.3		3.1	
	Hydes & Lavery 2005	*C. duthaeie*	SW Australia (Nearshore)	-15.5		4.8	
	Maberly et al. 1992	*C. fragile*	Rockpool, East Coast Scotland	-15.01			

	Maberly et al. 1992	*C. fragile*	Sheltered Rockpool, East Coast Scotland	-14.08			
	Maberly et al. 1992	*C. fragile*	Sheltered Rockpool, East Coast Scotland	-10.23			
	Maberly et al. 1992	*C. fragile*	Fife Ness, East Coast Scotland	-15.38			
	Raven et al. 2002	*C. convulutum*	Brighton Beach / Papatowai Beach, New Zealand	-14.54			
	Raven et al. 2002	*C. fragile*	California, USA	-11.7			
	Raven et al. 2002	*C. fragile*	California, USA	-11.15			
	Raven et al. 2002	*C. fragile*	Brighton Beach / Papatowai Beach, New Zealand	-12.04			
	Raven et al. 2002	*C. fragile*	Brighton Beach / Papatowai Beach, New Zealand	-15.46			
	Raven et al. 2002	*C. fragile*	Helmsdale, Scotland	-12.87			
	Raven et al. 2002	*C. fragile*	St. Andrews, Scotland	-13.26			
	Raven et al. 2002	*C. hubsii*	Catalina Island, CA	-8.17			
	Raven et al. 2002	*Codium sp.*	Fifeness, Scotland	-10.86			
	Raven et al. 2002	*Codium sp.*	Gran Canaria	-9.86			
	Raven et al. 2002	*Codium sp.*	Gran Canaria	-14.47			

Prey Group	**Source**	**Species**	**Sampling Location**	$\delta^{13}C$ (‰)	**± SD**	$\delta^{15}N$ (‰)	**± SD**

	Raven et al. 2002	*Codium sp.*	Hampton Bay, Long Island, NY	-15.76	
	Wang & Yeh 2003	*C. mamillosum*	sublittoral, North Taiwan	-14.2	
Dictyosphaeria	Kelly 2012		Palmyra Atoll		
	Kelly 2012		Palmyra Atoll		
	Raven et al. 2002	*D. sericea*	Rottnest Island, WA, Australia	-6.33	
Halimeda	Kelly 2012		Palmyra Atoll	-11.25	6.66
	Kelly 2012		Palmyra Atoll	-4.86	10.02
	Kelly 2012		Palmyra Atoll	-7.86	8.05
	Kelly 2012		P.S.	-4.76	8.60
	Lepoint et al. 2000	*H. tuna*	Gulf of Calvi, Corsica	-19.3	1.3
	Raven et al. 2002	*Halimeda sp.*	Gran Canaria	-11.33	
	Raven et al. 2002	*Halimeda sp.*	Singapore	-6.83	
	Wang & Yeh 2003	*H. macroloba*	Tidal Pool, South Taiwan	-21.2	
	Wang & Yeh 2003	*H. opuntia*	Tidal Pool, South Taiwan	-19.7	
Unknown sp.	Kelly 2012		Palmyra Atoll	-10.75	7.02

Valonia	Kelly 2012		Palmyra Atoll	-11.82		8.06	
	Kelly 2012		Palmyra Atoll	-16.84		8.82	
	Raven et al. 2002	*V. clavata*	Gran Canaria	-14.83			
Phaeophyta				-11.52	4.89	7.14	3.00
Acathophora	Kelly 2012		Palmyra Atoll	12.50		8.58	
	Lin & Fong 2008	*A. spicifera*	Nearshore reef, Opunohu Bay, Moorea			6	
	Wang & Yeh	*A. spicifera*	Upper-tidal pool, East Taiwan	-13.9			
Dotyophycus	Kelly 2012		Palmyra Atoll	-7.96		8.86	

Prey Group	**Source**	**Species**	**Sampling Location**	δ13C (‰)	**± SD**	δ15N (‰)	**± SD**
Dictyota	Lepoint et al. 2000	*Dictyota spp.*	Gulf of Calvi, Corsica	-17.4		3.6	
	Umezawa et al. 2002	*Dictyota spp.*	Offshore Reef, Ishigaki Island, Japan			2	
	Umezawa et al. 2002	*Dictyota spp.*	Nearshore Reef, Ishigaki Island, Japan			8	
	Newell et al. 1995	*D. dicotoma*	Peninsular Malaysia	-19.94		10.36	

	Raven et al. 2002	*D. cervicornus*	Stetson, GOM	-15.06	
	Raven et al. 2002	*D. dichotoma*	N of Oban, Scotland	-18.43	
	Raven et al. 2002	*D. dichotoma*	N of Oban, Scotland	-19.68	
	Raven et al. 2002	*D. dichotoma*	Filey, England	-13.06	
	Raven et al. 2002	*D. dichotoma*	Finnoy, Norway	-12.06	
	Raven et al. 2002	*D. menstrualis*	W Flower Gardens, GOM	-11.06	
	Raven et al. 2002	*D. menstrualis*	Stetson, GOM	-10.06	
	Raven et al. 2002	*D. menstrualis*	Stetson, GOM	-9.06	
	Raven et al. 2002	*D. menstrualis*	Stetson, GOM	-8.06	
	Raven et al. 2002	*D. pfaffi*	Stetson, GOM	-7.06	
	Raven et al. 2002	*D. pfaffi*	E Flower Garden, GOM	-6.06	
	Raven et al. 2002	*D. pulchella*	Stetson, GOM	-5.06	
	Raven et al. 2002	*D. menstrualis*	E Flower Garden, GOM	-4.06	
Dotyophycus	Kelly 2012		Palmyra Atoll	-7.96	8.66
Turbinaria	Kelly 2012		Palmyra Atoll	-8.46	9.70

Rhodophyta				-17.72	5.34	6.84	1.18
Asparagopsis	Kelly 2012		Palmyra Atoll	-17.09		7.96	
	Raven et al. 2002	*A. armata*	Stricland Bay, WA, Austrailia	-29.71			
	Raven et al. 2002	*A. armata*	Stricland Bay, WA, Austrailia	-29.55			
	Raven et al. 2002	*A. taxixformis*	Catalina Island, CA	-28			

Prey Group	**Source**	**Species**	**Sampling Location**	δ^{13}C (‰)	**± SD**	δ^{15}N (‰)	**± SD**
Ceramium	Kelly 2012		Palmyra Atoll	-15.67			
	Kelly 2012		Palmyra Atoll	-14.57			
	Kelly 2012		Palmyra Atoll	-8.91			
	Kelly 2012		Palmyra Atoll	-8.68			
	Maberly et al. 1992	*C. rubrum*	Rockpool, East Coast Scotland	-13.09		7.47	
	Maberly et al. 1992	*C. rubrum*	Tentsmuir drift, East Coast Scotland	-19.56		3.8	
	Raven et al. 2002	*C. rubrum*	Bergen, Norway	-18.29		3.1	

	Raven et al. 2002	*C. shuttleworthianum*	Bergen Store Kalsoy, Norway	-19.26	4.8
	Raven et al. 2002	*C. shuttleworthianum*	Flamborough England	-19.13	
Galaxaura	Kelly 2012		Palmyra Atoll	-11.34	7.77
	Wang & Yeh 2003	*G. marginata*	Tidal pool, East Taiwan	-16.2	
	Kelly 2012		Palmyra Atoll	-10.58	7.80
	Kelly 2012		Palmyra Atoll	-16.40	6.43
	Raven et. al 2002	*Gelidiopsis sp.*	Stetson, GOM	-19.68	
	Kelly 2012		Palmyra Atoll	-15.22	6.34
	Kelly 2012		Palmyra Atoll	-17.4	5.63
	Dailer et al. 2010	*H. musciformis*	Kahana, West Maui		6.6
	Dailer et al. 2010	*H. musciformis*	South Maui		6.8
	Hyndes & Lavery 2005	*Hypnea sp A*	SW Australia	-19.8	6.8
	Hyndes & Lavery 2005	*Hypnea sp B*	SW Australia	-19.6	5.4

	Raven et al. 2002	*H. volubilis*	Stetson, GOM	-19.42			
	Raven et al. 2002	*H. volubilis*	Stetson, GOM	-21.09			
	Raven et. al 2002	*H. volubilis*	E Flower Garden, GOM	-18.56			
	Raven et al. 2002	*Hypnea sp.*	Gran Canaria	-21.75			

Prey Group	**Source**	**Species**	**Sampling Location**	δ13C (‰)	**± SD**	δ15N (‰)	**± SD**
	Wang & Yeh 2003	*H. spinella*	Sublittoral, North Taiwan	-19.8			
	Wang & Yeh 2003	*H. japonica*	Sublittoral, North Taiwan	-21.2			
Jania	Kelly 2012		Palmyra Atoll	-7.49		7.53	
	Raven et al. 2002	*J. micrathandia*	Rottnest Island, WA, Australia	-22.55			
	Raven et. al 2002	*J. rubeus*	S Coast of Devon, UK	-12.57			
Spirulina	Kelly 2012		Palmyra Atoll				
Spyridia	Kelly 2012		T.H.				
Gelidium	Kang et al. 2008	*G. amansii*	Samchoek Coast, Korea	-16.8		4.7	

	Raven et. al 2002	*G. latifolium*	Bergen Store Kalsoy, Norway	-15.86			
Invertebrate				-11.69	5.22	9.52	0.29
Black Sponge	Kelly 2012	*Gelidiopsis sp.*	Palmyra Atoll	-4.29		9.39	
	Kelly 2012		Palmyra Atoll	-15.89		9.19	
Clay Colored Sponge	Kelly 2012		Palmyra Atoll	-8.96		9.72	
Orange Sponge	Kelly 2012		Palmyra Atoll	-16.56		9.23	
Purple Tunicates	Kelly 2012		Palmyra Atoll	-8.90		9.87	
Red Tunicates/ Sponge	Kelly 2012		Palmyra Atoll	-15.55		9.74	

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