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## Ecology and Conservation of Green Turtles in the Nearshore Waters of Waikiki Beach

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The Hawaiian green turtle, *Chelonia mydas*, has been listed and protected under the U.S. Endangered Species Act since 1978. Equivalent legal protection is also afforded by the State of Hawai'i. Selected nearshore foraging and resting habitats in the main Hawaiian Islands have been a focus of research on this species. On O'ahu, sites such as Kane'ohe Bay, Kawela Bay, Maunaloa Bay, and West Beach are among the important areas used by green turtles for such purposes (Balazs et al. 1987, Balazs and Pooley 1991). Additionally, in recent years, an area has been identified off Waikiki Beach where prominent sightings of turtles occur on a daily basis. The area fronts the Sheraton Waikiki Hotel (21°16'48"N, 157°49'59"W) and is unique because of the number of tourists swimming, snorkeling, and even sunbathing on air mattresses while the turtles swim and feed around them. In the past, Waikiki has not been a haven for sea turtles, although occasionally they were reported there. It would appear that only in the past 3-5 years has the number of turtles off Waikiki increased and their presence become more visible.

An effort was made in the present study to better define the ecology and conservation status of the aggregation of turtles fronting the hotel. Research was undertaken to gather basic information on several important aspects, including the environmental characteristics of the habitats used by the turtles for feeding and underwater resting, the approximate number of turtles present and their size classes, the daily feeding patterns and food sources, and any adverse impacts to the turtles, both from humans as well as from natural factors such as disease and shark predation.

A recovery plan to promote the biological recovery and long-term conservation of green turtles in the Hawaiian Islands has been prepared (NMFS 1992). The work that was undertaken off Waikiki is consistent with several recommendations for field research

contained in the recovery plan.

### Methods

Between October 1990 and August 1991, 20 underwater surveys were conducted to determine the environmental characteristics of the study area, including foraging sites and resting habitats. This was accomplished by snorkeling in and around the general area where the turtles were seen. Visual surveys were conducted from the shoreline to observe (1) turtles foraging and (2) the characteristics of the nearshore and intertidal habitats. In addition, the study site was observed from the upper floors (usually a room on the 12th floor) of the hotel, providing an ideal vantage point for sighting and censusing turtles.

Capture methods consisted of (1) entrapment in large mesh nets previously used to safely sample turtles at other sites in Hawai'i and (2) capture by hand while skin diving. Once a turtle was captured it was tagged for long-term identification. Two different tags were used—a highly visible blue plastic tag and a tag made of the highly corrosion resistant alloy, Inconel. Two or three tags were applied to each turtle, depending on the size of the animal. Tagging sites consisted of the trailing edges of the front and rear flippers. Besides tagging, painted letters were applied to each turtle's carapace to facilitate short-term recognition from a distance.

Body measurements and weight were recorded for each turtle. Measurements included straight-line and curved carapace length, straight-line and curved carapace width, and straight-line plastron length. Other measurements included head width, right front flipper width, and tail length.

Food sources were determined by sampling the turtle's mouth shortly after capture, or by gently inserting a plastic tube lubricated with vegetable oil into the esophagus to the upper portion of the fore-stomach (crop). Seawater was then infused at a low pressure

to flush food particles for collection and identification (Balazs 1980; in press).

### Results

#### Environmental setting

Waikiki Beach is located on the south shore of the Island of O'ahu and extends from the Ala Wai Yacht Harbor to Diamond Head, a distance of about 3 km. It is, undoubtedly, the most visited beach in all the Hawaiian Islands and ranks among the best recognized tourist destinations worldwide. The number of beachgoers on any given day can reach into the thousands. One of two main areas, where tagging occurred, fronts the Sheraton Waikiki Hotel. This site is divided by an old seawall that extends seaward for about 30 m and curves toward Diamond Head, parallel to shore, for 20 m. This seawall was used in our capture efforts as a barrier to trap turtles by rapidly swimming out a net to form an enclosure while a turtle was seen feeding. Both sides of the seawall close to shore are shallow with a depth of 1-2 m. The majority of the bottom here consists of sand with some hard calcareous substrate. Patches of vertical reef start approximately where the seawall starts to curve.

A second site discovered during the course of the study that became a focus for tagging is located at 21°16'35"N, 157°49'35"W in water 3 m deep about 300 m off the Kapahulu seawall. The Kapahulu seawall is located 600 m east of the Sheraton Waikiki. This site, designated in our work as "Grace's Ledge," was ideal for hand capturing turtles frequently found resting in the recess of this limestone structure. Three other smaller recesses a short distance away were found to be used occasionally by turtles for resting.

On five occasions, surveys were made along the intertidal shoreline of Waikiki to look for fecal pellets. No pellets were encountered. This was considered an important find-

Table 1.—Body measurements and weights of 15 green turtles captured off Waikiki Beach.

Primary tag No.	Date and site	Carapace length (cm)		Plastron length (cm)	Weight (kg)
		Straight	Curved		
N840	4-26-91 (S)	37.6	39.5	31.2	7.7
N844	4-26-91 (S)	42.0	45.0	33.5	10.9
N535	11-15-90 (G)	42.5	45.5	34.5	12.3
N842	4-26-91 (S)	42.9	46.0	33.8	10.9
N776	3-28-91 (G)	43.2	46.5	33.7	12.7
N573	12-20-90 (N)	43.7	47.0	34.7	13.6
N741	3-15-91 (S)	44.7	47.0	35.3	15.0
N778	3-29-91 (G)	48.9	53.0	40.2	16.4
N570	12-14-90 (G)	49.5	53.0	40.7	20.5
N691	3-1-91 (S)	49.9	53.3	39.7	21.4
N781	3-29-91 (G)	60.1	63.5	47.1	28.6
Y47	12-14-90 (G)	61.2	65.0	49.9	35.5
N793	4-5-91 (S)	61.3	65.2	49.5	32.7
N744	3-15-91 (S)	69.3	74.0	56.1	51.4
N796	4-5-91 (S)	80.7	86.2	64.4	81.8

Table 2.—Identification of dietary components flushed from four green turtles captured off Waikiki Beach.

Primary tag No./ study site/date	Straight carapace length (cm)	Sample contents	%
			Composition
N691-Sheraton Waikiki 3-1-91	49.9	<i>Spyridia filamentosa</i>	30
		<i>Gelidium pusillum</i>	30
		<i>Laurencia nidifica</i>	20
		<i>Dictyota friabilis</i>	10
		<i>Ulva fasciata</i>	10
		<i>Lyngbya</i> sp.	Trace
		<i>Ceramium</i> sp.	Trace
N741-Sheraton Waikiki 3-15-91	47.7	<i>Pterocladia capillacea</i>	80
		<i>Hypnea musciformis</i>	15
		<i>Acanthophora spicifera</i>	5
		<i>Ectocarpus indicus</i>	Trace
		<i>Sargassum</i> sp.	Trace
N844-Sheraton Waikiki 4-26-91	42.0	<i>Hypnea musciformis</i>	45
		<i>Sargassum</i> sp.	30
		<i>Ulva reticulata</i>	15
		Paper	10
		<i>Ectocarpus indicus</i>	Trace
N776-Grace's Ledge 3-28-91	43.2	<i>Ulva fasciata</i>	100
		Terrestrial plant material	Trace
		Amphipods (commensural)	Trace
		Unidentified spine	Trace

ing because of the large number of beach users and the potential for negative public reaction if large numbers washed ashore (Balazs et al. 1990).

#### Ecological aspects of turtles captured

Netting efforts conducted on six occasions in front of the Sheraton Waikiki Hotel resulted in eight turtles being captured (Table 1). Six of the turtles were caught on the Sheraton (west) side of the seawall, and two were caught on the Diamond Head (east) side bordering the Royal Hawaiian Hotel. All netting attempts were conducted in the late afternoon because the number of turtles observed from the hotel room was consistently greater at that time of day. Six turtles were hand captured at Grace's Ledge (one turtle was caught twice), and one was caught in front of the Waikiki Natatorium. All turtles were captured during the day as nighttime efforts were not attempted. The straight carapace lengths of the 15 turtles captured ranged from 37.6-80.7 cm. Their weights ranged from 8-82 kg (Table 1). The largest turtle, the only adult captured, was determined to be a maturing male on the basis of its long, thick tail.

Stomach samples collected from four of the turtles resulted in the identification of several species of benthic algae (Table 2). Two of the three turtles captured in front of the Sheraton Waikiki contained *Hypnea musciformis*, a red alga introduced to the Hawaiian Islands from Florida in 1974 (Abbott 1987, Russell and Balazs, in prep.). One of the turtles at Grace's Ledge sampled for stomach contents was found to have been feeding exclusively on the green alga, *Ulva fasciata*. *Ulva fasciata* and *U. reticulata* were both highly visible species at the Sheraton Waikiki study site. Various other algae and related samples shown in Table 3 were identified from the external surfaces of the turtles.

Over the 10 months of this study, three turtles were found dead along Waikiki Beach. Two of these turtles died from obvious boat propeller slashes. The third turtle (tag N535), which was the first turtle tagged at Grace's Ledge, died from entanglement and forced submergence in a fisherman's gillnet. Identification of the stomach contents of the three turtles revealed that considerable foraging had taken place on *H. musciformis*, *Ulva* spp., *Codium* spp., and *Pterocladia capillacea* (Table 4).

Eight of the 15 turtles captured showed some evidence of external injury or abnormality, although in most instances they were minor. One turtle (tag N535) had obvious

healed puncture marks from a threeprong (Hawaiian sling) spear on its head.

One of the turtles captured at Grace's Ledge (tag Y47) had been originally tagged in December 1989 after being found entangled in a fisherman's gillnet set in shallow water off the Kapahulu seawall. A Waikiki life-guard rescued the turtle and turned it in to the Waikiki Aquarium. A few days later the turtle was tagged and transported for release by one of us (GHB) to Kawaikui Beach Park, about 8 km east of Waikiki on O'ahu's south shore. During the one year period following its release the turtle grew 3.6 cm in straight carapace length. This same turtle was recaptured a second time (again at Grace's Ledge) after 4 more months in the wild. The growth during this period was 1.2 cm in straight carapace length. These rates are relatively rapid compared to turtles residing at other sites thus far studied in the Hawaiian Islands (Balazs 1982).

Submergence intervals (breath-hold times) were recorded on two turtles that were meticulously observed from a room at the Sheraton Waikiki Hotel. Both turtles were foraging during this period. Their average submergence times were relatively short (1 min 46 sec, and 2 min 11 sec). Submergence times ranged from 35 sec to 3 min 30 sec (n = 32).

#### Foraging habitat appraisal

Surveys conducted from shore and underwater demonstrated an abundance of various algae in the nearshore waters fronting the hotel. Algae that were highly abundant included *U. reticulata* and *U. fasciata*. An assortment of detached algae was also seen along the sand bottom adjacent to the seawall. Loose algae collected were identified as *Codium* spp., *Sargassum* spp., and *H. musciformis*.

The number and frequency of turtles sighted from shore were always greater during late afternoon to early evening than in the morning and early afternoon. Also, the number of turtles sighted was greater during these times when high tides occurred.

Underwater surveys taken at Grace's Ledge indicated that there were no foraging habitats in the immediate vicinity.

#### Resting habitat appraisal

Hawaiian green turtles spend most of their time foraging, resting on the bottom, and swimming to the surface to breathe. The turtles' resting periods are often spent at the bottom in or near caves, reef outcroppings,

Table 3.—Identification of samples scraped from the external surfaces of three green turtles off Waikiki Beach.

Primary tag No./ study site	Straight carapace length (cm)	Sample contents	% Composition
N741-Sheraton Waikiki 3-15-91	44.7	<i>Sphacelaria furcigera</i>	90
		<i>Achrochaetium</i> sp.	10
		<i>Chaetomorpha gracilis</i>	Trace
		<i>Lyngbya</i> sp.	Trace
		Round worm	
N744-Sheraton Waikiki 3-15-91	69.3	5 <i>Ozobranchus branchiatus</i> on front flipper	
Y47-Grace's Ledge 12-14-90	62.4	1 <i>O. branchiatus</i> in mouth	

ledges, or crevices. Two important resting locations were discovered in this study—Grace's Ledge and a site known as Canyons. Canyons is located about 400 m off Fort DeRussy in Waikiki, in water 10 m deep at 21°16'38"N, 157°50'32"W. This site was brought to our attention by personnel of the vessel Explorer operated by Atlantis Reef Divers. The Explorer visits this site daily to conduct scuba diving with tourists and other

clients. In addition to resting motionless on the bottom, turtles have been seen at this location being "cleaned" by surgeon fish and wrasses. Additional studies are needed for a better understanding of the significance of this behavior and what factors contribute to the establishment of discrete cleaning stations.

John Wilson, a video specialist and professional diver on the Explorer, reported the

Table 4.—Identification of dietary components from three green turtles found dead on Waikiki Beach.

Primary tag No./ cause/date	Straight carapace length (cm)	Sample contents	% Composition
Propeller slashes 10-9-90	53.0	<i>Ulva reticulata</i>	90
		<i>Acanthophora spicifera</i>	5
		<i>Amansia glomerata</i>	Trace
		<i>Champia parvula</i>	Trace
		<i>Gelidiella acerosa</i>	Trace
		<i>Gracilaria coronopifolia</i>	Trace
		<i>Lyngbya majuscula</i>	Trace
Z227 Gillnet mortality 12-17-90	42.5	<i>Hypnea musciformis</i>	30
		<i>Pterocladia capillacea</i>	30
		<i>Ulva reticulata</i>	25
		<i>Codium edule</i>	15
		<i>Acanthophora spicifera</i>	Trace
Propeller slashes 4-3-91	50.0	<i>Ulva fasciata</i>	50
		<i>Pterocladia capillacea</i>	40
		<i>Amansia glomerata</i>	10
		<i>Bryopsis pennata</i>	Trace
		<i>Polysiphonia howei</i>	Trace
		Cellophane	Trace
		Fishing line	Trace

underwater sighting of three tagged turtles at Canyons. Two of these turtles (tags N842 and N844) had been netted in front of the Sheraton Waikiki, and the other (tag N570) had been hand-captured at Grace's Ledge.

#### Adverse impacts to the population

Several potential and actual impacts to the turtles off Waikiki were identified in this study, in addition to the ones previously mentioned relating to boat collisions and gillnets. Plastics and other synthetic debris were commonly seen along the beach and in the nearshore waters. Buoyant litter of this nature can be ingested by or can entangle sea turtles and have harmful effects (Balazs 1985). One of the turtles (tag N844) sampled off the Sheraton Waikiki was found to have eaten paper (Table 2).

Disease and predation by sharks were not identified in this study as major factors. On one occasion, a turtle was observed with a section of its carapace missing, but healed. This may have resulted from impact by a boat, or from shark attack.

During the course of the study only one turtle was sighted with fibropapillomas (tumors). This turtle was seen at Canyons and documented on videotape by John Wilson as being in poor condition because of emaciation and numerous large tumors. The turtle was subsequently found dead—washed ashore at Magic Island near Ala Moana Beach Park, immediately west of Waikiki Beach. The prevalence of tumors on green turtles is substantially greater at several other locations on O'ahu and elsewhere throughout the Hawaiian Islands. For example, in Kane'ohe Bay an estimated 50% of the turtles are afflicted with this disease (Balazs and Pooley 1991).

Other potential adverse impacts from humans were discovered at Grace's Ledge during November 1990. An illegal mooring buoy was found attached to the ledge by a chain and rope, immediately over the turtle resting site. Three possible consequences could have resulted from this mooring had it not been reported to authorities and subsequently removed. First, the mooring line could have entangled a turtle, causing it to drown. Secondly, power boats using the mooring increased the likelihood of collision with a turtle. And lastly, the buoy served to "mark" the ledge thereby attracting visitors to it and increasing the level of disturbance.

#### Conclusions

During this 10-month study 15 turtles were captured, tagged, and released off

Waikiki Beach. Only one species, the green turtle, was encountered. Green turtles feed in shallow waters within 100 m of shore, and were commonly seen engaged in this activity in front of the Sheraton Waikiki. Food sources utilized off Waikiki Beach consisted primarily of the benthic algae *U. fasciata*, *U. reticulata*, *H. musciformis*, *P. capillacea*, *Spyridia filamentosa*, and *Gelidium pusillum*. Sizes of the turtles tagged ranged from 37.6 cm (8 kg) to 80.7 cm (82 kg). Resting habitats for turtles were identified at Grace's Ledge off the Kapahulu seawall and at Canyons off Fort DeRussy. None of the turtles tagged and released had signs of disease, although one turtle was seen with fibropapillomas, and subsequent to this study a few others with the disease have been reported in the area. The findings from this study lead to the tentative conclusion that the green turtle population off Waikiki Beach is relatively large (perhaps > 100 individuals), and in a generally healthy condition. However, adverse impacts especially from gillnet fishing and boat traffic are causes for concern that should be addressed. Efforts need to be made to enhance the protection of these turtles and the habitats upon which they depend. The educational and ecotourism aspects of viewing turtles in a benign fashion, from both above and below the water, should be promoted wherever possible.

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