

DIEL MOVEMENT PATTERNS OF GREEN TURTLES (*CHELONIA MYDAS*) AT KIHOLO BAY, HAWAII

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ABSTRACT

The diel movement patterns of two green turtles were studied at Kiholo Bay, Hawaii, over a period of 7 months with the use of sonic tags. The data indicate that the turtles spent the nighttime hours in the protected lagoon (Wainanali`i Pond). They entered the lagoon from the bay by 1800 hrs. each evening. They usually left the lagoon for the bay each morning by 0659 hrs. In the early morning hours they typically fed on benthic algae in the shallows of the bay. The turtles spent from 35% to 80% of the daylight hours in the bay, with the remainder of the time spent in the lagoon. Two green turtles which were fitted with sonic tags and translocated to Puako, Hawaii, 7.92 nautical miles north of Kiholo, returned to Kiholo within two months of their release. Because of the unique and specific diel movement patterns of the study animals and the site fidelity demonstrated by the translocated turtles, the Kiholo Bay area takes on added importance as a sea turtle habitat.

PROBLEM STATEMENT

Hawaiian green turtles (*Chelonia mydas*) are residents of coastal waters for much of their lives. Their daily movement patterns have not been studied extensively and are not well known. In an effort to better understand these patterns, a study was done involving the long-term tracking of tagged turtles at Kiholo Bay, Hawaii.

LITERATURE REVIEW

Kiholo Bay, located on the west coast of the Big Island (Figure 1), is the study site. The bay is located at 19°51.681'N latitude and 155°55.441'W longitude and stretches for two miles along the leeward coast of the island. Wainanali`i is a brackish water lagoon that opens up to the bay through two shallow, sheltered channels. Located at the north end of Kiholo Bay, Wainanali`i lies between the 1859 lava flow from Mauna Loa and a sand and boulder peninsula a quarter of a mile in length (Clark 1985). Due to the various underground freshwater springs there is a layer of fresh water that sits on the top of the lagoon. There are several black sand and pebble beaches on the coast of the bay.

The bay and the pond are important feeding and sleeping sites for juvenile Hawaiian green turtles. The endangered *Eretmochelys imbricata* (Hawksbill turtle) has also been captured and tagged at Kiholo since 1987 in a cooperative study by the National Marine Fisheries Service and the Hawaii Preparatory Academy. Both of these turtles are protected by the U.S. Endangered Species Act and Wildlife Laws of the State of Hawaii. Unfortunately, net fishing occurs at Kiholo. We observed several turtles temporarily caught in a net, and there have been reports of turtle deaths resulting from net fishing. An apparently butchered green turtle's carapace and plastron were found on 1/11/93 in Wainanali`i lagoon, indicating that illegal poaching is occurring at the site.

Most Hawaiian green turtles hatch at French Frigate Shoals (FFS) in the Northwestern Hawaiian Islands. The hatchlings swim out to sea and spend the first couple of years in the open ocean and move inshore to coastal areas of the main islands when they are approximately 35 cm in length (Balazs 1980). It is believed that turtles navigate through some or all of the following

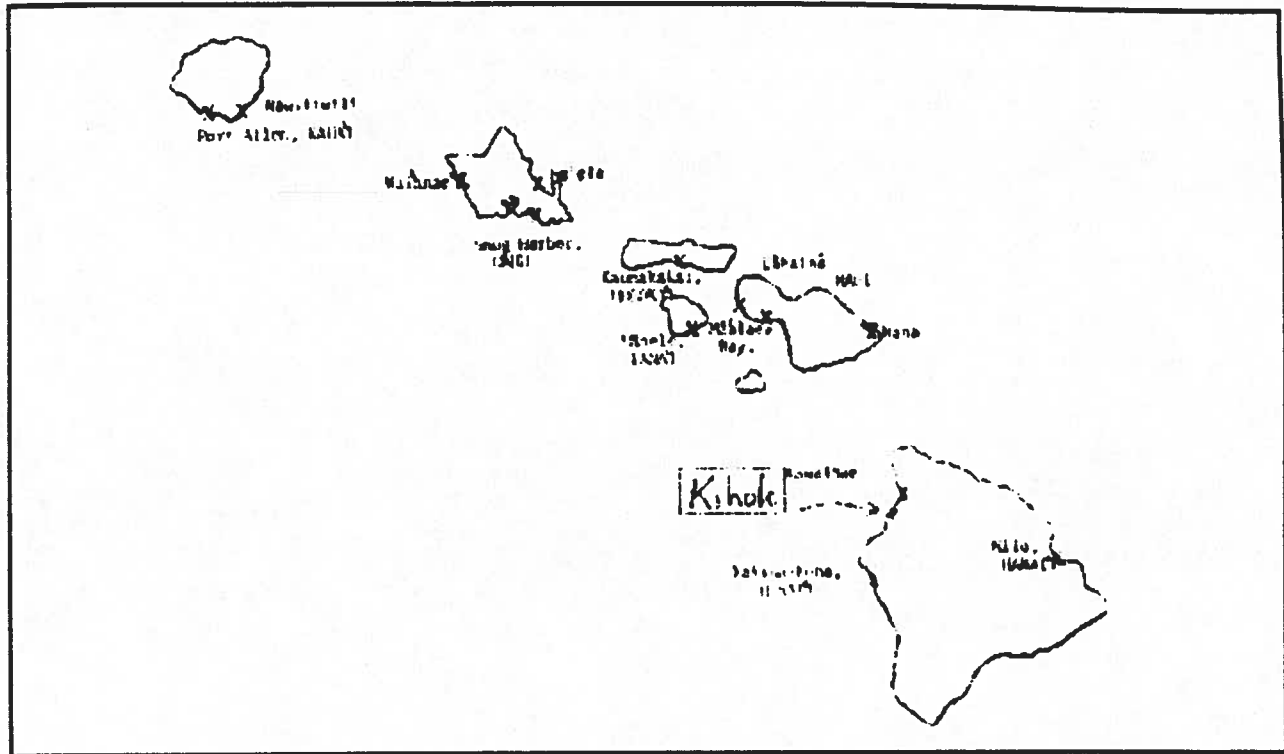


Figure 1. Map of the main Hawaiian Islands showing the approximate location of Kiholo Bay, Hawaii.

senses: magnetic, inertial guidance, Coriolis force, wave action, currents, olfactory cues (Balazs 1980), and chemosensory (Lohmann 1992). When mature, the females migrate to FFS approximately once every two years and the males do so once a year to reproduce. The life span of sea turtles is unknown; however, it has been observed that from the size of 35 cm in length, *Chelonia mydas* may take 11-59 years to reach maturity, depending on their resident foraging areas. The sea turtles spend the majority of their lives in these coastal areas, where they feed and rest. Feeding occurs primarily at high tides where the ocean is not more than 10 m deep and is frequently less than 3 m deep (Balazs 1980). The principal food of *Chelonia mydas* is marine benthic algae (Balazs 1980), which is present at Kiholo.

Information concerning the daily movements and habitat use of *Chelonia mydas* is pertinent to developing conservation programs for this threatened species and its habitat. Individuals have been tracked with the use of sonic tags in San Diego Bay on a daily basis. The study site was the effluent channel of San Diego Gas and Electric Power Company's plant at Chula Vista. The power plant was thermally polluting the water in the effluent channel, causing it to be 2.8° C warmer than the San Diego Bay. McDonald and Dutton recorded the daily movement of green turtles throughout the bay and channel. The turtles moved into the effluent channel when bay temperatures dropped, and they moved out of the effluent channel when the temperature exceeded 32.3° C in the summer. The data recorded illustrated that the turtles tended to spend a period of 3 hours or longer in one place. McDonald and Dutton concluded that the turtles move in and out of the channel depending on the bay and channel temperatures (McDonald and Dutton 1992). This study and others indicate that green turtles tend to follow fairly regular behavior patterns and show long-term site fidelity (Morrow and Buelha 1983; Marc Rice, Per. Com).

Various techniques for tracking the movement of sea turtles have been used. These include flipper tags, Radio Telemetry (Dizon and Balazs 1982), satellite tracking, sonic transmitters

(McDonald and Dutton 1992), Passive Integrated Transponder (PIT), and ultrasonic depth sensitive transmitters (Balazs, unpublished).

We tracked *Chelonia mydas* with sonic tags in Kiholo Bay to determine if the turtles followed a daily routine in their movements and behavior. If turtles at Kiholo Bay utilize the north end of the bay and Wainanali`i lagoon exclusively as a home range, this site takes on added importance as a turtle habitat and should be protected.

METHODS AND MATERIALS

Methods of study included tracking turtles with sonic equipment. A total of four turtles captured on two separate occasions were sonically tagged. The turtles were hand captured at night by snorkelers in Wainanali`i lagoon. The chosen turtles were previously tagged with flipper tags, so they had a known history at Kiholo Bay (Table 1). The turtles were tagged with Sonotronic™ high-power tags (CHP-87-L). The transmitters measured 100 mm in length, 18 mm in diameter, and weighed 12 grams. The transmitters were attached to the shell over the rear flipper on the marginal scutes by drilling two small holes through the scute edge to fasten the transmitter with monel wire and monofilament line. Elastomer putty was used as a bed to place the transmitters on. The frequency of the tags ranged from 71 to 79 KHz. Various pulse codes identified the transmitting tags (348, 357, 366, and 375). Before attachment the transmitters were tested. The pulse signals from the sonic transmitters are received by a Sonotronic™ DH-2 directional hydrophone and a Sonotronic™ ultrasonic receiver USR-4D. All turtle capturing, tagging, handling and transmitter attachment was conducted under the direct professional supervision of George Balazs.

Table 1. Tag and historical information for sonic tagged green turtles at Kiholo Bay, HI. (Data compiled and provided by George H. Balazs, Southwest Fisheries Center Honolulu Laboratory, National Marine Fisheries Service)

Key

LFL-Left Front Flipper
RFL-Right Front Flipper
LHF-Left Hind Flipper
RHF-Right Hind Flipper
PIT-Passive Integrated Transponder

Sonic Tag # 348 attached to green turtle which was released at 1144 hours, 2/12/93.

Tag information:

<u>Tag Number</u>	<u>Date Tagged</u>	<u>Tag Type</u>	<u>Tag Position</u>
H282	04/22/92	I681	LFL
H283	04/22/92	I681	RFL

Historical information:

<u>Date</u>	<u>Type of Encounter</u>	<u>Straight Carapace Location</u>	<u>Length(cm)</u>
04/22/92	Near shore	Kiholo, HI	42.0
02/12/93	Near shore	Kiholo, HI	43.7

Table 1 (continued)

Sonic Tag #357 attached to green turtle which was released at 1329 hours, 2/12/93.

Tag information:

<u>Tag Number</u>	<u>Date Tagged</u>	<u>Tag Type</u>	<u>Tag Position</u>
3483	10/16/80	I681	RFL
3484	10/16/80	I681	L12
Y702	10/24/90	I681	R34
Y703	10/24/90	I681	LHF

Historical information:

<u>Date</u>	<u>Type of Encounter</u>	<u>Straight Carapace Location</u>	<u>Length(cm)</u>
10/16/80	Near Shore	Kiholo, HI	39.6
10/24/90	Near Shore	Kiholo, HI	57.1
1/13/92	Near Shore	Kiholo, HI	59.2
4/22/92	Near Shore	Kiholo, HI	59.7
2/12/93	Near Shore	Kiholo, HI	60.9

Sonic Tag #366 attached to green turtle which was released at Puako, HI on 4/7/93 at 1327 hrs.

Tag information:

<u>Tag Number</u>	<u>Date Tagged</u>	<u>Tag Type</u>	<u>Tag Position</u>
8903	2/11/88	I681	R34
8904	2/11/88	I681	LFL
H15	1/13/93	I681	RHF
7D230705	2/12/93	PIT	PIT

Historical information:

<u>Date</u>	<u>Type of Encounter</u>	<u>Straight Carapace Location</u>	<u>Length(cm)</u>
2/11/88	Near Shore	Kiholo, HI	39.1
10/26/88	Near Shore	Kiholo, HI	40.3
3/1/89	Near Shore	Kiholo, HI	41.0
5/4/89	Near Shore	Kiholo, HI	41.6
10/19/89	Near Shore	Kiholo, HI	43.5
4/25/90	Near Shore	Kiholo, HI	44.4
3/4/91	Near Shore	Kiholo, HI	45.4
1/13/92	Near Shore	Kiholo, HI	45.6
2/12/93	Near Shore	Kiholo, HI	47.2
4/6/93	Near Shore	Kiholo, HI	47.5

Table 1 (continued)

Sonic Tag #375 attached to green turtle which was released at Puako, HI on 4/7/93 at 1325 hours.

Tag information:

<u>Tag Number</u>	<u>Date Tagged</u>	<u>Tag Type</u>	<u>Tag Position</u>
Y105	3/1/89	I681	LFL
Y106	3/1/89	I681	RFL
R786	2/12/93	I681	RHF
7F49 1 C28	2/12/93	PIT	PIT

Historical information:

<u>Date</u>	<u>Type of Encounter</u>	<u>Straight Carapace Location</u>	<u>Length(cm)</u>
3/1/89	Near Shore	Kiholo, HI	46.0
5/3/89	Near Shore	Kiholo, HI	46.6
10/19/90	Near Shore	Kiholo, HI	47.9
10/24/90	Near Shore	Kiholo, HI	50.3
4/21/92	Near Shore	Kiholo, HI	53.7
2/12/93	Near Shore	Kiholo, HI	55.1
4/6/93	Near Shore	Kiholo, HI	55.5

During excursions to Kiholo Bay we monitored the turtles for periods up to 48 hours over a period of seven months (Table 2). Tracking was carried out from a double kayak and a thirteen foot Boston Whaler with a 25 horsepower outboard engine. By rotating the directional hydrophone we estimated the location of the turtles. On a sector map of Kiholo Bay (Figure 2) we recorded the bay sector the turtle was thought to be occupying. We collected data on nineteen separate dates. For each turtle we sorted the data by time. For each hour there were 1-8 data entries. This data was converted into percentages of occurrence in the bay or lagoon.

Turtles with pulse codes 366 and 375 were transported to Puako at 19° 58.241' N latitude, 155° 50.792' W longitude on 4/7/93, which is 7.92 nautical miles from the capture site. Monitoring of these turtles occurred for two hours after release. This was done to observe the behavior of the turtles and to determine that the tags were functioning properly.

Table 2. Chronological list of observation periods at Kiholo Bay, Hawaii.

<u>DATE</u>	<u>OBSERVATION PERIOD</u>	<u>DATE</u>	<u>OBSERVATION PERIOD</u>
	<u>(HOURS)</u>		<u>(HOURS)</u>
2/12/93	1144-2400	4/28/93	1060-1133
2/13/93	0000-2400	5/07/93	1717-1747
2/14/93	0000-1027	6/02/93	1830-1940
3/05/93	1821-2400	6/28/93	1738-2222
3/06/93	0000-1115	6/29/93	0106-2141
3/24/93	0840-1500	6/30/93	0115-1054
4/06/93	1325-2400	9/14/93	1925-2000
4/07/93	0000-2400	9/16/93	2005-2235
4/08/93	0000-0930	9/17/93	0523-1613
4/11/93	0931-1140		

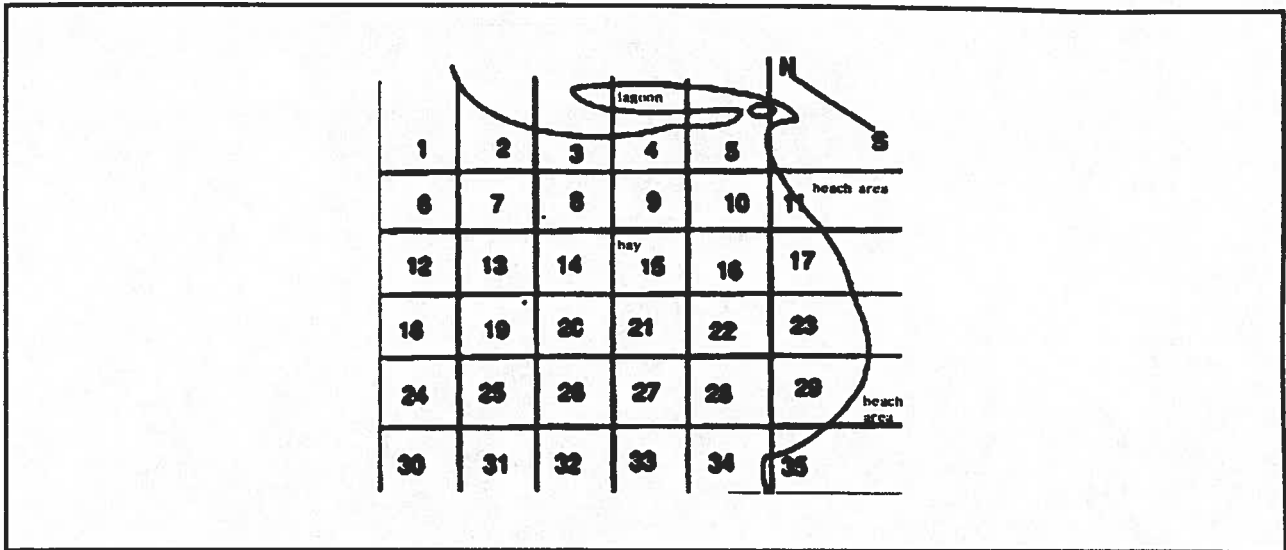


Figure 2. Sector map of Kiholo Bay and Wainanali'i Pond (lagoon) used to record the location of monitored turtles

RESULTS

After tagging the turtles on February 12, 1993, the turtles exhibited what may be unusual behavior for the two days following the tagging procedures. The turtles stayed in the lagoon for at least 48 hours straight, which seemed unusual when compared to data obtained on subsequent trips. During this period, the two sonic tagged turtles spent 100% of their time in the lagoon for a period of 48 hours and were still there when monitoring was terminated. This behavior is contrary to what we saw during the rest of the study. On 1/12/94 two more sonic tags were placed on turtles which were released in the lagoon at 1100 hrs. These turtles remained in the lagoon through the termination of monitoring some 24 hours later. Because of this unusual behavior, we have excluded the data gathered on 2/12, 2/13, and 2/14 from our discussion. This data is included in Figures 3 and 5.

The data collected shows that between 1600 hrs and 0559 hrs turtle 348 spent 100% of the time in the lagoon. Between 0600 hrs and 0659 hrs turtle 348 moved out of the lagoon and into the bay. By 1659 hrs turtle 348 returned to the lagoon. Turtle 348 spent 80% of the time in the bay during the daylight hours between 0600 hrs and 1559 hrs. During this time many turtles were observed feeding in the bay. It should be noted however that it was often difficult to determine the location of the tagged turtles in the bay because of sonic obstacles (rocks, coral heads, wave action, etc.).

Sonic contact with 348 was lost some time prior to 9/26/93. We did not recover the sonic tag for this turtle but this animal was recaptured on 1/11/94 and appeared to be robust and in good health. Another sonic tag was attached to 348. Figure 4 gives a graphical representation of the location of turtle 348 in the lagoon and the bay.

Turtle 357 spent 100% of the time in the lagoon between 1800 hrs and 0559 hrs. Turtle 357 moved out of the lagoon and into the bay between 0600 hrs and 0659 hrs. Turtle 357 returned by 1800 hrs to the lagoon. Turtle 357 spent 100% of the time in the lagoon from 1200 to 1459 hrs. Turtle 357 spent 35% of the time in the bay during the hours between 0600 hrs to 1859 hrs. Our data collection ended for 357 on 9/16/93 when we located the detached transmitter very close to the shore in about two feet of water between algae covered rocks. Figure 6 shows the daily movement patterns for 357 given as % occurrence in the bay or lagoon.

Table 3. Data summary of turtles #357 and #348 showing percent of time each turtle spent in the bay or in the lagoon over a 24-hour period. There are two sets of data for each turtle: one including the February data and one excluding the February data.

TIME	% LAGOON #357 without Feb. Data	% BAY #357 without Feb. Data	% LAGOON #357 with Feb. Data	% BAY #357 with Feb. Data	% LAGOON #348 without Feb. Data	% BAY #348 without Feb. Data	% LAGOON #348 with Feb. Data	% BAY #348 with Feb. Data
0000-0059	100	0	100	0	100	0	100	0
0100-0159	100	0	100	0	100	0	100	0
0200-0259	100	0	100	0	100	0	100	0
0300-0359	100	0	100	0	100	0	100	0
0400-0459	100	0	100	0	100	0	100	0
0500-0559	100	0	100	0	100	0	100	0
0600-0659	40	60	100	0	20	80	57	43
0700-0759	67	33	80	20	0	100	40	60
0800-0859	80	20	83	17	40	60	50	50
0900-0959	57	43	63	37	20	80	43	57
1000-1059	83	17	71	29	33	67	50	50
1100-1159	50	50	60	40	25	75	20	80
1200-1259	100	0	100	0	0	100	0	100
1300-1359	100	0	100	0	0	100	67	33
1400-1459	100	0	100	0	0	100	50	50
1500-1559	0	100	33	67	67	33	75	25
1600-1659	40	60	75	25	100	0	100	0
1700-1759	67	33	57	43	100	0	100	0
1800-1859	100	0	80	20	100	0	100	0
1900-1959	100	0	100	0	100	0	100	0
2000-2059	100	0	100	0	100	0	100	0
2100-2159	100	0	100	0	100	0	100	0
2200-2259	100	0	100	0	100	0	100	0
2300-2359	100	0	100	0	100	0	100	0

On two occasions, 4/11/93 and 5/07/93, the coast from Kiholo to Puako was monitored for turtles 366 and 375 but no pulse codes were heard. On 6/02/93 turtles 366 and 375 were located in the lagoon, nearly two months after being released at Puako. Turtle 366 was monitored regularly until 9/07/93 when we found the detached transmitter near shore, in sector 35 (Figure 2). Turtle 375 has not been located since 6/02/93.

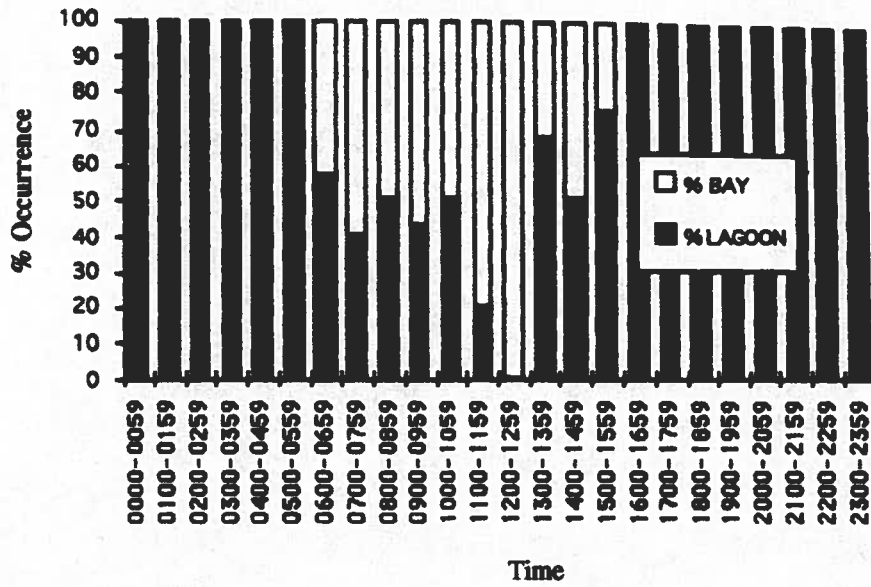


Figure 3. Diel site location (bay and lagoon) distribution of turtle number 348 (all data included). Distribution given as % occurrence per hour interval.

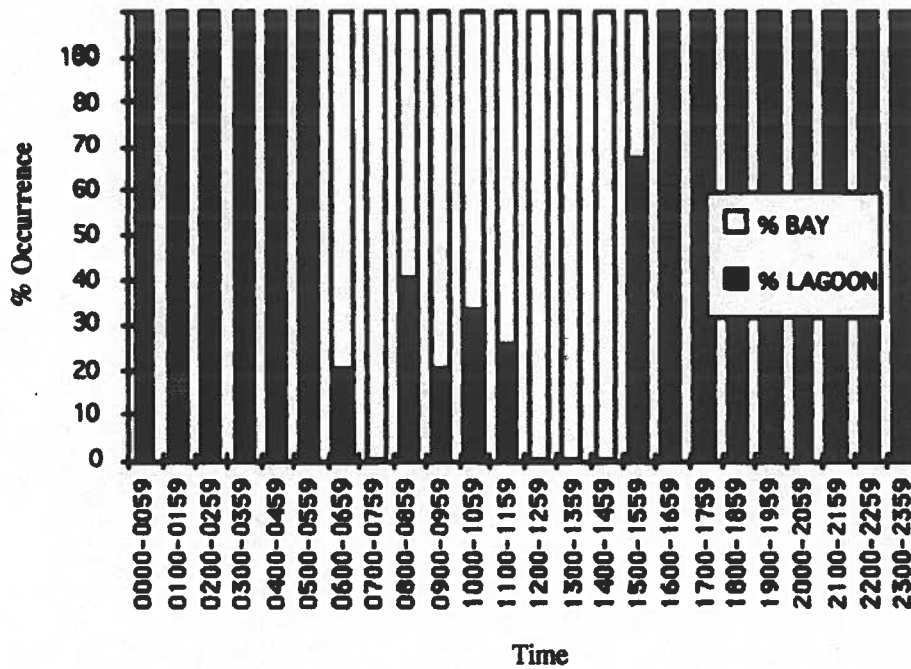


Figure 4. Diel location (bay and lagoon) distribution of turtle number 348 without data from February.

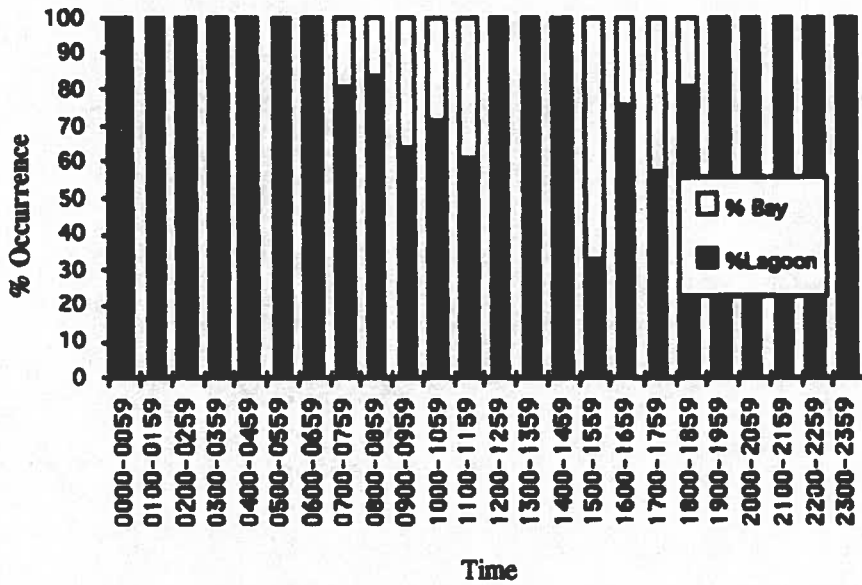


Figure 5. Diel location (bay and lagoon) distribution of turtle number 357 (all data included).

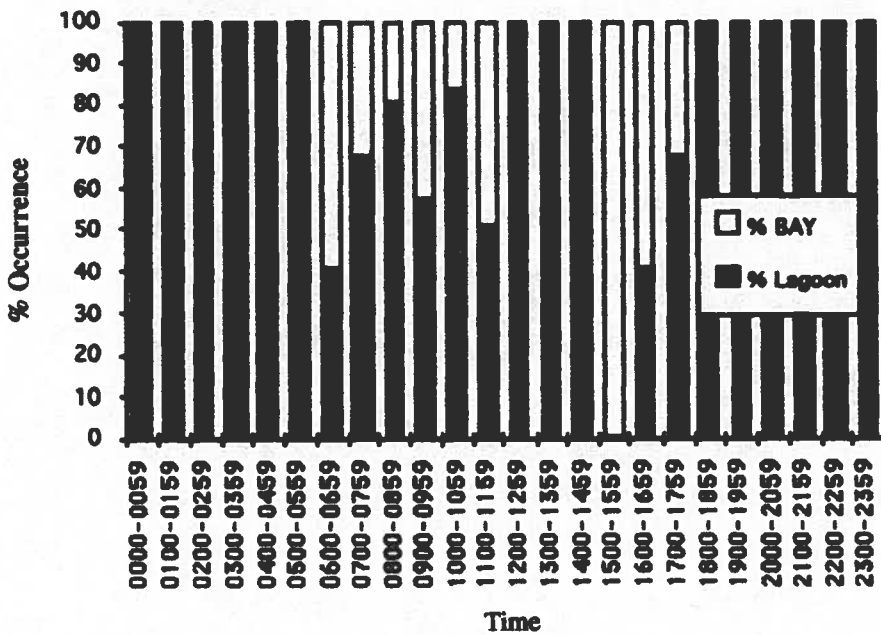


Figure 6. Diel location (bay and lagoon) distribution of turtle number 357 without data from February.

DISCUSSION AND CONCLUSION

Our data show that the turtles go into the lagoon in the evening to rest and move out of the lagoon early in the morning between the hours of 0500 and 0659. This implies that the turtles spend many of the daylight hours in the bay, presumably to feed. Our data collection spanned seven months in which the turtles could be located regularly. This shows that these turtles spend a large amount of their juvenile lives at Kiholo. In addition, the tag history shows that these turtles were "long time" residents of Kiholo (357 was first tagged at Kiholo in 1980). The fact that turtles 366 and 375 returned to Kiholo after translocation suggests that they are faithful to their resident foraging areas. Each turtle's pattern of behavior is unique. Wainanali`i lagoon and Kiholo Bay are used by the turtles as forage and resting sites. Because of the exclusive use of the resident foraging area and apparent long-term site fidelity, Kiholo Bay takes on added importance as a turtle habitat and should be protected from activities that negatively impact the turtles. Net fishing and boat traffic should be banned in the lagoon area to protect the juveniles so that the future generations are preserved and the area should be closely monitored to reduce poaching. At this time there is little human habitation in the area, but the future will undoubtedly see increased demand as a recreational resource.

BIBLIOGRAPHY

- Balazs, George H. 1980. Synopsis of Biological Data on the Green Turtle in the Hawaiian Islands. U.S. Dep. Commer., NOAA Tech Memo NMFS SWFC7.
- Clark, John R. K. 1985. *Beaches of the Big Island*. University of Hawaii Press.
- Dizon, Andrew and George H. Balazs. 1982. *Radio Telemetry of Hawaiian Green Turtle at Their Breeding Colony*. NMFS Review.
- Lohmann, Kenneth J. 1992. How Sea Turtles Navigate. *Scientific American*. Jan. 1992.
- McDonald, Donna, and Peter Dutton. 1992. Status of Sea Turtles in San Diego Bay. Report to U.S. Fish & Wildlife Service.
- Morrow, Robert J. and Elizabeth K. Buelna. 1985. *The Hawaiian Monk Seal and Green Turtle on Necker Island*. 1983. NOAA Technical Memorandum NMFS. NOAA-TM-NMFS-SWFC-55.
- Rice, Marc. 1994. Personal Communication.

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