Characterization Of Foraging and Internesting Habitat For Three Hawksbill Sea Turtles in Maui, HI

FINAL REPORT
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EXECUTIVE SUMMARY

The hawksbill sea turtle (*Eretmochelys imbricata*) is a pantropical species and critically endangered throughout its range. The hawksbill population in Hawai'i is further jeopardized because it is the most isolated in the world, having no known interchange with any other hawksbill populations (NMFS, 1998). There are less than 25-30 nesting females in the Hawaiian Islands population. Their entire nesting habitat, diet and feeding habits in Hawaiian waters are unknown, but preliminary information from a cooperative research project has shown that the nesting and feeding distribution of these turtles is apparently limited to beaches and coral reef habitat of the islands of Maui, Hawai'i, O'ahu and Moloka'i (Ellis et al., in press).

During the internesting interval, when sea turtles remain in the nearshore waters of their nesting habitat, they are especially vulnerable to anthropogenic disturbance (Meylan, 1984). On the positive side, although this species' situation is precarious, the recovery of the Hawai'i population is more likely than any other Pacific population because most of its life cycle occurs within Hawai'i State waters where protection and recovery is entirely possible if appropriate actions are taken now to protect its habitat (NMFS, 1998). Hawai'i Wildlife Fund (HWF) is beginning to address some of these critically important recovery actions for the endangered hawksbill sea turtle in Hawai'i, including the characterization of the coral reef habitat they utilize during resting and foraging.

This report identifies and characterizes the foraging and internesting habitat for three turtles that were tagged and instrumented after nesting events on the islands of Maui and Hawai'i from 1996-1998.

INTRODUCTION

The hawksbill sea turtle in Hawai'i is a member of the coral reef ecosystem, resting and foraging in waters less than 100 feet deep off Maui, Moloka'i, O'ahu and Hawai'i. It is a critically endangered species with fewer than 25-30 nesting females in the population. Data from a cooperative study of the Hawai'i Wildlife Fund (HWF) and the National Marine Fisheries Service (NMFS) in the last three years suggests that nesting hawksbill turtles in Hawai'i do not migrate away to other places, but also feed in Hawaiian coral reefs (Ellis et al., in press). This means that much of the critical life history of this turtle is in areas where protection and population recovery is possible and, compared with other Pacific populations, stands the best chance for recovery (NMFS, 1998).

However, we cannot adequately protect the hawksbill and its habitat until we first identify and characterize this habitat. The marine habitat these endangered sea turtles use before and after nesting (hawksbills may lay up to five egg clutches in a season, with each clutch containing nearly 200 eggs) in Hawai'i is largely unknown, but HWF research shows that they occupy coral reefs just offshore of their nesting areas. In recent years, the state and federal agencies tasked with protection of sea turtles have encouraged community-based management of the lands where sea turtles nest in Hawai'i. This habitat is degraded but the large community -led effort to rejuvenate this habitat has made progress on Maui during the last three years.

The nearshore marine environment where the females rest between nestings (the internesting interval) is just as important to the survival of the species as the nesting habitat is, but very little research and conservation efforts have been expended on the hawksbill in Hawai'i. The NMFS Recovery Plan for Hawaiian Sea Turtles (1998) lists one of the recommended recovery actions for hawksbills thusly:

"Foraging and resting areas are for the most part currently unknown. Baseline information is required to understand natural and man-induced habitat alterations.

Important foraging and resting grounds should be identified for special consideration as natural preserves."

These objectives also dovetail with the Clinton administration's concern for the welfare of U.S. reef ecosystems and President's intention to set aside many of these areas for protection. (The President's Fiscal Year 2001 budget request to Congress includes a total of $ 26 million, an increase of $ 15.5 million over FY 2000 appropriations, specifically to implement recommendations of the United States Coral Reef Task Force (CRTF) and "...halt the rapid loss and degradation of coral reef ecosystems. If appropriated, this unprecedented funding would significantly strengthen federal, state, territory and non-governmental efforts to protect, restore and sustainably use valuable U.S. coral reefs.")

These sites must be identified and the reef habitat characterized for all of the associated nesting beaches in Hawai'i to ensure appropriate seasonal management and to preclude disruption of the turtles in this critical habitat.

Efforts to identify the nesting and foraging habitat of the endangered hawksbill turtles in Hawai'i are described. Hawai'i Wildlife Fund (under federal and state research permits) conducts intensive monitoring of the Maui nesting beaches during July through September and flipper tagging of female turtles after nesting for long-term identification.

In the summers of 1996, 1997 and 1998, satellite and radio transmitters were placed on three female hawksbills to monitor their marine habitat use patterns. Tracking these turtles enabled us to identify sites that are important resting areas during the critical internesting interval when the females' eggs are developing, and the foraging areas they utilize after nesting season.

In the fall of 1999 and winter of 2000, Hawai'i Wildlife Fund staff performed three dive surveys to characterize the coral reef habitat these turtles inhabit during this time and the areas they inhabited as identified by radio triangulation.

This report identifies and characterizes the foraging and internesting habitat for three turtles that were tagged and instrumented after nesting events on the islands of Maui and Hawai'i.

OBJECTIVES

1. Identify and characterize (through biological surveys of the reef habitat) the nearshore marine environment used by female hawksbill turtles in Hawai'i during their internesting interval.

2. Identify and characterize (through biological surveys of the reef habitat) the nearshore marine environment used for long-term foraging and resting by hawksbill turtles in Hawai'i.

METHODS

Identification of foraging and internesting habitat:

Identification of the areas used for long-term foraging and internesting habitat by female hawksbill turtles was begun in 1996 using radio and satellite telemetry (Balazs et al., 1998 and Ellis et al., in press).

In 1996, a female hawksbill turtle was instrumented with radio and satellite transmitters following a nesting event on Big Island and tracked to Kahului, Maui (Turtle no. 25695, Tilley). In 1997 and 1998, two different hawksbill females were instrumented on Maui after nesting events, and tracked to identify their internesting habitat and subsequent foraging grounds on Big Island (Turtle nos. 4802, Hapa, and 4801, Sasha).

The turtles that were tracked in their internesting habitat (Hapa and Sasha) were monitored daily for nearly a month each, and several times were tracked for 24 hour cycles. These turtles were also tracked to their foraging grounds, but those areas were not assessed nor habitat characterized.

The general migration route of the turtle that left the nesting area (Tilley) was tracked by George Balazs (NMFS) with satellite transmitters (Balazs et al., 1998 and Ellis et al., in press) (Figs. 1-3). When relocated in her foraging habitat, Hawai'i Wildlife Fund ascertained the precise location (not possible with satellite telemetry alone) of Tilley on a daily basis for at least five months and assessed her daily activity patterns via radio frequency monitoring. All of the turtles' positions were determined via triangulation from two different shore-based stations and positions were recorded on NOAA charts (Figs 4-6).

HWF conducted survey dives on each foraging and internesting habitat identified from 1996, 1997 and 1998 transmitter deployment using the methodology described below.

Reef Surveys:

Underwater surveys using SCUBA equipment were employed to describe the internesting habitat of two and foraging area of one hawksbill sea turtles. These areas were defined by the grouping of 6 to 9 sites for each turtle corresponding to the locations of triangulated radio transmitter fixes. Of these sites, 2 or 3 were selected for each turtle based primarily upon depth and the proximity to other sites. Depth was a limiting factor of diver safety and restricted time to conduct surveys, as several of the sites were located at depths of 100 ft or more. Survey sites were chosen with highest proximity to other sites to maximize the likelihood of describing the most important locations.

One reconnaissance dive was conducted on August 19, 1999, to scope out the terrain of the hawksbill habitat in order to assist in survey planning. The quantitative underwater surveys were conducted on October 17, 1999 off of Wailea, Maui for turtle no. 4801 (referred to as "Sasha"); February 4, 2000 off of Kihei, Maui for turtle no. 4802 ("Hapa"); and March 25, 2000 for turtle no. 25695 ("Tilley) off of Kahului, Maui. In all cases, dives were necessarily vessel based due to the distance from shore (0.5 to 2 miles). The surveys consisted of the collection of quantitative data characterizing the sea floor substrate and amount of live coral coverage, and qualitative data describing some of the reef inhabitants observed (fish and other vertebrates).

Relatively new reef survey methodologies developed by the University of Hawaii's Coral Reef Assessment and Monitoring Project (CRAMP) were employed to obtain data methodologically compatible with statewide standards, as well as to assess the feasibility of using the new methods for volunteer monitoring programs. The focus of this methodology is to record standardized and archivable high-resolution video surveys that are then used to characterize and monitor the fauna and flora of the reef substrate.

We employed the video surveying technique using 3 different models (dependent on equipment availability) of high resolution video cameras to document the survey areas: a Ricoh R-18 h Hi8 video camera, a Sony 900 DSR 3 CCD video camera, and a Sony CCD-TRV81 Hi8 NTSC video camera. The video surveys were conducted by spooling out three 10m transect lines side by side along the sea floor roughly 5m apart and parallel to shore to maintain the same depth. The videographer then slowly filmed (at a preferred rate of no less than 3 min/10m transect) perpendicularly to the sea floor along the transect length at a height of 0.5m above the substrate. The transect lines used were plastic underwater measuring tape reels clearly marked at each centimeter.

To analyze the data, 5 - 10 non-overlapping sections (video frames) were randomly selected along the length of each 10m transect. The video was played back on a TV monitor and paused at each of the randomly selected frames. Clear vinyl acetate sheets marked with 50 randomly generated points were laid over the monitor screen and the substrate type underlying each point was then recorded. The collection of points from each frame were then averaged for each transect and for each site to determine percent coverage of various corals and substrate types. For a full list of benthic species and substrate types intended as recording categories, refer to Table 1. (This list is consistent with the categories used by CRAMP.)

Due to the high mobility of reef fish, quantitative fish abundance and identification surveys can only be adequate when an area is monitored repetitively over a long period of time. Since this study involved only one-time surveys at each site, such intensive quantitative efforts were not justified and in fact, would be such gross underestimates of biodiversity as to be virtually useless. Nevertheless, in order to give some idea of the kinds of mobile inhabitants using the area, notes were taken on the fish and other inhabitants observed at each site. To help document these observations, the videographer filmed a 360° panorama at the beginning and end of most transects.

RESULTS

Triangulated radio transmitter fixes defined between 6 and 9 sites for each turtle. Overall the depths of these sites ranged from 10ft to 125 ft with an overall average depth of 69ft. (Table 2). We were able to conduct reef surveys at 6 of the 21 sites and qualitatively assess areas around 3 additional sites.

Reef surveys were conducted at bottom depths between 45 and 78 ft. Generally, the surveys done in waters 60 ft or less showed very rich coral coverage - between 75% and 90%. These reefs tended to be either large fields of coral with occasional small sand pits (10 ft to 30 ft in diameter), large coral mounds with narrow sand channels separating neighboring mounds, or the tops of pinnacle ridges. Dominant coral species were primarily *Porites compressa*, *Porites lobata*, and both plate and encrusting forms of *Montipora verrucosa*. The two surveys completed at deeper depths, 65 ft and 78 ft, showed lower amounts of coral coverage: 17.4% and 0.8% respectively. The former consisted primarily of coral rubble and algae with sparse amounts of coral (*P. compressa*) while the latter site consisted of large areas of sand and halimeda beds with an occasional occurrence of *Pocillopora meandrina*. A reconnaissance dive at a deeper site (where no actual survey was performed due to the depth of the water - 109 ft) showed an area consisting entirely of dead coral rubble with some algae but no coral observed.

Internesting Habitat

Turtle no. 4801 - Sasha:

Sasha was monitored via radio telemetry for nearly a month in her internesting habitat, from July 18, - August 9 1998, nesting twice more before departing for her foraging habitat in Big Island waters (Figure 3). Six sites were identified (Figure 4.). These sites were among the shallowest (ranging from 40 ft to 95 ft deep, averaging a water depth of 63 ft) and closest to shore: 0.2 miles to 0.6 miles from shore. Sites 3 and 5 had 89.5% and 82.9% coral coverage respectively, comprised almost entirely of *P. compressa* (Table 3). Both of these reef areas were of the type with large extensive mounds of high coral concentration separated by narrow sand channels and contained a few sand pits interspersed within the mound. The mounds rose some 6 to 10 feet above the sand channels. Fish seen in both areas included commonly seen wrasses, butterflyfish, surgeonfish and damselfish. Contrastingly, Site 1 at 78 ft was composed primarily of extensive sand and halimeda beds. Fish species at this sight included Hawaiian dascyllus (*Dascyllus albisella)* hovering above the occasional *P. meandrina* coral heads as well as several Randall's pufferfish (*Torquigener randalli*).

Additional reconnaissance dives in this area revealed that the sites where Sasha was located lies right along a habitat boundary of very rich coral coverage extending almost uninterrupted for at least another quarter mile to the north of Sites 3, 4 and 5 while expansive sand and halimeda beds at depths of 80 to 100 ft almost exclusively dominate for at least a half mile to the south of Site 2. Near Site 2 and within 500 ft of Site 1, however, lies an island mound of rich coral coverage rising up from approximately 100 ft at the sand to a depth of 50 ft.

Turtle No. 4802 - Hapa:

Hapa was monitored for less than a month in her internesting habitat, nesting one more time between her tagging on September 22, 1997, and her departure for Big Island on October 13, 1997 (Figure 2). This turtle's nesting was the first observed nesting on Maui in recent history (Mangel et al., in press). Her 6 inter-nesting sites (Figure 5) were a little further offshore (ranging from 1.1 to 1.6 miles offshore) but at similar depth range (45 to 125 ft, averaging 72 ft) (Table 2). All but Site 3 (125 ft) were in water depths of 70 ft or less.

Site 1 was characterized by rich and diverse coral coverage, comprising 81.8% of the substrate. This site was dominated mostly by *M. verrucosa*, but also included substantial amounts of *P. compressa, P. lobata*, and *M. patula* with occurrences of *Pocillorpora meandrina, Pavona varians*, *Montipora flabellata*, and *Porites rus*. This reef at 55 ft was an expansive field with a rugged surface due to the competitive and upward growth of the coral. Many common reef fish were observed in the vicinity: butterflyfish (including a rarely seen dark phase longnose butterflyfish (*Forcipiger longirostrus*), surgeonfish, damselfish, wrasses; and also several slate pencil urchins.

The Site 2 surveys were conducted along the crest of a mounded ridge at 65 ft depth with one side dropping off rapidly to 100 ft or more. This site was dramatically different from Site 1, although only 10 feet deeper at its shallowest. This site was relatively sparse with only 17.4% coral coverage and 15% algae, some of which was halimeda, with the remainder of the substrate composed of rock and coral rubble (Table 3). The corals represented were primarily *P. compressa*, but also included some *P. lobata* and *P. meandrina*. Other inhabitants observed at this site included the egg sac of a Spanish dancer nudibranch (*Hexabranchus sanguineus*), a green linckia sea star (*Linckia guildingi*), and a crown of thorns sea star (*Acanthaster planci*). Few fish were seen.

Foraging Habitat:

Turtle No. 25695 - Tilley:

Tilley was tracked by satellite telemetry from her nesting grounds on Big Island to her foraging grounds in Kahului Bay (Ellis et al., in press) (Figure 1) and was subsequently monitored via radio telemetry in her foraging grounds for the next five months (from October, 1996 - March, 1997). There were 9 sites identified in Kahului Bay (Figure 6). These sites had the greater variability in terms of depth with Sites 3 and 4 close in towards shore (both less than half a mile from shore) and in surprisingly shallow water – only 10 ft! The overall range of depths spanned from 10 ft to 110 ft and averaged 72 ft deep (Table 2). Excluding the 10ft depths, all other sites had depths of 45 ft or greater. Sites 3 and 4 were not observed because they were located near a turbulent surf zone. Three of the sites (Sites 7, 8, 9) at this location were eliminated since the duration of the turtle's stay here was only a single day (April 19, 1997). However, Sites 1 and 2, and Sites 5 and 6 each had close groupings that could be surveyed.

Site 6 was located along the top of a pinnacled ridge approximately 1200 ft long by 200 ft wide rising vertically from around 75 ft (Figure 6). The survey was conducted along the centerline of the ridge at a depth 45 ft. It had high coral coverage (75.4%) fairly equally distributed between *Montipora* and *Porites* species with observed occurrences of *Pavona varians* and *Pavona duerdeni* as well (Table 3). Many common reef fish species were abundant; also observed were several large green sea turtles, a large school of rudderfish, a possible surface sighting of an unidentified dolphin, and humpback whales were heard singing nearby. Site 5 was 1000 ft WNW of the ridge at a depth of around 75 ft, but the substrate was not observed.

No quantitative surveys were conducted at Sites 1 and 2 because of the depth (109 ft), however a reconnaissance dive at Site 1 and near Site 2 showed only a flat rubble floor with some algae, but no coral was observed. It is interesting to note on the map (Figure 6) however that within 500 ft NW of both Sites, about one km diameter area of mounds and ridges rises up to depths of 50 to 60 ft.

DISCUSSION

Although our sample size is small (n = 3 turtles), some consistencies begin to emerge when comparing the reef habitats that these hawksbill turtles occupied in Maui waters. All three turtles were located at water depths between 40 and 110 ft, each averaging depths nearly 70 ft (Sasha – 63 ft, Hapa – 72 ft, Tilley – 72 ft). Excluding the shallowest and deepest sites (10 ft and 125 ft depths, respectively), all sites were fairly equally distributed in water depths between 40 and 110 ft deep: 39% (7/18) at 40 – 60 ft, 33% (6/18) at 61 to 80 ft, and 28% (5/18) between 90 and 110 ft. Turtles using these areas are presumed to be either resting or foraging on the ocean floor between surface respirations. Substrate habitats that vary in depths by as much as 60 to 70 ft can vary dramatically in benthic composition and biodiversity. The survey data appear to support this by revealing varying and even contrasting habitat types, with areas ranging from expansive sand and halimeda beds, to areas of rubble and sparse coral coverage, and on to areas of extensively rich and diverse coral fields. At first glance, this description could suggest that these hawksbill turtles may not necessarily prefer a specific habitat composition, but may instead prefer a variety of habitat types.

A closer look at the distribution of these sites reveals that not only do these sites occur at contrasting habitat types, but also, most of the sites seem to line up along the edge of habitat boundaries. The reconnaissance dives around Sasha's sites revealed them to all lie along a boundary of two habitat extremes: one a rich coral area continuing extensively to the north and the other a vast area of sand and halimeda heading off towards the south.

These habitat boundaries can also be marked by abrupt changes in depth such as the Tilley Sites 5 and 6. Site 6 is a coral rich habitat atop a pinnacled ridge and Site 5 is 1000 ft away and about 30 ft deeper along the sea floor where the habitat is probably quite different (Figure 6). Also Tilley Sites 1 and 2, with no obvious coral at 109ft, both occur within 500 ft of a large mound rising up to a depth of 50 ft which could potentially support significant coral growth. Looking at the map of site locations for Hapa (Figure 5), several of these sites also appear to lie along boundaries of dramatic vertical relief.

That apparent boundary edges may occur at the same areas and depth ranges the turtles occupy could simply be coincidental, or it could signify a preference on the turtle's part. However, since the habitats revealed in this survey varied so dramatically, we would need a larger sample size to be able to draw any conclusions as to habitat preferences. In addition, it is important to note that none of these turtles were actually observed in the water, their approximate locations in the reefs could only be located by triangulation on radio signals.

The actual depths for some of the sites (those not surveyed) could possibly be as much as 10 to 15 ft shallower than listed. For those sites not surveyed, depth estimates were determined using the nearest nautical chart depth soundings in the vicinity. Since the actual location of the turtle was not specifically known, the high end of the depth estimates were assumed, primarily for dive planning purposes as well as to place a lower bound on the depth the turtle was likely to reside while in the vicinity of that site. The depth range estimates varied primarily between 10 and 15 ft. Therefore, it is likely that the turtles were slightly shallower than the reported depths at unsurveyed sites.

The habitat utilized by these three hawksbills must presumably provide shelter from predators (tiger sharks are known predators of green sea turtles in Hawai'i) as well as food, and in the case of the nesting turtles, close proximity to the nesting habitat. Perhaps hawksbills seek out reefs with high topographic relief and biodiversity for some or all of these reasons. But we do not know whether the turtles rested in the sand channels and sand pits or on the coral itself. Starbird et al. (1999) reported that hawksbill turtles near Buck Island in the U.S. Virgin Islands were observed resting motionless among sea grass on a sandy sea floor on 13 occasions. Several hawksbill sea turtles have been observed foraging (and filmed) in shallow waters off Maui (at Molokini and North Beach) and appear to be feeding on coral, encrusting sponges or even other invertebrates (C. Robertson and R. Newboldt, pers. comm.).

The next step for understanding the importance of Hawai'i's reefs to endangered hawksbill turtles is to determine exactly what components of these deep reefs are important to them, and to do this we must dive these reefs when the hawksbills are there. We have approached George Balasz with this request and hope to both instrument additional hawksbills this summer and accompany him on a dive to their identified habitat.

Discussion of Methodology:

This project was invaluable for furthering the knowledge of the lay public and professionals who wish to survey deep reefs. We worked closely with several key members of the team conducting Hawai'i's CRAMP program in order to ensure that our methodology was replicable, and encourage others to do so. We offer the following observations to assist in future such projects.

In conducting our reef surveys, we experienced a significant amount of variability in filming technique. Therefore, the resolution was not consistently good enough to discern between some similar looking species or substrates. To maintain consistency and minimize identification errors, we necessarily had to reduce the identification categories down to coral genus and consolidated some similar looking substrate categories. For example, turf algae, coralline algae, and bare rock could be discerned in some cases, but not in others, so they were grouped into one category called rock/algal turf. Only those categories that were identified and represented within the transects are listed in Table 3. Some smaller, potentially important categories such as porifera (sponges) could have occurred within the transect, but may not have been discernible due to some of the resolution problems encountered. This lack of resolution is particularly troublesome for this project since hawksbills are known sponge feeders in other parts of the world; therefore the presence or absence of sponges in our surveys is significant, yet we could not measure it. Hawai'i has fewer species of porifera than other places, and much of them are encrusting. In order to document the presence/absence of sponges, we need the highest resolution possible.

The video survey methodology employed with this study depends heavily on the consistency, training and skill of the underwater videographer. In order to get good resolution, the videographer must film continuously along the transect with slow, steady and precise control. Factors that are most variable are swim speed, distance between camera and substrate, and camera pitch. Swim speed must be maintained at a slow, steady rate taking no less than 3 minutes to complete the 10m transect. A faster or unsteady rate does not allow the equipment to adjust to its highest resolution and can leave the image blurry.

Distance between the camera and substrate is also critical in the analysis stage and should be maintained at 0.5 m from the reef surface. Maintaining a consistent distance ensures that similar size areas are viewed and analyzed, and straying too far away can significantly obscure the detail making species identification difficult or impossible. The pitch of the camera can also have a biasing affect in the analysis stage. The camera must be kept nearly perpendicular to the plane of the reef surface. If it strays significantly in either direction, it can distort the area covered in the field of view, and may additionally introduce a bias towards vertical structures. For example, if a camera is filming a stand of finger coral at an angle, the finger coral may present more of a surface area in the field of view, obscuring whatever may lie below or behind it. This would misrepresent the substrate, biasing it to show higher concentrations of the coral than may actually be present.

Because of the precision and skill needed to accomplish these tasks, sometimes compounded by strong current and surge, any monitoring program using volunteers to carry out this methodology should have a thorough training session on the techniques and skills needed to obtain good quality data. The brunt of the burden lies on the videographer as it is their skills and understanding that most directly affect the quality of the survey.

In addition, the video survey methodology also depends on highly technical and expensive equipment, costing thousands of dollars. This expense, coupled with the training required for videographers, can make video surveying cost-prohibitive. Even though this project employed highly skilled, experienced videographers and divers, the primary problems encountered stemmed primarily from the lack of training and understanding of the specific techniques required for this emerging methodology.

We recommend that future such projects be funded at a level that includes training in this methodology (e.g., allowing for training dives and collection of data with subsequent analysis to determine quality - this type of filming can only be taught by doing it!) or that such training programs be funded independently for video transect work.

The logistical problems of obtaining the high tech video recording equipment (both for surveying and for later analysis), scheduling highly trained personnel and securing a vessel to get out to the sites during appropriate weather conditions were challenging, but not insurmountable. Interestingly, most of these sites were also located in areas of high wind and high swell; therefore weather was also a prohibitive logistical concern, preventing easy access to these sites by our team as well as all other recreational and professional human usage patterns. On the positive side, this relative inaccessibility may offer a protective feature for the endangered hawksbill sea turtles.

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LIST OF TABLES AND FIGURES

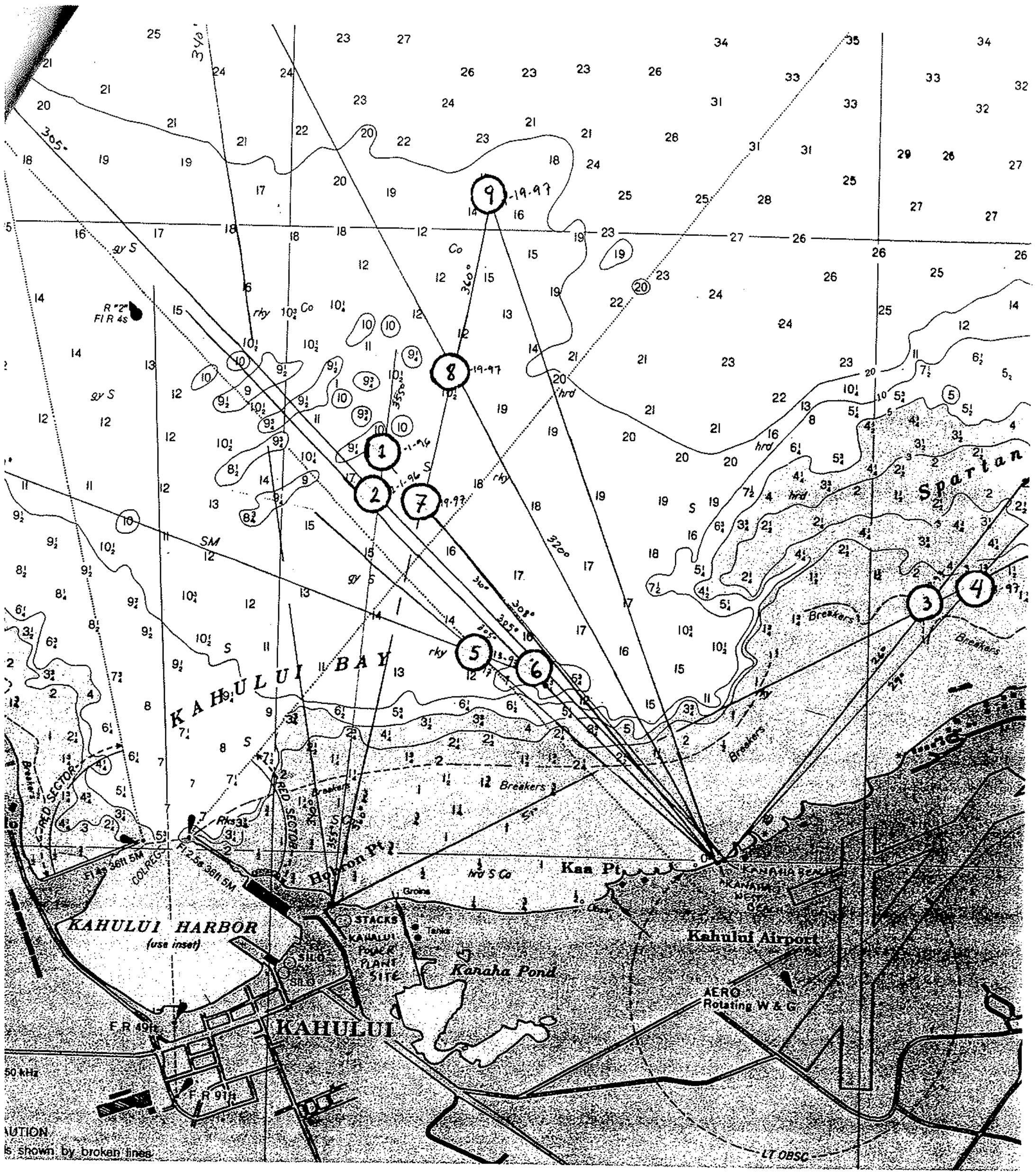

Figure 6. Map of Hawksbill Turtle No. 25695 (Tilley) Site Locations, Kahului, Maui, from Radio Transmitter Triangulation.