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Technical Report 178

Twenty Years of Conservation and Research Findings of the Hawai'i Island Hawksbill Turtle Recovery Project, 1989 - 2009

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The Hawaii-Pacific Islands Cooperative Ecosystem Studies Unit is a coalition of governmental agencies, non-governmental organizations and universities that promotes research, education and technical assistance to support better stewardship of imperiled natural and cultural resources within the Pacific. The HPI CESU is one of 17 cooperative ecosystem studies units across the U.S.

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Abstract

Prior to 1989, available information on nesting hawksbill turtles (*Eretmochelys imbricata*) in the Hawaiian Islands was minimal. From 1987 to 1990, personnel from Hawai‘i Volcanoes National Park conducted reconnaissance along the southern coastline of Hawai‘i Island to confirm evidence of nesting activity, identify hawksbill nesting beaches, and evaluate threats. Thereafter, the Hawai‘i Island Hawksbill Turtle Recovery Project (HIHTRP) was established to monitor and manage nesting sites, document nesting events, collect baseline data, ensure hatchlings safely reach the ocean, and mitigate threats. Between 1993 and 2009, the number of beaches monitored for nesting activity expanded from eight to 17, with variable coverage at each site. Flipper tagging of nesting adult females has occurred since 1991. Primary findings from twenty years of data collection include: **1)** The southern coast of Hawai‘i Island has the highest documented hawksbill nesting activity in the Main Hawaiian Islands; **2)** Nesting season (egg laying to hatchling emergence) begins in April and extends to February with a peak egg laying period from late-July to mid-September; **3)** The mean seasonal cohort observed was 11.6 ± 1.2 (n= 18) with a range of 3 to 18 turtles; **4)** The mean number of nests per turtle was 3.3 ± 0.2 per season (n= 20) with a range of 1 to 6 nests; **5)** The mean remigration interval was 3.5 ± 0.1 years (n= 106) with a range of 2 to 10 years; **6)** Nesting turtles demonstrated a high degree of nesting site fidelity, with 87% of individuals documented using only one nesting site. Forty-eight of these individuals were documented at the same beach in multiple years. Thirteen percent of nesting females were documented at multiple sites; **7)** The mean nest to next crawl inter-nesting interval was 18.6 ± 0.1 days (n= 276) (range 13 to 24 days), while the mean nest to nest inter-nesting interval was 20 ± 0.2 days (n= 277) (range 13 to 30 days); **8)** The mean incubation period was 62.5 ± 0.4 days (n= 446) with a range of 50 to 101 days; **9)** The mean clutch size was 175.2 ± 1.5 eggs (n= 631) with a range of 78 to 274 eggs; **10)** The mean nest hatch success of eggs was 71.9 ± 1.0% (n= 640) with a range of 0 to 100%; **11)** Between 1991 and 2009, 100 adult females were tagged, with a mean of 5.3 ± 0.7 (n=19) and range of 1 to 11 per season; **12)** Between 1988 and 2009 a total of 742 nests (most occurring at Kamehame, ‘Āpua Point, and Pōhue Bay) were documented with a mean of 35 ± 4.0 (n= 21) and range of 8 to 69 per season; **13)** Between 1989 and 2009, over 80,775 hatchlings are estimated to have entered the Pacific Ocean from Hawai‘i Island; **14)** Primary threats to nest and hatchling success all of which have been significantly addressed were non-native mammalian predators, alien plants, artificial lights, hatchling stranding, vehicular traffic, and incompatible recreational use of nesting beaches; **15)** Volcanism including land subsidence remains as an uncontrollable factor.

Introduction

Hawksbill sea turtles (*Eretmochelys imbricata*) [Linnaeus, 1766]), known as honuʻea or ʻea in Hawaiian (Pukui and Elbert, 1971), are found in tropical and circum-tropical waters of the Atlantic, Pacific, and Indian Oceans (Witzell, 1983; Ernst, et al. 1994). Juveniles and adults are closely associated with coral reef foraging habitat and feed primarily on sponges (Meylan and Donnelly, 1999; Balazs, 1978a) although a wider variety of prey species have been identified in various foraging locations. For centuries, humans have harvested hawksbill eggs, meat, and shells (Meylan, 1999). Patterned scutes that overlap on a hawksbill carapace have historically been used as "tortoiseshell", "bekko", and "carey" (or "una" in Hawaiian) to make jewelry (Ernst, et al., 1994; Meylan, 1999). International trade in "bekko" is one of the primary reasons for the decline of hawksbill populations worldwide within the last 100 years. Currently, hawksbills are the rarest of all sea turtle species in the Pacific Ocean. On June 2, 1970, hawksbills became the first marine turtle species to be listed under the U.S. Endangered Species Act (35 FR 8491). Hawksbills worldwide are classified as critically endangered on the International Union for Conservation of Nature and Natural Resources (IUCN) Red List (Hilton-Taylor, 2000) and are listed under Appendix I of the Convention for International Trade of Endangered Species (CITES) (Groombridge and Luxmoore, 1989).

Current global estimates are between 60,000 and 78,000 nesting adult female hawksbills based on estimates that 20,000 to 26,000 females nest annually throughout their range with an average three year remigration interval (Spotila, 2004). Hawksbills are known to nest in at least 60 countries (Groombridge and Luxmoore, 1989; Bjorndal, 1999). In the United States (not including U.S. territories), hawksbill nesting has been documented in southern Florida and the Main Hawaiian Islands (MHI) (Balazs, 1978b; Katahira et al., 1994; Florida Fish and Wildlife Conservation Commission 2007). In the MHI, small numbers of hawksbills have been observed nesting on a few beaches on the islands of Hawaiʻi, Maui, and Molokaʻi (Katahira et al., 1994; King et al., 2007; Balazs, 1982). In addition, Balazs (1978b; pers. comm.) reported evidence of low level nesting on Oahu. The majority of documented nests in Hawaiʻi have occurred in the district of Kaʻū on the southeastern coast of Hawaiʻi Island (Katahira et al., 1994).

Predation, alterations to nesting habitat, volcanism, increasing coastal development, and numerous other limiting factors threaten the recovery of hawksbill sea turtles (U.S. Fish and Wildlife Service (FWS) and National Marine Fisheries Service (NMFS), 1998). Prior to 1989, there was little information about Hawaiian hawksbills and minimal management of populations in Hawaiʻi. Reports from the 1970s and 1980s documented occasional nesting on Hawaiʻi Island at several beaches along the southeast coast including Kahuwai (aka Orr's Beach), Kalapana, Punaluʻu, Kāwā (Balazs, 1978b) and Halapē (HAVO Backcountry logbooks). In 1989, Hawaiʻi Volcanoes National Park (HAVO) established a monitoring program that has since grown to become the Hawaiʻi Island Hawksbill Turtle Recovery Project (HIHTRP), an informal partnership between Federal, State, and County agencies, the Pacific Cooperative Studies Unit (PCSU)-University of Hawaiʻi-Mānoa, various non-profit organizations, educational institutions and private landowners, to monitor and protect hawksbill nesting habitat on Hawaiʻi Island. Beginning in 1988 through 2009, project personnel conducted coastline surveys to identify nesting habitat and monitored and protected confirmed nests. Nesting biology was documented by tagging and measuring adult females and recording data including remigration intervals,

internesting intervals, number of nests, egg incubation periods, clutch sizes, nest hatch success rates and other data described in more detail throughout this report. Project personnel also performed community outreach and on- and off-site interpretation to educate the public about Hawai‘i’s sea turtles and their habitat. This technical report summarizes information collected by HIHTRP on the nesting activities of hawksbill turtles on Hawai’i Island between 1989 and 2009.

Methods

General Site Descriptions

Data presented are from fifteen sites located on Hawai‘i Island (19°34’ N, 155°30’ W), the south-easternmost island in the State of Hawai‘i (Table 1). While seventeen sites have had confirmed nesting activity in at least one season since monitoring began in 1989, no data are presented for two of those sites due to lack of monitoring coverage. Sixteen sites are located along the southern coastlines of the island, while the remaining site is on the northern coastline (Figure 1). Nesting sites are typically small (less than 0.1 hectare), isolated pockets of sand, with scattered cobblestone and/or coral, found intermittently along rocky cliffs. Beach vegetation varies by site, but typically includes naupaka (*Scaevola taccada*), pōhuehue (*Ipomoea pes-caprae*), and various non-native plants. For the purposes of this report, suitable nesting habitat is defined as an area above the high tide line with substrate in which a nesting turtle is capable of digging an egg chamber. Human accessibility of nesting beaches and differences in land ownership among Federal, State, and County agencies, and private landowners resulted in varying degrees and types of public use at each site. Detailed site descriptions, threat assessments, and results summaries for each nesting beach can be found in Appendix A.

Nesting Beach Monitoring

In 1987, a gravid adult female hawksbill was discovered dead in a lava crack in HAVO. This was a “turning point” for hawksbills on Hawai‘i Island. There were previous reports of nesting hawksbills in HAVO. However, as a result of this incident, HAVO took action to protect this species. In the fall of 1988 and summer of 1989, aerial reconnaissance was conducted by helicopter (Hughes 500) to identify potential nesting beaches along 34 km of coastline within and adjacent to HAVO. The entire island coastline was surveyed by helicopter in summer of 2003. Surveys were done during the nesting season to look for evidence of turtle nesting activity such as substrate or vegetation disturbances like digs, tracks, and/or body pits. Personnel also looked for beaches that could be accessed from the ocean by turtles, which had suitable vegetation and substrate for nesting activity to take place. Suitable habitat was identified using Mortimer’s (1982) four general requirements for nesting beaches: 1) accessible from the sea; 2) high enough to prevent inundation of eggs by tides or water table; 3) substrate must facilitate gas diffusion; and 4) substrate must be moist and fine enough to prevent collapse of the egg chamber during construction. Once potential nesting habitat was identified, sites were assessed for potential threats and accessibility for project personnel (some potential nesting sites were inaccessible due to either property ownership or terrain). Personnel then surveyed accessible sites on the ground for hawksbill nesting activity.

Monitoring coverage at nesting sites varied between 1989 and 2009 based on seasonal nesting activity observed at each beach and available staff and resources. Nests were first documented at ‘Āpua Point in 1988. From 1989 to 1992, monitoring was limited to occasional night beach monitoring and day checks at ‘Āpua Point, Halapē, Kamehame, Punalu‘u, and Horseshoe by park staff and volunteers (Figure 1). Continuous nightly monitoring at beaches where nesting was confirmed began in 1993 when additional funds from FWS allowed for expansion of the HIHTRP monitoring program to include a full-time monitoring technician

(through the University of Hawai‘i PCSU program) and additional NPS and University of Hawai‘i PCSU volunteers. Personnel typically spent two to four months working full time with the program after receiving standard sea turtle monitoring training. Training included: trapping and euthanizing non-native predators, flipper tagging adult females, measuring adult females, marking nest sites, and nest excavation and inventory. Personnel also performed additional surveys to identify nesting habitat and looked for nesting activity at new beaches. Additional beaches were incorporated into the monitoring program once new nesting activity was reported and confirmed. Arrangements were made with landowners that allowed personnel to access some sites.

Throughout the study period, site monitoring typically began in late May or early June and continued until the last documented nest was excavated, which ranged from mid-November to early February (see Appendix A for data on monitoring effort and results at each site). Beaches with observed nesting activity or with the greatest level of threats to nesting success (due to human impacts, predators, or poor habitat conditions) received nightly monitoring coverage. The remaining beaches were day-checked on a regular basis and if nesting was documented, nightly monitoring followed.

Night monitoring involved at least two personnel patrolling the beach every hour on foot from approximately 18:00 to 02:00. If nesting turtles were observed on the beach, personnel remained on the beach and performed data collection until the turtle returned to the ocean, which sometimes occurred after sunrise. Personnel checked the beach each morning at approximately 06:00 to look for signs of turtle activity missed after 02:00. Day-checks for turtle activity involved beach patrols on foot to look for digs, tracks, possible nests, hatchling emergences, nest predation, and signs of disturbance.

Table 1. Locations of Hawksbill Nesting Beaches, Hawai‘i Island (Decimal Degrees)

Nesting Site	Latitude (N)	Longitude (W)
Waimanu	20.145723	-155.637646
Kahuwai (Orr’s Beach)*	19.533333	-154.831667
‘Āpua Point	19.257977	-155.193450
Keauhou	19.266652	-155.234783
Halapē	19.270567	-155.254841
Kākīwai	19.266971	-155.277500
Kamehame	19.144672	-155.465303
Punalu‘u	19.136016	-155.504436
Horseshoe	19.130801	-155.508245
Koloa	19.131231	-155.507553
Nīnole	19.129458	-155.512255
Kāwā	19.113299	-155.525465
Ka‘ili‘ili	19.108124	-155.528244
Kahakahakea	18.991309	-155.776367
Pōhue Bay	19.010594	-155.797302
Humuhumu Point	19.017636	-155.828995
‘Āwili Point	19.020673	-155.843945
Manuka	19.079285	-155.902519

* nesting documented prior to 1989.

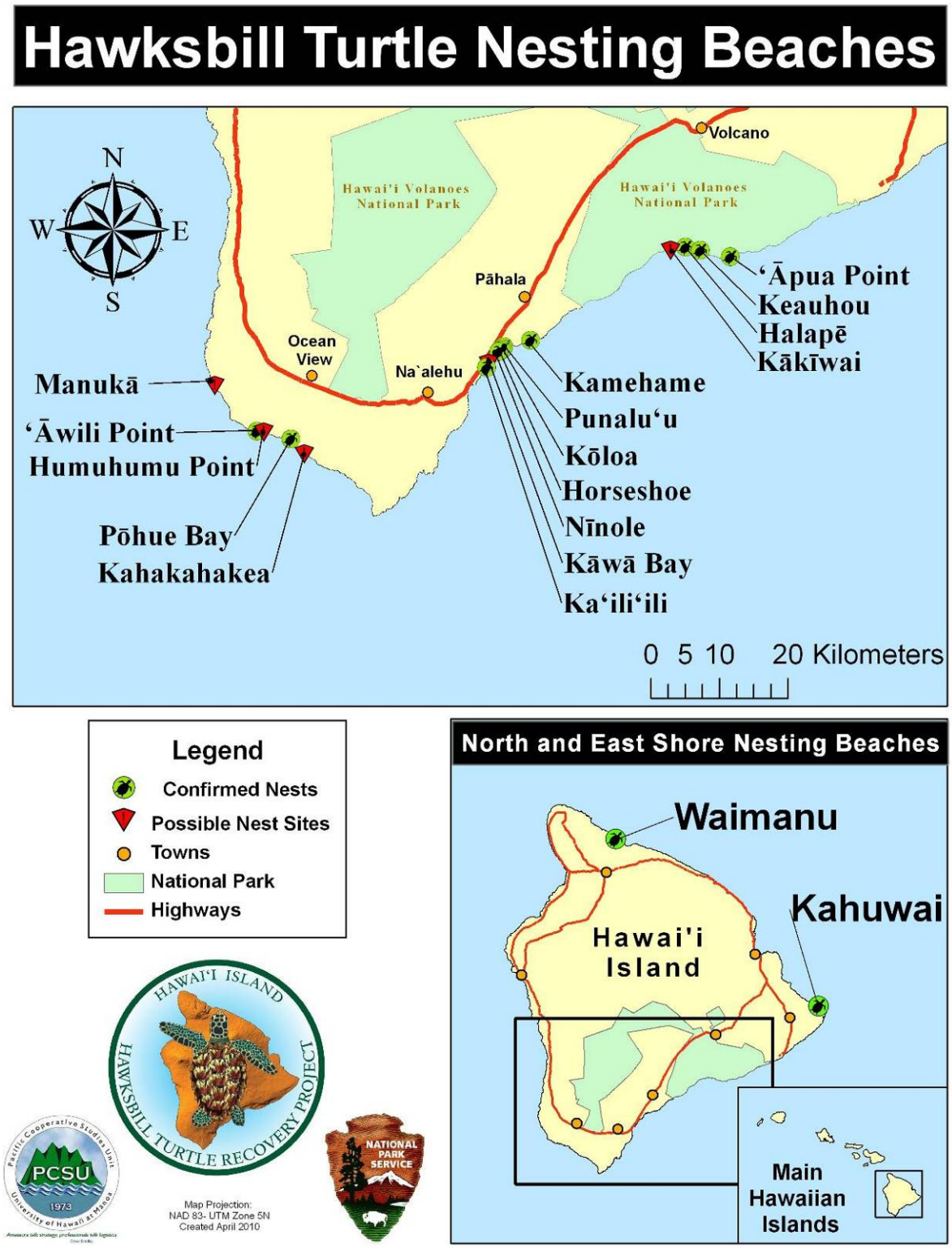

Figure 1. Map of Hawai‘i Island hawksbill nesting sites.

Data Collection

Nesting Events

Personnel observed the behavior of turtles crawling on the beach at night to determine whether the emerging turtle was a nesting hawksbill or a basking green turtle. When a hawksbill was observed, time and nesting activities were recorded. Weather, tide, moon phase, and moon presence were recorded at the time of emergence from the surf. Times of crawls, digs, egg laying, covering, and returning to the ocean were also recorded. Maps were sketched to show each crawl pattern, false nest location, and nest location. Nesting turtles were examined when they had finished covering their nest or were on their way back to the ocean. Personnel briefly restrained the turtle by covering her head with a towel (to keep her calm) and elevating her front flippers to keep her from crawling away. Each flipper was checked for external tags to ensure there was a readable tag on each flipper (Figure 2). If the turtle was previously tagged, tag numbers were recorded and if necessary, tags were adjusted or cleaned. If the turtle had not been previously tagged or if the tag(s) had come off, model #681 inconnel style tags (issued by NOAA-Pacific Islands Fisheries Science Center) were applied proximal of and adjacent to the first large scale on the posterior edge of the flipper (Balazs, 1999). From 1991 (when tagging began) to 1999, only the anterior flippers were tagged. Starting in 2000, tags were applied to all four flippers to mitigate the risk of tag loss. Standard straight carapace length (SCL) and straight carapace width (SCW) measurements were taken using *Haglof Mantax* calipers (Figure 3). All turtles were checked for external injuries and abnormalities.

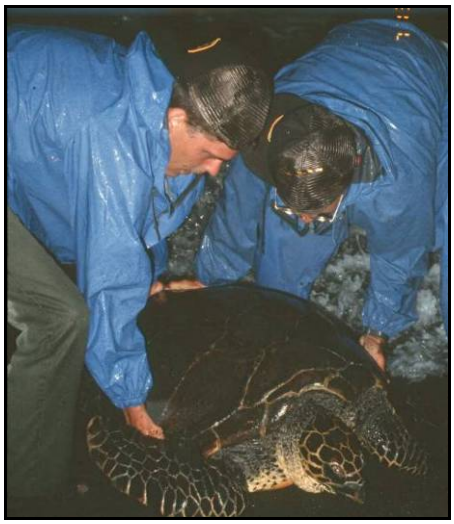

Figure 2. Project personnel identify a post nesting adult female.

Figure 3. Measuring standard carapace length.

Data collected was used to calculate individual remigration intervals and inter-nesting intervals. Two different inter-nesting intervals were recorded for individual females returning to a site within a season: "Nest to next crawl" inter-nesting interval was defined as the number of days from when a turtle laid a nest until she returned to crawl again, regardless of whether she

nested successfully upon return. "Nest to nest" inter-nesting interval was defined as the number of days from when a turtle laid a nest until she was documented laying another nest. In some instances this interval was the same, while other times an individual false-crawled before returning again to nest on a later date.

During each observed oviposition (Figure 4), two 5 cm diameter fishing bobbers were inserted above the nest chamber labeled with the nest number, date, and observer's initials. A 2.5 X 7.5 cm double faced aluminum tag with similar information was tied to one of the bobbers with string and left on the substrate surface over the nest. These bobbers allowed personnel to positively identify each nest before beginning an excavation. After oviposition, the nest chamber was marked with a ring of coral and surveyors tape. As often as possible, nests documented by the project were protected *in situ*. In cases where nests were in imminent danger from severe and predictable erosion and/or inundation, they were translocated using protocols adopted from Boulon (1999).

Figure 4. A hawksbill laying a nest.

Figure 5. Personnel constructing a nest enclosure and sign

In areas with high predator densities and/or public use 1 inch x 2 inch (2.5 cm x 5 cm) wire mesh enclosures (Figure 5) were constructed around nests to provide protection from predators, vehicles, and people. After 45 days of incubation, nest enclosures were cut open or removed to prevent hatchlings from becoming trapped.

Hatching Events and Excavations

Monitoring for hatching activity began 45 days after each oviposition. During emergence (Figure 6), personnel counted hatchlings and during 2001 - 2007 measured SCL and SCW of a random sub-sample of 20 hatchlings per nest. If no hatchlings were observed an estimate from the tracks were made. Personnel also monitored for possible hatchlings from unobserved nests. The area around the nest was searched and hatchlings stranded in vegetation and rock cobbles, or disoriented by artificial lights/campfires were rescued and released near the water. Nearby beach users were asked to minimize artificial lighting. At 'Āpua Point primarily (but at other sites as well), where hatchlings were routinely trapped in rocks or cobblestone, a temporary corral made of plastic lawn edging was constructed around each nest to allow personnel to safely collect

hatchlings. Hatchlings were then transported to a sandy part of beach with a clear path to the ocean. Lawn edging was removed if personnel were absent due to a change in shift or if they were day-checking another site in order to prevent desiccation or exhaustion of hatchlings in the event of a mid-day emergence. If nests showed evidence of hatching during the day we attempted to provide 24 hour nest monitoring but were not able to in every case.

Figure 6. Hatchling main emergence.

Approximately 48-72 hours following a major hatchling emergence, nests were excavated to determine hatch success, rescue and release stranded hatchlings trapped within the nest cavity, inventory nest contents, and collect samples for genetic analysis. The number of live hatchlings, dead hatchlings, empty eggshells, pipped hatchlings, partially developed embryos, and undeveloped eggs were recorded. Nest dimensions from the beach surface to the top and bottom of the nest, and width at the bottom of the chamber were recorded. All dates of hatchling activity were recorded to determine incubation periods. Nest hatch success was determined by the following equation:

$$\text{Nest Hatch Success} = \frac{\text{\# eggshells - \# dead hatchlings in nest}}{\text{\# eggshells + \# partially developed + \# undeveloped + \# pipped (Total Eggs)}} \times 100\%$$

As part of a separate collaborative study beginning in the late 1990's, genetic material from the nest, usually a dead hatchling, was collected and sent to the NOAA Pacific Islands Fisheries Science Center in Honolulu for eventual analysis by the NOAA Southwest Fisheries Science Center (Peter Dutton, in preparation).

Education and Outreach

Throughout the study period, personnel conducted numerous educational and outreach activities to increase awareness of sea turtle conservation efforts for various beach user groups, students, and nearby communities.

Results

Nesting Females

Between 1991 and 2009, a total of 100 adult female hawksbills were tagged on Hawai‘i Island at eight beaches (Table 2). The highest number of newly tagged adult females were tagged at Kamehame Beach (n = 45). Pōhue Bay and ‘Āpua Point had the second and third most tagged females with 20 and 19 respectively. Since tagging began in 1991, between one and eleven new turtles were tagged every year with a mean of 5.3 ± 0.7 (n= 19). Additional nesting activity by either unidentified turtles or turtles tagged at another location was documented or reported at Kākīwai (2001, 2007), Horseshoe (1989, 1993), Kōloa (2003-2006), Nīnole (1990-91, 95, 97-99, 2004-05, 2009), Kahakahakea (2005, 2008-2009), Humuhumu Point (2008-2009), Manukā (2004), Pololū (2003), Waimanu (2001, 2009), Kahuwai (Pre-1989), Kapoho (2005), Kaimū (2007), and Kalapana (Pre-1978). See Appendix A for monitoring effort.

Table 2. Newly tagged adult female hawksbills per year at each site. Hawai‘i Island, 1991-2009.

Year	Total Tagged	‘Āpua Point	Keauhou	Halapē	Kamehame	Punalu‘u	Ka‘ili‘ili	Pōhue Bay	‘Āwili Point
1991	4	2	0	0	2	0	0	0	0
1992	3	1	0	0	2	0	0	0	0
1993	11	2	0	0	9	0	0	0	0
1994	3	1	0	0	2	0	0	0	0
1995	6	0	0	0	6	0	0	0	0
1996	4	0	0	0	4	0	0	0	0
1997	6	2	0	0	2	0	2	0	0
1998	6	1	0	0	4	1	0	0	0
1999	5	1	0	0	2	0	0	2	0
2000	3	0	0	1	1	0	1	0	0
2001	2	1	1	0	0	0	0	0	0
2002	3	1	0	1	0	0	0	1	0
2003	1	0	0	1	0	0	0	0	0
2004	2	1	0	1	0	0	0	0	0
2005	8	1	0	0	2	0	0	4	1
2006	6	1	0	0	1	0	0	4	0
2007	8	1	0	1	1	0	0	5	0
2008	8	1	0	3	1	0	1	1	0
2009	11	2	0	0	5	1	0	3	0
Total	100	19	1	8	45	2	4	20	1

The mean adult female standard carapace length and width were 82.3 ± 0.1 cm (n= 685) and 63.3 ± 0.1 cm (n= 673), respectively. The length ranged from 72 to 90 cm and the width ranged from 52 to 71 cm.

The mean number of confirmed nests per turtle in one season between 1991 and 2009 was 3.2 ± 0.2 (n= 19 seasons) with seasonal means ranging from 2.1 to 4.5 (Figure 7). Within a single season, individual females laid between one and six nests. Several individuals were observed crawling on beaches, however they were never documented nesting, so they may have nested at another place and time undetected.

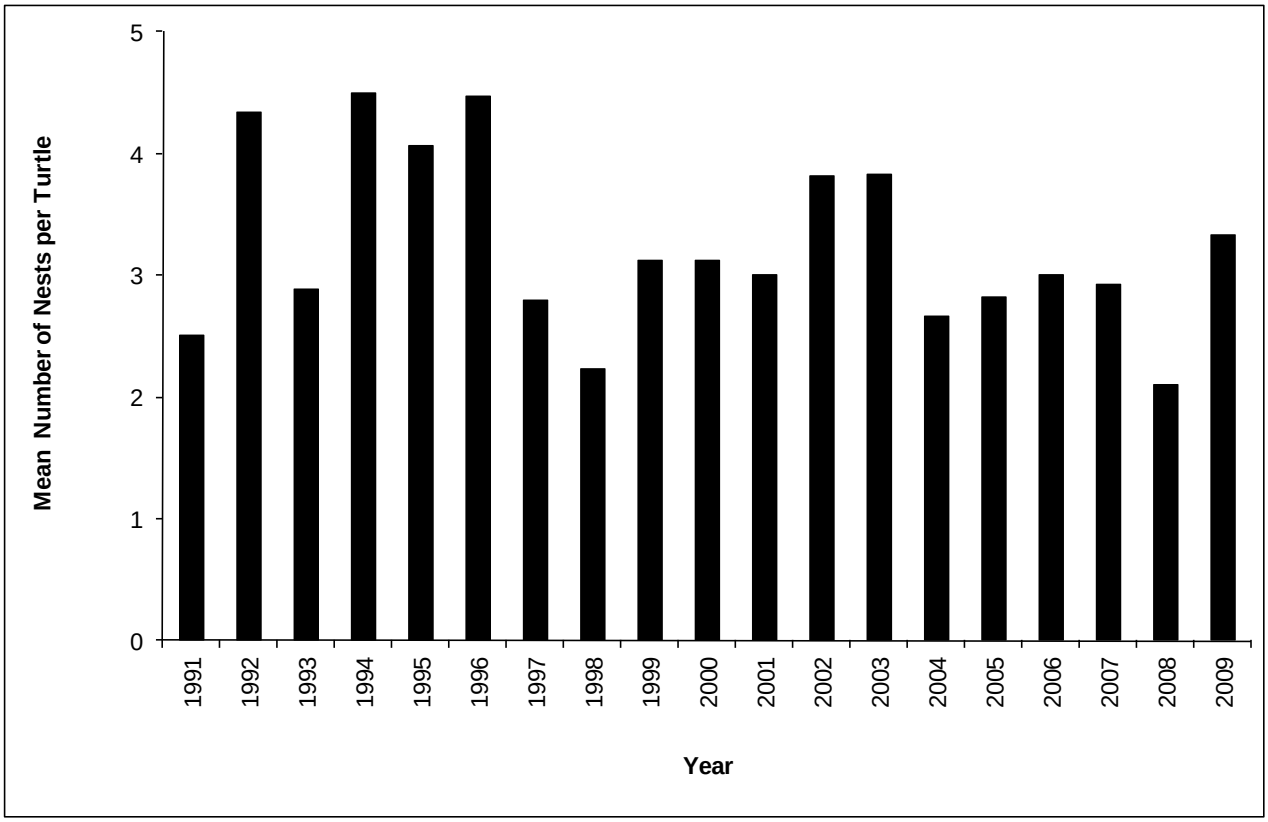

Figure 7. Mean nests per turtle per season on Hawai‘i Island from 1991-2009 (n= 19).

Inter-nesting Intervals

There were two different types of inter-nesting intervals recorded, as described in the methods. The mean nest to next crawl inter-nesting interval was 18.6 days ± 0.1 (n= 276) and ranged from 13 to 24 days. The mean nest to nest inter-nesting interval was 19.9 days ± 0.2 (n= 277) and ranged from 13 to 30 days. Data that were 1.5 times outside the interquartile range were excluded as outliers since beach coverage was not always comprehensive and nests may have been missed.

Remigration

Among the 100 tagged females, a total of 106 remigration intervals were recorded (Figure 8). The mean remigration interval was 3.5 ± 0.1 years (n=106) with a range of two to ten years.

The median remigration interval was three years. In addition to three confirmed dead females, 17 individuals were not observed returning after nine or more seasons. These individuals may have dropped out of the reproductive population, lost their tags and were counted as newly tagged, have a longer remigration interval, or may be nesting at other unknown beaches in Hawai‘i. These 20 animals represent 20% of tagged females.

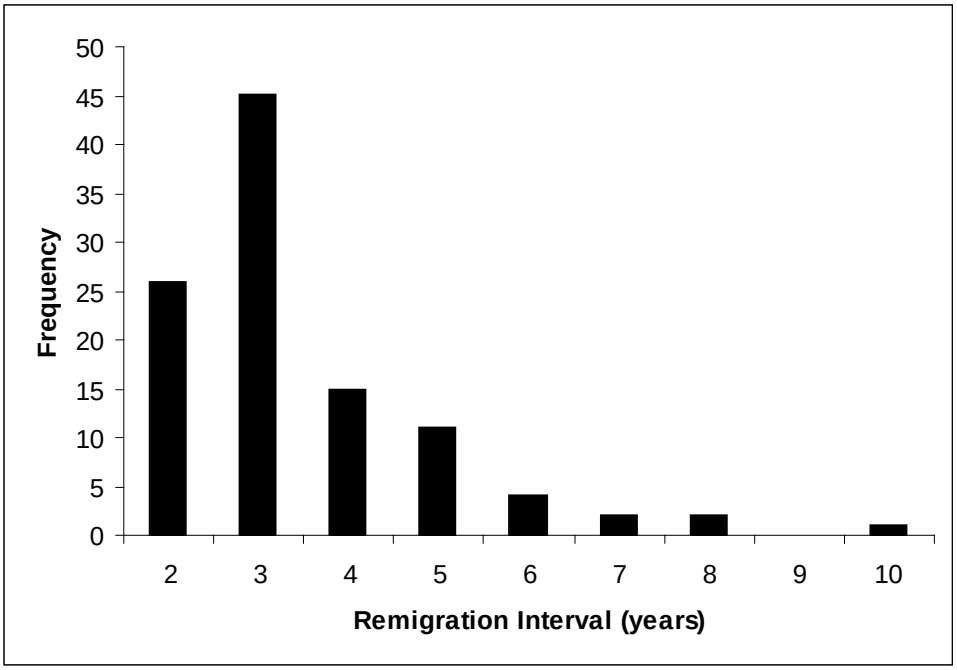

Figure 8. Distribution of the remigration interval of hawksbills tagged on Hawai‘i Island from 1993-2009 (n= 106).

Nest Site Fidelity

Hawai‘i Island hawksbills demonstrated high nesting site fidelity. Out of 100 tagged individuals, 87 turtles (87%) tagged at a specific beach were observed returning solely to the same beach. Forty-seven of these individuals were observed at the same site in multiple years. Between 1991 and 2009, 13 turtles (13%) were documented using multiple beaches during the same nesting season or in subsequent seasons (Table 3). The farthest distance between emergence sites of an individual in a single season was approximately 32 kilometers, between Kamehame and Halapē. There was no documentation of successful nesting from this individual (ID# 63) so it is possible she nested at an unknown location along this remote coast. Six of the 13 turtles were originally tagged at Kamehame and were observed at Halapē, Punalu‘u, Kōloa, Kāwā, or Ka‘ili‘ili in subsequent seasons. These nesting beaches are scattered along approximately 42 kilometers of coastline.

Table 3. Tagged hawksbills observed at multiple nesting sites on Hawai‘i Island, 1991-2009.

Turtle ID #	Location Tagged (Year)	Locations Observed (Year)	Distance Between Sites (km)[1]
23	Kamehame (1995)	Punalu‘u (1995, 1999), Kamehame (1999), Nīnole (2009)	3.9, 5.2
26	Kamehame (1995)	Punalu‘u (1998)	3.9
31	Kamehame (1996)	Punalu‘u (2003)	3.9
34	Ka‘ili‘ili (1997)	Kamehame (2004)	6.0
42	‘Āpua Pt. (1998)	Keauhou (2001), Halapē (2004, 2007), ‘Āpua Pt. (2007)	8.0
46	Kamehame (1999)	Punalu‘u (1999), Kōloa (2003)	4.5
48	Kamehame (1999)	Kōloa (2004)	4.5
61	Kamehame (2005)	Ka‘ili‘ili (2005), Kāwā (2005)	6.0
63	Kamehame (2005)	Halapē (2007), Kamehame (2007)	32.0
65	Pōhue (2005)	Humuhumu Pt.(2008)	3.2
66	Pōhue (2005)	Kahakahakea (2005)	3.9
95	‘Āpua Pt. (2009)	Halapē (2009)	8.0
99	Punalu‘u (2009)	Kamehame (2009)	3.9

[1] These distances are approximations between nesting sites

Nesting Events

A total of 742 nests were documented between 1988 and 2009 (Figure 9). The beach with the most activity was Kamehame with 403 nests. ‘Āpua Point was the second most active site with 151 nests. Evidence of adult female emergence was also documented at Kākīwai, Kahakahakea, Humuhumu Point, and Manukā but no nests were confirmed at these locations. In addition, several other sites had reports of activity from community members, but project personnel were unable to confirm hawksbill activity. These sites include Pololū, Kapoho, and Kaimū.

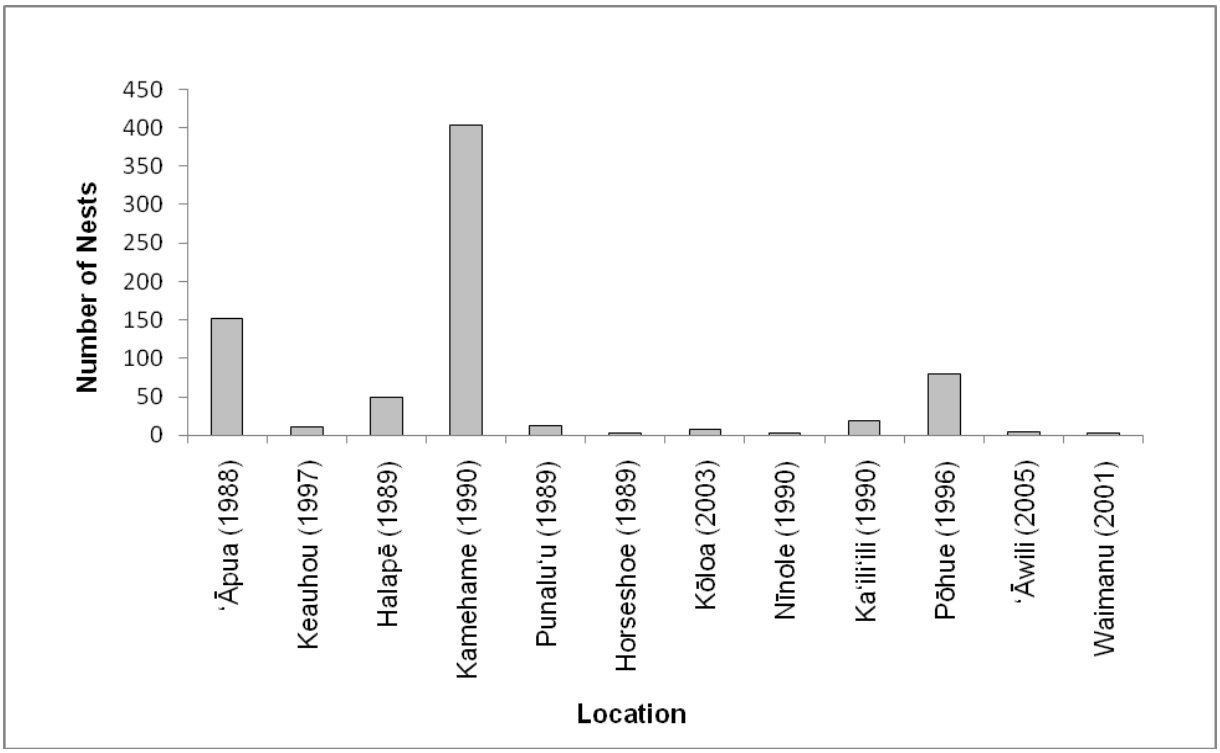

Figure 9. Number of nests at each beach on Hawaiʻi Island from 1988 to 2009 (n= 742). The number in parenthesis equals the year monitoring began at this site. (*Note: although a nest was excavated at Pōhue in 1993, regular monitoring did not begin until 1996).

Based on data from 1,425 crawls, the most common time of adult female emergence from the surf was between 20:00 to 21:00 hours (n= 287) (Figure 10). Beach monitoring effort varied over the years due to the number of personnel, weather conditions, and other factors. In general, hourly beach checks were conducted between dusk and 02:00. Occasionally, individuals with a previous history of coming up after 02:00 were predicted to emerge and monitoring schedules were adjusted. In general, there was minimal beach coverage between the hours of 02:00 and 06:00. Ten nesting females were found already digging or laying eggs during 06:00 beach checks and were not included in time of arrival data.

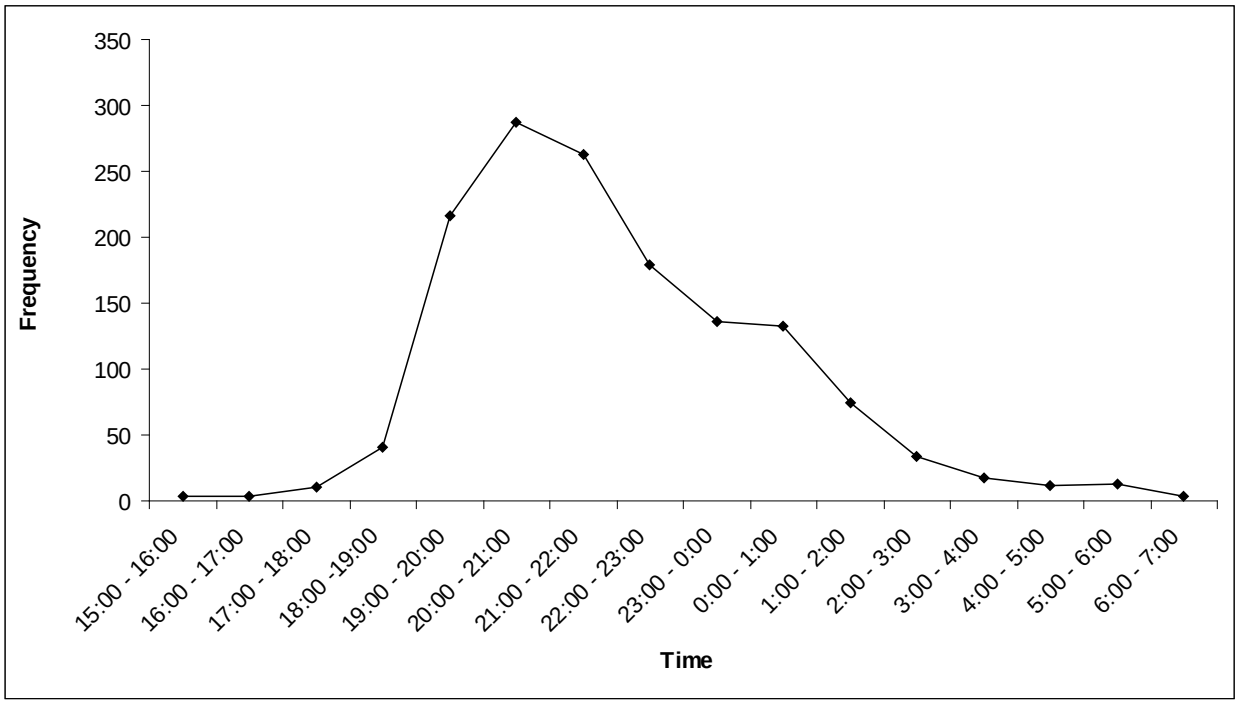

Figure 10. The frequency of arrival times for hawksbill beach crawls, Hawai'i Island, 1989 – 2009 (n= 1,425).

The mean duration of nesting activity (from the time adult female turtles emerged to when she returned to the ocean) was 3 hours and 15 minutes (n= 329 nests observed). The shortest nesting event observed was 1 hour and 10 minutes, while the longest lasted 10 hours and 45 minutes. Occasionally, nesting turtles were first observed already engaged in some stage of nesting activity on the beach; the exact time of emergence and total nesting duration for these individuals are unknown.

Nest Dimensions

Overall, the mean nest depth from substrate surface to the top of the egg chamber was 29.5 ± 0.4 cm (n= 558) with a range of 1 to 66.5 cm. The mean depth from substrate surface to the bottom of the egg chamber was 46.7 ± 0.5 cm (n= 558) with a range of 11 to 88 cm. The mean width at the bottom of the chamber was 30.3 ± 0.3 (n= 543) with a range of 10 to 87 cm.

Nest Translocations

Project protocols were to leave all nests *in situ* unless they faced imminent danger. Thirteen nests (2%) were translocated because of high risk of tidal inundation or insufficient egg chamber construction by the nesting female. Between 1993 and 2009 seven nests laid at Kamehame were translocated to avoid inundation. The first was translocated in 1993 immediately after oviposition and resulted in no evidence of hatchling emergence. When excavated after 86 days of incubation, it was unclear whether eggshells encountered were from hatchlings emerging or from a unhatched eggs decomposing since some eggshells contained yolk stains and predatory ants. The second translocation at Kamehame, also in 1993, was of a nest that was washed out by

high surf. Fifteen eggs were retrieved and re-buried in substrate above the high tide but none hatched successfully. In 1994 a nest was translocated soon after oviposition and resulted in 90.7% hatch success (above the average for the entire data set.) In 1998, a nest was translocated because it was uncovered by high surf after 80 days of incubation. One hundred seventy-one eggs and nine hatchlings out of shells were reburied in a dry location. Subsequently, hatchlings emerged intermittently for several days resulting in an overall hatch success of 36.1%. A nest laid in the inundation zone in 1999 had a 7.8% hatch success. In 2009, two nests were originally laid near the cliff face on the southwest side of the beach, an area that was frequently inundated by high tide. Both nests were relocated to more suitable substrate in the naupaka (*Scaevola taccada*) vegetation region above the high tide line. The translocations were conducted immediately after the post-nesting turtle returned to the ocean. One had a 26.1% hatch success rate while the other had a 91.5% hatch success rate. It is important to note that although the first translocation was below the beach average, the second translocation was 33.8% above the season's average hatch success at Kamehame. None of the eggs or hatchlings from any of these nests would have survived without these emergency translocation measures.

Figure 11. Project personnel translocating a nest at Kōloa, Hawai'i Island.

Figure 12. Eggs are carefully placed in a cooler during a nest translocation.

Personnel translocated all four nests laid at Kōloa in 2003 because of their proximity to the high tide line (Figures 11 and 12). The first nest was discovered on a day check and was presumed past the recommended 12 hour translocation window (Boulon 1999) and was left it *in situ*. Over the following 24 days, it was continuously inundated by high tides so an emergency translocation was performed. The nest failed to hatch and all 198 eggs did not show any signs of development. After recording this initial nest, personnel were assigned to camp at this site during the turtle's (ID# 46) predicted inter-nesting window and observed three more nests being laid. Each clutch was translocated immediately following oviposition. Wire mesh cages were then installed around the nests to protect the eggs from predation. A mongoose tunneled under the one of the cages and destroyed several eggs from one nest. Therefore, nest cage design was modified. Despite predation, the nest still had 60.6% hatch success (Table 4). The two remaining nests had hatch success rates of 62.1% and 61.4% (Table 4).

On two occasions in 2007, a turtle (ID# 81), at Pōhue Bay missing its entire left rear flipper was unable to dig an egg chamber, which resulted in the deposition of eggs on the sand. These were the first documented cases on Hawai‘i Island of a hawksbill laying its eggs without attempting to dig an egg chamber. Personnel immediately translocated the eggs, using standard protocols (Boulon 1999), to a suitable site. The nest hatch success rates were 34.9% and 40.0% (Table 4).

Table 4. Hawksbill nests translocated by HIHTRP, Hawai‘i Island, 1989-2009.

Turtle ID #	Reason Translocated	Hatch Success (%)	Year	Location
Unknown	Saltwater inundation	0	1993	Kamehame
15	Saltwater inundation	UNK[1]	1993	Kamehame
Unknown	Saltwater inundation	90.7	1994	Kamehame
Unknown	Saltwater inundation	36.1	1998	Kamehame
13	Saltwater inundation	7.8	1999	Kamehame
Unknown	Saltwater inundation	0.0[2]	2003	Kōloa
46	Saltwater inundation	62.1	2003	Kōloa
46	Saltwater inundation	60.6	2003	Kōloa
46	Saltwater inundation	61.4	2003	Kōloa
81	Eggs laid on sand	34.9	2007	Pōhue
81	Eggs laid on sand	40	2007	Pōhue
9	Saltwater inundation	26.1	2009	Kamehame
100	Saltwater inundation	91.5	2009	Kamehame

[1] Unable to distinguish between two different nests.
[2] Nest was translocated 24 days after discovered.

Hatching Events and Excavations

Clutch Size

Clutch size for each nest was determined during excavation. Mean clutch size was 175.2 ± 1.5 eggs (n= 631) with a range of 78 to 274 eggs (Figure 13). Data outside 1.5 times the interquartile range were excluded as outliers; some nests were in such close proximity to each other that differentiating the two nests during excavation was difficult. Additionally, old

eggshells that were left to decay in nest chambers after excavation may have been counted during a more recent excavation if they were close enough to the newer nest.

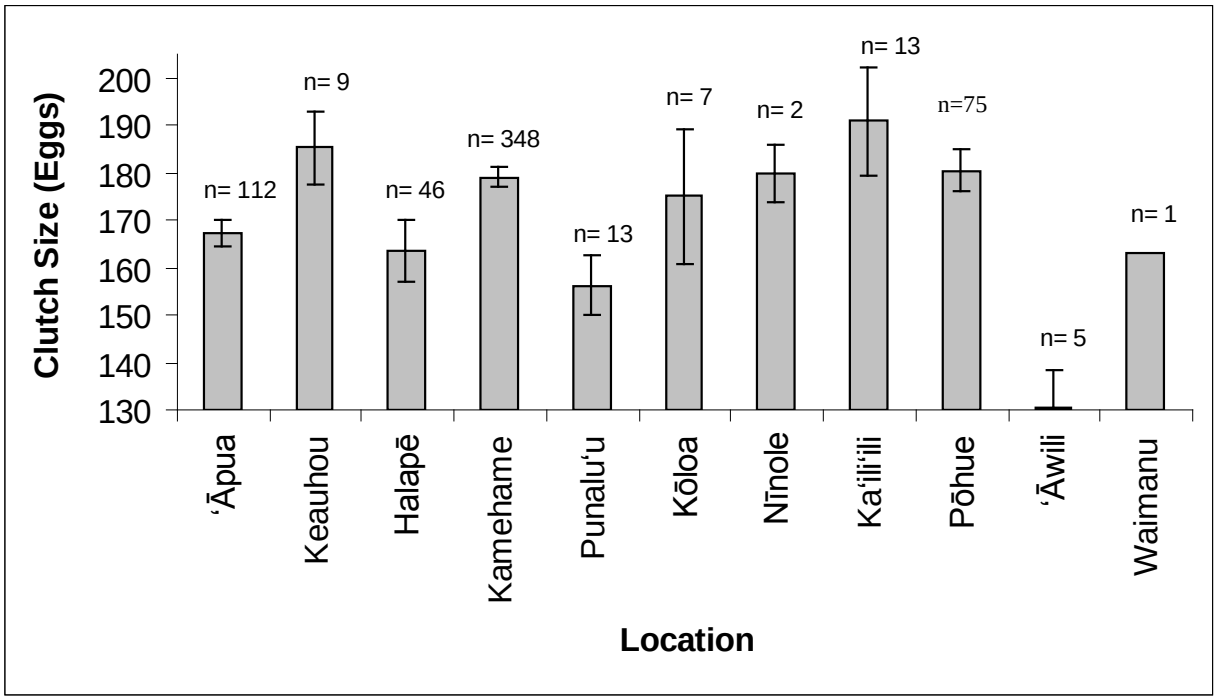

Figure 13. Mean clutch size for the hawksbill by beach from 1989-2009, Hawaiʻi Island (n= 631).

Incubation

Overall, the mean incubation time was 62.5 days ± 0.4 (n= 446) with a range of 50 to 101 days and varied across beaches (see Appendix A for individual beach data) (Figure 14). Keauhou and Halapē had the lowest mean incubation duration of 56 days, while Punaluʻu averaged 73 days and the shadier cave side of Kamehame beach extended up to 101 days.

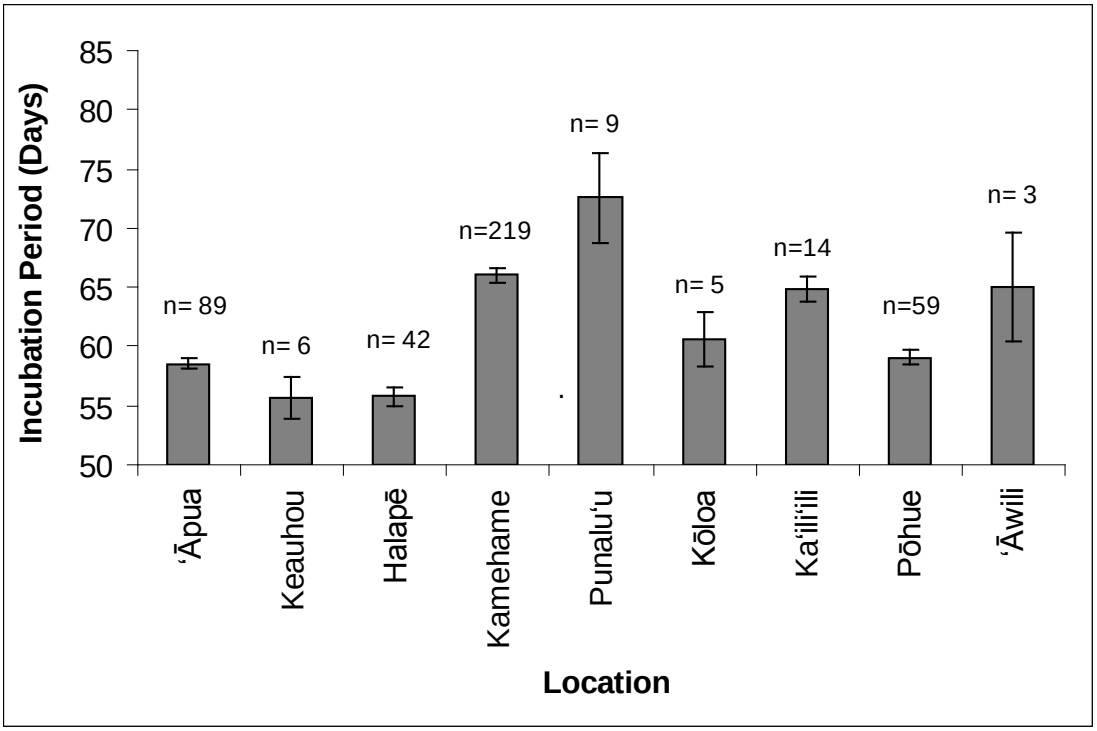

Figure 14. Mean incubation period for the hawksbill by beach from 1989-2009, Hawaiʻi Island (n= 446).

Total Hatchlings

An estimated 80,775 hatchlings reached the ocean from beaches monitored by project personnel on Hawai'i Island between 1989 and 2009 (Figure 15 and 16). This number is based on 666 nests that were excavated and evaluated for hatch success (Figure 17 and 18). From this estimate, an average of 121 hatchlings from each nest reached the ocean. More than half of these hatchlings (58%) were recorded at Kamehame. In addition, a total of 1,474 hatchlings were found dead on rocks or the beach at various locations. Over 800 of the dead hatchlings were observed at ʻĀpua Point; the majority were trapped between rocks on their way to the ocean and died. Some appear to have emerged during the daytime and died from heat stress or desiccation. Dead hatchlings represent approximately 2% of all hatchlings believed to have successfully hatched from nests throughout the study period.

Figure 15 and 16. An estimated 80,775 hawksbill hatchlings reached the ocean off Hawaiʻi Island between 1989 and 2009.

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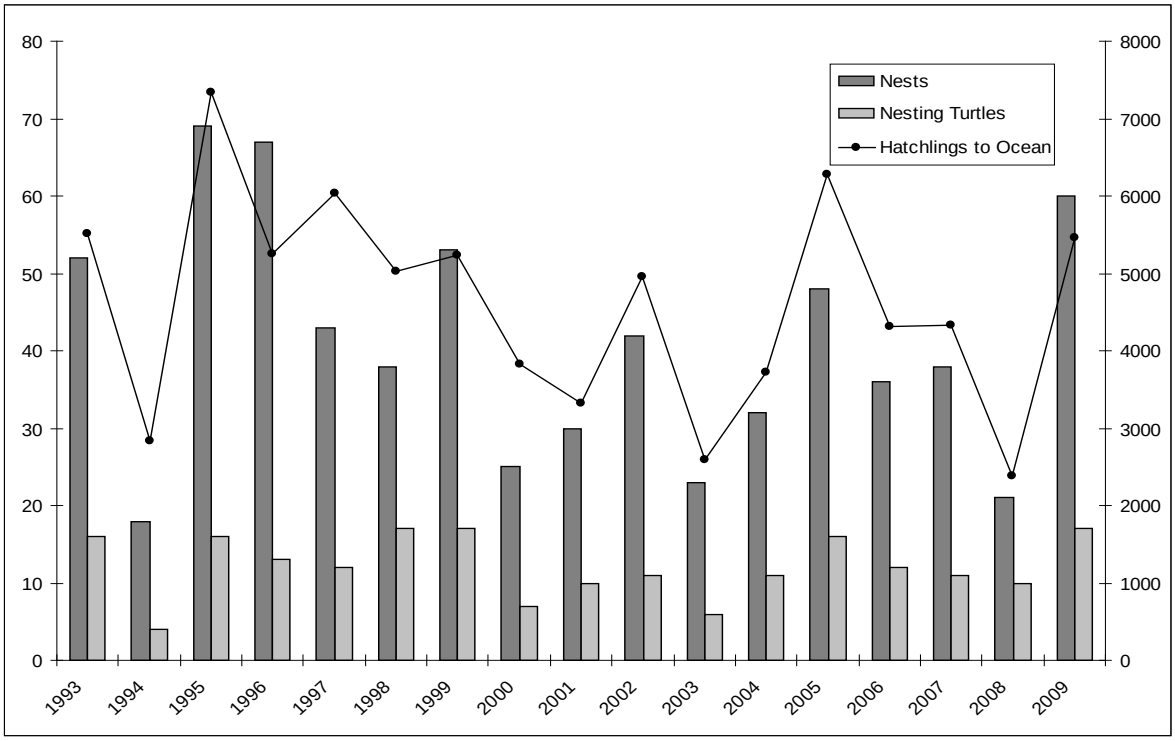

Figure 17. Number of documented hawksbill nests, nesting females, and estimated hatchlings to reach the ocean, Hawai‘i Island, 1993-2009.

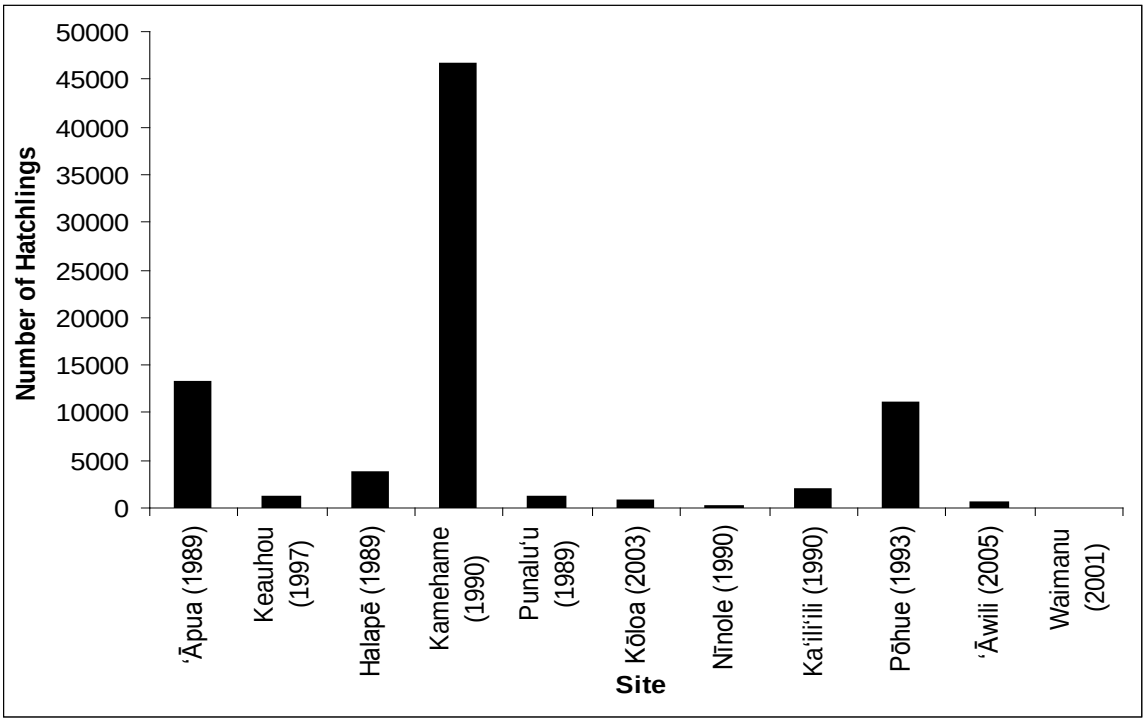

Figure 18. Number of hawksbill hatchlings to reach the ocean by site on Hawai‘i Island from 1989-2009. The year monitoring began at each site is in parentheses. (n=80,775). (*Note: a nest was excavated at Pōhue in 1993, but no monitoring began until 1996.)

Hatch Success

The mean hatch success was 71.9 ± 1.0% (n= 640) with a range of 0.0% to 100.0%. Mean hatch success varied widely across nest sites from 49.1% at Halapē to 83.3% at ʻĀwili Point (Figure 19). Overall hatchling/nest success was calculated by subtracting the number of dead hatchlings found on the beach from the hatch success. However, this percentage is not reported because, for unobserved hatchling emergences, we may have missed hatchlings being predated. Also, we could not always identify which nest a dead hatchling on the beach may have come from. Hatchling mortality on the beach at sites with coverage since management began is negligible.

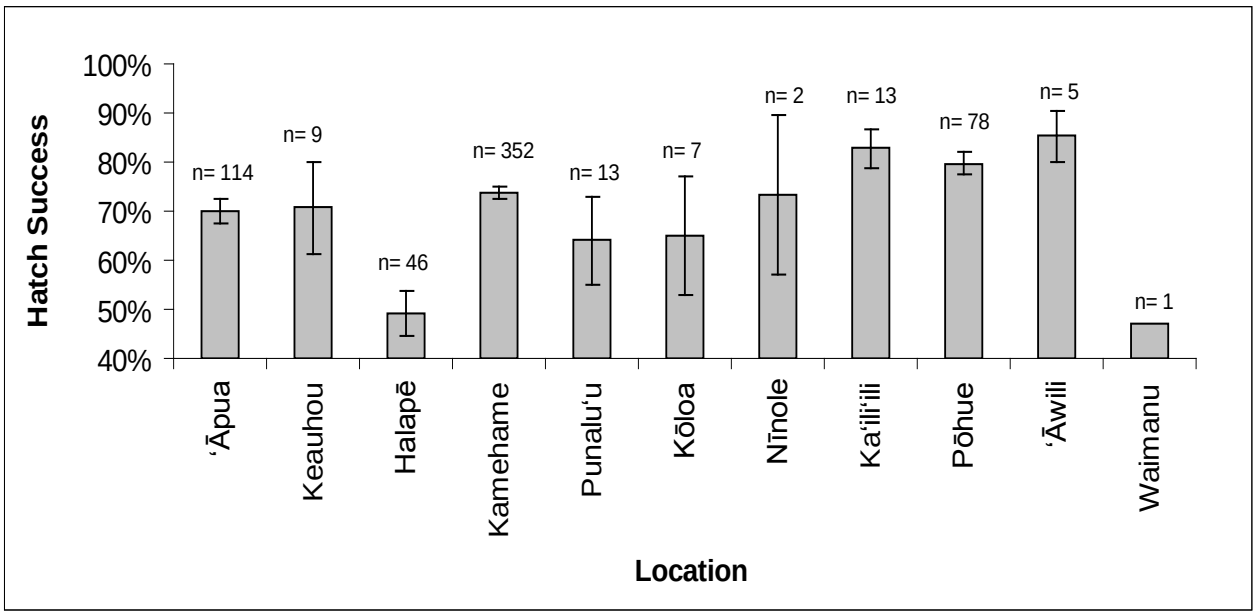

Figure 19. Mean hawksbill hatch success rates by site on Hawaiʻi Island. (n=640).

Nest Predation

At least twenty-three nests (about 3%) were documented as having some predation by mammalian predators (mongooses, rats, feral cats). Documented predation occurred at six different sites: eight nests at Kamehame, five at Pōhue, three at Halapē, two at Keauhou, two at Kōloa, two at Kaʻiliʻili, and one at Punaluʻu. It is likely that more nests were predated, but were not observed. Most predation was recorded in the earlier years of the project.

Density-dependent Nest Destruction

At least 46 nests were found damaged by nesting females. Thirty-six nests were damaged at Kamehame, eight at ʻĀpua Point, and one each at Halapē and Punaluʻu. Nesting females damaged eggs by either digging up a nest previously laid or damaging their own nest while covering it up. In each case, eggs were reburied if they were not destroyed by the nesting female. This was a frequent event at Kamehame where nest overcrowding was an issue due to the limited beach size above high tide suitable for nesting at this site.

Dates of Hatching Activity

The three earliest hatchling emergences were documented at Pōhue Bay on June 6th, June 25th, and July 9th 2007. Prior to the 2007 season, the earliest documented nest was laid in late-May resulting in hatchling emergence in late-July. Beach coverage typically began in June, so it is possible that earlier nests were missed. However, there were no observations of hatchlings in June until 2007. Peak hatchling emergences were from mid-August to late-September. The latest documented emergence was on February 8, 2010. While there were some occasional daylight emergences, the majority were during darkness hours.

Hatchling Carapace Measurements

The mean standard carapace length (SCL) of hatchlings sampled was 4.0 ± 0.0 cm (n= 4,250) with a range of 2.7 to 4.9 cm. The mean standard carapace width (SCW) was 2.9 ± 0.0 (n= 4,213) with a range of 1.9 to 2.8 cm. Hatchling carapace measurements did not vary by which turtle laid the nest, by year, or by site.

Hatchling Strandings and Rescue

At several of the beaches monitored, hatchlings had to crawl across rocky and cobblestone beaches to reach the ocean. The highest numbers of stranded hatchlings were found at ʻĀpua Point. Across all beaches, project personnel rescued and assisted approximately 25,511 hatchlings (31.6%) of the total estimated to the ocean. This includes hatchlings that were assisted during nest excavations. For more details, see Table A3 in Appendix A.

Education and Outreach

Throughout the study period, personnel conducted numerous educational and outreach activities to increase awareness of sea turtle conservation efforts to various beach users, students and nearby communities (Figure 20). Over 500 personnel who participated in project activities received education and training about sea turtle conservation and management. This training enabled them to serve as on-site interpreters for sea turtle conservation, and to educate and promote compatible beach activities to various beach users. In addition, personnel held educational field trips for teachers and students, where participants visited nesting beaches and learned about nesting turtles. Personnel also presented interpretive talks at a variety of venues (e.g. educational fairs, workshops, schools and park visitor programs) to inform the general public about sea turtle conservation. Also, to increase community awareness, the project held public excavation events where the media and general public were invited to witness nest excavations and assist hatchlings to the sea.

Data on the actual number of events was not recorded. However, a conservative estimate is between five and fifteen formal outreach events performed each year, including public nest excavations, student field trips, teacher workshops, classroom or public presentations, and exhibits at fairs. Additionally, on-site interpretation and informal educational outreach were conducted daily by field personnel to hundreds of beach users at nesting beaches each season. Coastal trash cleanups were performed and informational brochures were distributed to local residents and visitors.

Figure 20. Larry Katahira educates children at a Punaluʻu community nest excavation.

Discussion

Status of Hawai‘i Island Population and Nesting Numbers

Statewide, 107 nesting hawksbills have been tagged. One hundred have been tagged on Hawai‘i and seven on Maui (Hawai’i Wildlife Fund, 2010). In addition, the National Marine Fisheries Service (NMFS) Pacific Islands Fisheries Science Center Marine Turtle Research Project (MTRP) reports tagging 15 hawksbills (mostly sub-adults) since 1996 (Balazs and Hargrove pers. comm.). Typically, fewer than 20 nesting females are reported annually in the state of Hawai‘i. Most documented accounts of sea turtles in Hawai‘i refer to the honu or green turtle (*Chelonia mydas*). Some of these accounts may have mistaken hawksbills for greens as misidentification between the two species is common. Furthermore, due to wide ranging isolated nesting habitat scattered along remote coasts, limited field coverage, and the elusiveness of the hawksbill, some nesting females may have nested undiscovered. Despite sporadic reports of nesting activity in the main Hawaiian Islands since the late 1960’s (Ernst and Barbour 1972, Balazs 1978b), historical data are limited. As a result, long-term population trends for the entire population, or for nesting females in particular, remains a challenge. Current research into the historical ecology of hawksbills shows populations across the Pacific and Hawai‘i were severely depleted by the tortoiseshell trade (K. S. Van Houtan pers. comm.).

On Hawai‘i Island, the increasing number of newly tagged adult females in recent seasons (Table 2) is a positive indication that, despite the relatively small number of hawksbills in this population, recruitment of new nesters continues. Further data analysis is required to determine whether or not hawksbills nesting on Hawai‘i Island have an increasing, decreasing, or stable trend. It is possible that the hawksbill population in Hawai‘i may historically have always been small. Outside of Hawai‘i, estimates of the age when hawksbills reach sexual maturity are 20-25 years (Spotila, 2004). Limpus (1992) reported age at maturity for Australian hawksbills to be 15-25 years old. Bone samples collected from dead stranded adult females by HIHTRP were sent to NMFS to aid in skeletochronology research on the age of sexual maturity in Hawai‘i (Figure 21 and 22). Preliminary results indicate an estimate of approximately 20 years old and 80 cm SCL (Snover, et. al. unpublished data). Since management of most nesting beaches by HIHTRP has been for less than 20 years, attributing an increase in the number of nesters to our protective efforts may be premature, although such gains may occur in the near future.

Figure 21. Turtle ID #47 found dead at ʻĀpua Point, Hawaiʻi Island.

Figure 22. Personnel collect remains for the NMFS skeletochronology research.

An increase in the number of new females tagged may not necessarily translate to an increase in the breeding population. The total number of nesting females can fluctuate dramatically between years (e.g. 16 in 1993, 6 in 2003, 16 in 2005, and 17 in 2009). Between 2005 and 2009 there have been fewer remigrants observed. Among females tagged on Hawaiʻi Island, at least three have died. Also, it is possible that a few newly tagged turtles may be previously tagged individuals that had lost their old tags. Prior to 2000, females were tagged on two flippers. Beginning in 2000, turtles were tagged on all four flippers. Of the 97 tagged females that could be still alive, 17 have not been observed in nine or more seasons. Including the three dead tagged females, these 20 individuals represent 20% of tagged females. Based on remigration intervals (2 to 10 years) it is likely that some of these animals have permanently disappeared from the reproductive population.

Hawaiʻi Island Population Compared to Hawksbills Elsewhere

The results of data collection by the HIHTRP, when compared to other U.S. hawksbill nesting beaches (Florida Fish and Wildlife Conservation Commission, 2007), indicate that the principle nesting ground for hawksbills in the U.S., excluding territories, is in Hawaiʻi. Genetic material collected from nest samples over ten seasons was sent to the NMFS Marine Turtle Molecular Ecology Laboratory for genetic analysis and archiving. Preliminary results from these samples suggest that the five haplotypes identified within this local population were all unique to Hawaiʻi (Dutton and Leroux, 2008 unpubl. data).

In general, nesting data for hawksbills along the Kaʻū coast did not differ significantly from populations found worldwide (Table 5). In Barbados, hawksbills were found to nest continuously year round with a peak from June to August (Beggs, et al., 2007). We found that the nesting period in Hawaii follows a strong seasonal pattern with nesting taking place primarily in early summer thru early fall with a peak between July through September. Nest site fidelity was high with only 13% of individuals using multiple beaches. This percentage may be an underestimate, as some nesting may have gone undetected. These numbers are similar to Barbados, where 17% of 1,250 nesting females were observed using multiple sites in the same

nesting season (Beggs, et al., 2007). Based on carapace size, turtles that came up to nest (mean carapace length was 82.3 cm) were comparable to hawksbills at other beaches outside of Hawai‘i. The mean carapace length of 17 populations around the globe was 78.6 cm (Van Buskirk and Crowder, 1994) and range of the means for populations worldwide was reported between 66 and 86 cm (Witzell, 1983). Hawai‘i Island hawksbills averaged 3.3 (range 1 to 6) clutches per turtle per season. In Barbados, a much larger sample of 1,250 turtles yielded 4.1 clutches per season (range of 1 to 6) and 4.1 is also what Limpus, et al. (1983) reported for other Pacific hawksbills on Campbell Island, Queensland, Australia. Maui, Hawai‘i nesters average four clutches per season (King, et al. 2007).

Table 5. Number of hawksbill nests in the Pacific Region. Data is from 2006 nesting season. Outside Hawai‘i data is from SWOT Report Volume 3 (Mast, et. al 2008).

Location	Nests
Hawai‘i Island, U.S.A	36
Maui, U.S.A.	4
Palau	74
Fiji	5
Samoa and American Samoa	27
Solomon Islands	631

Primary differences between Hawai‘i Island hawksbills and populations elsewhere were inter-nesting intervals and clutch size. The average inter-nesting interval recorded on Hawai‘i (20 days) is higher than data reported from hawksbills globally (13-16 days, Spotilla, 2004). Also, local individuals on average have larger clutch sizes (175 eggs per nest) than those reported globally (130 eggs from 17 populations (Van Buskirk and Crowder, 1994). Statistical analysis to determine if these differences are significant is planned for the future.

While mean incubation across all beaches was comparable to populations outside of Hawai‘i Island, large fluctuations occurred across beaches (50 to 101 days). This could be related to differences in temperature at nesting sites and may possibly result in different outcomes in nest hatch success (Hillis-Starr and Phillips, 2000). As mentioned previously, temperature data loggers were placed at six nest sites in various years between 1998 and 2009 as part of a collaborative study with NMFS and Dr.Thane Wibbels. The preliminary results suggest that Hawai‘i Island nesting beaches are producing an approximately 50/50 hatchling sex ratio but data analysis is still in progress (Wibbels and Estes, pers. comm.).

For hatchlings along the Ka‘ū coast, hawksbill nest hatch success (72%) appears to be average compared with reports from other locations (Van Buskirk and Crowder, 1994); but higher than the 38% reported on Maui (Table 6). Mean carapace size of hatchlings was also similar to populations outside of Hawai‘i (Van Buskirk and Crowder, 1994).

Table 6. Global hawksbill mean nest hatch success by location.

Location	Hatch Success (%)	Citation
Hawai'i Island, U.S.A	72	Seitz, et al. This report
Maui, U.S.A.	38	King, et al. 2007
Jumby Bay, Caribbean	75	Richardson, et al. 1999
Bahia, Brazil	52 - 78	Marcovaldi, et al. 1999
Tortuguero, Costa Rica	58	Bjorndal, et al. 1985
Western Samoa	71	Witzell and Banner, 1980
Seychelles	86	Diamond, 1976
Malaysia	60	Chan and Liew, 1999
Milman Island	79	Dobbs, et al. 1999

Threats to Hawai‘i Island Population

Primary threats identified to hawksbill nesting sites along the Ka‘ū coast were incompatible human activity, non-native egg and hatchling predators, and habitat loss caused by invasive weeds, changes in beach conformation, volcanism, tidal inundation that resulted in nest overcrowding and/or damage to nests and injury to hatchlings. The extent of each threat varied among the beaches and is described in detail for each nesting beach along with management recommendations in Appendix A. A general discussion of threats is provided below.

Human impacts are most pervasive at beaches accessible by vehicle or within short walking distance to roads. Off-road vehicles can damage nests and hatchlings and compact sand, making nesting more difficult for females and emergence more difficult for hatchlings. Artificial lights disorient females and hatchlings, increasing the risk of strandings, injury, and death. Of all the sites monitored, Punalu‘u, Horseshoe, Kōloa, and Nīnole are the easiest to access for humans and experience the heaviest public use. Access was unrestricted and a paved public road leads to Punalu‘u black sand beach and a network of unimproved roads lead to the other beach sites. Until 2005, approximately half of Punalu‘u beach was regularly plowed and flattened for use as an access road, reducing the amount of nesting habitat. A condominium complex and golf course are located inland of these nesting sites. The area was a highly popular among residents for recreation, camping, and fishing. In addition, this beach is a popular tourist destination. People regularly drove vehicles on the nesting habitat, made fires, used artificial lights at night, littered the beach, and used fishing line and nets at these sites. Throughout the study period there were several instances of hatchlings that became disoriented by streetlights and car lights emitted from the parking lot at Punalu`u Beach Park. Two adult females were disoriented by artificial lights from a nearby streetlight, and a third by the lights of a beach house. In these cases, management intervention was needed to redirect or physically assist turtles and hatchlings back to the ocean. Other beaches with significant amounts of human activity are Kāwā and Ka‘ili‘ili. At these sites, artificial lights from campers and fishermen, and vehicles driving on nesting habitat are major concerns. Between 1998 and 2001, Pōhue experienced similar impacts from

off road vehicles on nesting habitat, camping, artificial lighting, and trash, but these impacts subsided and nesting habitat has improved since this private property came back to the previous management. At remote beaches (ʻĀpua Point, Halapē and Humuhumu Point), four dead turtles, found in lava cracks or boulders, may have been disoriented by lights from campers while prospecting for a nesting site. In addition, three adult females required assistance getting back into the ocean at these sites. Throughout the study period, project personnel worked with adjacent landowners, Federal, State, and County agencies and local communities and schools to increase public awareness on the impacts of light pollution, and human activities on sea turtle conservation in an effort to promote more compatible beach use (e.g. reducing artificial lights or retrofitting artificial lights with downward directing shields, limiting off-road driving on beaches during nesting season). At beaches within Hawaiʻi Volcanoes National Park, campers that were issued backcountry permits were provided with brochures about sea turtle conservation that included information on ways to minimize incompatible human actions, and with red cellophane to cover their flashlights.

Threats from non-native predators (e.g. mongoose, rats, feral cats and pigs) that destroy eggs and prey on hatchlings were a concern at all nesting beaches. Animals were often concentrated where human food and trash were found. Predation by black rats, mongooses, and feral cats has also been reported at other nesting sites around the U.S. (Hillis 1990 and Hillis-Starr 2000, Seabrook, 1989). Efforts to work with landowners to reduce the number of predators in the vicinity of nesting sites, erect temporary enclosures around nests, and conduct regular trash clean-ups at beaches have been effective in reducing the number of nests depredated.

Unfavorable site conditions, including volcanism, changes in beach conformation and loss of nesting habitat were a concern at several beaches. At ʻĀpua, changes in beach conformation that resulted from the 1975 earthquake created a significant barrier to emergent hatchlings trying to reach the sea. Hatchlings were often stranded in cobblestones and needed to be rescued. Approximately, 72% of all hatchlings that reached the ocean at this site were directly assisted by project personnel. In addition, three adult turtles were found stranded in the boulders in the vicinity of the point. Two were dead and the third was returned to the ocean.

Nest overcrowding was a major issue at Kamehame beach and may become an increasing concern at other nesting beaches. The small beach area and relatively high number of nests resulted in females digging up other nests on occasion. In some instances, females had to be redirected away from established nests. Also, translocation of nests that were in danger of being inundated or exposed (unburied) by waves was needed at Kamehame, Koloa and Pōhue. Our findings support evidence that nest translocations can be successful and increase the nest hatch success above 0% when performed within the recommended timeframe (Boulon 1999). Ten of the 13 translocations were conducted shortly (<6 hours) after oviposition. Nest hatch success ranged from 26% to 91%. Nest translocation could potentially be utilized at ʻĀpua Point in the future. For the last twenty years, nests have not been moved within this site as we have relied on having nearly continuous onsite coverage. Hatchling survival at this site is low unless there are personnel on site to monitor nests and assist hatchlings to the ocean across the cobblestone beach. If circumstances permit, in the future personnel may relocate nests to a more suitable location at this site where hatchlings are more likely to reach the ocean without assistance. Alternatively, translocating nests to other sites such as Keauhou and Halapē, where hatchlings

would have unobstructed access to the ocean may also be an option, although much more costly. The project recognizes that performing translocations can put eggs at higher risk and must be done with adherence to strict protocols; we will evaluate the utility and feasibility of this nest management technique as needed in the future.

At several beaches (e.g. Halapē, Kamehame, Pōhue, Punaluʻu) available nesting habitat is further reduced by encroachment of invasive koa haole (*Leucaena leucocephala*) christmasberry (*Schinus terebinthifolia*), fountain grass (*Pennisetum setaceum*), coconut (*Cocos nucifera*), and other non-native plants. Roots of these species form dense matrices in the sand making it difficult for females to dig nests and trapping hatchlings that become entangled during emergence, both of which were observed on numerous occasions during the study period. At several sites, personnel have communicated with landowners to identify and reduce threats from non-native plants. Across all beaches, future sea level rise predicted as a result of global climate change may reduce the already limited nesting habitat, although no studies have been completed at this time to predict sea level rise for these particular sites.

Eight nesting females with missing front or hind flippers or with other deformities were observed. Some of these nesters were capable of egg chamber construction independently while others were not. In the latter, personnel either assisted the turtle with digging an egg chamber or buried eggs deposited on the sand. No hawksbills were observed with visible signs of fibropapilloma, despite sharing beaches with infected basking green sea turtles (*Chelonia mydas*). This was a common occurrence at Kamehame where we worked with NMFS Pacific Islands Fisheries Science Center to remove severely infected green turtles to receive diagnosis from a veterinarian.

While this project summarizes onshore activities of hawksbills and the threats to nesting beaches on the Island of Hawaiʻi, additional work by scientists, either in collaboration with HIHTRP or as separate studies, is underway to understand the inter-nesting behavior and in-water habitat use of individuals. These include satellite and radio telemetry studies that have identified post-nesting migration routes and foraging grounds along the Hamakua Coast of Hawaiʻi Island (see Appendix C) (Balazs, et. al, 2000; Graham, 2009; Parker, et al. 2009), and observations of tagged individuals in waters off Maui and Johnston Atoll (Graham, 2009; C. King, U. Keuper-Bennett and P. A. Bennett, unpubl. data). Other than one individual seemingly live-tracked tracked past Johnston Atoll, it appears that most Hawaiian hawksbills tracked thus far reside strictly within the waters of the MHI. Such studies will contribute towards understanding and addressing threats at sea where turtles spend the majority of their time.

Conclusions

Monitoring over the last two decades combined with reports prior to the inception of the project have identified 17 nesting sites, primarily along the southern coast of Hawai‘i Island. There are also unconfirmed reports from several additional sites. Though nesting activity is low (fewer than 20 observed nesting females a year), most of these sites are used consistently by nesting hawksbills and appear critical to species reproduction on the island. Over the last twenty years, through funding provided primarily by NPS, FWS, Hawai‘i Natural History Association (HNHA), and NMFS, project personnel provided continuous nightly coverage at four to six beaches, routinely monitored ten others, and responded to reports at five other beaches. More than 500 people were directly involved in monitoring and protection of nesting sites. Participants included NPS volunteers and staff, PCSU interns and technicians, adjacent land managers/owners, and individuals from the surrounding communities. A total of 100 adult nesting turtles were identified; 742 nests were documented and over 80,000 hatchlings were estimated to have reached the ocean. Additional educational outreach efforts (e.g. field trips, brochures, news articles, presentations at schools, workshops, conservation meetings) increased public awareness and support for the project among beach users and surrounding communities. Threatened by small mammalian predators, human activity, and habitat modification, future hawksbill nesting activity on the island will depend largely on continued monitoring and management of nesting beaches and community education. Based on our findings from 1989 to 2009, we have the following objectives for continued conservation efforts in the future:

1) *Continue and expand monitoring and protection at documented nesting sites.* Due to limitations in resources and personnel, our focus is primarily on monitoring beaches that have the most documented activity and the greatest threats to hatchling survival. However, it is clear that all known nesting beaches need to be monitored and managed, regardless of their activity levels that season. Furthermore, we know that some individuals use multiple beaches, consequently an individual nesting at one beach could arrive unexpectedly at another unmonitored and unprotected beach. Increasing coverage at potential sites and monitoring beaches occasionally during non-peak season could assist in documenting potential new turtles. Given the small number of nesting turtles each year, efforts should be made to document and monitor as many nesting turtles, nests, and hatchlings as possible to continue expanding our knowledge base and encourage the recovery of this species. Protective actions will continue to include predator control, habitat improvement through invasive plant management, visitor education, and hatchling assistance.

2) *Secure long-term funding for the project.* From 1989 to 1992, a limited amount of monitoring was funded and staffed by HAVO that covered primarily beaches within the park. Since then, the project has grown slowly into a partnership among Federal and State agencies, PCSU-University of Hawai‘i-Mānoa, private landowners, and non-profit organizations. From 1993 to 2001, FWS, NPS, and HNHA were the primary funding partners for this program. Over recent years the project has continued through yearly funding provided by grants from State and Federal agencies (NPS, NMFS, FWS), donations

from HNHA and World Turtle Trust, and in-kind support from generous private landowners and volunteer personnel. Securing adequate and long term funding in the face of rising operating costs and budget reductions continues to be a significant challenge.

3) *Expand surveys to identify additional nesting beaches.* Due to an increase in primary threats over the past few years, such as numerous incompatible coastal developments (both constructed and proposed) and the rapid spread of invasive species, it would be beneficial to expand our nest search around the entire island. Confirmed nesting beaches on the island are scattered over 240 kilometers of coastline from ʻĀwili Point in the south to Waimanu in the north. There are many potential nesting beaches on the island to be surveyed for nest activity. While we have identified numerous potential beaches around the island either through surveys or reports from community members, systematic follow-up monitoring is often difficult due to a lack of access, personnel, or resources. We need to continue to work with landowners to gain access to these sites.

4) *Continue with education and outreach efforts.* Building support in the community is imperative for the long-term success of the project. In particular, increasing public awareness on the harmful impacts of off-road vehicles, trash, artificial lights and predators is needed to reduce incompatible human actions during critical nesting periods.

5) *Strengthen partnerships.* We need to further strengthen our partnerships with private landowners, County, State, Federal agencies, educational institutions, non-profits, and community members to secure funding, gain access to potential nesting beaches, and promote responsible stewardship of coastal resources.

6) *Additional analysis of long-term data sets.* This technical report is a first step in consolidating and reporting twenty years of monitoring and data collection at nesting beaches on Hawaiʻi Island. Additional research and analysis of data by the authors is planned over the next few years to evaluate population trends, the influence of local environmental factors on nest success, and other biological characteristics of this nesting aggregation.

Specific management recommendations for each nesting beach are provided in Appendix A.

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Agency: U.S. Fish and Wildlife Service
Pacific Islands Fish and Wildlife Office,
Grant Numbers from FY00 to FY09
12200-9-J-008 FY00, FY01
12200-2-G-001 FY02, FY04
C26267 Landowner Incentive Program (LIP) 2006
#2006 Private Stewardship Grant Program (PSGP) 2006
N0160 Private Stewardship Grant Program (PSGP) 2007
12200-6-N-012
Discretionary Fund 2006-2009

Agency: NOAA National Marine Fisheries Service
Pacific Islands Regional Office
Grant Numbers from FY07 to FY09
NA07NMF4540171
NA08NMF4540524
NA09NMF4540158

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APPENDIX A: Site Descriptions and Results Summaries for Individual Nesting Beaches

<u>ʻĀpua Point</u>

ʻĀpua Point is a windswept, rocky, cobblestone/coral beach with scattered pockets of sand (Figure A1). It is located approximately 9.7 km south of Chain of Craters Road in Hawaiʻi Volcanoes National Park (HAVO). The total area of the beach is nearly 4,300 m^2 with approximately 760 m^2 of suitable nesting habitat (Figure A2). The total beach area is defined by the debris line that marks high tide inwards towards dense vegetation. Suitable nesting habitat is defined as an area above the high tide line with substrate in which a nesting turtle is capable of digging an egg chamber. At ʻĀpua Point the majority of nesting habitat is separated from the ocean by a stretch of cobblestones, which was created by a 7.2 magnitude earthquake and tsunami in 1975. This barrier impedes most hatchlings from reaching the ocean on their own. Adjacent to the stretch of cobblestone is a sandy area that hatchlings can successfully transverse to reach the ocean. Common vegetation found inland beyond the cobble stones and sandy area at this site includes: naupaka (*Scaevola taccada*), coconut (niu) (*Cocos nucifera*), beach morning glory (pōhuehue) (*Ipomoea pes-caprae*), and maunaloa vine (*Canavalia cathartica*).

Figure A1. Aerial view of ʻĀpua Point, Hawaiʻi Island.

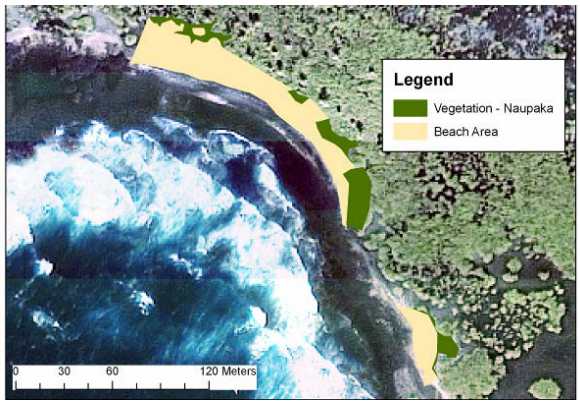

Figure A2. Map of the nesting habitat at ʻĀpua Point, Hawaiʻi Island.

ʻĀpua Point Observed Nesting Activity and Nest Success

Prior to the 1980's, hawksbills were observed on this beach (J. Leialoha personal communication). Evidence of nesting activity was first documented by HAVO and NMFS personnel during low level aerial surveys in fall of 1988. In March 1989, four nests were located and excavated to determine species, estimate nest productivity, and document evidence of predation and other limiting factors (Balazs and Choy, unpublished report, 1989). HAVO Resource Management personnel began monitoring intermittently for nesting activity in July 1989. Continuous monitoring began during the nesting season in 1990 and tagging of adult females started in 1991.

Between 1991 and 2009, a total of 19 adult females were tagged at ‘Āpua Point (Table A1). On average, one to two nesting turtles were documented each season (n= 21), although as many as four nesting turtles were observed (1996, 2005, 2009). No nesting activity was documented in two out of 21 monitoring seasons (2000, 2003). Among tagged females, mean nesting turtle remigration interval was 3.0 ± 0.3 years (n= 29) with a range of two to eight years. The mean nest-to-next crawl inter-nesting interval was 18.6 ± 0.4 days (n= 48) with a range of 15 to 24 days. The mean nest-to-nest inter-nesting interval was 19.2 ± 0.5 days (n= 41) with a range of 15 to 29 days.

Table A1. Hawksbill activity and monitoring effort, ‘Āpua Point, Hawai‘i Island, 1988-2009.

Year	Observed Nesting Turtles	Observed Turtles	Newly Tagged Turtles	Remigrant Turtles	Monitoring Days	Monitoring Nights
1988	0[1]	0[1]	0	0	0[5]	0[5]
1989	0	0	0	0	15	41
1990	0	0	0	0	11	46
1991	2	2	2	0	2	91
1992	1	1	1	0	2	92
1993	3	4	2	2	3	143
1994	2	2	1	1	1	166
1995	2[2]	2[2]	0	1	1	141
1996	4	4	0	4	0	147
1997	2	3	2	1	1	140
1998	3	4	1	3	2	172
1999	1	3[3]	1	2	3	173
2000	0	0	0	0	2	83
2001	1	2	1	1	2	137
2002	3	3	1	2	2	171
2003	0	0	0	0	18	64
2004	2[4]	4	1	3	2	174
2005	4	4	1	3	3	187
2006	2	2	1	1	4	146
2007	1[4]	2[3]	1	1	2	164
2008	1	2	1	1	13	141
2009	4[4]	4	2	2	14	166
Total	38	48	19	28	103	2785
Mean n=21	1.8	2.3	0.9	1.3	4.9	132.6

[1] Nests and/or crawls found, but no turtles were observed.
[2] One turtle was observed nesting but not tagged.
[3] Adult female hawksbill found dead.
[4] One of these individuals was observed nesting at Halape in same year.
[5] Some monitoring occurred, but no records in monitoring database.

A total of 151 nests were documented between 1988 and 2009 (Table A2). The mean incubation period was 58.5 ± 0.5 days (n=90) with a range of 50 to 73 days. The mean clutch

size was 167.3 ± 2.6 eggs (n= 112), with a range of 86 to 244 eggs. The mean nest hatch success was 69.9% ± 2.5% (n= 114) with a range of 4.5 to 100.0%. From the 151 nests, an estimated 13,209 hatchlings reached the ocean. Most hatchlings were assisted by onsite personnel who rescued hatchlings trapped in cobblestones and boulders.

Table A2. Hawksbill nest results, ʻĀpua Point, Hawaiʻi Island, 1988-2009.

Year	Nests	Nests Excavated	Mean Incubation (days)	Mean Clutch Size (eggs)	Mean Nest Hatch Success (%)	Hatchlings to Ocean
1988[1]	4	4	ND	ND	ND	ND
1989	8	1	ND	169.0 n=1	97.0 n=1	370
1990	6	5	ND	120.5 ± 34.5 n= 2	ND	109
1991	4	4	59.5 ± 2.5 n=2	171.5 ± 4.9 n= 4	49.6 ± 15.5 n=4	323
1992	6	2	ND	ND	ND	62
1993	13	11	60.4 ± 1.2 n=7	169.7 ± 4.5 n=11	78.2 ± 8.4 n=11	1,365
1994	9	9	59.4 ± 1.0 n=5	188.6 ± 9.1 n=9	83.2 ± 5.8 n=9	1,367
1995	7	6	60.0 ± 2.2 n=7	161.5 ± 5.2 n=6	77.7 ± 6.9 n=6	745
1996	21	17	58.7 ± 1.5 n=10	169.3 ± 8.3 n=12	66.9 ±7.4 n=13	1,441
1997	7	7	57.4 ± 2.3 n=5	172.1 ± 6.5 n=7	70.0 ± 12.4 n=7	765
1998	7	7	59.0 ± 1.5 n=4	184.0 ± 14.6 n=7	67.9 ± 11.5 n=7	873
1999	6	5	64.0 ± 1.6 n=6	155.2 ± 2.9 n=5	79.3 ± 9.7 n=5	616
2000	0	0	NA	NA	NA	0
2001	2	2	53.0 ± 0 n=2	156.5 ± 26.5 n=2	29.6 ± 5.0 n=2	90
2002	9	9	59.9 ± 2.0 n=9	162.9 ± 12.2 n=9	63.1 ± 12.3 n=9	903
2003	0	0	NA	NA	NA	0

Year	Nests	Nests Excavated	Mean Incubation (days)	Mean Clutch Size (eggs)	Mean Nest Hatch Success (%)	Hatchlings to Ocean
2004	5	5	59.3 ± 3.8 n=4	146.8 ± 6.7 n=5	47.3 ± 13.5 n=5	343
2005	11	11	58.3 ± 1.2 n=9	169.0 ± 5.7 n=11	72.7 ± 7.9 n=11	1,318
2006	5	5	56.8 ± 1.0 n=4	163.8 ± 2.9 n=5	65.6 ± 9.6 n=5	522
2007	2	2	56.5 ± 1.5 n=2	165.5 ± 10.5 n=2	82.2 ± 10.1 n=2	270
2008	4	3	54.5 ± 2.1 n=4	191.3 ± 17.3 n=3	73.9 ± 14.1 n=3	417
2009	15	14	55.5 ± 0.9 n=11	155.1 ± 11.7 n=11	70.9 ± 6.8 n=14	1,310
Total	151	129	NA	NA	NA	13,209
Mean	7.0 n=21yrs	6.0 n=21yrs	58.5 ± 0.5 n= 90 nests	167.3 ± 2.6 n=112 nests	69.9 ± 2.5 n=114 nests	629 n=19 yrs

[1] Nesting activity discovered in Fall 1988 and nests were excavated in March 1989.
ND=No Data.
NA=Not Applicable.

ʻĀpua Point Monitoring Effort

ʻĀpua Point was the first site that received intensive monitoring coverage on a regular basis. This site was given priority based on the high incidences and potential for hatchling fatalities along the rocky, cobblestone substrate. However, hawksbill activity was not observed after three months of intensive monitoring during the peak egg laying season (June through August) in 2000 and 2003 (Table A2). Therefore, during these two seasons personnel were reassigned to cover other nesting sites that had more documented activity. Throughout these periods, day checking and occasional camping occurred at ʻĀpua Point.

ʻĀpua Point Threats

For the most part, nesting females were successful in their ability to navigate over the cobblestones to the vegetation at ʻĀpua Point (Figure A3). However, the habitat alteration that resulted from the 1975 earthquake created a significant barrier to emergent hatchlings that attempted to reach the sea (Figure A4). Hatchling strandings were highest at ʻĀpua among all nesting beaches that were monitored (Table A3). In 1989, 350 hatchlings were found dead and 370 live hatchlings were rescued. This trend of stranded hatchlings continued in subsequent years. The majority of stranded hatchlings were stuck among the cobblestones and died from dehydration and desiccation, or were rescued by personnel (Figure A4). Of the hatchlings found

dead or rescued several were entangled in beach vegetation. Furthermore, additional hatchlings were preyed upon as they struggled to reach the ocean. In response to this problem, onsite personnel observed where nests were laid and placed lawn edging around the nest (Figures A5 and A6) to coral the hatchlings so they could be released on a sandy part of the beach (Figure A7). In other cases, a corridor or runway was made to provide hatchlings a safe passageway to the ocean (Figure A8).

Throughout the history of the Project, three adult females were found stranded in the boulders of ʻĀpua Point (ID#5 in 1998, ID#1 in 1999, ID#47 in 2007). Of these turtles, two were found dead. The other one (ID#5) was released to the ocean, but was never observed again. It is probable that these three turtles became stuck in the rocks while prospecting for a nesting site.

Figure A3. Nesting hawksbill found crawling over cobblestones, ʻĀpua Point, Hawaiʻi Island.

Figure A4. Hawksbill hatchlings stranded among cobblestones, ʻĀpua Point, Hawaiʻi Island.

Figures A5 and A6. Lawn edging was placed around nests to prevent hatchlings from getting stranded. ʻĀpua Point, Hawaiʻi Island.

Figure A7. Personnel release hatchlings on the sandy beach at `Āpua Point, Hawai‘i Island.

Figure A8. A corridor provides hatchlings a safe journey to the ocean at `Āpua Point, Hawai‘i Island.

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Table A3. Hawksbill hatchling stranding and rescue statistics, Hawai‘i Island, 1989-2009.

Site	Hatchlings to Ocean	Hatchlings Rescued	Percent Rescued (%)	Hatchlings Dead on Rocks/Beach	Dead on Rocks/Beach (%)
‘Āpua Point	13,209	9,538	72.2	845	6.4
Keauhou	1,172	499	42.6	12	1.0
Halapē	3,702	1,927	52.1	187	5.0
Kamehame	46,696	9,175	19.6	144	0.3
Punalu‘u	1,263	483	38.2	2	0.2
Kōloa	753	484	64.3	0	0.0
Nīnole	209	96	45.9	0	0.0
Ka‘ili‘ili	2,056	625	30.4	189	9.2
Pōhue Bay	11,082	2,659	24.0	107	1.0
‘Āwili Point	556	23	4.1	0	0.0
Waimanu	77	2	2.6	2	2.6
Totals	80,775	25,511	31.6	1,488	1.8

At ‘Āpua Point human impact was low compared to other sites due to its remote backcountry location, lack of vehicle access, and lack of drinking water. Consequently, anthropogenic disturbances were limited to marine debris washed up on shore, occasional artificial lights from campers, and trash and food scraps left by campers that attracted predatory mongoose and rats. Following recommendations by project personnel, the park designated nesting areas off-limits to camping and re-located campsites to reduce interference with nesting

activity. HAVO issued backcountry permits to visitors accompanied with informational pamphlets to educate campers on ways to minimize adverse impacts on nesting activities (e.g. reduce artificial lighting, pack out trash). Additional information was provided to campers onsite by project personnel, and in some instances visitors accompanied by project personnel were provided the rare opportunity to observe hawksbill nesting activities.

An additional threat to beach habitat at this site was non-native maunaloa that was encroaching over the nesting habitat and entrapping hatchlings. Since 2005, personnel have occasionally uprooted plants found growing on the nesting beach.

‘Āpua Point Management Recommendations

Intensive monitoring is essential to protect nesting females and nests, and especially to assist hatchlings to reach the ocean safely. Continuous non-native predator and non-native plant control, as well as educating beach users is needed for the overall success of hawksbills nesting at ‘Āpua Point.

Keauhou Landing

Keauhou is a gray-black sand beach located approximately 5 km west of ‘Āpua Point (Figure A9). A point divides the nesting sites into two inlets with tide pools and rocky pockets of sand lining the shoreline. The vegetation is comprised of milo (*Thespesia populnea*), naupaka, and copious amounts of highly invasive koa haole (*Leucaena leucocephala*). The beach area is approximately 1,030 m^2 with approximately 550 m^2 of suitable nesting habitat (Figure A10).

Figure A9. Aerial view of Keauhou, Hawai‘i Island.

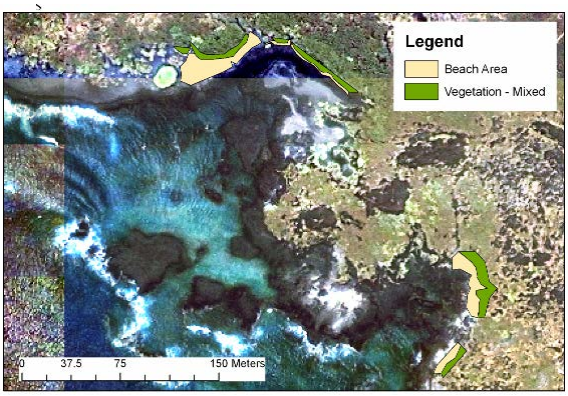

Figure A10. Map of hawksbill nesting habitat at Keauhou, Hawai‘i Island.

Keauhou Observed Nesting Activity and Nest Success

The first documented nest at Keauhou was discovered as a result of mongoose predation in 1997 (Table A4). A camper found eggshells and mongoose scat and thus informed project personnel. The first and only adult female (ID #52) tagged here was in 2001. The only

documented nesting turtle remigration interval was five years. However, a turtle (ID #42) previously tagged at ʻĀpua Point was also observed nesting at Keauhou in 2001 (Table A4). The mean nest to next crawl inter-nesting interval was 19.3 ± 1.4 days (n= 4) with a range of 16 to 22 days. The mean nest to nest inter-nesting interval was 21.7 ± 0.3 days (n= 3) with a range of 21 to 22 days.

Table A4. Hawksbill activity and monitoring effort, Keauhou, Hawaiʻi Island, 1997-2009.

Year	Observed Nesting Turtles	Observed Turtles	Newly Tagged Turtles	Remigrant Turtles	Monitoring Days	Monitoring Nights
1997[1]	0	0	0	0	23	0
1998	0	0	0	0	49	0
1999	0	0	0	0	47	0
2000	0	0	0	0	49	0
2001	2[2]	2	1	1	17	123
2002	0	0	0	0	65	0
2003	0	0	0	0	52	0
2004	0	0	0	0	124	7
2005	0	0	0	0	113	5
2006	1	1	0	1	44	71
2007	0	0	0	0	122	1
2008	0	0	0	0	113	0
2009	0	0	0	0	95	0
Total	3	3	1	2	913	207
Mean n=13yrs	0.2	0.2	0.1	0.2	131.9	24.6

[1] Nests and/or crawls found, but no turtles were observed.
[2] One of these nesting females was tagged at ʻĀpua Point.

A total of 10 nests were documented between 1997 and 2009 (Table A5). The mean incubation period was 55.7 ± 1.7 days (n= 6), with a range of 53 to 64 days. The mean clutch size was 185.3 ± 7.7 eggs (n= 9), with a range of 146 to 228 eggs. The mean nest hatch success was 70.7 ± 9.3% (n= 9), with a range of 3.2 to 94.7%. From the nine excavated nests, an estimated 1,172 hatchlings reached the ocean.

Table A5. Hawksbill nest results, Keauhou, Hawai‘i Island, 1997-2009.

Year	Nests	Nests Excavated	Mean Incubation (days)	Mean Clutch Size (eggs)	Mean Nest Hatch Success (%)	Hatchlings to Ocean
1997	1	1	ND	173.0; n=1	56.7; n=1	98
2001	5	5	57.0 ± 2.4 n=4	187.2 ± 14.3 n=5	81.2 ± 5.0 n=5	752
2006	4	3	52.5 ± 0.5 n=2	186.3 ± 2.2 n=3	58.0 ± 27.4 n=3	322
Total	10	9	NA	NA	NA	1,172
Mean	0.8 n=12yrs	0.8 n=12yrs	55.7 ± 1.7 n=6 nests	185.3 ± 7.7 n=9 nests	70.7 ± 9.3 n=9 nests	390.7 n=3yrs

ND=No Data.
NA=Not Applicable.

Keauhou Monitoring Effort

Personnel primarily checked this site on day hikes from either ‘Āpua Point or Halapē. If evidence of nesting activity was observed, personnel then camped at this site. Personnel most likely visited Keauhou more often than was documented since records of day checks at Keauhou were not kept until the mid 1990’s, and became more frequent following the discovery of the predated nest in 1997.

Keauhou Threats

Keauhou is a remote HAVO backcountry campsite with a three walled shelter and catchment water provided for campers. This site received more visitors than ‘Āpua Point. In addition, visitors could access this site by boat since Keauhou is one of the only sheltered bays along this coast for boat mooring. Campers could also access this site with stock animals. As with ‘Āpua Point, HAVO issued permits and turtle informational pamphlets to campers.

Personnel were also able to mitigate human threats (e.g. artificial lights, trampling) in a variety of ways. One nest was laid in the middle of a walking path in 2001. Fortunately, personnel were on site to identify the location and protect the nest with fencing. This prevented trampling of the nest by campers and pack animals. Personnel on site also prevented hatchling disorientation due to artificial light produced by campers. Campers occasionally made fires on the beach that could have misled hatchlings to become stranded and die. Personnel regularly dismantled fire rings when they were encountered. In addition, discarded food and trash left by campers attracted feral cats, rats, and mongooses to the area that required personnel to routinely monitor and clean up.

Keauhou Management Recommendations

Continued non-native predator control and nest protection is crucial at this site to address high densities of predators and human recreational use. Koa haole should also be controlled to prevent further encroachment of nesting habitat. In addition, project personnel need to be present during the nesting season to locate and protect adult females, nests and hatchlings, educate campers, and direct human activity away from nests. Personnel can check this site during the day for signs of activity while performing nighttime monitoring at nearby sites with higher amounts of nesting activity. If nesting activity is documented, nighttime monitoring and nest protection measures should be implemented.

Halapē

Halapē is a cove of white sand speckled with bits of lava rock, located 2.6 km west of Keauhou (Figure A11. It is located below Hōlei Pali at the windward base of Pu‘u Kapukapu. Vegetation cover includes naupaka, pōhuehue, coconut trees, milo, ‘uhaloa (*Waltheria indica*) and numerous non-native weeds such as koa haole and running pop (*Passiflora foetida*). The nesting beach is separated into three pockets of sand, each adjacent to the ocean allowing nesting hawksbills to enter directly from the ocean (Figure A12). The total area of the beach is approximately 3,000 m^2 with approximately 2,300 m^2 of suitable nesting habitat. Among HAVO’s four designated coastal backcountry campsites, Halapē is the most visited by humans. In addition to the nesting beach, nests have been discovered both in and directly adjacent to designated campsites. Approximately 0.3 km southwest of Halapē is Halapē Iki, a small beach separated into two small pockets of sand and dominated by milo, coconut, and koa haole.

Figure A11. Aerial view of Halapē. Hawai‘i Island.

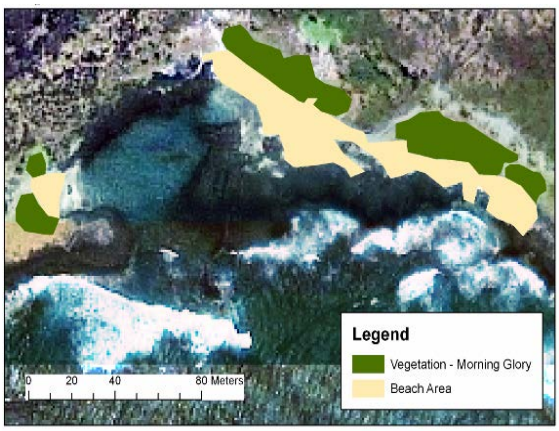

Figure A12. Map of nesting habitat at Halapē, Hawai‘i Island.

Halapē Observed Nesting Activity and Nest Success

On several occasions in the 1970’s reports were given to HAVO staff and noted in backcountry logbooks by hikers who observed turtles crawling along the beach. The results of these nesting events were not recorded and thus are unknown. The first adult female on record at

Halapē was found dead in a large crack in the substrate in August 1987. The first nest documented by HIHTRP was reported by campers in 1989. Although nests were documented, prior to 2000 there were no adult females or actual nesting events observed due to minimal monitoring coverage. Following an increase in monitoring coverage, nine turtles were tagged between 2000 and 2009 (Table A6). In addition, two individuals tagged at other locations were documented nesting at Halapē. The mean nesting turtle remigration interval was 5.0 ± 1.0 years (n=2) with a range of 4 to 6 years. The mean nest to next crawl inter-nesting interval was 20.0 ± 0.7 days (n= 8) with a range of 17 to 22 days. The mean nest to nest inter-nesting interval was 21.6 ± .7 days (n= 9) with a range of 19 to 26 days.

Table A6. Hawksbill activity and monitoring, Halapē, Hawai‘i Island, 1987-2009.

Year	Observed Nesting Turtles	Observed Turtles	Newly Tagged Turtles	Remigrant Turtles	Monitoring Days	Monitoring Nights
1987	0	1[1]	0	0	0[5]	0
1988	NC	NC	NC	NC	NC	NC
1989[2]	0	0	0	0	5	16
1990	0	0	0	0	0	2
1991	0	0	0	0	5	1
1992	0	0	0	0	0	1
1993	0	0	0	0	11	8
1994	0	0	0	0	1	0
1995	0[2]	0	0	0	25	23
1996	0	0	0	0	9	0
1997	0[2]	0	0	0	7	23
1998	0[2]	0	0	0	53	25
1999	0[2]	0	0	0	52	10
2000	1	1	1	0	10	128
2001	0[2]	0	0	0	42	22
2002	1	1	1	0	26	78
2003	1	1	1	0	5	112
2004	2[3]	2	1	1	4	165
2005	0	1	0	1	65	69
2006	1	1	0	1	43	84
2007	2	3[4]	1	2	1	170
2008	3	3	3	0	8	144
2009	1	2[3]	1	1	17	116
Total	12	16	9	6	389	1,197
Mean n=21yrs	1.0	0.7	0.4	0.3	18.5	57.0

[1] Found newly dead, upside down in a crack with over 320 eggs.
[2] Nests and/or crawls found, but no turtles were observed.
[3] One turtle was observed nesting at ʻĀpua Point during same year.
[4] One turtle was observed at Kamehame during same year.
[5] HAVO Personnel recovered dead adult female.
NC=NO COVERAGE.

From 1989 to 2009, a total of 49 nests were documented and 46 of these were excavated (Table A7). The mean incubation period was 55.8 ± 0.8 days (n= 42), with a range of 51 to 80 days. The mean clutch size was 173.6 ± 5.4 eggs (n= 46), with a range of 85 to 242 eggs. The mean nest hatch success was 49.1 ± 4.5% (n= 46), with a range of 2.6 to 97.1%. From the 46 excavated nests, an estimated 3,702 hatchlings reached the ocean.

Table A7. Hawksbill nest results, Halapē, Hawaiʻi Island, 1989-2009.

Year	Nests	Nests Excavated	Mean Incubation (days)	Mean Clutch Size (eggs)	Mean Nest Hatch Success (%)	Hatchlings to Ocean
1989	1	0	NA	NA	NA	ND
1990	0	0	NA	NA	NA	0
1991	0	0	NA	NA	NA	0
1992	0	0	NA	NA	NA	0
1993	0	0	NA	NA	NA	0
1994	0	0	NA	NA	NA	0
1995	5[1]	4	58.0 ± 0.0 n=2	190.8 ± 13.7 n=4	37.6 ± 18.8 n=4	280
1996	0	0	NA	NA	NA	0
1997	0	0	NA	NA	NA	0
1998	2	2	55.0 ± 2.0 n=2	232.0 ± 10.0 n=2	73.6 ± 23.6 n=2	295
1999	0[2]	0	NA	NA	NA	0
2000	2	2	80.0 n=1	132.5 ± 6.5 n=2	57.7 ± 1.3 n=2	153
2001	0[2]	0	NA	NA	NA	0
2002	2	2	60.5 ± 1.5 n=2	157.5 ± 7.5 n=2	29.0 ± 11.0 n=2	93
2003	5	5	58.3 ± 1.9 n=3	182.2 ± 18.3 n=5	35.9 ± 15.4 n=5	266
2004	7	7	56.0 ± 1.7 n=7	170.6 ± 18.6 n=7	40.7 ± 10.3 n=7	450
2005	1	1	52.0 n=1	191.0 n=1	31.4 n=1	60
2006	4	3	55.8 ± 0.5	164.0 ± 7.6	82.8 ± 1.3 n=3	407

Year	Nests	Nests Excavated	Mean Incubation (days)	Mean Clutch Size (eggs)	Mean Nest Hatch Success (%)	Hatchlings to Ocean
			n=4	n=3		
2007	7	7	54.0 ± 1.0 n=7	164.6 ± 17.8 n=7	52.4 ± 15.2 n=7	609
2008	9	9	54.1 ± 1.3 n=9	166.2 ±3.3 n=9	66.0 ± 6.4 n=9	945
2009	4	4	52.5 ± 1.0 n=4	188.5 ± 11.1 n=4	20.7 ± 7.1 n=4	144
Total	49	46	NA	NA	NA	3,702
Mean	2.3 n=21yrs	2.2 n=21yrs	55.8 ± 0.8 n=42 nests	173.6 ± 5.4 n=46 nests	49.1 ± 4.5 n=46 nests	336.5 n=11yrs

[1] Three nests were predated.
[2] Tracks and digs found but no nests were confirmed.
ND=No Data.
NA=Not Applicable.

Halapē Monitoring Effort

Campers and park personnel reported nesting turtle observations dating back to the 1970s. Intermittent monitoring at Halapē began in 1989. Each season, the amount of nightly coverage depended on whether or not evidence of nesting activity was observed, how many personnel were available, and the level priority relative to other nesting sites. In general, if nesting activity was observed, continuous nightly coverage was provided during the inter-nesting window. If nesting activity was not confirmed, the beach was day checked regularly throughout the season by personnel who hiked from ʻĀpua Point.

Halapē Threats

Ghost crabs (*Ocypode* spp.) were observed regularly at Halapē and likely contributed to hatchling mortality. In addition, hatchlings were occasionally found trapped in the roots of vegetation, either inside the egg chamber or on the beach after they emerged. In some areas, hatchlings became trapped on lava rocks. Hatchlings that emerged during the heat of the day were often found dead.

As mentioned earlier, in November 1975, a 7.2 earthquake occurred along this coast and generated a localized tsunami. The land subsidence and tsunami altered the coastline and nesting habitat at ʻĀpua, Keauhou, and Halapē (Figures A13-15). The effects of this on nesting activity are not known due to the lack of data prior to the commencement of this project.

Figure A13. Halapē coastline prior to 1975 tsunami, Hawai‘i Island.

Figure A14. Halapē coastline post 1975 tsunami, Hawai‘i Island.

Figure A15. Halapē coastline 2008, Hawai‘i Island.

Halapē is located in a Federally designated wilderness area. Despite its remote location, this beach is the most popular backcountry campsite in HAVO (Table A8). For many years, unofficial and unregulated campsites, trails, and fire pits were located in hawksbill nesting habitat. These impacts lead to sand compaction which created unsuitable nesting conditions and prevented natural colonization and regeneration of native plants. High densities of mongooses and cats were documented at Halapē and are possibly the result of discarded food and litter from campers.

In August 1987, an untagged adult female turtle was found dead in a rock fracture along with approximately 320 eggs (J. Leialoha, personal communication). Based upon backcountry records and interviews with hikers, the presence of campers and lights may have disoriented the

turtle that consequently crawled away from the beach and into the fracture. Partially as a result of this incident, sections of the beach where turtles nest were designated as off limits to campers. These campsites and trails were closed and relocated in 1990 to restore the nesting beach to natural nesting conditions and to reduce human impacts on turtles. Additional campsites were established approximately 50 meters to the east of the nesting areas. While there was some initial resistance to the area closure, over time most campers have become highly supportive of hawksbill conservation efforts. Many campers have had the opportunity to observe hawksbill activity with project personnel. Personnel protected confirmed nests with fence enclosures, removed garbage, and created corridors for hatchlings to assist them the ocean. Small wooden signs were strategically placed to inform campers about the turtle nesting area. The increased presence and onsite education provided by project staff encourages people to act responsibly and has played a critical role in mitigating the threats that backcountry users pose to nesting females, nests, and hatchlings.

Table A8. Number of permitted campers, including project personnel, at HAVO backcountry hawksbill nesting sites, 2006-2009 (www.nature.nps.gov/stats).

Year	Halapē	ʻĀpua Point	Keauhou
2006	1,858	699	760
2007	1,808	488	405
2008	1,795	678	538
2009	2,006	698	639

Restoration of nesting habitat began in 1990 when campsites were relocated to allow native strand vegetation, primarily pōhuehue, naupaka, and ʻuhaloa to recover. The area was restored by tilling compacted sand, and uprooting selected non-native plants such as sourbush (*Pluchea odorata*), kiawe (*Prosopis pallida),* and indigo (*Indigofera suffruticosa*). Project personnel and HAVO staff also worked to prevent koa haole from encroaching into nesting habitat.

Halapē Management Recommendations

Nest hatch success is below average in comparison to other beaches along the Kaʻū coastline. Nests at Halapē often incubate for shorter durations (<55 days) and produce trickles of hatchlings that occasionally emerge during hot daylight hours instead of during lower temperatures such as at night or in early morning. Daytime emergence increases hatchling exposure to dehydration and desiccation. Incubation time may or may not be a factor in trickle emergences and low hatch successes. Project personnel are working collaboratively with NOAA biologist George Balazs and researchers from the University of Alabama (Wibbles and Estes, pers. comm.) and are currently deploying temperature data loggers in order to better understand the relationship between temperature, incubation time, and hatch success. Continued management to control invasive plants, predators, and human activity is strongly recommended. Shade and watering experiments of the nests at Halapē could be conducted to determine if decreased sun exposure would increase nest hatch success. The popularity of this site for backcountry campers requires careful onsite management to protect turtles while educating

campers. To prevent overcrowding of nest sites, the park should consider the possibility of reducing the amount of campers during heavy nesting seasons.

Kākīwai

Southwest of Halapē, below the sea cliffs of Pu‘u Kaone, is a crescent shaped black sand beach in the lee of Kākīwai Point (Figure A16). This site is inaccessible by land. In 2001 and 2007, HAVO personnel observed nesting turtle tracks at this site either from the air and/or from sea. However, on rare limited site visits, personnel were unable to locate any nests.

Figure A16. Kākīwai Point, Hawai‘i Island.

Kamehame

Kamehame is a black cinder sand-olivine beach at the base of a 15 meter tall littoral cone (Figure A17). It is located along the windward Ka‘ū coastline, below the town of Pahala. During periods of high surf, sections of the beach are eroded to the base of underlying boulders. The total area of the beach is approximately 630 m^2 with nearly 95 m^2 of suitable nesting habitat. The nesting habitat is located on the northern end of the beach, along the naupaka vegetation along the high tide line (Figure A18). An additional nesting area is located in proximity to a shallow cave. The southern area below the littoral cone is consistently inundated by high surf. Much of the surrounding property is owned by the State of Hawai‘i Department of Land and Natural Resources and is leased out for cattle ranching. In 2001, The Nature Conservancy of Hawai‘i (TNC) purchased a 9.7 hectare parcel adjacent to the beach. Within this parcel lies a limited access 4-wheel drive road through the ranch that provided vehicle access to the site from Highway 11. There is also a coastal trail between Kamehame and Punalu‘u Beach Park (approximately 3.9 km long) that allowed access for people to fish and hike at Kamehame. While public access at Kamehame is primarily limited to foot traffic, 4-wheel drive vehicles and all-terrain vehicles (ATVs) do occasionally cross the property from the adjacent land.

Figure A17. Aerial view of Kamehame, Hawai‘i Island.

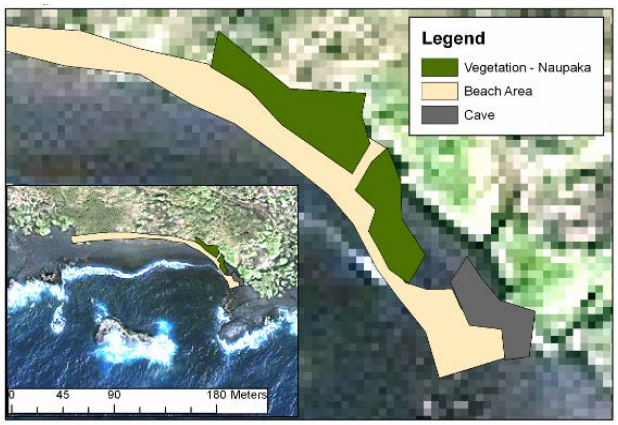

Figure A18. Map of nesting habitat at Kamehame, Hawai‘i Island.

Kamehame Observed Nesting Activity and Nest Success

Almost half (46%) of the total number of hawksbills tagged on Hawai‘i Island have been at Kamehame, where intermittent monitoring began in 1989. The first two nests documented showed evidence of predation by mongooses and feral cats. The first adult female (ID #2) tagged at this site was encountered in 1991. Since then, a total of 46 nesting turtles have been tagged (Table A9). The mean remigration interval was 3.5 ± 0.2 years (n= 70) but ranged between two to eight years. The mean nest to next crawl inter-nesting interval was 18.4 ± 0.1 days (n = 181) with a range of 13 to 24 days. The mean nest to nest inter-nesting interval was 20.0 ± 0.2 days (n= 190) with a range of 13 to 30 days.

Table A9. Hawksbill activity and monitoring, Kamehame, Hawai‘i Island, 1989-2009.

Year	Observed Nesting Turtles	Observed Turtles	Newly Tagged Turtles	Remigrant Turtles	Monitoring Days	Monitoring Nights
1989	0	0	0	0	2	0
1990	0[1]	0	0	0	2	0
1991	1	2	2	0	2	56
1992	1	2	2	0	3	40
1993	10	11	9	2	4	149
1994	2	2	2	0	5	134
1995	12[2]	12[2]	6	6	4	170
1996	8	10	4	6	6	163
1997	7	7	2	5	1	179
1998	11	12	4	8	2	194
1999	11[2]	12	2	10	13	189
2000	5	5	1	4	7	158

Year	Observed Nesting Turtles	Observed Turtles	Newly Tagged Turtles	Remigrant Turtles	Monitoring Days	Monitoring Nights
2001	5	6	0	6	12	175
2002	6	6	0	6	8	170
2003	3	3	0	3	3	167
2004	4	4	0	4	7	176
2005	5[3]	7	2	5	0	166
2006	3	3	1	2	1	155
2007	2[4]	3	1	2	4	160
2008	2	2	2	0	3	164
2009	6	9[2]	6	3	11	186
Total	104	118	46	72	100	2,951
Mean n=21yrs	5.0	5.6	2.2	3.4	4.8	140.5

[1] Although turtles were not observed, two nests were found.
[2] One turtle was observed nesting at Punaluʻu and Kamehame.
[3] One turtle was observed nesting at Kamehame, Kāwā, and Kaʻiliʻili.
[4] One turtle was observed nesting at Halapē and Kamehame.

A total of 403 nests were documented at this site between 1990 and 2009 (Table A10), the most at any one site within the State of Hawaiʻi. The number of nests documented per season ranged from two nests in 1990 to 54 nests in 1995. One of the most productive nesting females in project history (ID # 2) has laid 16 nests at Kamehame over 18 years; 2009 was her sixth documented nesting season. Her remigration interval mean was 3.6 ± 0.6 (n=5) with a range of two to five years. The 16 nests had a mean clutch size of 183 ± 3.7 eggs (n=16) and a mean hatch success of 80.6% ± 3.8% (n=16). See Appendix B.

Since 1993, when the project began continuous night monitoring throughout the season, nesting activity has exhibited high annual variation. Highest numbers of nests occurred during the mid to late 1990's. Between 2006 and 2008, nesting activity declined to an all time low, (9, 8, and 4 nests per year compared to 54 in 1995); and then rebounded in 2009 (21 nests).

Table A10. Hawksbill nest results, Kamehame, Hawai‘i Island, 1990-2009.

Year	Nests	Nests Excavated	Mean Incubation (days)	Mean Clutch Size (eggs)	Mean Nest Hatch Success (%)	Hatchlings to Ocean
1990	2	0	NA	NA	NA	ND
1991	6	6	61.0 ± 3.0 n=2	171.6 ± 2.6 n=5	86.1 ± 11.4 n=5	807
1992	4	4	ND	162.3 ± 5.3 n=3	85.1 ± 8.0 n=3	505
1993	36	30	62.6 ± 1.4 n=14	157.6 ± 7.5 n=27	92.4 ± 2.2 n=28	3,937
1994	9	9	71.2 ± 2.2 n=5	175.9 ± 11.1 n=9	91.6 ± 1.8 n=8	1,460
1995	54	46	69.9 ± 2.9 n=18	174.0 ± 5.9 n=42	78.9 ± 3.1 n=43	5,867
1996	45	33	60.9 ± 2.0 n=14	164.7 ± 6.7 n=28	79.9 ± 3.8 n=28	3,648
1997	30	28	67.6 ± 2.3 n=13	183.3 ± 8.1 n=24	83.6 ± 3.4 n=26	4,434
1998	26	26	70.4 ± 3.4 n=5	195.3 ± 7.8 n=26	68.4 ± 4.7 n=26	3,433
1999	38	36	67.7 ± 2.1 n=30	166.7 ± 5.2 n=36	60.0 ± 4.2 n=36	3,563
2000	19	19	66.6 ± 1.4 n=17	208.6 ± 8.1 n=19	78.0 ± 5.0 n=19	3,037
2001	22	22	60.6 ± 1.5 n=18	188.4 ± 8.9 n=22	61.8 ± 4.3 n=22	2,486
2002	27	27	64.1 ± 1.3 n=23	185.4 ± 7.2 n=27	69.3 ± 5.1 n=27	3,350
2003	13	13	72.23 ± 2.9 n=12	177.6 ± 12.1 n=13	81.5 ± 3.0 n=13	1,854
2004	13	13	68.7 ± 3.3 n=11	196.7 ± 7.2 n=13	74.4 ± 7.9 n=13	1,911
2005	17	15	67.1 ± 2.2 n=10	174.6 ± 11.9 n=14	69.5 ± 8.7 n=15	1,978
2006	9	9	66.3 ± 4.4 n=4	172.6 ± 19.2 n=8	68.6 ± 11.2 n=8	966

Year	Nests	Nests Excavated	Mean Incubation (days)	Mean Clutch Size (eggs)	Mean Nest Hatch Success (%)	Hatchlings to Ocean
2007	8	8	64.9 ± 1.4 n=8	201.9 ± 5.6 n=8	53.1 ± 10.2 n=8	830
2008	4	4	62.7 ± 2.6 n=3	200.5 ± 24.1 n=4	77.4 ± 10.1 n=4	630
2009	21	20	63.8 ± 1.8 n=12	175.2 ± 6.8 n=19	57.7 ± 7.9 n=20	2,000
Total	403	368	NA	NA	NA	46,696
Mean	20.2 n=20yrs	18.4 n=20yrs	66.0 ± 0.6 n=219 nests	179.1 ± 2.1 n=348 nests	73.8 ± 1.3 n=352 nests	2457.7 n=19yrs

ND=No Data.
NA=Not Applicable.

The overall mean incubation period at Kamehame was 66.0 ± 0.6 days (n= 219) (Table A10). However, considerable variation was detected in the incubation period as it ranged from 51 to 101 days. This variation occurred because some nests were laid in front of or underneath a cave that covered the nests with more shade than the naupaka-sand interface of the main beach. The mean incubation period for nests at the naupaka-sand interface was 64.1 ± 0.5 days (n= 182) with a range of 51 to 91 days. On the shadier, cave side of the beach the mean incubation period was 75.5 ± 1.7 days (n= 37) with a range of 58 to 101 days (Table A11). Incubation time also increased when nests were exposed to high surf or heavy rain. The mean clutch size was 179.1 ± 2.1 eggs (n= 348) with a range of 80 to 274 eggs. The mean nest hatch success was 73.8 ± 1.3% (n= 352), but varied considerably between zero and 100 percent. Some of the zero percent hatch success nests were the result of surf inundation. Some nests however, were able to withstand increased moisture regularly and continued to have a high hatch success with a slightly longer incubation period. An estimated 46,696 hatchlings reached the ocean at this site between 1990 and 2009 (Table A10).

Table A11. Hawksbill nest incubation by location at Kamehame, Hawai‘i Island, 1991- 2009.

Days	Naupaka-sand Interface	Cave Interface
Mean	64.1	75.5
N (# nests)	182	37
Std. Er.	0.5	1.7
Min	51	58
Max	91	101

Kamehame Monitoring Effort

The amount of personnel devoted to monitoring and protection of nest sites increased steadily over the years. Intermittent monitoring began in 1989 with occasional day checks to

follow up on reports of incidental sightings. Night monitoring started when the tagging program was initiated in 1991. In 1993, funding from FWS helped increase monitoring efforts and enabled almost continuous nightly coverage throughout the nesting season. Because Kamehame usually has the most activity, this area has received the most coverage of all project sites to date.

Kamehame Threats

Nest overcrowding has resulted in at least 33 occasions where a nest was destroyed during a subsequent nesting attempt by an adult female. On several occasions, an individual destroyed her own previously laid nest. When a nesting turtle was observed digging on a previously laid nest, personnel carefully relocated the nesting female to prevent further egg destruction.

During the majority of nesting seasons, Kamehame appeared to be experiencing more nesting activity than the beach could feasibly support. The overcrowding of nests also created uncertainty during excavations, which caused the process to be occasionally omitted or discontinued to avoid disturbing other unhatched clutches of eggs in the immediate proximity. Such overcrowding was especially evident in 1993, 1995, and 1996, and resulted in the lack of excavation data for certain nests. In addition, overcrowding of nests can contribute to hatchling mortality when nests are laid on top of each other. At least 33 nests (12.2% of total nests) were impacted by another nesting female, and at least 772 eggs were reported destroyed from these impacts.

The majority of the beach is subjected to regular high tides causing a decrease in suitable habitat. To prevent tidal inundation, seven nest translocations were performed at Kamehame with varying hatch success rates (Table A12). High surf, rain, and flooding incidents occurred regularly. Rain and flooding were especially heavy in 1990, 1994, and 2000. In some cases, eggs were completely washed away from beach erosion. In other cases, the cooling effects of the water may have slowed down incubation, but did not appear to affect overall hatch success. At times, beach monitoring effort was interrupted by high surf, flooding incidents, and several hurricane evacuations.

Table A12. Nest translocation history and hatch success percentages for Kamehame, Hawai‘i Island, 1990-2009 (n=7).

Year	Hatch Success (%)
1993	0
1993	UNK
1994	90.7
1998	36.1
1999	7.8
2009	26.1
2009	91.5
Mean	42.0

Human impact was relatively low at this beach, compared to the nearby beaches like Punalu‘u. State and private access by vehicles have been limited to primarily project personnel

since the late 1990s. Prior to that, the beach experienced more recreational use by campers and fishermen. Fishing nets and artificial lights (e.g. dive lights, lanterns, flashlights, and campfires) were threats encountered by turtles. Also, recreational users reported finding predated eggshells to HAVO staff. Since the late 1990s, the increased presence of project personnel has reduced potentially harmful night-time activities during the nesting season. Occasionally, people still access this beach mostly for fishing and seafood gathering via ATV or four wheel drive, on foot, or by boat.

Koa haole and Christmasberry (*Schinus terebinthifolius*) encroached on the nesting habitat. These plants formed dense thickets and their roots were impenetrable for nesting turtles. Since 2002, the project worked to remove these invasive plants (Figure A19). After their initial removal, naupaka was planted to prevent alien species from re-establishing and to increase the amount of nesting habitat. Since then, control efforts continued every year to keep invasive plants from encroaching on limited nesting space.

Figure A19. Local youth assist personnel with non-native plant control.

Kamehame Management Recommendations

Both predation and overcrowding of nests have been significant concerns at this site. Without project personnel on site, many eggs and nests would have been dug up and destroyed by nesting turtles. Monitoring, predator control, habitat restoration and preparation for sea level rise, visitor education, and if needed, translocation of nests must be continued in order to maximize nest success at this site. The current ungulate fence should be moved further back from the ocean to create more nesting habitat above high surf levels.

Punaluʻu

Punaluʻu is approximately 3.9 km southwest of Kamehame along the windward Kaʻū coast. This beach consists of black cinder sand and is located along a protected bay between Kahiola and Puʻumoa points (Figure A20). The total area of the beach is approximately 7,360 m^2 with approximately 3,900 m^2 of suitable nesting habitat (Figure A21). The north side of the beach is lined with coconut trees and contains a brackish water pond. The south side of the beach has

naupaka and residences are located behind the beach. The adjacent land is privately owned, primarily by Sea Mountain Five, LLC. A large area of the beach was drastically altered by a bulldozed sand road that was in use until 2005. The road was a threat to nesting turtles and hatchlings because it was plowed between the ocean and the nesting habitat. Currently, the road is not maintained and the beach has been allowed to recover to a more natural state. Several private residences, a concession stand, an abandoned restaurant, and a one-acre leased Hawai‘i County Park that includes pavilions, restrooms, campsites, a parking lot, and street lights all border the beach (Figure A22). A paved road leads directly to the beach. This is the most accessible beach in Ka‘ū and was heavily impacted by human activities compared to other nesting sites described in this report. Because of the high visitation, Punalu‘u has also been the site of much sea turtle education and outreach.

Figure A20. Aerial view of Punalu‘u, Hawai‘i Island.

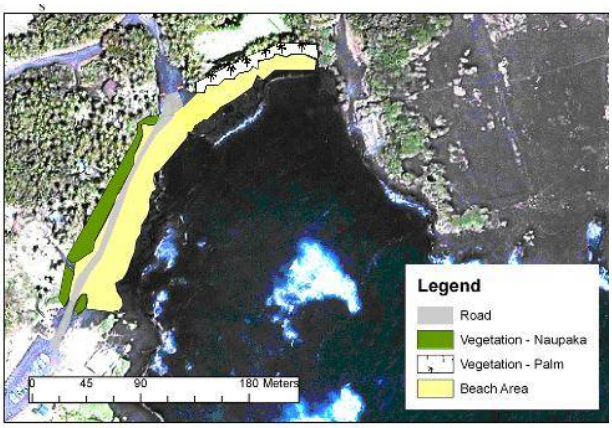

Figure A21. Map of the nesting habitat at Punalu‘u, Hawai‘i Island.

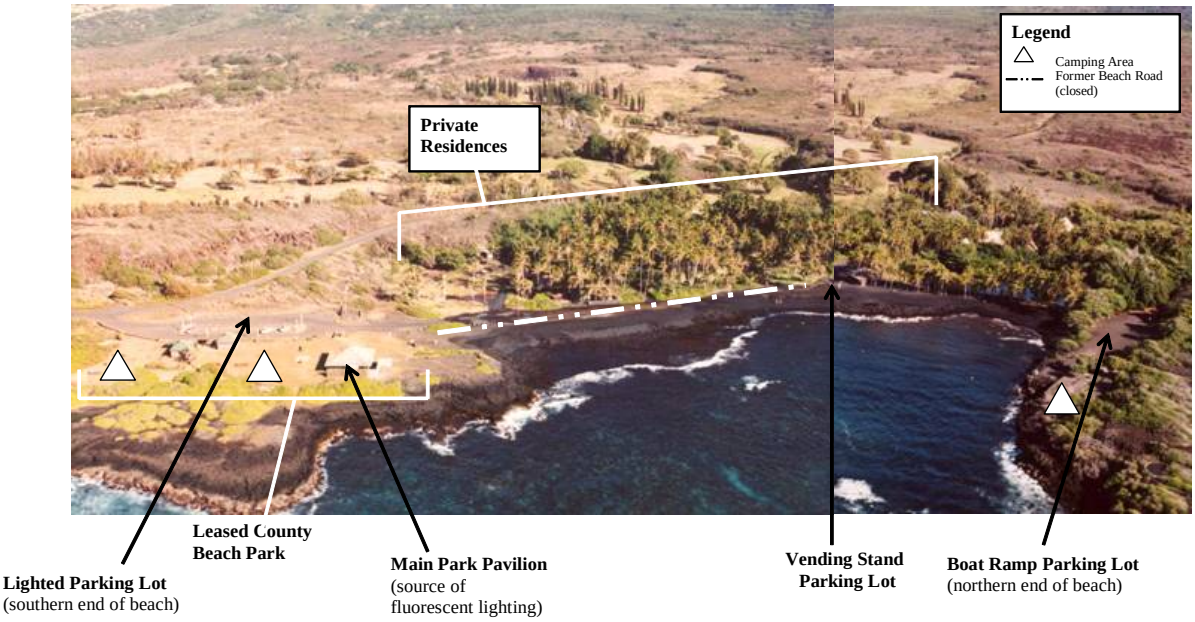

Figure A22. Punalu‘u, Hawai‘i Island.

Punalu‘u Observed Nesting Activity and Nest Success

A clutch of hawksbill eggs was reported near the concession stand by a local couple in 1974 and low frequency nesting was subsequently reported by Balazs (1978b) and by HAVO staff (1989). Although only two individuals (ID #43, and ID #99) were tagged (1998 and 2009 respectively) at Punalu‘u between 1991 and 2009, four other turtles tagged at Kamehame (3.9 km Northeast) were observed at Punalu‘u during various seasons between 1991 and 2009 (Table A13).

Table A13. Hawksbill activity and monitoring effort, Punalu‘u, Hawai‘i Island, 1989-2009.

Year	Observed Nesting Turtles	Observed Turtles	Newly Tagged Turtles	Remigrant Turtles	Monitoring Days	Monitoring Nights
1989[1]	0	0	0	0	7	0
1990	0	0	0	0	1	0
1991	0	0	0	0	10	0
1992	0	0	0	0	10	0
1993	0	0	0	0	17	0
1994	0	0	0	0	18	0
1995	1[2]	1	0	1	25	10
1996	0	0	0	0	23	21
1997	0	0	0	0	30	13
1998	0	2	1	2	64	74
1999	2[2]	3[3]	0	3	95	61
2000	0	0	0	0	110	1
2001	0[1]	0	0	0	84	3
2002	0[1]	0	0	0	119	0
2003	1	1	0	1	67	50
2004	0[1]	0	0	0	111	28
2005	0[1]	0	0	0	145	10
2006	0[1]	0	0	0	138	1
2007	0	0	0	0	128	9
2008	0	0	0	0	151	0
2009	1[4]	1[4]	1	0	84	141
Total	5	8	2	7	1,437	422
Mean n=21yrs	0.2	0.4	0.1	0.3	68.4	38.4

[1] Nests and/or crawls found, but no turtles were observed.
[2] Turtles previously tagged at Kamehame.
[3] One turtle was tagged at Kamehame but only observed nesting at Punalu‘u. The other turtle was tagged at Punalu‘u and rescued from the pond in 1998.
[4] One turtle was observed nesting at Punalu‘u and also observed at Kamehame.

From 1989 to 2009, a total of thirteen nests were documented (Table A14). Although residents occasionally reported additional nests and hatchling sightings, personnel were sometimes unable to find them. In addition, personnel sometimes observed adult female tracks but again were unable to locate nests. The mean incubation period was 72.6 ± 3.9 days (n= 9), with a range of 58 to 89 days. Shading from mature coconut palms may have contributed to a large variation in incubation times. The mean clutch size was 156.2 ± 6.4 eggs (n= 13), with a range of 125 to 188 eggs. The mean nest hatch success was 64.1 ± 8.8% (n= 13), with a range of zero to 96.8%. Some of the nests with zero percent hatch success nests were located near mature coconuts with roots that may have made it difficult for nesting females to construct their egg chambers. From the thirteen excavated nests, an estimated 1,263 hatchlings reached the ocean.

Table A14. Hawksbill nest results, Punaluʻu, Hawaiʻi Island, 1989-2009.

Year	Nests	Nests Excavated	Mean Incubation (days)	Mean Clutch Size (eggs)	Mean Nest Hatch Success (%)	Hatchlings to Ocean
1989	1	1	81.0 n=1	125.0 n=1	96.8 n=1	121
1995	1	1	75.0 n=1	147.0 n=1	72.8 n=1	107
1996	1	1	ND	188.0 n=1	89.9 n=1	169
1998[1]	0	0	NA	NA	NA	0
1999	4	4	89.0 n=1	169.3 ± 8.8 n=4	38.8 ± 22.4 n=4	240
2003	1	1	60.0 n=1	184.0 n=1	63.6 n=1	117
2009	5	5	69.6 ± 5.1 n=5	142 ± 7.1 n=5	70.9 ± 8.8 n=5	509
Total	13	13	NA	NA	NA	1,263
Mean	0.6 n=21yrs	0.6 n=21yrs	72.6 ± 3.9 n=9 nests	156.2 ± 6.4 n=13 nests	64.1 ± 8.8 n=13 nests	60.1 n=6yrs

[1] Although nests were not documented, tracks and digs were found.
ND=No Data.
NA=Not Applicable.

Punaluʻu Monitoring Effort

Prior to 1989, hawksbill nesting activity was reported by residents. Aerial surveys of the coast were performed in 1988 and 1989. Intermittent monitoring began in 1989. Often, Punaluʻu was monitored when personnel camping at Kamehame day-hiked to Punaluʻu to look for signs of nesting activity. Occasionally, nesting activity was reported by residents and project personnel followed up to confirm. Due to the relatively low activity at this beach, continuous nightly monitoring was conducted only in seasons with confirmed nesting activity.

Punalu‘u Threats

At Punalu‘u, the fibrous roots of the non-native coconut palms created an obstacle for nesting females and their hatchlings (Figure A23). Naupaka, which also grows in the area, has weak bristly roots which tend to be both easier for nesting females to break when digging an egg chamber, as well as less inhibiting to hatchlings when they emerge. Closing the beach road at Punalu‘u provided turtles with access to suitable nesting habitat in naupaka, but even in these areas coconut roots penetrate the substrate. Of the five nests documented in 2009, all were located in the naupaka-sand interface, but four nests contained roots from coconut palms. Several turtles were observed abandoning nesting attempts after having trouble digging through dense roots. In some instances, the nesting female would move to a new site and in areas with thin coconut roots she could break through while digging and lay eggs. However, the coconut roots can grow rapidly during the two to three month incubation period and trap hatchlings underground. Project personnel assist trapped hatchlings during nest excavations. In one severe case, a root system with two roots of approximately 1.5 cm in diameter ran diagonally across a nest (Figures A24 and A25). In addition, other smaller roots were spread throughout the entire substrate. When the nest was excavated, the roots had to be carefully cut in order to free 38 live hatchlings trapped within. These rescued hatchlings consisted of half of the total hatchlings to successfully reach the ocean from this nest.

Figure A23. Coconut palm roots in egg chamber, Punalu‘u, Hawai‘i Island.

Figures A24 and A25. A few of the 38 hatchlings trapped by coconut palm tree roots rescued during excavation at Punalu‘u, Hawai‘i Island.

Punalu‘u experienced the highest level of human impact among all project sites. This beach is the one of the only easily accessible public access beaches along the southern coast of the island. Therefore, nesting turtles and hatchlings face multiple anthropogenic threats related to the high amounts of continuous 24 hour human presence from people camping, fishing, driving, and using artificial lights at the pavilion and from nearby residences. Cars and buses had access to drive across the beach until 2005 when the road was closed (Figures A26, A27, and A28). This closure reduced sand compaction from vehicles and allowed the nesting habitat to be restored (Figure A29).

The continuous human presence negatively impacts sea turtles since they are very sensitive to artificial lighting. On undeveloped beaches the brightest direction is typically toward the broad horizon of the ocean. However, on developed beaches, lights from humans can present false cues and actually lead turtles away from the water. Witherington and Martin (2000) found that hawksbills were most attracted to light from ultraviolet to yellow region of the spectrum (wavelengths from 400-600 nanometers). There are five main sources of artificial light identified at Punalu‘u consisting of white (a mixture of all wavelengths of the visible spectrum), yellow, vehicular, campfire light, and flashlights. White light from the pavilion and yellow light from the parking lot originated from the southwest end of the beach near the county beach park area. White light also originates from the vacation rental house, located near the middle of the beach and the concession stand parking lot area. Vehicular light originated from all three parking areas: the southwest end at beach park, by the concession stand, and the on the northeast end of the beach near the boat ramp (Figures A30, A31, A32, and A33). Campfire light also originated from the parking lot area on the northeast end of the beach as well. Although the wavelengths of each source of light were not measured, hawksbills were observed being attracted towards all light sources during the course of the study period.

In 1989, the first observation of apparent artificial light interference was documented when hatchlings were discovered crawling toward and in the lighted pavilion parking lot. The hatchlings were collected and released. In 1995, a nesting female, (Turtle ID #23), was disoriented by a streetlight. Instead of returning to the ocean after nesting, she traveled across the street toward the light. A resident found her in the morning on the road shoulder under the light and contacted project personnel who assisted in returning her to the ocean (Figure A34).

Again, in 1998, artificial light caused a nesting female, (Turtle ID #46,) to become disoriented and crawled into a brackish pond where she became entangled in fishing line. The turtle was retrieved by George Balazs of NMFS and UH Hilo Strandings Team in 1999, having lived in the pond for close to a year.

At Punalu‘u during the 2009 nesting season, of the 16 recorded cases of hawksbill light disorientation three cases involved the disorientation of an adult female while the remaining 13 involved disorientation of hatchlings. The most drastic case of adult female disorientation was caused by white light emitted from a vacation rental house adjacent to the beach (Figures 30 and 32). After covering a nest in the sandy area in front of the house a nesting female, (Turtle ID # 99), was facing the ocean but quickly turned 180 degrees to orient herself with the house lights and began approaching them. Personnel intervened by physically facing the turtle towards the

water and directing her off the lawn. She immediately reoriented herself back towards the lights. Consequently, personnel carried her to the crest of the beach to face the ocean on the downward slope, allowing her to successfully return to the ocean.

The 13 remaining disorientation incidents in 2009 involved hatchlings. These were from various emergences from the five nests that year. Artificial lights caused a total of 85 hatchlings to crawl diagonally across the beach instead of towards the water. On one occasion when both the pavilion and parking lot lights were on, five hatchlings were within two feet of reaching the ocean but appeared to be so drawn to the lights that they crawled parallel to the water line. In these instances, personnel would reorient hatchlings towards the water and allow them to crawl along the sand on their own. If hatchlings still did not reach the ocean, personnel would intercept the hatchlings and place them directly in the water. Personnel also attempted to block the artificial light either with their bodies or by building a small sand barricade that would corral the hatchlings down the beach and "shade" them from the artificial light. On all 13 occasions of hatchling disorientation, intervention successfully aided the hatchlings in reaching the ocean.

Figures A26 and A27. Tour buses and vehicles driving on the beach between the ocean and nesting habitat. Punaluʻu, Hawaiʻi Island.

Figure A28: Hawksbill crossing beach road after aborted nesting attempt, Punaluʻu, Hawaiʻi Island. **Figure A29.** Punaluʻu beach without the road in 2009 and personnel constructing nest cages.

Figure A30. T#99 lays one of five nests in the vicinity of the vacation rental house at Punalu‘u, Hawai‘i Island.

Figure A31. Tracks are visible in the morning.

Figures A32. Nesting female facing rental house.

Figure A33. Pavillion and parking lot lights on the southern end of Punalu‘u Beach. (These photographs do not accurately portray the amount of artificial light present on beach.)

Figure A34. A resident assists a disoriented hawksbill on the road in 1995, Punalu’u, Hawai‘i Island.

Punalu‘u Education and Outreach

Throughout the study period, HIHTRP performed outreach and education to hundreds of beach visitors, residents and school groups (Figure A35, A36, and A37). When nests were documented, personnel strived to engage the community. Public nest excavations were conducted, including several in 1999, 2003, and 2009, with hundreds of people in attendance, local children assisting in the release of hatchlings, and media coverage. These outreach events were well attended and well received among beach users.

Figures A35, A36, A37. Over 40 children assisted staff in releasing trapped hatchlings at the public nest excavation outreach event in 2009 at Punalu‘u, Hawai‘i Island.

Punalu‘u Management Recommendations

Project personnel should continue to monitor and protect nests, assist stranded hatchlings and adult females, and work with adjacent landowners, State, County and FWS to mitigate the effects of artificial lights, coconut tree roots, and roads. Due to the high level of human use by both local residents and visitors, a public education program that includes an educational display along with onsite interpreters could prove to be beneficial to encourage public stewardship to mitigate the threats to hawksbill nesting.

Light pollution at Punalu‘u could be reduced in three ways: education, changing light fixtures, and shielding existing light from the beach. Educational measures could include distribution of informational brochures, and installing a large interpretive sign possibly at the south end of the beach (along an outside wall of the pavilion for example) that contained information not only about light pollution but also about the history of the beach, the biology of sea turtles, the differences between greens and hawksbills, as well as other natural and human caused threats and mitigations. Other outreach efforts could include informational workshops that would educate beach homeowners, community members, and anyone else in attendance on how to reduce light pollution. Simple measures such as installing signs or stickers with a simple slogan (i.e., “Keep Sea Turtles in the Dark”) near the light switch in the pavilion for example, could increase public awareness of light pollution issues and encourage individuals to turn off the lights. Finally, having onsite interpretive staff could serve to educate people and reduce conflicts between wildlife and humans.

Changing the current white and yellow lights to wavelengths less discernible to turtles will reduce disorientation of adults and hatchlings. Witherington and Martin (2000)[1] noted that most turtles cannot detect red light (620-750nm), and thus recommended changes could include installing light of this wavelength in order to make the beach safe for both humans and turtles. Floodlights on the vacation rental house should be replaced with shielded downlights, illuminating only the stairs as needed for safety. The existing artificial light at the County beach park pavilion could be shielded with a screen or window that would block the light from polluting the beach. The shields could be installed so that pavilion users, for example, could open them during the day, thus enabling a beach view, but be able to close them at night, thus preventing turtles from being drawn southward along the beach.

Horseshoe, Kōloa, and Nīnole

Horseshoe, Kōloa, and Nīnole are small pockets of beach close in proximity to each other. These beaches are adjacent to Punalu‘u and span 0.8 km Southwest along the coast. Horseshoe is a pocket black sand, pebble, and coral rubble beach with naupaka vegetation and lava outcroppings. It is located roughly 200 m south of Punalu‘u. The total area of the beach is about 600 m^2 with nearly 380 m^2 of suitable nesting habitat.

Kōloa is a black cinder sand and pebble beach with a shallow inlet (Figure A38). It is located about 150 m south of Horseshoe. The total area of the beach is 200 m^2 with approximately 100 m^2 of suitable nesting habitat. The beach is surrounded by pahoehoe lava formations and naupaka, and is adjacent to a brackish water pond on the eastern side (Figure A39).

Nīnole is a pebble and cobblestone beach with a several scattered pockets of black cinder sand. It is located approximately 300 m south of Kōloa (Figure A40). The total area of the beach is approximately 2,700 m^2 with approximately 200 m^2 of potential nesting habitat. The beach is also surrounded by naupaka and is adjacent to a small brackish water pond on the eastern side (Figure A41).

Figure A38. Arial view of Kōloa, Hawai‘i Island.

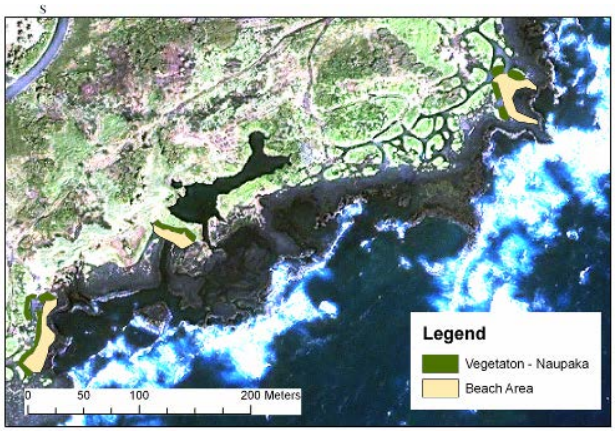

Figure A39. Map of the nesting habitat at Horsehoe, Kōloa, and Nīnole, Hawai‘i Island.

Figure A40. Hawksbill nesting habitat, interpretive sign and nest enclosure at Nīnole, Hawai‘i Island.

Figure A41. Nesting beach with tire tracks and fire pit at Nīnole, Hawai‘i Island.

Horseshoe, Kōloa, and Nīnole Observed Nesting Activity and Nest Success

At Horseshoe, three nest sites were excavated in 1989. One nest was almost completely destroyed by mongooses. The second nest was found with high mortality in late development stages as observed by dead hatchlings in eggshells. The third site was possibly a false nest since eggshells were not found. Another nest was reported in 1993; however, no nesting has been documented since (Table A15).

In 2003, the first documented nest at Kōloa was found. From 2003 to 2009, a total of seven nests were documented (Table A16 and A17). The mean incubation period was 60.6 ± 2.3 days (n= 5), with a range of 54 to 62 days. The mean clutch size was 175.1 eggs ± 14.2 (n= 7), with a range of 100 to 215 eggs. The mean nest hatch success was 65.0 ± 12.2% (n= 7), with a range of 0.0% to 96.0%. From the seven excavated nests, 753 hatchlings were estimated to have reached the ocean. Two female hawksbills, previously tagged at Kamehame in 1999 (ID#s 46 and 48), were documented nesting at Kōloa, one in 2003 and one in 2004. These cases demonstrate that some individuals use multiple nesting sites. The mean nest to next crawl inter-nesting interval was 18.3 ± 0.8 days (n= 4) with a range of 16 to 19 days. The mean nest to nest inter-nesting interval was 20.8 ± 2.0 (n= 4) and ranged between 16 to 25 days

Tracks and digs were found at Nīnole on 19 occasions during eight different seasons between 1990 and 2009 (Table A18). The cobblestone substrate usually caused difficultly for nesting females to dig a suitable egg chamber as observed by shallow digs found in the rocks. Although nesting activity was previously documented during various seasons, 2009 was the first year in which nests were confirmed as well as the first time an adult female was identified at Nīnole. The individual nesting was a remigrant (ID #23), and had not been seen in 10 years. She was documented nesting at Punalu‘u and Kamehame in previous seasons, making Nīnole her third confirmed nesting beach. The mean clutch size was 141.0 ± 6 eggs (n=2) with a range of 135 to 147 eggs. The mean nest hatch success was 73.4 ± 16.4 % (n=2) with a range of 57 to 89.8%. An estimated 209 hatchlings reached the ocean from the two nests at Nīnole (Table A19).

Table A15. Hawksbill nest results, Horseshoe, Hawai‘i Island, 1989-2009.

Year	Nests	Excavated	Mean Incubation (days)	Mean Clutch Size (eggs)	Mean Nest Hatch Success (%)	Hatchlings to Ocean
1989	2[1]	2	ND	ND	ND	ND
1993	1	0	ND	ND	ND	ND
Total	3	2	ND	ND	ND	ND

[1] One nest was predated and one nest did not hatch.
ND=No Data.

Table A16. Hawksbill activity and monitoring, Kōloa, Hawai‘i Island, 2003-2009.

Year	Observed Nesting Turtles	Observed Turtles	Newly Tagged Turtles	Remigrant Turtles	Monitoring Days	Monitoring Nights
2003	1[1]	1	0	1	62	59
2004	1[1]	1	0	1	94	50
2005	0[2]	0	0	0	140	15
2006	0[2]	0	0	0	90	36
2007	0	0	0	0	137	0
2008	0	0	0	0	151	0
2009	0	0	0	0	144	0
Total	2	2	0	2	818	160
Mean n=7yrs	0.3	0.3	0	0.3	116.9	22.9

[1] Turtles were originally tagged at Kamehame.
[2] Nests and/or crawls found, but no turtles were observed.

Table A17. Hawksbill nest results, Kōloa, Hawai‘i Island, 2003-2009.

Year	Nests	Nests Excavated	Mean Incubation (days)	Mean Clutch Size (eggs)	Mean Nest Hatch Success (%)	Hatchlings to Ocean
2003	4	4	58.0 ± 4.0 n=2	197.0 ± 6.9 n=4	44.3 ± 14.9 n=4	362
2004	3	3	62.3 ± 3.0 n=3	146.0 ± 24.0 n=3	90.4 ± 3.7 n=3	391
Total	7	7	NA	NA	NA	753
Mean	1 n=7yrs	1 n=7yrs	60.6 ± 2.3 n=5 nests	175.1 ± 14.2 n=7 nests	65.0 ± 12.2 n=7 nests	107.6 n=2yrs

Table A18. Hawksbill activity and monitoring, Nīnole, Hawai‘i Island, 1990-2009.

Year	Nesting Activity Occasions	Monitoring Days	Monitoring Nights
1990	1	1	0
1991	3	13	10
1992	0	9	0
1993	0	14	0
1994	0	18	0
1995	4	32	2
1996	0	44	0
1997	1	39	0
1998	2	107	0
1999	6	84	8
2000	0	85	0
2001	0	67	0
2002	0	106	0
2003	0	112	0
2004	1	124	2
2005	1	148	4
2006	0	128	0
2007	0	137	0
2008	0	151	0
2009	2	108	52
Total	21	1,527	78
Mean n=20 yrs	1.1	76.4	3.9

Table A19. Hawksbill nest results, Nīnole, Hawai‘i Island, 2003-2009.

Year	Nests	Nests Excavated	Mean Incubation (days)	Mean Clutch Size (eggs)	Mean Nest Hatch Success (%)	Hatchlings to Ocean
2009	2	2	ND	141.0 ± 6.0 n=2	73.4 ± 16.4 n=2	209

ND=No Data.

Horseshoe, Kōloa, and Nīnole Monitoring Effort

Occasional day checks at Horseshoe, Kōloa, and Nīnole started in the 1990s. Despite these checks, the first nesting activity at Kōloa was not recorded until 2003. Nests were likely laid at Kōloa before 2003, but were not detected due to high tides covering the small beach, heavy foot traffic and vehicle traffic. At Nīnole, night monitoring was infrequent unless nesting activity was observed on day checks, then personnel were assigned to camp at Nīnole, as was the case in 1999 and 2009.

Horseshoe, Kōloa, and Nīnole Threats

Despite being on private property, Horseshoe and Kōloa are easily accessible for recreational use and are popular among campers, fishermen, and families. At Kōloa, the protected inlet provides a safe place for small children to swim. Anthropogenic threats related to high recreational use at these sites include: four wheel drive vehicles, litter and debris, artificial lights and campfires, and entanglement in fishing gear. Non-native predators were abundant and likely attracted by trash left by beach users.

Nīnole is on the same private property where a proposed resort development was previously planned. This beach is also a popular fishing, diving, and camping site easily accessible by four wheel drive vehicles or by foot from the paved road. Anthropogenic threats were the same as for Horseshoe and Kōloa. Vehicles were driven over the entire rocky beach, including the nesting habitat causing the nesting substrate to be compacted. The nesting habitat was also often covered with fire pits and litter. Campers used artificial lights such as lanterns, flashlights, and fires that could potentially disorient nesting turtles and hatchlings. Turtles could also become disoriented from the bright artificial lights (from exterior lights and interior lights shown through windows) from the condominium complex that remained on constantly throughout the night. Other threats documented at this site included fishing activity and dense populations of mammalian predators including mongooses, rats, and cats.

Horseshoe, Kōloa, and Nīnole Education and Outreach

With the close proximity to Punalu‘u, personnel had frequent interactions with beach users and opportunities to inform numerous residents, visitors, and community organizations through onsite presentations and distribution of informational brochures. When nests at Kōloa and Nīnole were found, the public was invited to observe nest excavations. Educational signs were installed and maintained to inform beach users about the presence of nesting turtles.

Horseshoe, Kōloa, and Nīnole Management Recommendations

Horseshoe, Kōloa, and Nīnole are located in close proximity to each other and to Punalu‘u. These three relatively small nesting sites are located on the same private property and should all be managed similarly. There is a condominium complex and golf course located nearby and several development expansions have been proposed in recent years. For protection of beach habitat and turtles, any future development at these sites should be kept back from the ocean. An artificial lighting assessment should be conducted to determine the impact on wildlife. In order

to mitigate these impacts, wildlife friendly lighting and shields should be used that will minimize disturbances to nesting activity.

Although, these sites have not had as much nesting activity documented as others in this report, they are important habitat for hawksbills. The lower amount of nesting activity is possibly due to the higher amount of human activity. With their close proximity to other known nesting beaches (Kamehame, Punaluʻu, Kāwā, and Kaʻiliʻili) and since individual hawksbills occasionally use multiple beaches along the coast, Horseshoe, Kōloa, and Nīnole should be regularly monitored since nesting females, eggs, and hatchlings face numerous threats at these sites. When nesting activity is found, personnel need to be onsite to insure the safety of nesting females and to identify the exact location of nests. Additionally, nests need to be protected from predators by nest enclosures and other methods of predator control.

Because of the high volume of human use in the area, continued education of beach users to minimize recreational impacts on hawksbills is needed. Measures could include placing signs informing users about the presence of hawksbill nests, discouraging driving on nesting habitat, minimizing impacts from artificial lights, eliminating trash (e.g. fishing line, nets and plastics), and disassembling fire pits. In addition, measures that promote public stewardship of the area, such as public nest excavations and informal presentations and workshops, will build community support for conservation efforts.

Kāwā and Kaʻiliʻili

Kāwā is a gray and black sand, pebble, and cobblestone beach (Figure A42). At the northern end of the beach there is an intermittent streambed. The total area of the beach is approximately 2,050 m^2 with approximately 160 m^2 of potential nesting habitat (Figure A44). The beach is bordered by scattered vegetation that includes naupaka, Christmasberry, and koa haole. Vehicles accessed the site from an unrestricted short unimproved road from Highway 11 and were able to drive and park on the nesting habitat. This was a very popular spot for campers, fishermen, and surfers. In addition, there was a group of individuals that were permanently camping at this site.

Kaʻiliʻili is a cobblestone beach that has a few scattered pockets of black sand bordered by naupaka (Figure A43). It is located approximately 200 m southwest of Kāwā. Total area of the beach is approximately 470 m^2 with approximately 45 m^2 of suitable nesting habitat (Figure A44). Similar to Kāwā, access was unrestricted on this former private property via a short 4-wheel drive road from Highway 11 and vehicles were able to drive over the nesting habitat. With permission from the landowner, project personnel built a small rock wall and installed an interpretive sign to discourage this. However, these temporary measures were usually taken down.

In 2008, the State received funding from the Section 6 Recovery Land Acquisition Program (FWS) for the County of Hawaiʻi to acquire from the previous private landowners and protect approximately 3.2 km of coastline located at and around Kāwā Bay including Kaʻiliʻili Beach. Protecting these beaches and coastal wetlands was identified as the primary land protection priority by the County of Hawaiʻi Public Access, Open Space and Natural Resources

Preservation Commission, the Mayor, and the County Council. This property provides habitat for four federally listed species including the hawksbill turtle, green turtle, Hawaiian monk seal, Hawaiian coot (*Fulica alai*), and a candidate for listing, the orange-black Hawaiian damselfly (*Megalagrion xanthomelas*). A survey conducted by the NPS evaluated the area's resources and suitability for National Shoreline designation, concluded that these resources were of national significance and merited protection. Currently, the County of Hawai‘i is working to complete purchasing the property. However, there is a legal dispute about ownership and the case is in court.

Figure A42. Aerial view of Kāwā, Hawai‘i Island.

Figure A43. Ka‘ili‘ili Beach, Hawai‘i Island.

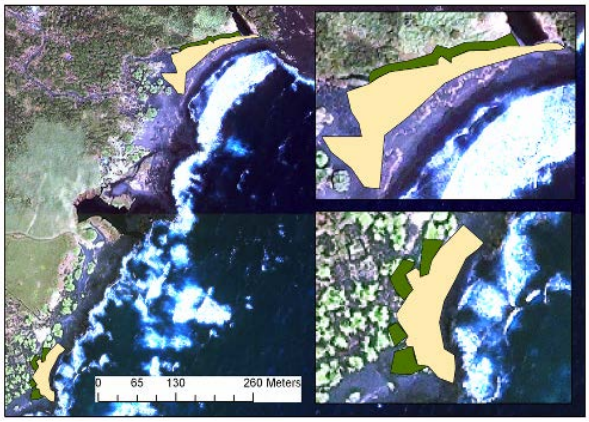

Figure A44. Map of the nesting habitat at Kāwā and Ka‘ili‘ili, Hawai‘i Island.

Kāwā and Ka‘ili‘ili Observed Nesting Activity and Nest Success

Kāwā was reported to be a hawksbill nesting site dating back to the 1970's (Balazs 1978b). During an initial HIHTRP survey in 1990, a beach resident reported a nest. Ranchers also informed project personnel of possible nesting activity in the early 1990's. Nesting activity was first documented by the project at Ka‘ili‘ili in 1992. Hawksbill tracks were found on two

occasions and nesting appeared to have occurred. However, the egg chambers were never located due to sand compaction and numerous tire tracks. At Ka‘ili‘ili, four nesting turtles were tagged between 1997 and 2008 (Table A20). Additionally, another turtle, (ID #61) tagged at Kamehame, crawled at both Kāwā and Ka‘ili‘ili in 2005. The mean nesting turtle remigration interval was 5.5 ± 1.5 years (n= 2) with a range of four to seven years. The mean nest to next crawl inter-nesting interval was 19.6 ± 0.6 days (n = 8) with a range of 18 to 22. The mean nest to nest inter-nesting interval was 20.2 ± 0.8 (n=6) and ranged from 18 to 23 days.

Table A20. Hawksbill activity and monitoring, Ka‘ili‘ili, Hawai‘i Island, 1992-2009.

Year	Observed Nesting Turtles	Observed Turtles	Newly Tagged Turtles	Remigrant Turtles	Monitoring Days	Monitoring Nights
1992	0[1]	0	0	0	14	1
1993	0[1]	0	0	0	22	2
1994	0	0	0	0	18	0
1995	0[1]	0	0	0	34	3
1996	0	0	0	0	15	0
1997	1	2	2	0	5	79
1998	0	0	0	0	75	12
1999	0[1]	0	0	0	56	0
2000	1	1	1	0	41	65
2001	0	0	0	0	48	0
2002	0	0	0	0	30	0
2003	0	0	0	0	62	0
2004	1	1	0	1	45	100
2005	0	1	0	1	87	27
2006	0	0	0	0	89	0
2007	0	0	0	0	75	3
2008[2]	1	1	1	0	21	16
2009	NC	NC	NC	NC	NC	NC
Total	4	6	4	2	737	308
Mean n=17yrs	0.2	0.4	0.2	0.1	43.4	18.1

[1] Nests and/or crawls found, but no turtles were observed.
[2] Coverage withdrawn during the middle of the season due to access issues.
NC=No Coverage, beach was not monitored.

From 1992 to 2009, a total of 18 nests were documented at Ka‘ili‘ili (Table A21). The mean incubation period was 64.9 ± 1.1 days (n= 13), with a range of 57 to 70 days. The mean clutch size was 190.9 ± 11.4 eggs (n= 13) with a range of 104 to 241 eggs. The mean nest hatch success was 82.7 ± 4.1 % (n= 13), with a range of 57.8 to 96.2%. An estimated 2,056 hatchlings reached the ocean from the 13 excavated nests.

Table A21. Hawksbill nest results, Ka‘ili‘ili, Hawai‘i Island, 1992-2009.

Year	Nests	Nests Excavated	Mean Incubation (days)	Mean Clutch Size (eggs)	Mean Nest Hatch Success (%)	Hatchlings to Ocean
1992	3	0	ND	ND	ND	ND
1993	1	0	ND	ND	ND	ND
1995	2	2	63.5 ± 5.5 n=2	199.5 ± 7.5 n=2	86.9 ± 9.3 n=2	348
1997	3	3	64.7 ± 0.9 n=3	185.3 ± 29.5 n=3	77.4 ± 10.2 n=3	426
2000	4	4	67.8 ± 1.0 n=4	191.0 ± 30.1 n=4	84.5 ± 9.1 n=4	634
2004	4	4	63.0 ± 2.4 n=4	190.8 ± 17.4 n=4	82.9 ± 7.6 n=4	627
2005	0[1]	0	0	0	0	0
2008[2]	1	0	0	0	0	21
2009	NC	NC	NC	NC	NC	NC
Total	18	13	NA	NA	NA	2,056
Mean	1.1 n=17yrs	0.8 n=17yrs	64.9 ± 1.1 n=13 nests	190.9 ± 11.4 n=13 nests	82.7 ± 4.1 n=13 nests	411.2 n=5yrs

[1] Although nests were not documented, tracks and digs were found at both Ka‘ili‘ili and Kāwā Bay.
[2] Coverage withdrawn during the middle of the season due to lack of access.
ND=No data.
NC=No Coverage, beach was not monitored.
NA=Not Applicable.

Kāwā and Ka‘ili‘ili Monitoring Effort

Intermittent monitoring began in the early 1990’s. Ka‘ili‘ili was checked on day checks and when signs of nesting activity were found personnel performed night monitoring. Monitoring at Kāwā was infrequent due to ownership conflicts between the beach inhabitants and legal land owners that resulted in limited access to project personnel. This conflict resulted in the withdrawal of beach coverage at both Kāwā and Kai‘ili‘ili in the summer of 2008.

Kāwā and Ka‘ili‘ili Threats

The rocky substrate at Kāwā and Kai‘ili‘ili often hindered nesting females’ ability to successfully dig nests (Figure A45). The rocky substrate also hindered hatchlings causing them to be trapped under rocks when emerging from nests. Hatchlings had difficulty maneuvering across the rocky substrate to the ocean causing them to be stranded amongst the cobblestones. The majority of hatchlings required assistance when emerging from their nest and when traveling to the ocean.

Figure A45. A hawksbill searching for suitable nesting habitat, Ka‘ili‘ili, Hawai‘i Island.

Recreational use was relatively heavy at these sites, especially Kāwā (Figure A46). Although they were privately owned, these beaches are among the few easily accessible along the Ka‘ū Coast. Surfing, fishing, diving, swimming, and camping were the primary activities. Four wheel drive vehicles drove on the marginal, rocky nesting habitat and tire tracks were observed throughout the beach. At these sites artificial lights from vehicular traffic, campers' flashlights, lanterns, and campfires were visible. Also conspicuous amounts of marine debris and litter were observed. Additionally, Kāwā contained several structures inhabited by individuals who lived year round on the beach, including one who claimed ownership of Kāwā. Disputes over land ownership made access and management of nesting habitat increasingly difficult for project personnel in the latter years of the study period.

Figure A46. Recreational use and vehicular traffic at Kāwā, Hawai‘i Island.

Kāwā and Ka‘ili‘ili Management Recommendations

Regaining safe access to monitor beaches and protect nests and hatchlings is a priority for these sites. In addition to marginal habitat and high density of non-native predators, human activities posed significant threats to nesting hawksbills. Outreach efforts should focus on educating community members and promoting active stewardship to protect and restore nesting habitat. Native Hawaiian activists should be included in the stewardship of these sites. These efforts could include posting of educational signs and distributing information brochures and interpretation onsite. Additional management priorities include working with the legal

landowners, and/or County, State and FWS to limit vehicle access on the nesting habitat, restoring native vegetation, reducing the impacts from artificial lighting, especially during the season, and performing non-native predator control, again during the nesting season.

Kamilo Point

Hawksbill hatchlings were found on several occasions in tide pools in proximity to Kamilo Point and reported by beach users. However project personnel found no evidence of turtle tracks or nest activity in the immediate area. It is possible that they hatched out at another nesting beach and were carried by currents to this site. There is also a possibility that they hatched from undetected nests in this area.

Kahakahakea and Hāliʻipalala

Kahakahakea and Hāliʻipalala are beaches comprised of white sand, coral rubble, lava fragments, and boulders (Figure A47). These sites are located on private property with limited access by 4-wheel drive. Ocean entry can be difficult for nesting females, especially during low tide since boulders and lava rocks line the entire length of the beaches. Pōhuehue is the primary vegetation along the beach. Vehicular access was allowed across the nesting habitat, although project personnel blocked the area closest to the ocean with rocks and rerouted the road behind (Figure A48). These beaches are privately owned and managed by Yamanaka Enterprises, along with nearby Pōhue Bay.

Figure A47. Aerial view of Kahakahakea, Hawaiʻi Island.

Figure A48. Nesting habitat and beach road diverted at Kahakahakea, Hawaiʻi Island.

Kahakahakea and Hāliʻipalala Observed Nesting Activity and Nest Success

These sites were identified as a potential nesting beaches during surveys. However, these sites received only minimal monitoring until the last four years. While these sites have yet to have a confirmed nest, nesting likely has occurred here. One nesting turtle (ID #66) that was tagged at nearby Pōhue Bay was documented false crawling at this beach on five occasions in 2005 (Table A22). This is another example of an individual using multiple nesting beaches along the coast. Personnel camping at Pōhue day checked Kahakahakea in seasons prior to 2005

but effort was sporadic and not recorded unless nesting activity was discovered. False crawls and digs were documented again in 2008 and 2009.

Kahakahakea and Hāli‘ipalala Monitoring Effort

Prior to 2005, these two adjacent beaches were only checked sporadically on dayhikes when personnel were night monitoring at Pōhue Bay. Since nesting activity was documented in 2005, these sites have received more frequent checks with personnel checking every few days when camping at Pōhue Bay.

Kahakahakea and Hāli‘ipalala Threats

A threat to nesting females, nests, and hatchlings at these sites included potential conflict with vehicles driving on the nesting habitat. Project personnel realigned the beach road across Kahakahakea in the late 1990s by creating a rock barrier and diverting vehicular traffic around the nesting habitat instead of directly across it (Figure A48). This mitigation still allowed the land managers and caretakers vehicle access along the property. Four wheel drive vehicles also accessed the entire beach at Hāli‘ipalala. In addition, Hāli‘ipalala hosted a fountain grass (*Pennisetum setaceum*) population that was encroaching on the nesting habitat. Personnel worked to remove these plants between 2007 and 2009 (see Pōhue section).

Kahakahakea and Hāli‘ipalala Management Recommendations

See next section Pōhue.

Table A22. Hawksbill nesting activity and monitoring, Kahakahakea, Hawai‘i Island, 2005-2009.

Year	Documented Nesting Crawls	Monitoring Days	Monitoring Nights
2005	5	37	33
2006	0	120	3
2007	0	125	3
2008	1	103	1
2009	1	54	0
Total	7	439	40
Mean n=5yrs	1.4	87.8	8.0

Pōhue Bay

Pōhue Bay is a black and white sand beach 2.5 km northwest of Kahakahakea and located on the same private property (Figure A49). The beach fronts a small sand-bottomed inlet. The total area of the beach is about 2070 m^2 with approximately 1020 m^2 of suitable nesting habitat (Figure A50). Pōhuehue and coconut are the primary vegetation on the beach. There is additional nesting habitat on the beach immediately south of the main beach; however, access from the ocean for nesting turtles is more difficult due to the lava fragments and rocky substrate.

Figure A49. Aerial view of Pōhue Bay, Hawai‘i Island.

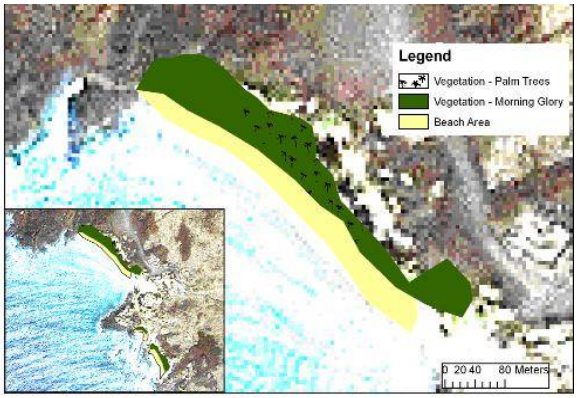

Figure A50. Map of the nesting habitat at Pōhue Bay, Hawai‘i Island.

Pōhue Observed Nesting Activity and Nest Success

As far back as the 1950’s, Kahuku Ranch employees reported nesting activity along this coastline including signs of nesting and hatchlings on the beach. The land managers, Yamanaka Enterprises (YE), observed hatchling tracks and found nests in 1986 or 1987 and reported these findings to HAVO resource manager and HIHTRP founder Lawrence Katahira. The first nest excavated by HIHTRP personnel was in 1993. This was also the first nesting beach documented on the southwest side of the island. However, due to lack of resources, the project was unable to follow up with more frequent monitoring until the late 1990’s. Road access to the beach was granted by the private landowner in 1996. Beach monitoring started more regularly in 1997 and has subsequently increased since then.

From 1999 to 2009, 20 turtles were tagged (Table A23). The mean remigration interval was 3.5 ± 0.5 years (n=2) with a range of 3 to 4 years. The mean nest to next crawl inter-nesting interval was 19.7 ± 0.4 days (n= 19) with a range of 18 to 24 days. The mean nest to nest inter-nesting interval was 20.6 ± 0.4 days (n= 19) and ranged between 18 to 24 days.

Table A23. Hawksbill activity and monitoring, Pōhue Bay, Hawai‘i Island, 1993-2009.

Year	Observed Nesting Turtles	Observed Turtles	Newly Tagged Turtles	Remigrant Turtles	Monitoring Days	Monitoring Nights
1993	0[1]	0	0	0	1	0
1994	NC	NC	NC	NC	NC	NC
1995	NC	NC	NC	NC	NC	NC
1996	0	0	0	0	0	23
1997	0[1]	0	0	0	7	0
1998	0[1]	0	0	0	25	34
1999	2	2	2	0	27	64
2000	0	0	0	0	30	27
2001	0	0	0	0	40	15
2002	1	1	1	0	29	84
2003	0	0	0	0	24	19
2004	0	0	0	0	30	9
2005	3	4	4	0	16	139
2006	5	5	4	1	14	181
2007	5	5	5	0	4	180
2008	1	1	1	0	19	154
2009	3	3	3	0	21	131
Total	20	18	17	1	287	1,060
Mean n=15yrs	1.3	1.4	1.3	0.1	16.9	62.4

[1] Nests were documented, but no turtles observed.
NC=No Coverage, beach was not monitored.

Between 1993 and 2009, 79 nests were documented. (Table A24) The mean incubation period was 59.1 ± 0.7 days (n= 59) with a range of 51 to 73 days. The mean clutch size was 179.8 ± 4.0 eggs (n= 75) with a range of 103 to 253 eggs. The mean nest hatch success was 79.7 ± 2.2% (n= 78) with a range of 6.0 to 100.0%. An estimated 11,082 hatchlings reached the ocean from these nests.

Table A24. Hawksbill nest results, Pōhue Bay, Hawai‘i Island, 1993-2009.

Year	Nests	Nests Excavated	Mean Incubation (days)	Mean Clutch Size (eggs)	Mean Nest Hatch Success (%)	Hatchlings to Ocean
1993	1	1	ND	212.0; n=1	96.7; n=1	205
1994	NC	NC	NC	NC	NC	NC
1995	NC	NC	NC	NC	NC	NC
1997	2	2	ND	201.0 ± 22.0 n=2	79.7 ± 14.9 n=2	309
1998	3	3	ND	166.0 ± 27.2 n=3	88.5 ± 10.9 n=3	423
1999	5	5	61.8 ± 1.9 n=4	185.4 ± 12.2 n=5	89.0 ± 3.0 n=5	820
2002	4	4	54.0 ± 1.4 n=4	228.3 ± 4.3 n=4	67.2 ± 10.6 n=4	608
2005	15	15	58.4 ± 1.3 n=12	180.2 ± 7.5 n=14	87.8 ± 2.0 n=15	2,455
2006	14	14	64.4 ± 1.5 n=10	164.4 ± 9.3 n=14	92.2 ± 2.6 n=14	2,093
2007	21	21	57.9 ± 1.1 n=17	182.7 ± 8.7 n=19	69.2 ± 4.5 n=21	2,630
2008	2	2	64.0 ± 4.0 n=2	153.0 ± 7.0 n=2	92.6 ± 3.3 n=2	281
2009	12	11	56.6 ± 1.4 n=10	175.7 ±9.9 n=11	0.7 ± 0.1 n=11	1,258
Total	79	78	NA	NA	NA	11,082
Mean	5.3 n=15yrs	5.2 n=15yrs	59.1 ± 0.7 n=59 nests	179.8 ± 4.0 n=75 nests	79.7 ± 2.2 n=78 nests	1,007.5 n=11yrs

ND=No Data.
NA=Not Applicable.
NC=No Coverage, beach was not monitored.

Pōhue Monitoring Effort

Despite confirming nesting activity in the early 1990’s, the lack of funding and personnel coupled with the site’s remoteness, made regular monitoring difficult. Since human access to Pōhue was limited by poor roads and locked gates, and because the hatchlings faced fewer physical obstacles in reaching the sea, priority for monitoring was initially given to ‘Āpua Point and Punalu‘u where nests faced greater threats. Beginning in the mid to late-1990’s, as more

resources became available, monitoring coverage became more frequent. Personnel were assigned to monitor beaches continuously when nesting activity was observed. In 2000-2001 and 2003-2004 nesting activity was not documented. As a result, monitoring effort was less in those seasons. Between 2005 and 2009, we documented an increased amount of nesting activity and correspondingly increased monitoring effort at this site. This enabled us to expand day checks to nearby beaches, which resulted in documented nesting activity at Kahakahakea and ʻĀwili Point in 2005 and Humuhumu Point in 2008.

Pōhue Threats

Personnel documented hatchlings trapped in their nests by the roots of coconut trees at Pōhue. These roots not only entrap hatchlings, but can also make it difficult for nesting females to construct egg chambers. In addition, ghost crabs were observed regularly on the beach and likely contributed to hatchling mortality.

Beginning in the 1990s, YE began working cooperatively with HIHTRP to reduce negative impacts by beach users. Vehicle access and camping was limited to protect and restore nesting habitat. Historically, beach access was limited first by the Hawaiian Monarchy through the Great Mahele in the 1830s, and then by various private landowners beginning in 1865. In recent times, a limited amount of people with permission were allowed to drive in and camp on the property. The beach also received use from occasional boaters and hikers. The land was always posted as private property, but during 1998 to 2000 under different management, gates were vandalized and cut open on a regular basis. During this time, trespassing occurred consistently. When the gates were not repaired, beach users began driving to Pōhue on a four wheel drive access road. Campers crowded the beach with tents, made fires, drove vehicles on the habitat, left the habitat littered with garbage and shined dive lights and other artificial lights over the beach and water at all hours of the night. In 1999, when project personnel obtained permission from the property manager to install signs to inform beach users about nesting hawksbills, they were intimidated by individuals and the signs were stolen. On several occasions, project personnel left the site for fear of their safety when beachgoers began discharging firearms.

YE regained management of the property in 2001. They repaired gates and employed caretakers who managed vehicular access to the beach so as to limit harmful impacts to the beach and marine resources. YE also developed working arrangements with the Hawaiian Volcano Observatory (HVO), NPS, West Hawaii Fishery Council, University of Hawaii at Hilo (Marine Science Center) and Native Hawaiian Elders to expand resource study and preservation. Protection efforts included control of invasive species and on-site education of natural resources in the area to students from the local community and other youth groups and organizations (e.g. YCC, Alu Like, Imi Pono no ka Āina).

In addition to these land-based threats, artificial lights from dive boats also posed a threat to hatchlings and turtles. For example, in 2005, a commercial dive boat was moored in Pōhue Bay for a night dive. The boat shined bright lights into the water to attract marine life for the divers. That same night a nest hatched. Fortunately, personnel were able to alert the boat crew and passengers and talk them out of the dive so that the hatchlings would not be attracted to the boat and the predatory fish.

With permission from the property manager, personnel removed some of the smaller coconut trees that had been planted in nesting habitat and pōhuehue vegetation began to recover at beaches where vehicle access was limited. Control of invasive fountain grass encroaching onto the nesting habitat and adjacent coastline was carried out from 2007 through 2009, removing approximately 1,200 fountain grass plants from the nesting habitat at Kahakahakea and Hāliʻipalala and nearby Hosaka Flats (Figure A51 and A52).

Figure A51. Fountain grass (*Pennisetum setaceum*) near Pōhue, Hawaiʻi Island.

Figure A52. Personnel removing fountain grass from nesting habitat. Hāliʻipalala, Hawaiʻi Island.

Pōhue Management Recommendations

The increased amount of nesting activity over the past four seasons (2005-2009) has been an encouraging sign. Effective partnering with the landowners will help ensure that nesting females, nests, and habitat are protected in the future. Management efforts should be continued to reduce harmful impacts caused by human disturbance. Additional management should include predator control throughout the nesting season, continued control of invasive vegetation, and continued monitoring at all nesting sites on the property.

Humuhumu Point (Road to the Sea)

Figure A53. Unnamed beach and turtle sign near Humuhumu Point, Hawai‘i Island.

Humuhumu Point lies at the bottom of the “Road to The Sea”. Approximately 1.6 km south of the Road to the Sea and Humuhumu Point is an unnamed storm beach pocket of sand, cobble stones, and coral rubble (Figure A53). While the site is accessible to the public, the property is privately owned. Access to the beach from the ocean for nesting hawksbills may be difficult due to a lava shelf.

Humuhumu Point Observed Nesting Activity and Nest Success

Prior to 2008, this site had been identified as potential nesting habitat on surveys. Personnel occasionally walked by this site on their way between Pōhue Bay and ‘Āwili Point. However, no nesting activity had been documented until the discovery of a dead turtle in a lava crack indicated that nesting hawksbills may be using this site (Figure A54). A gravid adult female (ID #65) and approximately 123 eggs were found in an anchialine pool crack (Figure A55). This turtle was previously tagged at Pōhue Bay in 2005. This discovery also reconfirmed that some individual hawksbills use multiple nesting sites along a coastline. In 2009, adult female tracks and digs were found here (Table A25). However, we were unable to confirm any nests.

Figures A54 & A55. The lava crack and skeletal remains of Turtle ID #65 with eggs inside the crack. Humuhumu Point, Hawai`i Island 2008.

Table A25. Hawksbill activity and monitoring, Humuhumu Point, Hawai‘i Island, 2008-2009.

Year	Observed Nesting Turtles	Observed Turtles	Newly Tagged Turtles	Remigrant Turtles	Monitoring Days	Monitoring Nights
2008	0	1[1]	0	1[2]	54	0
2009	0[3]	0	0	0	24	5
Total	0	1[1]	0	1[2]	78	5
Mean n=2yrs	0	0	0	0.5	39	2.5

[1] Turtle found dead in a crack behind the beach with 123 eggs.
[2] Turtle was previously tagged at Pohue in 2005.
[3] Tracks found, no turtles observed.

Humuhumu Point Threats

The adult female that was discovered in 2008 had fallen into a crack in the lava, became trapped and died. This situation is similar to the adult female that was found dead in a crack at Halapē in 1987. Nesting females are sensitive to disorientation when crawling on land and can become trapped in cracks, boulders, and vegetation. It is possible that these nesters were disoriented by artificial lights from beach users but no one observed these emergences so the actual cause is unknown. Cracks in the substrate are a natural threat at nesting beaches.

Humuhumu Point is situated near the “Road to the Sea” which is an open, accessible road to the shoreline. This area is frequented by campers, fishermen, and beachgoers who accessed this site with four wheel drive vehicles and ATVs. In addition to driving on the beach, the presence of artificial light from campfires, lanterns, flashlights, dive lights, etc. may have had an impact on hawksbills at this site and/or discouraged them from using this area.

Humuhumu Point Management Recommendations

Personnel will need to strengthen partnerships with private landowners, State, Federal, and County agencies, educational organizations, non-profits, and community groups to find funding and to better manage coastal ecosystem integrity and promote responsible stewardship of coastal resources. Humuhumu Point is currently private property and is for sale. It would be beneficial if this site could be purchased and managed for conservation.

‘Āwili Point (Road to the Sea)

‘Āwili Point is a black and green sand beach, located at the base of a littoral cone (Figure A56). The site is similar to Kamehame. The beach is narrow and steep on the eastern side, but flattens and widens on its western end. At high tide, surf regularly washes up to the cliff face, causing the suitable nesting habitat to be located on the western end of the beach. The total area of the beach is approximately 3,230 m^2 with approximately 440 m^2 of suitable nesting habitat (Figure A57). The nesting habitat is comprised of pōhuehue, naupaka, and the non-native tree heliotrope (*Messerschmidia argentea*). The beach is located on unencumbered state land. ‘Āwili Point can be reached by an 11.3 km gravel and lava road (Road to the Sea), which is one of the few public ocean access roads in Ka‘ū. Two-wheel drive vehicles can access most of the road but the last stretch to the ocean is a rugged four-wheel drive road.

Figure A56. Aerial view of ‘Āwili Point, Hawai‘i Island. Nesting habitat is on the left with access road behind.

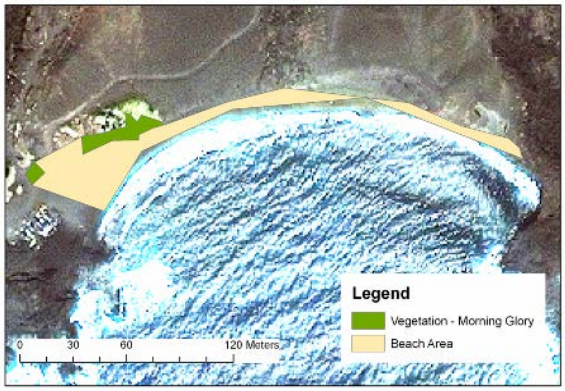

Figure A57. Map of the nesting habitat at ‘Āwili Point, Hawai‘i Island.

‘Āwili Point Observed Nesting Activity and Nest Success

One turtle (ID #62) was tagged here in 2005 (Table A26). Her only confirmed nest to next crawl internesting interval was 19 days and her only confirmed nest to nest internesting interval was 19 days. Four nests were documented during the 2005 season. In 2008, an unidentified nester laid one confirmed nest. It is possible that she laid other nests that were not located.

From 2005 to 2009, a total of five nests were documented (Table A27). The mean incubation period was 65.0 ± 4.6 days (n= 3), with a range of 56 to 71 days. The mean nest hatch success was 83.3 ± 6.1% (n= 4), with a range of 66.1 to 95.0%. The mean clutch size was 137.8 ± 3.9 eggs (n= 4), with a range of 127 to 146 eggs. From these nests at least 556 hatchlings reached the ocean.

Table A26. Hawksbill activity and monitoring, ‘Āwili Point, Hawai‘i Island, 2003-2009.

Year	Observed Nesting Turtles	Observed Turtles	Newly Tagged Turtles	Remigrant Turtles	Monitoring Days	Monitoring Nights
2003	0	0	0	0	1	1
2004	0	0	0	0	0	1
2005	1	1	1	0	76	12
2006	0	0	0	0	52	26
2007	0	0	0	0	51	1
2008	0[1]	0	0	0	34	54
2009	0	0	0	0	35	0
Total	1	1	1	0	249	95
Mean n=7yrs	0.1	0.1	0.1	0	35.6	13.6

[1] Nest and/or crawls found, but no turtle was observed.

Table A27. Hawksbill nest results, ‘Āwili Point, Hawai‘i Island, 2005-2009.

Year	Nests	Nests Excavated	Mean Incubation (days)	Mean Clutch Size (eggs)	Mean Nest Hatch Success (%)	Hatchlings to Ocean
2003	0	0	NA	NA	NA	NA
2004	0	0	NA	NA	NA	NA
2005	4	4	65.0 ± 4.6 n=3	137.8 ± 3.9 n=4	83.3 ± 6.1 n=4	461
2006	0	0	NA	NA	NA	NA
2007	0	0	NA	NA	NA	NA
2008	1	1	ND	102.0; n=1	93.1; n=1	95
2009	0	0	NA	NA	NA	NA
Total	5	5	NA	NA	NA	556
Mean	0.7 n=7yrs	0.7 n=7yrs	65.0 ± 4.6 n=3 nests	137.8 ± 3.9 n=4 nests	83.3 ± 6.1 n=4 nests	278 n=2yrs

NA=Not Applicable.
ND=No Data.

‘Āwili Point Monitoring Effort

‘Āwili Point’s similar to Kamehame with black sand and naupaka vegetation, causing project personnel to suspect this beach as having high potential for nesting. This site was one of the furthest from the project’s home base and was difficult to access because of the rough four wheel drive road. Due to the distance, lack of personnel and the extreme wear on vehicles, ‘Āwili Point was only checked once or twice a year. In 2005, increased night monitoring coverage at Pōhue enabled more day checks to this site. As a result, nesting hawksbill tracks

were observed on a day check in 2005. Personnel followed up with monitoring that night and were able to observe and tag a nesting turtle. Wire mesh enclosures were placed around the nests to further protect them from predators and human activities. Since 2005, ʻĀwili Point has been checked more frequently, primarily on foot via a coastal hiking trail with some nighttime monitoring when activity was found.

ʻĀwili Point Threats

Similar to Kamehame, much of the beach is inundated by high tides. Therefore, only a portion of the beach is suitable for nests to survive the approximate two month incubation duration. As with other beaches, crab predation may also be a factor in hatchling mortality.

ʻĀwili Point was frequented by campers and fishermen. Tire tracks and fire pits were numerous and the area was littered with garbage during the study period. For example, in the fall of 2007 there was an entire vehicle in numerous pieces spread across the beach. This area was also popular with all-terrain vehicle enthusiasts. The beach and the vegetation were frequently covered with tire tracks (Figures A58 and A59). Both nesting turtles and hatchlings faced danger of being hit by vehicles. Nests may have been compacted from vehicles and hatchlings could become trapped in tire ruts on their way to the sea. It is also likely that nesting turtles may have been frightened away and/or disoriented by campfires, lanterns, dive lights, and vehicle lights. These same artificial light sources may also have disoriented hatchlings leading them away from the ocean. Additionally, informational signs put up by project personnel to deter people from driving on the nesting habitat were filled with bullet holes.

Figures A58 & A59. ʻĀwili Point, Hawaiʻi Island. Hawksbill nesting habitat is crisscrossed by tire tracks.

ʻĀwili Point Management Recommendations

To manage the recreational impact at Humuhumu Point, ʻĀwili Point and Manukā, it would be difficult to keep the current course of the roads, permanently block off vehicular access to the nesting habitat, and still allow access to fishing grounds along the coast. Future work needs to be done with the landowner and the State of Hawaiʻi to possibly reroute the roads in order to solve this problem and install permanent barriers to prevent vehicles on beaches if we are to protect the nesting habitat from vehicular traffic, human activity, predators, and weeds.

Furthermore, there needs to be continued monitoring and protection of hawksbills at these sites to mitigate both natural and human caused threats. Onsite interpretation by personnel could alert and inform beach users of the presence of endangered sea turtles and encourage individuals to practice low impact recreation when at these sites.

Manukā Bay

Manukā Bay is located 8.4 km northwest of ʻĀwili Point. The beach consists of coral rubble, lava fragments, and white sand. In the summer of 2004, a camper reported to project personnel a sea turtle nesting crawl. As with ʻĀwili Point, Manuka is on unencumbered state land across a four wheel drive road from the Manukā Natural Area Reserve. HIHTRP personnel followed up with several field trips. Nesting turtle digs were documented at one of the campsites. However, personnel were unable to locate eggs or hatchlings. The area has not received adequate monitoring. Increased monitoring and future work needs to be done with the State to manage this site for successful nesting.

Waimanu

Waimanu is the only confirmed nesting beach on the northern, Hamākua Coast of Hawaiʻi Island (Figure A60). Depending on seasonal conditions (local storms, wave swell, current, and tidal factors), the beach is composed of either grey sand or cobblestones and boulders. Typically, the beach is much larger during the summer than the winter, when large surf washes much of the sand away. Located on State land in a remote valley, the beach is accessed by a 14.5 km hiking trail, helicopter, and boats. Vegetation along the beach includes naupaka, pōhuehue, hala (*Pandanus tectorius*), and ironwood *(Casuarina equisetifolia*). This site is a popular backcountry campground managed by the Hawaiʻi Department of Land and Natural Resources (DLNR).

Figure A60. Aerial view of Waimanu, Hawaiʻi Island.

Figure A61, A62 and A63. Circle indicates location of nest at Waimanu, Hawai`i Island. Driftwood marks nest location post- excavation. Substrate in nest is sandy, void of rocks.

Waimanu Observed Nesting Activity and Nest Success

Very little monitoring has occurred, and reported nesting activity has been limited to two years (2001 and 2009). The only nest excavated had a clutch size of 163 and a hatch success rate of 47% (Figures A61, A62, and A63; Table A28).

Table A28. Hawksbill nest results, Waimanu, Hawaii Island, 2001-2009.

Year	Nests	Nests Excavated	Mean Incubation (days)	Mean Clutch Size (eggs)	Mean Nest Hatch Success (%)	Hatchlings to Ocean
2001	1	0	ND	ND	ND	ND
2009	1[1]	1	ND	163; n=1	47.2; n=1	77
Total	2	1	NA	NA	NA	77
Mean	1 n=2yrs	0.5 n=2yrs	ND	163 n=1 nest	47.2 n=1 nest	77 n=1yr

[1] Nests found, but no turtles were observed.
ND=No Data.
NA=Not Applicable.

Waimanu Management Recommendations

HIHTRP informed DLNR personnel of the nesting activity and provided brochures to distribute to campers. HIHTRP needs to continue to work with DLNR to consistently monitor and manage this site and inform recreational users and area residents of hawksbill nesting activity. If nests are found, additional measures are needed to protect nests and hatchlings from predators and minimize potential conflict from incompatible recreational use.

Pololū

Pololū is approximately 11.6 km northwest of Waimanu. Biological interns from the U.S. Geological Survey were camping there and reported observing a nesting turtle in 2003. They described an adult turtle emerging from the surf and digging on the beach. It is unknown what species of turtle was observed. Project personnel followed up with monitoring and probed the area, but did not discover any nests.

Other sites

Other sites where turtle activity has been reported include Pāpa‘i, located approximately 12.8 km southeast of Hilo, and Kahuwai (Orr’s Beach) where nesting was documented by John Orr and confirmed by Balazs between 1976 and 1984. Balazs 1978 also reported nesting at Kalapana. Residents reported seeing possible nesting turtles and tracks at Kapoho, located near Cape Kumukahi, the island’s eastern most point but it is unconfirmed and conceivable this could be by green turtles. Other sites include: Ka‘aha, located within HAVO between Kālu‘e Point and ‘Opihinehe.

Literature Cited

[1] Witherington, B.E., and Martin, R.E. 2000. Understanding, assessing, and resolving light-pollution problems on sea turtle nesting beaches. 2nd ed. rev. Florida Marine Research Institute Technical Report TR-2. 73p.

APPENDIX B: Detailed Data Summaries for Tagged Adult Females and Nesting Activity

Turtle ID # indicates the chronological order in which animals were tagged.

Tags are listed in the order in which they were applied to animal.

[ ] indicates tag is no longer on animal.

All tags are size 681 Inconnel alloy manufactured by the National Band and Tag Company, Newport, Kentucky. Tags supplied by NOAA, Pacific Island Fisheries Science Center, Honolulu, Hawai‘i.

Tag address inscription reads

"WRITE HIMB
UNIVERSITY
HAWAII 96744"

Table B1. Adult female hawksbills tagged, Hawai‘i Island, 1991- 2009.

Turtle ID #	Tag Numbers				Date Originally Tagged	Location Tagged
	Left Front Flipper (LFF)	Right Front Flipper (RFF)	Left Rear Flipper (LRF)	Right Rear Flipper (RRF)		
1	N-451	N-452	no tag	no tag	7/19/91	‘Āpua Point
2	N-404	N-403	71-M	[72-M], [2D87], 2D86	8/4/91	Kamehame
3	N-454, B-585	[N-455], Q-179, 577-X	579-X	578-X	9/3/91	‘Āpua Point
4	N-439	N-440	[444-X], 439-X	B-800	9/3/91	Kamehame
5	N-443	N-444	no tag	no tag	8/4/92	‘Āpua Point
6	[N-468], B-770, B-769	N-467	no tag	no tag	8/4/92	Kamehame

Turtle ID #	Tag Numbers				Date Originally Tagged	Location Tagged
	Left Front Flipper (LFF)	Right Front Flipper (RFF)	Left Rear Flipper (LRF)	Right Rear Flipper (RRF)		
7	N-411	B-760, 406-X	423-X	417-X	9/19/92	Kamehame
8	[R-108], B-706, 552-Z	[R-109] 550-Z	no tag	no tag	7/3/93	Kamehame
9	R-111	R-110	no tag	no tag	7/4/93	Kamehame
10	R-112	R-114	no tag	no tag	7/7/93	Kamehame
11	R-156, R-185	[432-X], R-157, R-184	433-X	434-X	7/14/93	Kamehame
12	R-129	[R-130], 568-X	574-X	573-X	7/17/93	ʻĀpua Point
13	R-159, 575-Z	R-158, B-562	no tag	no tag	7/18/93	Kamehame
14	[R-162], B-759	[R-161], 332-Z	343-Z	342-Z	7/24/93	Kamehame
15	R-164	[R-163], B-765	337-Z	[338-Z], 8A48	7/25/93	Kamehame
16	[R-170], [R-171], [546-Z], 528-X	[R-169], 537-X	[562-Z], [529-X], 534-X	563-Z	8/5/93	Kamehame
17	[R-177], B-768, 410-X	[R-180], R-183	553-X	409-X	8/24/93	Kamehame
18	R-138	R-137	no tag	no tag	8/25/93	ʻĀpua Point
19	[R-188], [B-785], B-561	[R-189], [B-560], [63-D], 62-D	no tag	no tag	6/23/94	Kamehame
20	[R-194], 1D51	R-195	435-X	[436-X], 440-X	7/29/94	Kamehame
21	J-86	[J-83], [B-590], 570-X	595-X	[589-X], 488-X	8/4/94	ʻĀpua Point
22	[430-X], B-757	B-755, 431-X	B-767	B-766	6/18/95	Kamehame
23	[B-763], B-762	[B-761], B-733	2D12	2D13	6/28/95	Kamehame

Turtle ID #	Tag Numbers				Date Originally Tagged	Location Tagged
	Left Front Flipper (LFF)	Right Front Flipper (RFF)	Left Rear Flipper (LRF)	Right Rear Flipper (RRF)		
24	[B-771], [548-Z], 557-Z	[549-Z], 558-Z	561-Z	559-Z	7/7/95	Kamehame
25	B-775, 306-Z	B-772	437-X	438-X	7/11/95	Kamehame
26	[B-774], 61-D	B-773	no tag	no tag	7/17/95	Kamehame
27	B-778	[B-777], 89-D, 556-X	411-X	412-X	8/11/95	Kamehame
28	[404-X], [B-543], B-556	B-538, 405-X	402-X	403-X	6/12/96	Kamehame
29	B-713	B-714	345-Z	344-Z	6/25/96	Kamehame
30	B-565	B-566	no tag	no tag	8/12/96	Kamehame
31	[B-569], 60-M	[B-568], 59-M	58-M	57-M	8/20/96	Kamehame
32	B-634	[B-633], 82-M	341-Z	[339-Z], 73-M	7/4/97	Kamehame
33	[Q-935], Q-925	Q-936	no tag	no tag	7/16/97	Ka‘ili‘ili
34	[Q-996], [Q-937], [67-M], 81-M	[Q-997], 68-M	[Q-996], [Q-937], [69-M], 75-M	70-M	7/31/97	Ka‘ili‘ili
35	[B-596], [Q973], 8A59	B-597	8A65	8A58	8/2/97	‘Āpua Point
36	B-573	Q-974	no tag	no tag	8/25/97	‘Āpua Point
37	B-637	B-638	93-M	94-M	9/4/97	Kamehame
38	98-D	97-D	no tag	no tag	7/2/98	Kamehame
39	95-D, 415-X	[93-D], [Q-849],425-X	420-X	418-X	7/7/98	Kamehame
40	[91-D], 65-D	[90-D], 64-D	408-X	407-X	7/6/98	Kamehame

Turtle ID #	Tag Numbers				Date Originally Tagged	Location Tagged
	Left Front Flipper (LFF)	Right Front Flipper (RFF)	Left Rear Flipper (LRF)	Right Rear Flipper (RRF)		
41	Q-828	Q-827	533-X	532-X	7/23/98	Kamehame
42	[Q-197], 450-X	[Q-192], 459-X	460-X	[452-X], 464-X	8/3/98	‘Āpua Point
43	[92-D]	94-D	no tag	no tag	8/23/98	Punalu‘u
44	276-Z	[277-Z], 290-Z	no tag	no tag	7/7/99	Pōhue Bay
45	284-Z	282-Z	no tag	no tag	7/11/99	Pōhue Bay
46	[553-Z], 507-X	[555-Z], 508-X	510-X	517-X	8/1/99	Kamehame
47	[378-Z], 594-X	379-Z	590-X	592-X	9/11/99	‘Āpua Point
48	304-Z	[305-Z], 100-M	98-M	99-M	9/13/99	Kamehame
49	333-Z	334-Z	[942-Z], 500-X	[944-Z], [527X], 496-X	6/16/00	Kamehame
50	581-Z, 587-Z	582-Z, 599-Z	583-Z	584-Z	7/8/00	Ka‘ili‘ili
51	387-Z	386-Z	391-Z	no tag	9/1/00	Halapē
52	[475-X], 8A50	474-X	473-X	472-X	6/29/01	Keauhou
53	[581-X], 582-X	[580-X], 585-X	[584-X], 587-X	[583-X], 586-X	7/9/01	‘Āpua Point
54	598-X	599-X	[597-X], 422-X	596-X	6/28/02	‘Āpua Point
55	477-X	478-X	479-X	480-X	7/9/02	Pōhue Bay
56	455-X	456-X	[457-X], 8A32	458-X	7/28/02	Halapē
57	[467-X], [466-X], 2D17	[468-X], 505-X	[465-X], 2D18	[462-X], 2D19	7/6/03	Halapē
58	482-X	481-X	484-X	483-X	6/22/04	Halapē

Turtle ID #	Tag Numbers				Date Originally Tagged	Location Tagged
	Left Front Flipper (LFF)	Right Front Flipper (RFF)	Left Rear Flipper (LRF)	Right Rear Flipper (RRF)		
59	557-X	558-X	560-X	[559-X], [2D50], 1D35	7/3/04	ʻĀpua Point
60	566-X	[564-X], 486X	[563-X], 567-X	562-X	6/14/05	ʻĀpua Point
61	90-M	89-M	92-M	91-M	6/23/05	Kamehame
62	492-X	497-X	498-X	495-X	7/8/05	ʻĀwili Point
63	96-M	1D78	95-M	97-M	7/10/05	Kamehame
64	85-M	88-M	84-M	83-M	7/16/05	Pōhue Bay
65	8A23	8A22	8A21	8A24	8/1/05	Pōhue Bay
66	8A20	8A18	8A34	8A17	8/5/05	Pōhue Bay
67	8A75	no tag	8A77	8A78	9/20/05	Pōhue Bay
68	8A99	8A63	8A98	8A97	6/6/06	ʻĀpua Point
69	8A36	8A35	8A40	8A37	7/13/06	Pōhue Bay
70	8A43	8A46	[8A47], 8A41	8A49	7/26/06	Kamehame
71	8A93	[8A92], 8A33	[8A91], 442-X	8A90	8/20/06	Pōhue Bay
72	8A98	8A89	445-X	447-X	9/9/06	Pōhue Bay
73	443-X	487-X	485-X	489-X	10/16/06	Pōhue Bay
74	1D46	1D47	1D48	1D49	5/26/07	Kamehame
75	[1D24], 1D18	[1D25], 1D17	1D20	1D19	6/6/07	Halapē
76	1D58	1D62	1D60	1D61	6/13/07	Pōhue Bay
77	1D64	1D65	1D66	1D67	6/22/07	Pōhue Bay

Turtle ID #	Tag Numbers				Date Originally Tagged	Location Tagged
	Left Front Flipper (LFF)	Right Front Flipper (RFF)	Left Rear Flipper (LRF)	Right Rear Flipper (RRF)		
78	[1D68], 2D01	[1D69], 2D02	Missing Flipper	1D84	6/25/07	Pōhue Bay
79	1D90	1D87	1D86	1D85	6/27/07	Pōhue Bay
80	1D42	1D43	1D44	1D45	6/28/07	ʻĀpua Point
81	1D91	1D93	1D92	Missing Flipper	7/30/07	Pōhue Bay
82	1D36	1D37	1D38	1D39	7/12/08	Kamehame
83	1D75	1D74	1D73	1D72	7/13/08	Halapē
84	1D71	1D70	1D76	1D77	7/17/08	Halapē
85	1D55	1D56	1D52	1D54	7/24/08	Halapē
86	1D79	1D80	2D09	1D81	8/1/08	Kamehame
87	1D94	1D95	1D97	1D98	8/3/08	Kaʻiliʻili
88	1D28	1D26	None	1D29	9/13/08	ʻĀpua Point
89	2D03	2D04	2D06	2D05	9/27/08	Pōhue Bay
90	2D56	2D57	2D58	2D59	6/3/09	Pōhue Bay
91	2D32	2D30	2D31	2D33	6/12/09	Kamehame
92	2D36	2D39	2D37	2D38	6/16/09	ʻĀpua Point
93	2D27	2D26	[2D29], 2D82	[2D28], 2D81	6/19/09	Kamehame
94	2D08	2D72	[2D07], 2D74	[1D96], [2D73], 2D67	7/20/09	Pōhue Bay
95	1D31	1D32	1D33	1D34	7/24/09	ʻĀpua Point
96	2D85	2D84	2D89	2D90	7/30/09	Kamehame

Turtle ID #	Tag Numbers				Date Originally Tagged	Location Tagged
	Left Front Flipper (LFF)	Right Front Flipper (RFF)	Left Rear Flipper (LRF)	Right Rear Flipper (RRF)		
97	2D76	2D77	2D80	2D78	8/4/09	Kamehame
98	2D71	2D70	2D69	2D68	8/7/09	Pōhue Bay
99[1]	Y254	[3D03], 2D55	3D01	3D02	8/19/09	Punaluʻu
100	2D94	[2D93], 2D95	2D88	2D91	9/1/09	Kamehame

[1] Y254 originally tagged as a juvenile at Kīholo Bay, west Hawaiʻi Island on 10/18/89 by George Balazs (NOAA). She was seen again at Kīholo Bay in 1990 and 1992. Not seen again until 8/19/09 at Punaluʻu, Hawaiʻi Island.

Table B2. Individual results for tagged hawksbills, Hawai‘i Island, 1991-2009

Turtle ID #	Mean Remigration Interval (years) (n=remigrations)	Total Crawls Documented (n=years)	Years Observed	Total Documented Nests	Mean Nest-to-Crawl Interval (days) (n=intervals)	Mean Nest-to-Nest Interval (days) (n=intervals)	Mean Clutch Size (eggs) (n=nests)	Mean Hatch Success (%) (n=nests)	Mean Standard Carapace Length (cm) (n=measurements)
1	2.0 ± 0.0 n=4	30 n=5	91, 93, 95, 97, 99	18	18.0 ± 0.5 n=12	17.4 ± 0.9 n=12	160.2 ± 10.1 n= 18	79.2 ± 25.1 n=18	82.4 ± 0.5 n=16
2	3.6 ± 0.6 n=5	113 n=6	91, 93, 96, 99, 04, 09	16	20.5 ± 1.7 n=10	26.9 ± 2.3 n=10	181.4 ± 8.2 n=16	80.6 ± 3.8 n=16	83.7 ± 0.2 n=36
3	2.5 ± 0.3 n=4	29 n=5	91, 93, 96, 98, 01	10	19.8 ± 1.3 n=6	19.5 ± 1.3 n=4	165.6 ± 6.2 n=10	58.8 ± 9.0 n=10	84.1 ± 0.3 n=19
4[1]	2.2 ± 0.2 n=5	62 n=6	91, 93, 95, 97, 99, 02	25	16.5 ± 0.6 n=17	17.4 ± 0.5 n=19	152.1 ± 5.3 n=22	80.2 ± 3.5 n=22	85.8 ± 0.3 n=26
5	2.0 ± 0.0 n=3	17 n=4	92, 94, 96, 98	5	17.8 ± 1.0 n=4	20.3 ±3.0 n=4	186.2 ± 10.0 n=5	61.1 ± 13.3 n=5	87.6 ± 0.4 n=9
6	3.0 ± 0.0 n=2	15 n=3	92, 95, 98	6	18.5 ± 0.5 n=2	22.0 ± 2.5 n=4	175.3 ± 8.4 n=6	82.5 ± 4.9 n=6	80.7 ± 0.2 n=6
7	3.3 ± 0.5 n=4	72 n=5	92, 95, 98, 01, 05	11	19.2 ± 0.6 n=6	20.2 ± 0.5 n=6	128.5 ± 29.6 n=10	56.4 ± 9.2 n=11	81.5 ± 0.3 n=24
8[1]	3.0 ± 0.0 n=2	35 n 3	93, 96, 99	7	18.5 ± 1.0 n=4	18.3 ± 1.0 n=4	184.0 ± 5.8 n=5	73.8 ± 12.1 n=5	83.4 ± 0.1 n=10
9	ND	1 n=1	93	0	ND	ND	ND	ND	82.0 n=1
10	ND	6 n=1	93	2	18.0 ± 0.0 n=2	18.0 ± 0.0 n=2	184.0 ± 3.0 n=2	46.7 ± 20.1 n=2	83.0 n=1
11	3.0 ± 0.0 n=4	38 n=5	93, 96, 99, 02, 05	18	19.1 ± 0.4 n=13	20.2 ± 0.6 n=13	204.7 ± 8.5 n=17	76.4 ± 5.2 n=17	83.7 ± 0.3 n=21
12	3.7 ± 1.2 n=3	14 n=4	93, 96, 98, 04	7	21.3 ± 0.7 n=3	21.7 ± 0.3 n=3	177.3 ± 5.1 n=6	21.2 ± 9.1 n=7	83.1 ± 0.7 n=9
13	3.0 ± 0.0 n=2	33 n=3	93, 96, 99	8	22.3 ± 0.4 n=5	21.5 ± 2.5 n=4	173.7 ± 12.3 n=6	59.4 ± 14.0 n=6	79.5 ± 0.2 n=16
14	3.3 ± 1.5 n=3	26 n=5	93, 95, 00, 03	16	18.8 ± 0.3 n=11	20.0 ± 0.7 n=10	199.1 ± 12.3 n=15	82.7 ± 3.3 n=15	85.5 ± 0.6 n=15
15	4.3 ± 2.1 n=3	19 n=5	93, 95, 00, 06	18	18.5 ± 0.6 n=8	19.0 ± 0.6 n=9	208.7 ± 9.2 n=15	69.5 ± 2.5 n=16	83.0 ± 0.4 n=13

Turtle ID #	Mean Remigration Interval (years) (n=remigrations)	Total Crawls Documented (n=years)	Years Observed	Total Documented Nests	Mean Nest-to-Crawl Interval (days) (n=intervals)	Mean Nest-to-Nest Interval (days) (n=intervals)	Mean Clutch Size (eggs) (n=nests)	Mean Hatch Success (%) (n=nests)	Mean Standard Carapace Length (cm) (n=measurements)
16	5.0 ± 1.0 n=2	30 n=3	93, 99, 03	7	18.0 ± 0.4 n=4	19.5 ± 0.5 n=4	183.6 ± 14.1 n=7	76.0 ± 8.1 n=7	83.9 ± 0.5 n=15
17	2. 7 ± 0.3 n=3	24 n=4	93, 95, 98, 01	14	18.6 ± 0.5 n=7	20.6 ± 0.9 n=10	208.7 ± 9.4 n=15	64.4 ± 6.3 n=15	86.6 ± 0.6 n=8
18	ND	1 n=1	93	0	ND	ND	ND	ND	80.0 n=1
19	2.0 ± 0.0 n=2	19 n=3	94, 96, 98	6	19.0 ± 1.0 n=2	18.0 n=1	177.8 ± 10.9 n=6	89.3 ± 1.1 n=6	78.3 ± 1.1 n=5
20[1]	4.3 ± 0.3 n=2	35 n=5	94, 98, 02, 07	11	19.2 ± 0.7 n=9	20.3 ± 0.7 n=8	193.6 ± 6.1 n=12	77.1 ± 5.4 n=12	87.7 ± 0.3 n=13
21	2.8 ± 0.3 n=4	20 n=5	94, 96, 99, 02, 05	4	18.7 ± 0.3 n=3	ND	216.3 ± 12.0 n=4	68.7 ± 10.7 n=4	87.2 ± 0.2 n= 12
22	3.3 ± 0.3 n=3	52 n=4	95, 98, 02, 05	17	16.9 ± 0.4 n=10	18.5 ± 0.9 n=13	176.3 ± 11.3 n=15	76.7 ± 3.2 n=16	77.5 ± 0.3 n= 27
23	7.0 ± 3.0 n=2	18 n=3	95, 99, 09	7	20.5 ± 1.5 n=2	24.5 ± 4.5 n=2	162.2 ± 7.6 n=5	60.5 ± 9.9 n=5	80.9 ± 0.2 n=9
24	4.0 n=1	28 n=2	95, 99	8	20.0 ± 0.0 n=2	21.4 ± 1.7 n=5	149.0 ± 7.0 n=7	62.0 ± 12.9 n=7	80.7 ± 0.5 n=8
25	2.3 ± 0.3 n=3	34 n=4	95, 97, 99, 02	21	18.4 ± 0.4 n=13	18.6 ± 0.4 n=17	171.9 ± 14.0 n=14	84.1 ± 5.3 n=15	83.7 ± 0.3 n=15
26[1]	3.0 n=1	13 n=2	95, 98	4	17.0 n=1	21.0 ± 4.0 n=2	129.5 ± 15.3 n=4	76.4 ± 7.5 n=4	83.0 ± 1.5 n=2
27	3.0 ± 0.0 n=2	28 n=3	95, 98, 01	8	21.3 ± 0.9 n=3	25.4 ± 1.7 n=5	204.4 ± 12.2 n=8	54.7 ± 10.0 n=8	87.5 ± 0.23 n=7
28	5.0 ± 0.0 n=2	48 n=3	96, 01, 06	12	16.4 ± 0.3 n=9	19.8 ± 1.3 n=9	132.3 ± 18.0 n=10	80.6 ± 3.8 n=10	76.4 ± 0.4 n=19
29	4.0 n=1	25 n=2	96, 00	8	17.6 ± 0.4 n=5	18.4 ± 0.3 n=5	170.4 ± 13.9 n=8	84.4 ± 5.1 n=8	83.8 ± 0.3 n=15
30[1]	3.0 n=1	34 n=2	96, 99	9	21.0 ± 1.1 n=6	20.7 ± 1.1 n=6	158.7 ± 7.5 n=7	76.4 ± 10.0 n=7	84.4 ± 0.5 n=4
31	7.0 n=1	8 n=2	96, 03	0	ND	ND	ND	ND	ND
32	3.5 ± 0.5 n=2	17 n=3	97, 00, 04	6	17.5 ± 0.5 n=2	29.0 n=1	234.0 ± 6.1 n=6	42.5 ± 10.9 n=6	87.8 ± 0.3 n=14
33	ND	7 n=1	97	3	20.0 ± 1.0 n=2	20.0 ± 1.0 n=2	185.3 ± 29.5 n=3	77.4 ± 10.2 n=3	ND

ND = No Data

Turtle ID #	Mean Remigration Interval (years) (n=remigrations)	Total Crawls Documented (n=years)	Years Observed	Total Documented Nests	Mean Nest-to-Crawl Interval (days) (n=intervals)	Mean Nest-to-Nest Interval (days) (n=intervals)	Mean Clutch Size (eggs) (n=nests)	Mean Hatch Success (%) (n=nests)	Mean Standard Carapace Length (cm) (n=measurements)
34	7.0 n=1	11 n=2	97, 04	4	17.0 ± 0.6 n=3	20.7 ± 2.1 n=3	164.3 ± 2.1 n=4	70.6 ± 17.0 n=4	81.6 ± 1.5 n=4
35	5.5 ± 2.5 n=2	7 n=3	97, 05, 08	3	ND	ND	186.7 ± 13.9 n=3	55.7 ± 23.4 n=3	85.8 ± 0.7 n=3
36	ND	1 n=1	97	0	ND	ND	ND	ND	ND
37	8.0 n=1	18 n=2	97, 05	4	17.0 ± 0.6 n=3	17.5 ± 0.5 n=2	203.0 ± 17.6 n=4	77.4 ± 9.3 n=4	84.0 ± 0.7 n=17
38	ND	1 n=1	98	1	ND	ND	166.0 n=1	95.8 n=1	ND
39	3.0 ± 0.0 n=2	40 n=3	98, 01, 04	9	18.4 ± 0.8 n=5	22.0 ± 2.6 n=4	213.1 ± 10.6 n=9	64.6 ± 6.8 n=9	81.5 ± 0.1 n=16
40	3.0 n=1	15 n=2	98, 01	0	ND	ND	ND	ND	80.8 ± 0.6 n=7
41	5.0 n=1	14 n=2	98, 03	5	19.0 ± 0.4 n=4	22.0 ± 1.7 n=3	152.4 ± 19.7 n=5	90.7 ± 2.3 n=5	74.7 ± 0.7 n=7
42	3.0 ± 0.0 n=2	11 n=4	98, 01	6	22.0 n=1	26.0 n=1	216.7 ± 16.2 n=7	72.0 ± 11.5 n=7	89.0 ± 0.2 n=7
43	ND	2 n=2	98	0	ND	ND	ND	ND	ND
44	ND	3 n=1	99	2	ND	ND	190.0 ± 3.5 n=2	83.9 ± 0.2 n=2	86.8 n=1
45	ND	2 n=1	99	2	ND	ND	161.5 ± 10.5 n=2	95.1 ± 4.9 n=2	80.2 n=1
46	4.0 n=1	10 n=2	99	4	19.0 ± 0.0 n=2	24.0 ± 1.0 n=2	195.0 ± 8.3 n=4	45.8 ± 15.3 n=4	81.2 ± 0.3 n=5
47	3.5 ± 0.5 n=2	11 n=2	99, 02, 06	6	19.6 ± 1.5 n=5	20.0 ± 1.2 n=4	157.2 ± 6.9 n=6	72.2 ± 12.6 n=6	83.0 ± 0.3 n=8
48	5.0 n=1	3 n=2	99, 04	3	17.5 ± 1.5 n=2	17.5 ± 1.5 n=2	136.7 ± 18.4 n=3	94.0 ± 1.2 n=3	83.8 ± 2.8 n=2
49	2.5 ± 0.5 n=2	19 n=3	00, 02, 05	6	19.3 ± 1.2 n=3	23.3 ± 2.9 n=3	232.4 ± 14.2 n=5	30.4 ± 15.3 n=5	81.5 ± 0.4 n=18
50	4.0 n=1	19 n=2	00, 04	7	19.5 ± 0.8 n=6	20.3 ± 1.1 n=4	187.0 ± 18.0 n=7	87.4 ± 4.7 n=7	85.5 ± 0.6 n=7
51	ND	4 n=1	00	2	17.0 n=1	20.0 n=1	132.5 ± 6.5 n=2	57.7 ± 1.2 n=2	84.5 ± 0.0 n=3
52	5.0 n=1	17 n=2	01, 06	5	19.3 ± 1.4 n=4	21.7 ± 0.3 n=3	179.2 ± 10.1 n=5	66.9 ± 16.1 n=5	84.5 ± 1.9 n=5

ND = No Data

Turtle ID #	Mean Remigration Interval (years) (n=remigrations)	Total Crawls Documented (n=years)	Years Observed	Total Documented Nests	Mean Nest-to-Crawl Interval (days) (n=intervals)	Mean Nest-to-Nest Interval (days) (n=intervals)	Mean Clutch Size (eggs) (n=nests)	Mean Hatch Success (%) (n=nests)	Mean Standard Carapace Length (cm) (n=measurements)
53	3.0 n=1	11 n=2	01, 04	2	16.5 ± 0.5 n=2	17.0 n=1	154.0 ± 1.0 n=2	46.8 ± 13.9 n=2	83.6 ± 0.1 n=7
54	3.5 ± 0.5 n=2	16 n=3	02, 05, 09	8	20.4 ± 1.2 n=5	23.8 ± 3.7 n=5	178.0 ± 9.1 n=8	57.3 ± 12.8 n=8	78.1 ± 0.2 n=13
55	4.0 n=1	8 n=2	02, 06	4	18.7 ± 0.7 n=3	19.5 ± 0.5 n=2	248.0 ± 7.6 n=4	70.9 ± 12.4 n=4	85.7 ± 0.2 n=6
56	4.0 n=1	4 n=2	02, 06	4	22.0 n=1	22.0 n=1	160.0 ± 5.8 n=4	66.8 ± 16.3 n=4	78.8 ± 0.3 n=3
57	6.0 n=1	15 n=2	03, 09	7	20.0 ± 1.0 n=3	21.4 ± 0.5 n=5	185.6 ± 13.7 n=7	28.5 ± 11.8 n=7	85.8 ± 0.4 n=12
58	ND	1 n=1	04	1	ND	ND	103.0 n=1	49.5 n=1	84.3 n=1
59	ND	13 n=2	04, 09	5	23.0 ± 6.0 n=3	17.3 ± 0.9 n=3	157.2 ± 4.6 n=5	60.3 ± 14.5 n=5	79.3 ± 0.6 n=11
60	ND	5 n=1	05	3	16.5 ± 0.5 n=2	16.5 ± 0.5 n=2	149.3 ± 1.5 n=3	95.1 ± 1.5 n=3	75.4 ± 0.2 n=7
61	ND	5 n=1	05	0	ND	ND	ND	ND	78.8 ± 0.6 n=5
62	ND	3 n=1	05	3	19.0 n=1	19.0 n=1	138.3 ± 5.8 n=3	81.1 ± 7.9 n=3	73.0 ± 0.6 n=4
63	2.0 n=1	5 n=1	05, 07	0	ND	ND	ND	ND	84.5 ± 1.8 n=3
64	ND	5 n=1	05	2	18.0 n=1	36.0 n=1	205.0 n=1	80.0 ± 1.4 n=2	85.8 ± 0.7 n=6
65	3.0 n=1	2 n=2	05, 08	0	ND	ND	ND	ND	82.5 n=1
66	ND	6 n=1	05	2	ND	ND	193.0 ± 8.0 n=2	91.5 ± 0.1 n=2	81.3 ± 0.7 n=6
67	ND	1 n=1	05	1	ND	ND	179.0 n=1	96.1 n=1	79.5 n=1
68	ND	5 n=1	06	2	16.0 n=1	16.0 n=1	191.5 ± 23.5 n=2	44.5 ± 9.6 n=2	83.4 ± 0.1 n=3
69	ND	6 n=1	06	3	19.5 ± 0.5 n=2	21.0 n=1	153.7 ± 7.2 n=3	94.7 ± 1.7 n=3	77.0 n=1
70	ND	5 n=1	06	2	20.0 ± 0.0 n=2	20.0; n=1	191.0 ± 43.0 n=2	38.5 ± 38.5 n=2	81.0 ± 0.4 n=4
71	ND	3 n=1	06	2	18.0 n=1	20.0 n=1	162.0 ± 2.0 n=2	99.4 ± 0.6 n=2	74.8 ± 0.3 n=2

ND = No Data

Turtle ID #	Mean Remigration Interval (years) (n=remigrations)	Total Crawls Documented (n=years)	Years Observed	Total Documented Nests	Mean Nest-to-Crawl Interval (days) (n=intervals)	Mean Nest-to-Nest Interval (days) (n=intervals)	Mean Clutch Size (eggs) (n=nests)	Mean Hatch Success (%) (n=nests)	Mean Standard Carapace Length (cm) (n=measurements)
72	ND	1 n=1	06	1	ND	ND	124.0 n=1	97.6 n=1	77.5 n=1
73	ND	1 n=1	06	1	ND	ND	168.0 n=1	97.0 n=1	79.3 n=1
74	2.0 n=1	10 n=2	07, 09	6	19.0 ± 2.0 n=2	24.0 ± 6.0 n=4	211.3 ± 6.6 n=6	22.0 ± 6.3 n=6	79.0 ± 0.1 n=6
75	ND	10 n=1	07	3	20.0 n=1	34.0 n=1	132.7 ± 13.2 n=3	31.2 ± 22.6 n=3	81.3 ± 0.4 n=4
76[1]	ND	8 n=1	07	4	19.7 ± 0.9 n=3	19.7 ± 0.9 n=3	241.5 ± 4.4 n=4	73.9 ± 10.6 n=4	84.0 ± 0.4 n=5
77	ND	4 n=1	07	2	21.0 n=1	22.0 n=1	197.0 ± 5.0 n=2	61.1 ± 7.1 n=2	86.5 ± 0.5 n=2
78	ND	7 n=1	07	5	19.3 ± 0.5 n=4	19.3 ± 0.5 n=4	140.0 ± 6.1 n=5	91.7 ± 3.3 n=5	75.6 ± 0.7 n=6
79	ND	8 n=1	07	4	20.5 ± 1.5 n=2	22.0 n=1	171.50 ± 7.64 n=4	52.1 ± 1.7 n=4	78.2 ± 0.6 n=5
80	ND	4 n=1	07	2	20.0 n=1	20.0 n=1	165.5 ± 10.5 n=2	82.2 ± 10.1 n=2	79.5 ± 0.3 n=4
81	ND	2 n=1	07	2	22.5 ± 1.5 n=2	23.5 ± 0.5 n=2	173.0 ± 13.0 n=2	37.5 ± 2.2 n=2	76.0 ± 0.0 n=2
82	ND	1 n=1	08	1	ND	ND	163.0 n=1	48.5 n=1	82.0 n=1
83	ND	4 n=1	08	2	ND	ND	182.0 ± 14.0 n=2	66.1 ± 26.8 n=2	80.0 ± 0.0 n=3
84	ND	3 n=1	08	1	ND	ND	209.0 n=1	77.0 n=1	84.5 ± 2.9 n=2
85	ND	3 n=1	08	2	19.0 n=1	19.0 n=1	144.5 ± 7.5 n=2	55.5 ± 4.4 n=2	81.8 ± 1.01 n=3
86[1]	ND	9 n=1	08	3	17.5 ± 0.5 n=2	20.5 ± 2.5 n=2	213 ± 29.2 n=3	87.0 ± 4.4 n=3	84.5 ± 0.0 n=6
87	ND	1 n=1	08	1	ND	ND	ND	ND	89.0 n=1
88	ND	1 n=1	08	0	ND	ND	ND	ND	84.1 n=1
89	ND	1 n=1	08	1	ND	ND	146.0 n=1	95.9 n=1	75.1 n=1
90	ND	4 n=1	09	3	ND	22.0 ± 1.0 n=2	186.0 ± 2.1 n=3	38.3 ± 19.3 n=3	83.3 ± 0.3 n=4

ND = No Data

Turtle ID #	Mean Remigration Interval (years) (n=remigrations)	Total Crawls Documented (n=years)	Years Observed	Total Documented Nests	Mean Nest-to-Crawl Interval (days) (n=intervals)	Mean Nest-to-Nest Interval (days) (n=intervals)	Mean Clutch Size (eggs) (n=nests)	Mean Hatch Success (%) (n=nests)	Mean Standard Carapace Length (cm) (n=measurements)
91	ND	6 n=1	09	2	19.5 ± 0.5 n=2	24.0 n=1	154.5 ± 6.5 n=2	42.4 ± 16.3 n=2	76.5 ± 0.12 n=3
92	ND	4 n=1	09	3	19.0 ± 1.0 n=2	19.5 ± 1.5 n=2	77.3 ± 10.8 n=3	84.9 ± 8.5 n=3	79.9 ± 0.3 n=4
93	ND	13 n=1	09	4	19.0 n=1	24.0 ± 1.0 n=2	168.8 ± 8.7 n=4	80.9 ± 4.4 n=4	77.5 ± 0.6 n=9
94	ND	7 n=1	09	3	ND	26.0 ± 8.0 n=2	191.0 ± 16.8 n=3	63.0 ± 0.9 n=3	86.0 ± 2.1 n=3
95	ND	1 n=1	09	1	ND	ND	153.0 n=1	15.0 n=1	77.8 ± 0.3 n=2
96	ND	6 n=1	09	1	ND	ND	183.0 n=1	81.4 n=1	80.8 ± 0.4 n=3
97	ND	1 n=1	09	0	ND	ND	ND	ND	75.7 n=1
98	ND	2 n=1	09	2	ND	ND	180.5 ± 32.5 n=2	75.1 ± 10.7 n=2	79.8 ± 0.4 n=2
99	ND	6 n=1	09	5	18.3 ± 0.9 n=3	17.5 ± 1.1 n=4	145.0 ± 8.4 n=5	74.0 ± 10.6 n=5	76.5 ± 0.1 n=5
100	ND	7 n=1	09	2	18.5 ± 0.5 n=2	19.0 n=1	188.0 n=1	45.7 ± 45.7 n=2	80.4± 0.3 n=5

[1] Turtle was outfitted with satellite transmitter (see Appendix C).

ND = No Data

Table B3. Adult female hawksbills found stranded by HIHTRP, Hawaii Island, 1987-2009.

Turtle ID#	Tag Numbers				Date Found	Location
	LFF	RFF	LRF	RRF		
UNK[1]	NT	NT	NT	NT	Aug-87	Halapē
23[2]	B-762, B-763	B-761, B-733	NT	NT	1995	Punalu‘u
5[2]	N-443	N-444	NT	NT	6/24/1998	‘Āpua Point
1[1]	N-451	N-452	NT	NT	10/21/1999	‘Āpua Point
43[2,3]	[92-D]	94-D	NT	NT	11/19/1999	Punalu‘u
47[1]	594-X	379-Z	NT	592-X	10/25/2007	‘Āpua Point
65[1]	8A23	8A22	8A21	8A24	9/3/2008	Humuhumu Point

[1] Found dead.
[2] Released alive.
[3] Rescued by G. Balazs and UH-Hilo.
NT=no tag

APPENDIX C: Satellite Tracking Maps of Hawaiian Hawksbills from Nesting Beach to Foraging Grounds

The following satellite tracking maps are presented illustrating the post nesting movements of nine adult female hawksbills from their nesting beaches to their foraging grounds (figures C2-11). Accuracy for Argos location codes that are included after the location date on the maps is included in Table C1. This study was a collaborative effort between HIHTRP, NOAA Pacific Islands Fisheries Science Center, and Hawai‘i Wildlife Fund between 1995 and 2006 (Figure C1).

All maps were generated by and appear courtesy of Denise Parker. Four individuals were tracked from Hawai‘i Island nesting beaches. These turtles ID numbers from Appendix B are correlated with their NOAA turtle ID number in Table C2. Three additional adult females from Hawai‘i Island that were presented in Appendix B (Turtle ID#’s 20, 76, 86) were satellite tracked in subsequent seasons and that data is not presented here.

These tracking maps were originally published in: Parker, D.M., Balazs, G.H., C.S. King, L. Katahira, and W. Gilmartin. 2009. Short-range movements of hawksbill turtles from nesting to foraging areas within the Hawaiian Islands. Pacific Science 63(3):371-382. The Abstract for that publication is as follows:

“Hawksbill sea turtles, *Eretmochelys imbricata*, reside around the main Hawaiian Islands but are not common. Flipper tag recoveries and satellite tracking of hawksbills worldwide have shown variable distances in post-nesting travel, with migrations between nesting beaches and foraging areas ranging from 35 to 2,425 km. Nine hawksbill turtles were tracked within the Hawaiian Islands using satellite telemetry. Turtles traveled distances ranging from 90 to 345 km and took between 5 to 18 days to complete the transit from nesting to foraging areas. Results of this study suggest that movements of Hawaiian hawksbills are relatively short-ranged, and surveys of their foraging areas should be conducted to assess status of the habitat to enhance conservation and management of these areas.”

Figure C1. (A) George Balazs and Larry Katahira attach a satellite transmitter to post nesting female, August 1995. (B) Hawksbill with satellite transmitter at Kamehame, Hawai‘i Island.

Table C1. Location Classes on Tracking Maps.

Class	Type	Estimated error*		Number of messages received per satellite pass
G	GPS	< 100m		1 message or more
3	Argos	< 250m		4 messages or more
2	Argos	250m < < 500m		4 messages or more
1	Argos	500m < < 1500m		4 messages or more
0*	Argos	> 1500m		4 messages or more
A	Argos	No accuracy estimation	Unbounded accuracy estimation	3 messages
B	Argos	No accuracy estimation	Unbounded accuracy estimation	1 or 2 messages
Z	Argos	Invalid location (available only for Service Plus/Auxiliary Location Processing)		

* Class 0 locations are available by request only.

From: http://www.argos-system.org/manual/index.html#3-location/32_principle.htm

Table C2. Adult female hawksbills outfitted with satellite transmitters, Hawai‘i Island, 1995-2006. Cross reference between Appendix B and Appendix C.

HIHTRP Turtle ID (Appendix B)	NOAA Turtle ID (Appendix C)
4	22126
8	24191
26	22134
30	25695

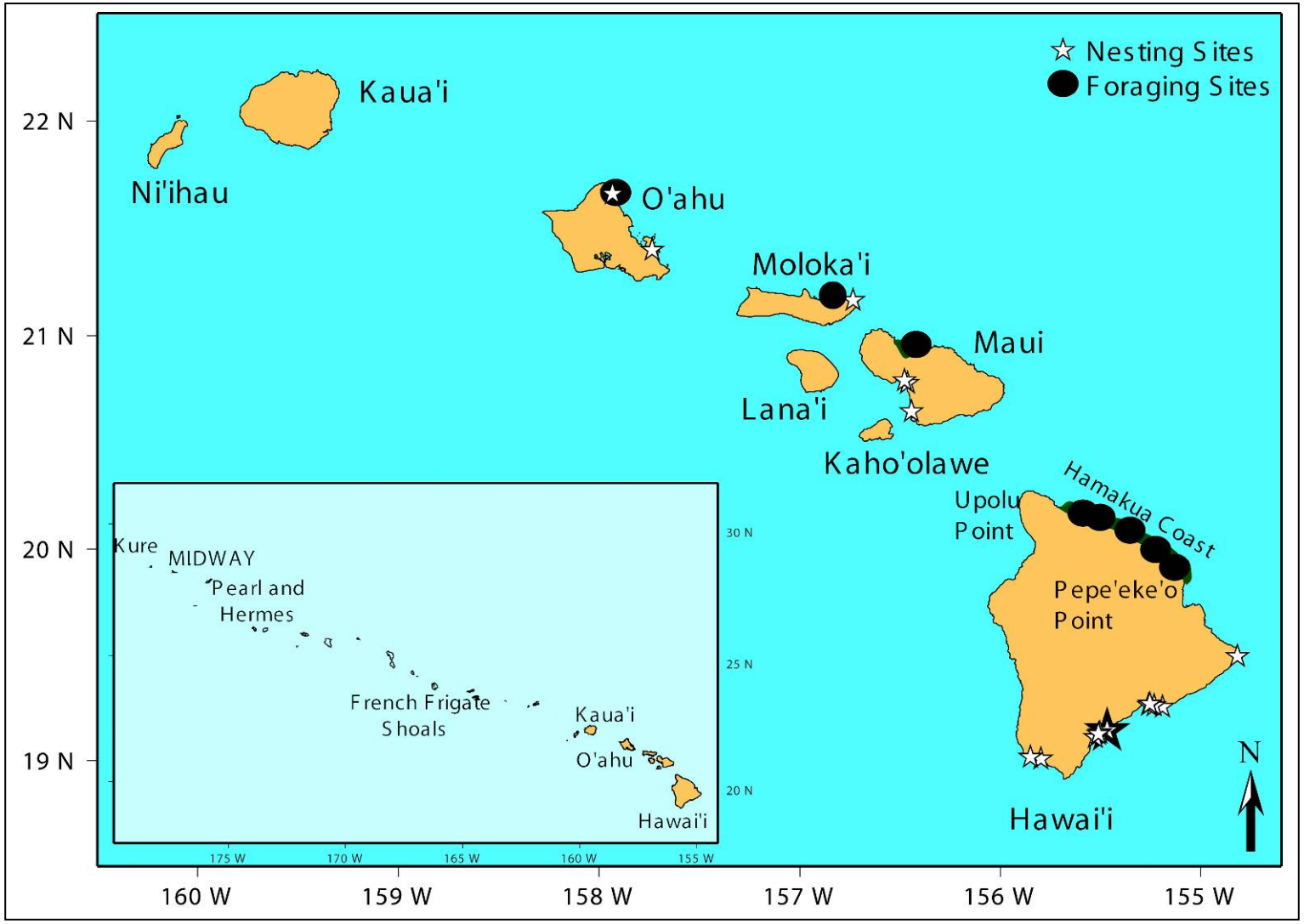

Figure C2. Distribution of foraging areas (indicated by black dots) as determined by satellite tracking of nine hawksbills from 1995 to 2006. Open stars indicate nesting sites. The entire Hawaiian Archipelago is in the inset for scale.

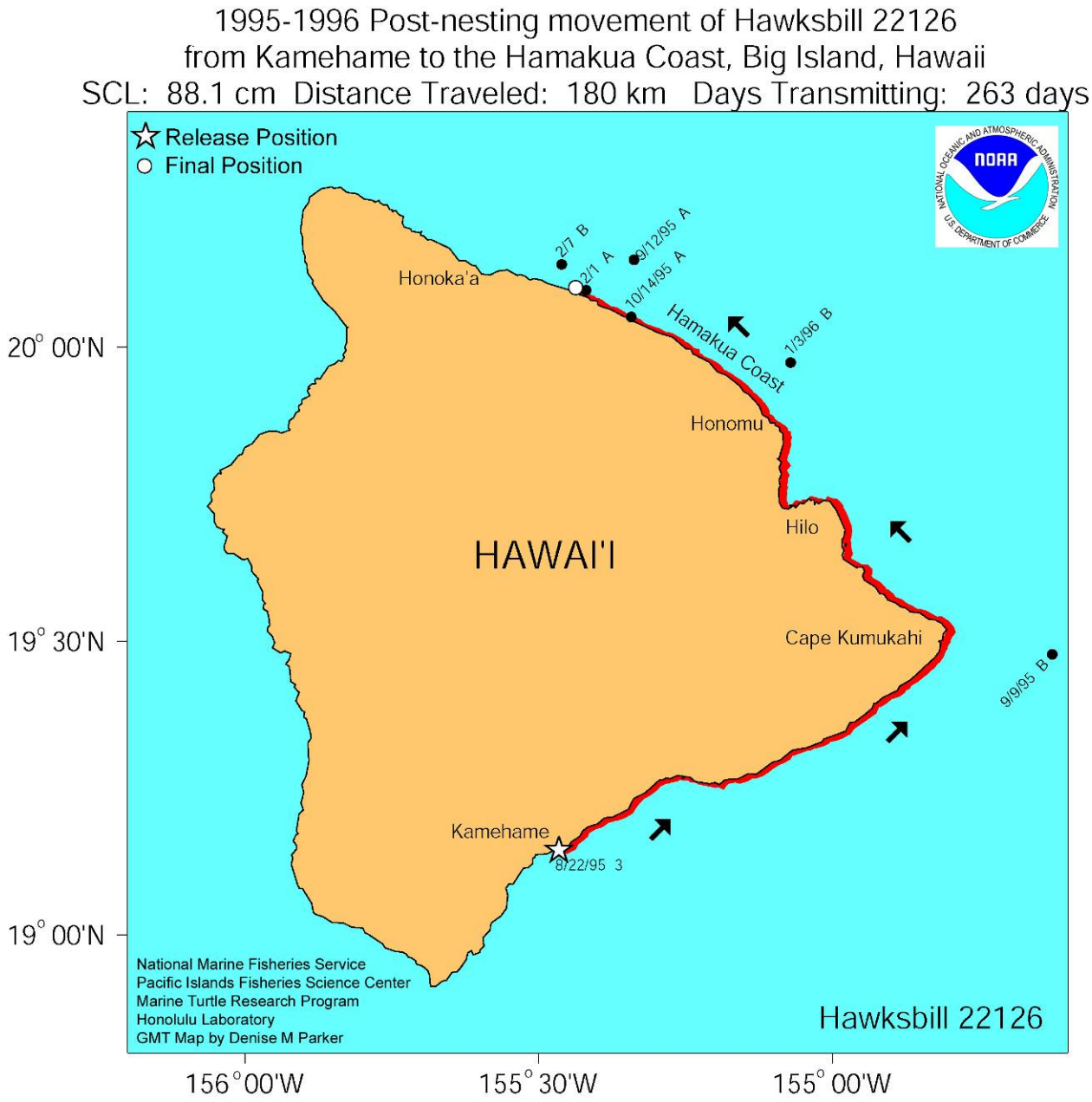

Figure C3. Travel route for NOAA Turtle ID 22126 (HIHTRP Turtle ID 4). This turtle traveled 180 km in a total of 10 days between Kamehame nesting beach to Honoka‘a, Hawai‘i Island.

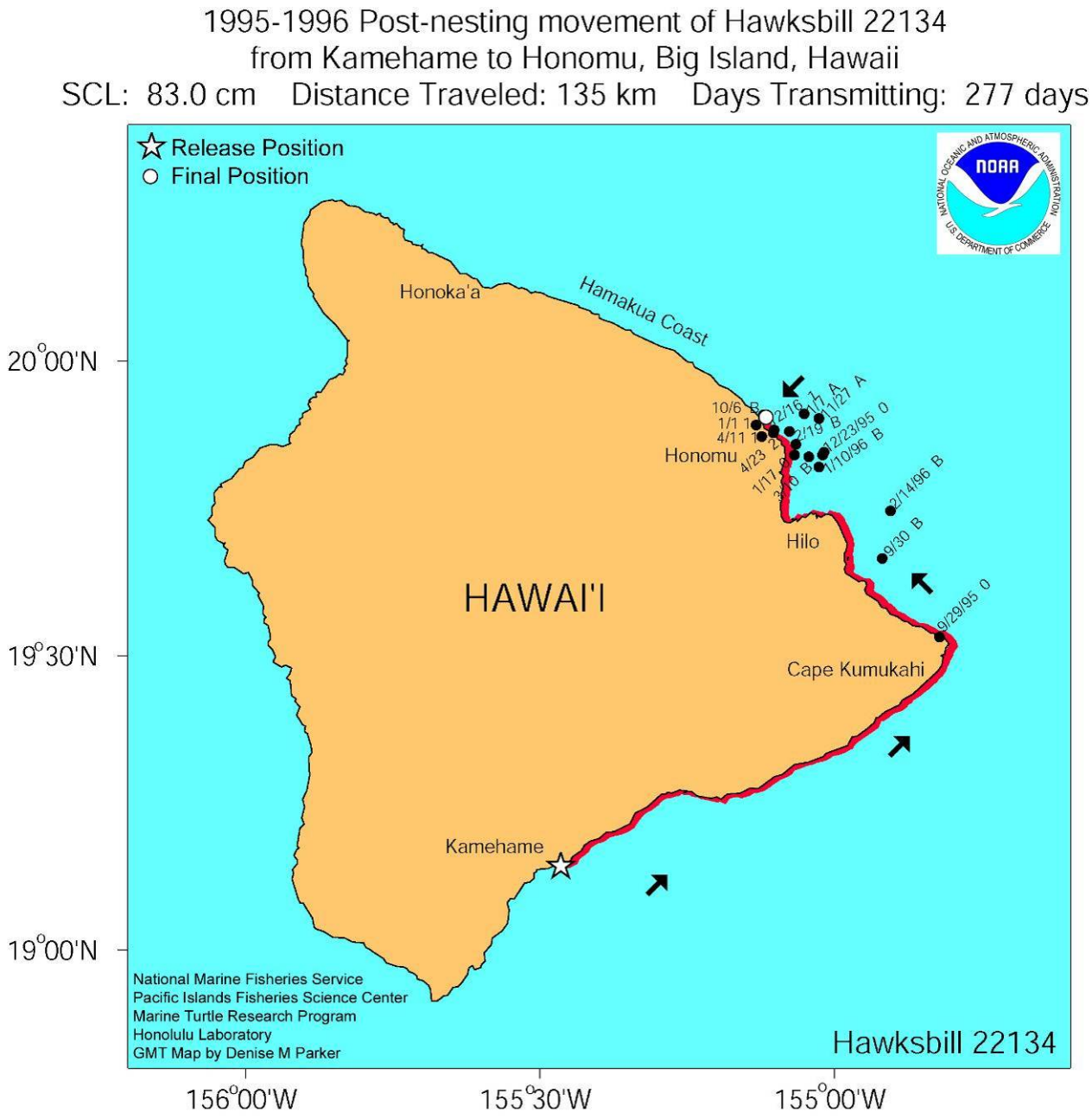

Figure C4. Travel route for NOAA Turtle ID 22134 (HIHTRP ID 26). This turtle traveled 135 km in 8 days between Kamehame nesting beach to Honomū, Hawai‘i Island.

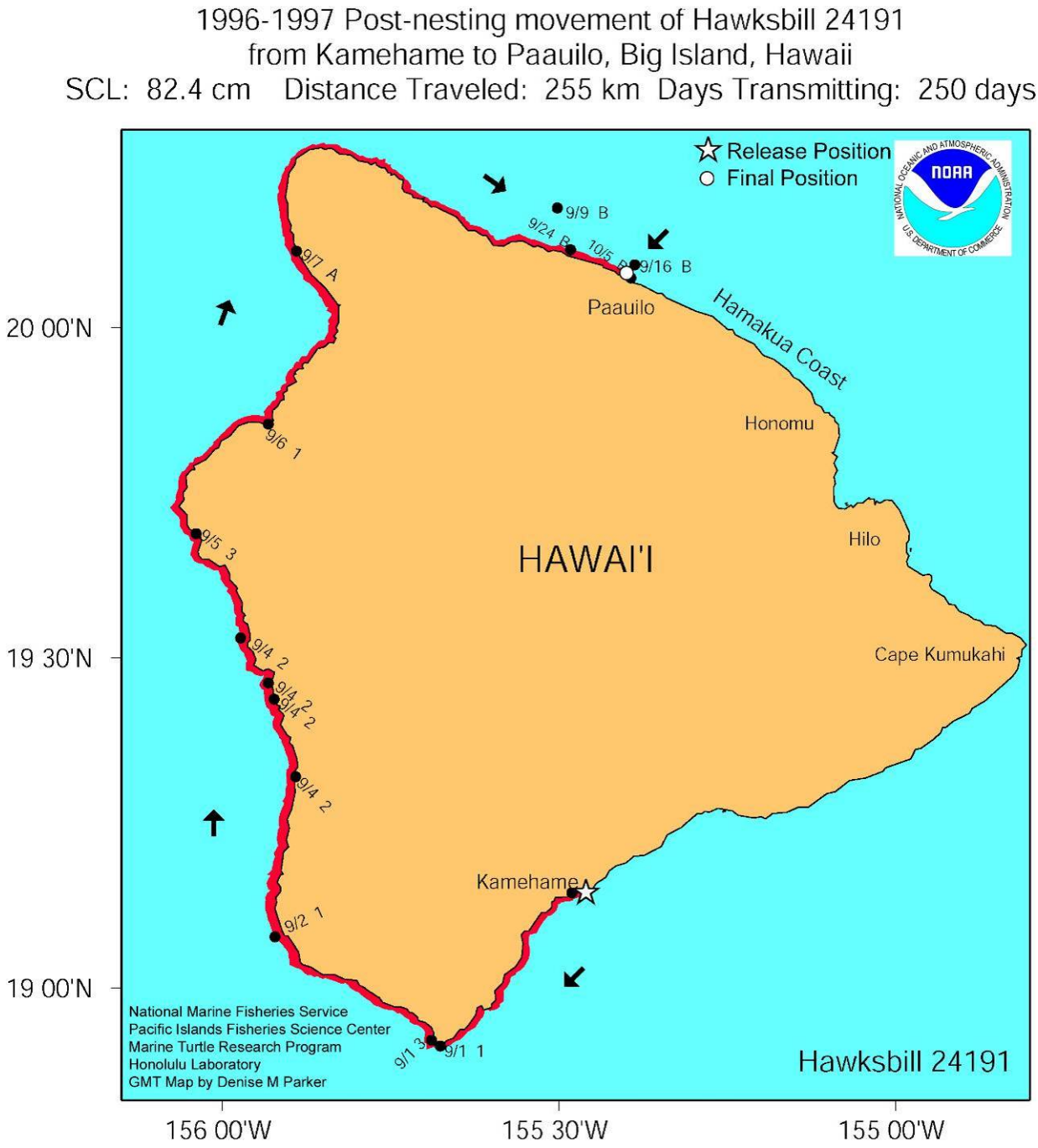

Figure C5. Travel route for NOAA Turtle ID 24191 (HIHTRP Turtle ID 8). This turtle traveled 275 km in 12 days between the Kamehame nesting beach and Pa‘auilo, Hawai‘i Island.

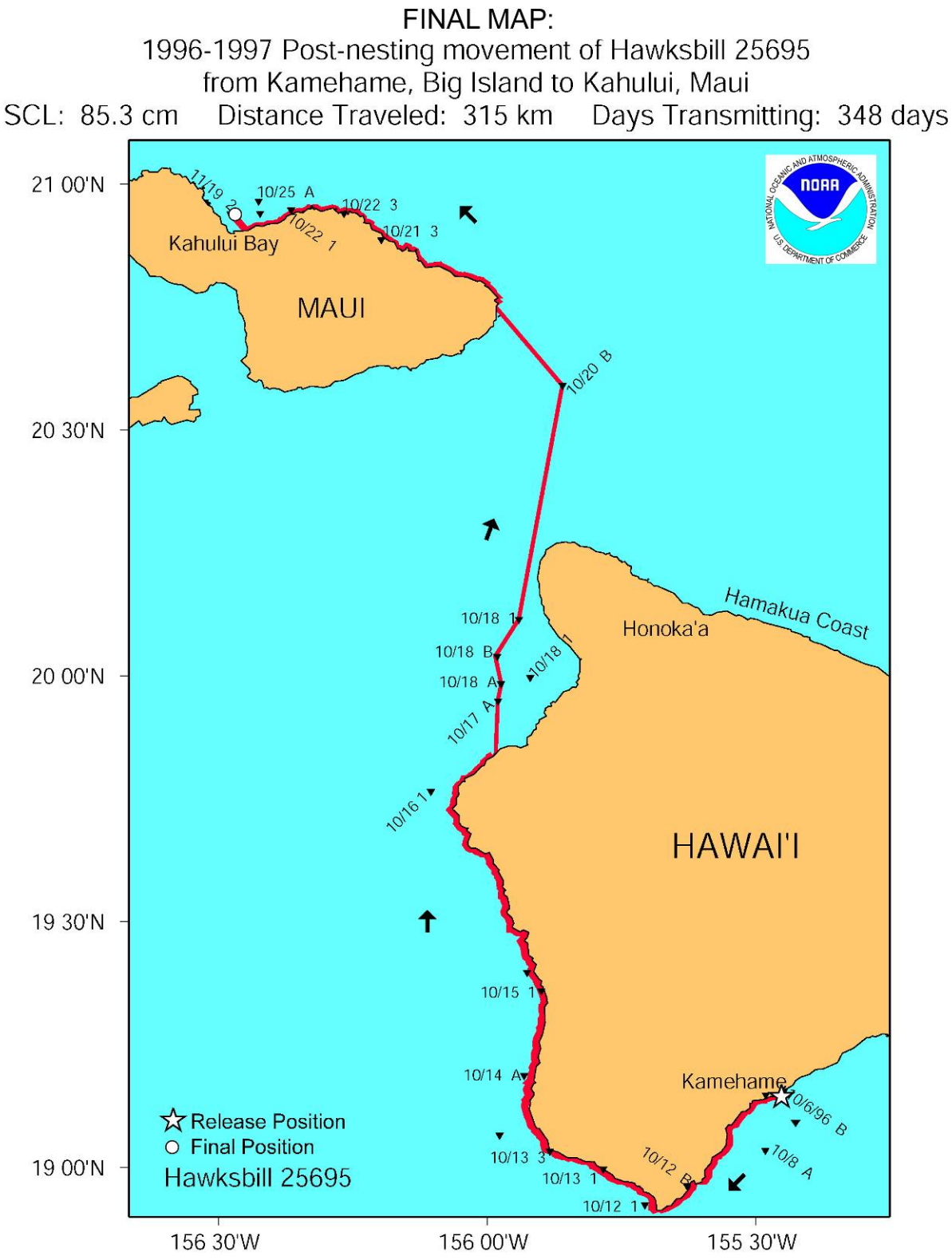

Figure C6. Travel route for NOAA Turtle ID 25695 (HIHTRP Turtle ID 30). This turtle traveled 345 km in 18 days from Kamehame, Hawai‘i Island, to Kahului, Maui.

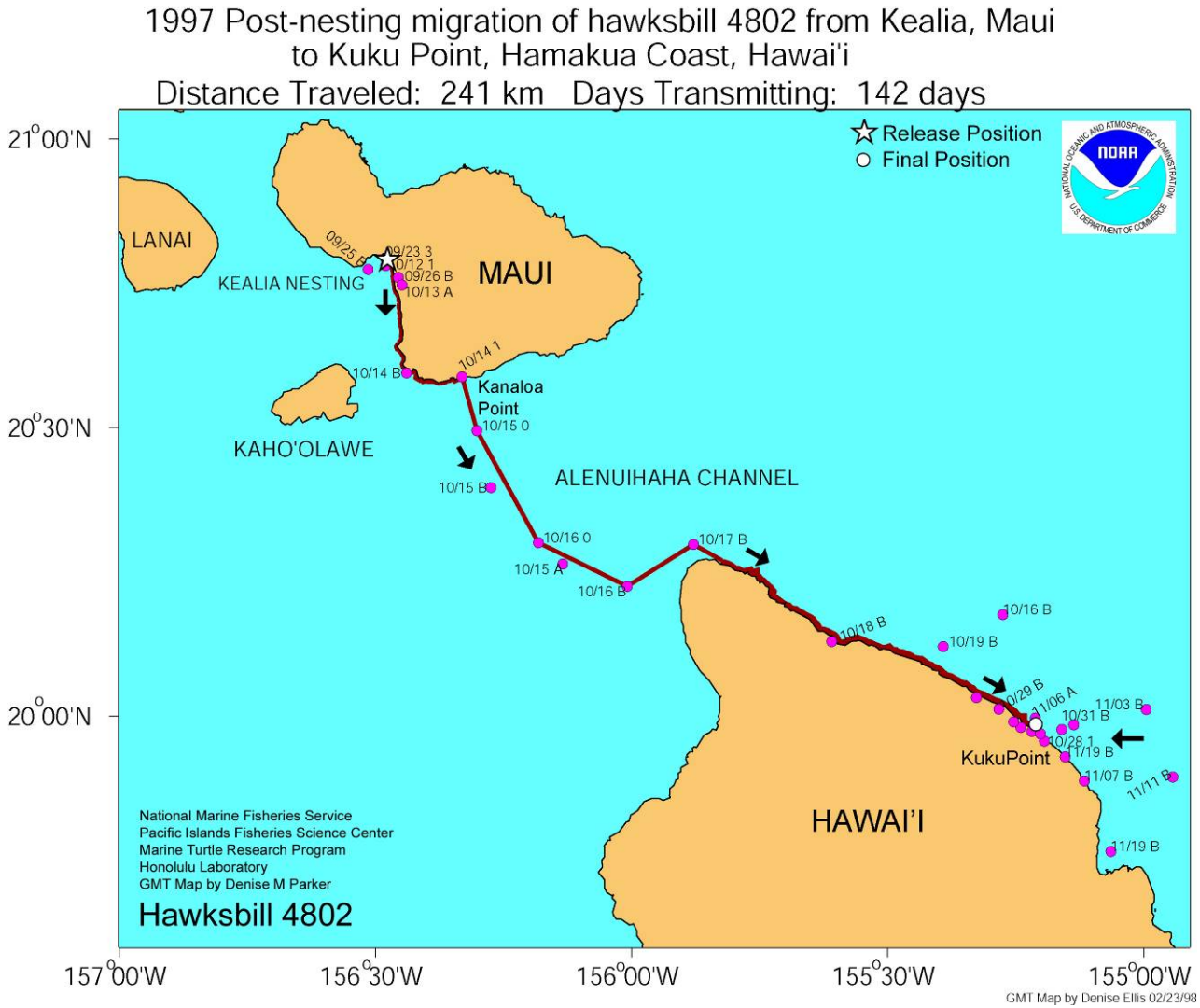

Figure C7. Travel route for NOAA Turtle ID 4802. This turtle traveled 241 km in 8 days between Keālia, Maui nesting beach and Kuku Point, Hawai‘i Island.

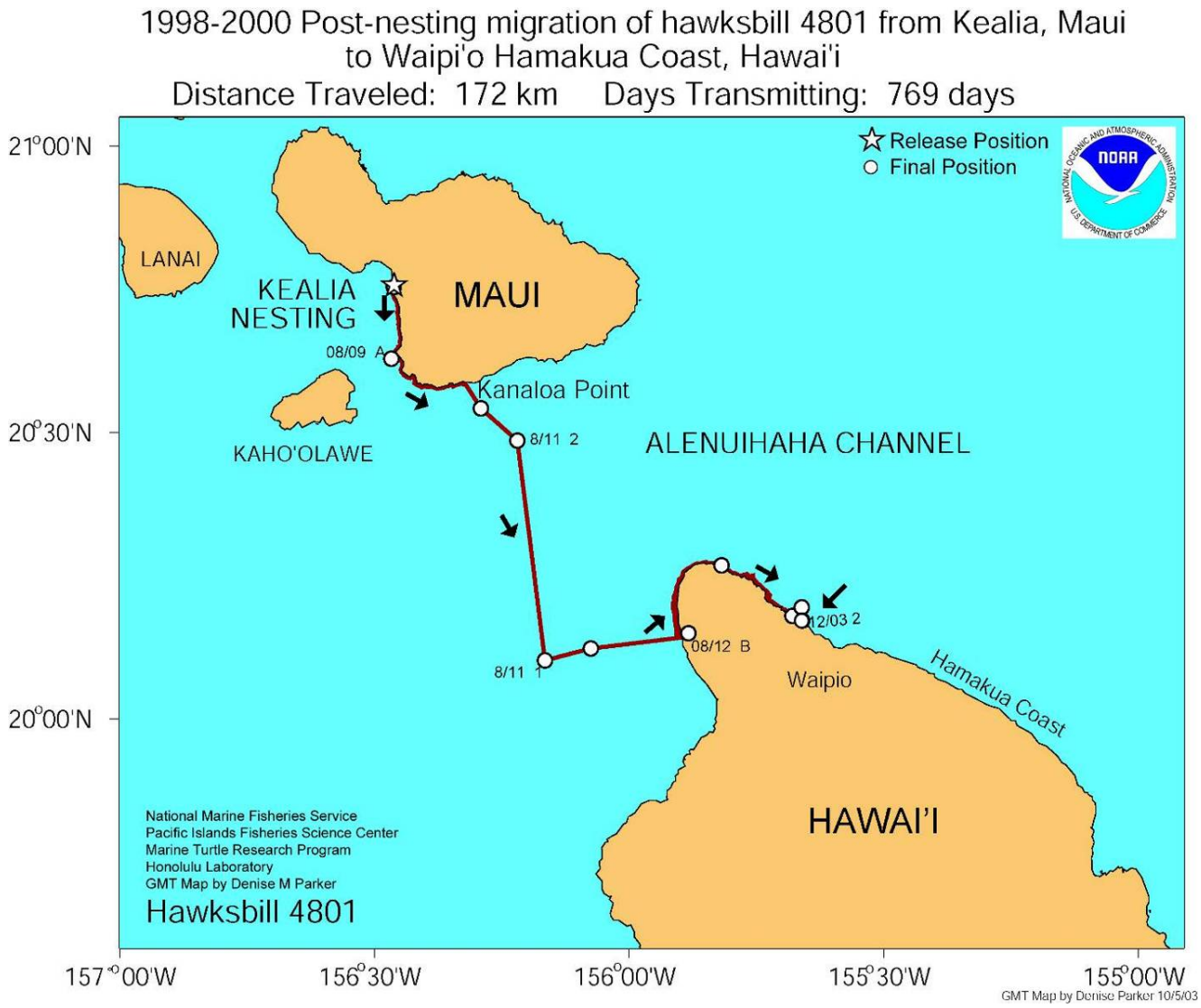

Figure C8. Travel route for NOAA Turtle ID 4801. This turtle traveled 172 km in 7 days between Kawililipoa Beach, Maui and Waipi‘o, Hawai‘i Island.

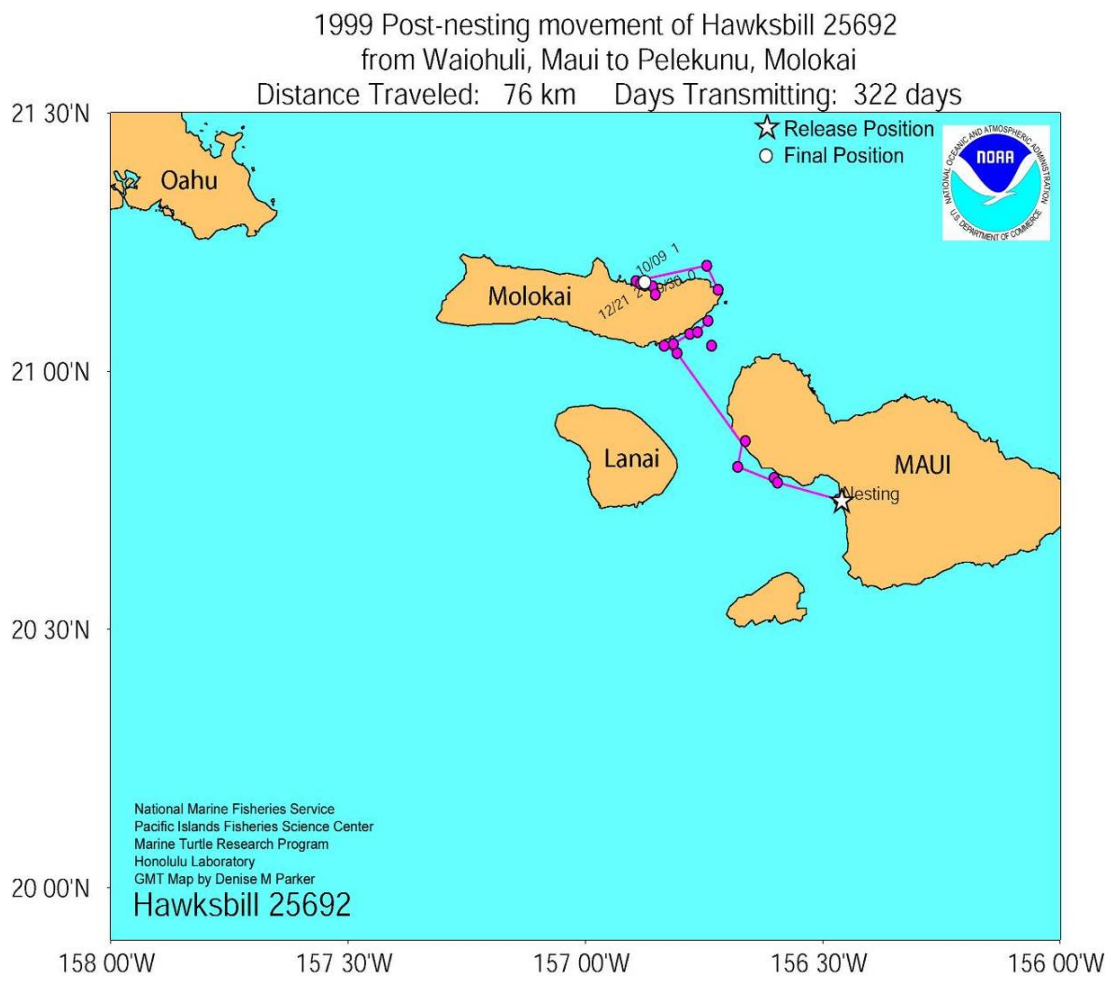

Figure C9. Travel route for NOAA Turtle ID 25692. This turtle traveled 90 km in 5 days from Kawililipoa, Maui, to Pelekunu, Moloka‘i.

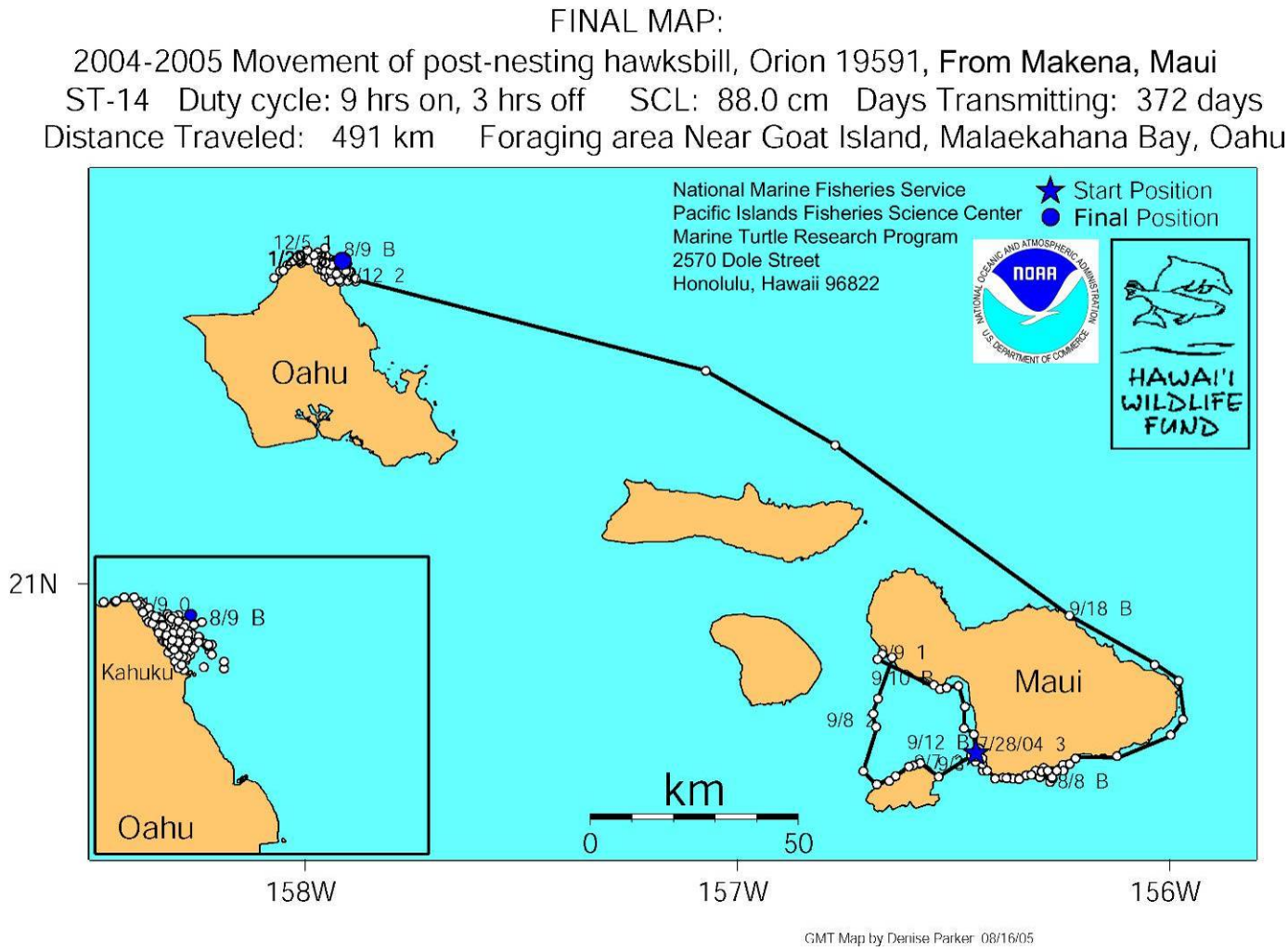

Figure C10. Travel route for NOAA Turtle ID 19591. This turtle traveled 280 km in 14 days from Oneloa, Maui, to Mālaekahana, O‘ahu.

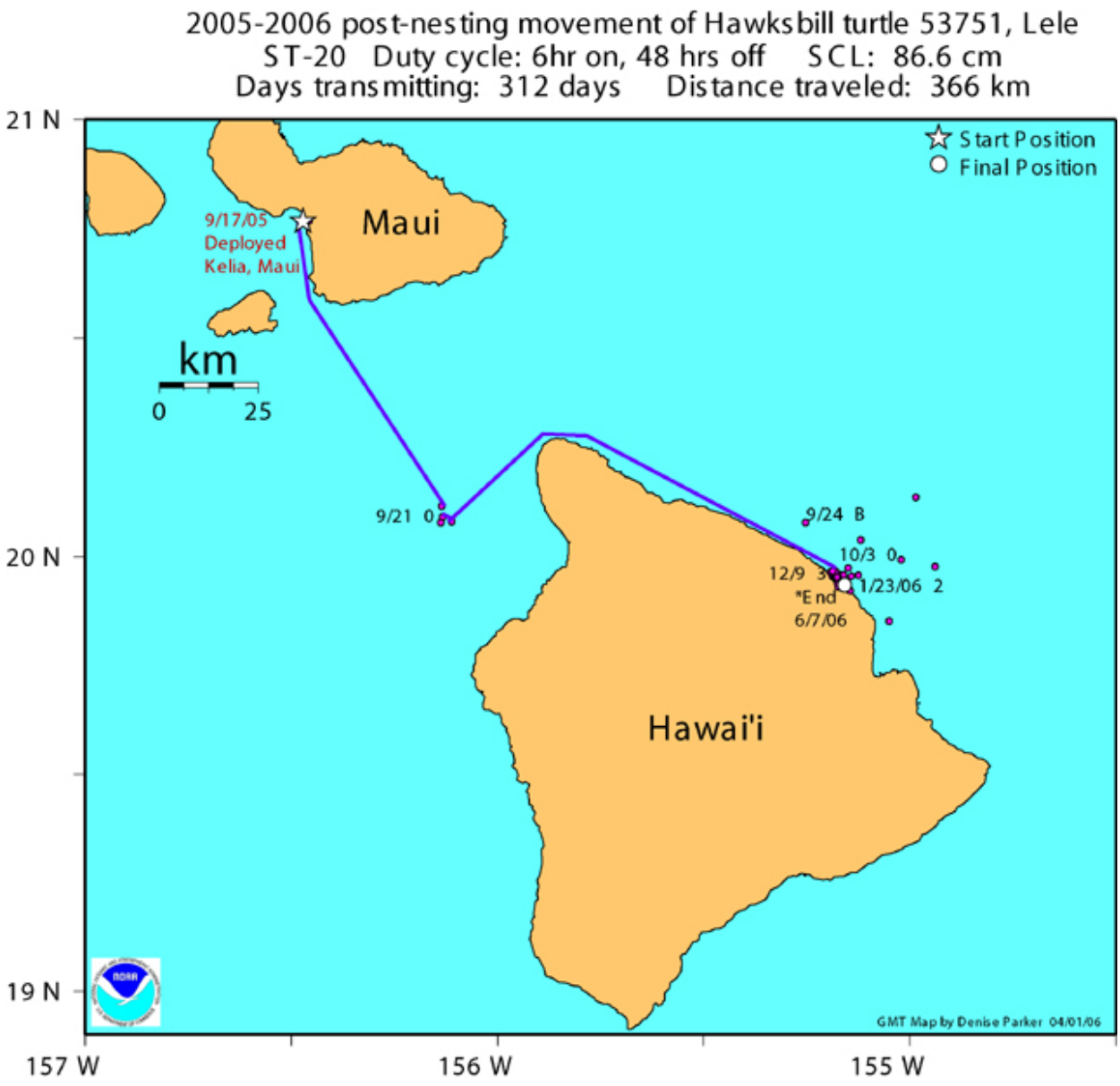

Figure C11. Turtle route for NOAA Turtle ID 53751. This turtle traveled 254 km in 16 days between the Keālia, Maui, nesting beach and Welokā, Hawai‘i Island.