Hawai'i Wildlife Fund's Hawksbill Recovery Project

Maui Nest Monitoring and Research Report

(1991-2012)

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Hawksbill Recovery Project

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Introduction

Little is known about the abundance and distribution of critically endangered Hawaiian hawksbill sea turtles (*Eretmochelys imbricata*) in the Pacific, since encountering them in their foraging and nesting habitats is very rare. Both of these habitats exist in geographically isolated Hawai'i, and hawksbills, known as "honuʻea" or "ʻea", face a variety of anthropogenic threats. Their nesting habitat is particularly vulnerable due to the burgeoning human population and increasing coastal development. Understanding hawksbill nesting population characteristics includes monitoring efforts, identification of potential and current threats and mitigation of these threats. Active research and cooperative, community-driven conservation actions that promote the understanding and protection of nesting and foraging habitats in Hawai'i are the keys to this species' survival.

Within the Hawaiian Archipelago, green sea turtles (*Chelonia mydas*, known as "honu") predominately nest in the Northwestern Hawaiian Islands with an increasing number nesting in the Main Hawaiian Islands, but hawksbills only nest in the Main Hawaiian Islands (Figure 1). The majority of Hawaiian hawksbills nest on Hawaiʻi Island, where they have been monitored for over twenty years. Smaller numbers are also known to nest on the islands of Maui, Molokaʻi and Oʻahu, with a statewide estimate thought to be at least seventy-five reproductive females with only 6-20 of these nesting each year (W. Seitz, National Park Service, pers. comm., 2010).

Hawksbill nesting activities were first documented on Maui in 1991 at Kealia (Figure 2). Hawaiʻi Wildlife Fund (HWF) organized a community-based effort to systematically monitor and mitigate these occurrences in 1996 after a passing car killed a second gravid female when she wandered onto North Kihei Road, either seeking suitable nesting habitat or disoriented by headlights (1993 was the first documented road fatality). HWF was formed specifically to focus on the conservation of the Hawaiian hawksbill turtle (and other protected native marine life) and was incorporated as a 501(c)(3) non-profit organization in 1996. For the last 17 years, HWF has conducted monitoring, research and conservation efforts on Hawaiian hawksbills and obtained all necessary Federal (U.S. Fish and Wildlife Service) and State of Hawaiʻi (Department of Land and Natural Resources) endangered species research permits. This project and the Hawaiʻi Island project are the only hawksbill nest monitoring programs in Hawaiʻi.

The primary objectives of HWF's Hawksbill Recovery Project are to identify individual nesting hawksbill turtles, take biopsy samples for genetic and stable isotope analysis, determine sizes of these females, the sites they use for nesting, the inter-nesting intervals, the number of nests laid in a season by each female, individual nesting behavior patterns, nest success, to relocate nests that may be threatened by tidal flooding or excessive trampling, and to attach transmitters to post-nesting females to track them to their long-term foraging/resting areas. During the course of this research, nesting females, nests and hatchlings are protected against dangers caused by predators, human disturbance, coastal lighting, non-native vegetation, and vehicular traffic.

Methods

A Hawaiian hawksbill-specific brochure was developed by NOAA and HWF for educational purposes (Figure 3). Since this is a community-based project, volunteer recruitment and spreading accurate information about what to look for during nesting season, and who to call if nesting females, tracks or hatchlings are found, has shown this brochure to be effective. Nesting season can begin as early as mid-May, with hatching events from July and continuing as late as early January. From June through September, the Maui Dawn Patrol, a community group of approximately 35 volunteers organized by United States Fish and Wildlife Service volunteers, walked Maui's four known South Maui nesting beaches (Kealia, Kalepolepo, Kawililipoa, and Oneloa) early each morning looking for evidence of nesting (Figure 4). Although there have been sporadic nesting events in Hana, the Dawn Patrol has not organized patrols there yet (Figure 5). HWF initiated patrols at potential hawksbill nesting beaches on Maui's South Shore (Oneuli and Little Beach, where two nests have been laid), and on Maui's North Shore where green sea turtles are known to nest, although no hawksbill nests have been identified yet.

Once nesting activity was discovered, a phone tree was activated to advise the Department of Land and Natural Resources Division of Aquatic Resources (DLNR DAR), the United States Fish and Wildlife Service (USFWS), and HWF. Each subsequent nesting and hatching event was intensely monitored by HWF. This typically entailed all-night vigils searching for the females to identify them and their nest sites, and guarding the nests during the course of hatching to ensure each hatchling reached the ocean safely.

Three days after the first major emergence from each nest, the nests were excavated by USFWS, DLNR-DAR and HWF to release any trapped hatchlings and to determine overall nest success. Nest remains were frozen and shipped to George Balazs, Leader of the Marine Turtle Research Program of the National Oceanic and Atmospheric Administration, National Marine Fisheries Service in Honolulu.

Basic analytical tests were run on the data using Microsoft Excel. Some data were missing or incomplete for the nests in the 1990s, so different analyses were conducted with different seasons and categories, depending on what data were available.

Results

Nesting Activity

Since 1991 when hawksbill nesting was first scientifically recorded, Maui hawksbill nesting activity was documented in every season except 1992, 1995, 2003, and 2007 (Figure 6). Prior to 1996, only two nests were confirmed. Hatchlings were found from one nest in 1991 (no excavation data available, as nest wasn't found), and one nest was laid at Kealia in 1993 (73.0% successful) prior to this female getting fatally struck on North Kihei Road. No nests were found in 1994, but multiple rescues occurred at Kealia (an unknown number of individuals, but likely just one): a nester got stuck in the mud, entangled in pickleweed, and crossed North Kihei Road twice. Five nests were found in 1996 by at least two different females, but one got fatally struck on North Kihei Road. This sparked the creation of HWF, and the subsequent data collected are summarized below.

The earliest recorded nesting activity of all seasons occurred on 5/18/98 and the last nest was excavated on 1/2/12, for a nearly 8-month nesting activity window (Table 1). A total of 72 nests and 56 false crawls were recorded on eight different beaches from 1991-2012: Kealia, Kalepolepo, Kawililipoa, Oneloa, Little Beach, Hana Bay, Koki, and Hamoa (Figures 4 and 5). The mean number of nests/year for this twenty-two year period was 3.3 ± 2.7 and the mean number of nesting females/year was 1.4 ± 1.1. Since monitoring was not consistent until 1996 when HWF was formed, earlier seasons were dropped from analysis, increasing the mean number of nests/year to 4.1 ± 2.4 with the number of nesting females to 1.6 ± 1.1 during these seventeen seasons (1996-2012). The mean number of nests laid per female per season was 2.7 ± 1.5 (range from 1-5 nests; n=26).

Eight nesting females have been tagged by HWF, with unknown hawksbills still nesting mainly in Hana (Figures 7 and 8). Each tagged hawksbill is referred to by their left front flipper (LFF) tag number and name chosen by HWF project participants (Table 1):

1) 1997: H-326 “Hapa” at Kealia
2) 1998: H-329 “Sasha” at Kawililipoa
3) 1999: H-330 “Hokulele” at Kawililipoa
4) 2000: H-332 “Lele” at Kealia
5) 2001: H-334 “Orion” at Oneloa
6) 2002: H-340 “Kolohe” at Kealia
7) 2009: H-343 “Kulu” at Kealia
8) 2011: H-336 “Uhane Niniu” at Oneloa

Table 1 lists the curved carapace measurements taken by HWF. Curved carapace length (CCL) sizes that ranged from 83.5-96.0 cm (mean= 89.4 ± 3.9 cm). The individual hawksbills, from largest to smallest, were: “Kealia '96” > “Lele” > “Orion” > “Hokulele” > “Sasha” > “Hapa” > “Uhane Niniu” > “Kolohe” > “Kulu”. Curved carapace width (CCW) sizes ranged from 76.5 to 87.0 cm (mean= 82.6 ± 3.2 cm) and the hawksbills’ rank from largest to smallest were slightly different: “Sasha” > “Orion” > “Hapa” > “Hokulele” > “Kealia '96” > “Lele” > “Uhane Niniu” > “Kolohe” > “Kulu”. Note that “Kealia ‘96” was struck by a passing car on N. Kihei Road, so measurements were taken of the split carapace. “Kealia ‘94” was found trapped in the mud after she crossed North Kihei Road, and only her straight carapace length was taken by rescuers (96.0 cm).

Three turtles have not returned in subsequent years after tagging: “Sasha” tagged at Kawililipoa in 1997, “Kulu” tagged in 2009 and “Uhane Niniu” in 2011. The remigration rates of five tagged individuals ranged from 3-13 years (mean 6.0 ± 3.2, n=8). Two hawksbills returned after 4, 5 and 7 years each (Figure 9, Table 2). Approximate growth rates from four tagged hawksbills were obtained upon their return to nest in subsequent season (Table 2). No measurements could be taken for “Lele” and “Hapa” in 2010 due to a freeze on all State permits. Therefore Hapa’s measurements, which after 13 seasons would have been valuable information, remain unknown. The largest CCL growth rate was 3.1 cm (“Lele” between 2000 and 2005) and the largest CCW growth was 1.6 cm (“Hokulele” between 1999 and 2006). “Orion” had a negative CCL growth rate due to her supracaudals being unevenly broken, making measurements difficult, and she was not measured in 2012.

Nesting Beach Identification

Since hawksbill nesting activity was first documented at Kealia in 1991, it has remained the most frequently utilized beach on Maui, with 25 nests by 4+ turtles over 12 seasons (“Hapa”, “Lele”, “Kolohe”, “Kulu”, plus at least one unidentified turtle) (Figure 10). There has been nesting activity from two known turtles (“Sasha” and “Hokulele”) at Kawililipoa for a total of 17 nests in four seasons. Oneloa has had 24 known nests by 2+ females over 6 seasons (“Orion”, an unknown who is referred to as turtle “Oneloa X” and “Uhane Niniu”, which may have been “Oneloa X”). The two nests that were laid at Little Beach, which is adjacent to Oneloa but separated by a rock groin, were done so by “Orion”. There was a false crawl (FC) at Kalepolepo in 2008 by an unknown female then a nest by a turtle that was later tagged at Kealia (“Kulu” in 2009). Hana nesting is more enigmatic since patrols are lacking, but Hana Bay has had activity for two seasons (hatchlings were found in 2001 and there were two false crawls in 2008) and one nest has been documented at Koki and one at Hamoa beaches in 2008. Only one nesting beach was identified before this project started in 1996, and only two nesting beaches were identified for the first 4 years of this project (1996-2000). Since 2001, three Hana beaches and three additional South Maui beaches have been identified.

Nesting Intervals

The mean nest to next false crawl attempt inter-nesting interval was 19.5 ± 2.2 (n=26). The mean nest to next successful nest was 19.9 ± 2.0 (n=38). The combined nest-to-attempt and nest-to-nest inter-nesting intervals ranged from 16-25 nights (mean= 19.8 ± 2.2, n=64). The first attempts at re-nesting, without including repeat attempts if unsuccessful the first time, were compiled to show the true remigration interval (Figure 11). Night 19 and night 20 were the most common remigration intervals, with 23.8% and 26.2% of the 42 attempts (mean= 19.4 ± 1.8, n=42). Although not included in Figure 11, two false crawls per night were the most attempts made by one turtle, and a two-night break was the most an individual turtle waited to re-attempt to nest after a false crawl (but they typically tried again that night or the next night). Nesting female size wasn't found to be different enough to confidently correlate any nest differences or behaviors by size.

Duration and Time of Nesting

Other useful information obtained for monitoring purposes was the time it generally took for hawksbills to nest successfully. Multiple factors were involved such as efficiency at which the nesters found a suitably spot versus having to re-dig, but the whole process typically took approximately two hours. The times of night individual hawksbills emerged from the ocean to nest were also recorded. Hourly blocks were chosen from 18:00-04:00 and the times (some were approximated if not seen crawling directly from the ocean by calculating what activities the turtle had completed by the time she was sighted) were assigned to blocks for analysis (n=59 from 1994-2012) (Figure 12). The most frequent time blocks were 22:00-23:00 (n=11), 24:00-01:00 (n=10), and 20:00-21:00 and 22:00-23:00 (n=9 each) (for a total of 66.1%). Only 6.8% of the emergences occurred before 20:00. Twenty-two percent of the known emergences occurred after 01:00. Three attempts by three different turtles were made between 03:00-04:00. The limited data for each hawksbill displayed some slight individual patterns, but nothing outstanding and other unknown factors besides time of night are likely involved. Orion was seen more than any other turtle (n=22), ranging from 20:00-21:00 to 03:00-04:00, but most frequently between 24:00-01:00 (n=7).

Radio and Satellite Telemetry

Six individuals were tracked with VHF and/or satellite transmitters to discover where they spend their time between nests and the migration routes to where these nesting females go, post-nesting (Table 3). Approximate inter-nesting and post-nesting locations were found for five of these hawksbills, while only the post-nesting location was found for one hawksbill. In 1997, “Hapa” was tracked between nests by VHF transmitter to the nearshore waters off the Hawaiian Islands Humpback Whale National Marine Sanctuary building in Kihei, which was ~2 miles away from Kealia. She traveled to the Hāmākua Coast of Hawaiʻi Island when she finished nesting (Figure 13). In 1998, “Sasha” was tracked off of Keawakapu Beach, which was ~4 miles from her nesting beach, Kawililipoa, and she also traveled to the Hāmākua Coast post-nesting (Figure 14). In 2004, “Orion” was tracked off of Nakaohu Point, which was ~16 miles away from Oneloa. She then did what no other tracked hawksbill has done- she undertook what appeared to be an exploratory swim between the islands of Maui and Kahoʻolawe before she swam south and east around Maui to Oʻahu (Figure 15). She didn’t do this in 2008, but instead swam directly back to Oʻahu after nesting, in the same south and east route around Maui (Figure 16). In 2005, “Lele” was tracked off of the Kealia Resort which was only about one mile from her nests at Kealia, then also swam to the Hāmākua Coast, making that the third out of five Maui nesters to utilize this Hawaiʻi Island stretch of coast (Figure 17).

In 1999, “Hokulele’s” inter-nesting habitat while nesting at Kawililipoa wasn’t found, but she traveled to Molokaʻi on her post-nesting migration (Figure 18). In 2011, “Uhane Niniu” seemed to spend her inter-nesting time at the western edge of the ʻAhihi Kinaʻu Natural Area Reserve (~2/3 of a mile from Oneloa) (Figure 19). She left Oneloa and headed around the leeward coast of Maui, then up through the Pailolo Channel to Molokaʻi where she swam near the leeward and westward coast. She then swam far to the north of Oʻahu and then south to Kauaʻi, where she spent about one week nearshore before heading offshore to the south (Figure 20). The tracking locations and dive durations lead us to believe that there were either major transmitter malfunctions, or she was injured and the transmitter ceased to transmit after 1/23/12.

Nest Characteristics

Successful nest incubation periods documented from 1996-2012 ranged widely from 50-73 days (mean= 60.9 ± 6.1, n=38) (Figure 21). Incubation periods varied by beach, with Kealia having the widest range, between 50-68 nights (mean= 56.2 ± 8.1, n=6). Kawililipoa had the same mean but with less variability, ranging from 52-64 nights: mean= 56.2 ± 3.3 nights, n=12. Oneloa's incubation periods were higher (57-73 nights), meaning the eggs there take longer to develop, and hatchlings didn't emerge from two of the nests: mean= 64.3 ± 4.9 nights, n=18. Little Beach’s incubation periods were affected by human trampling and not knowing exactly when the first emergences occurred, therefore cannot be reliably considered.

As mentioned above, some data were not available due to incomplete information taken and lost data from the beginning of this project. Table 4 organizes clutch sizes for these 64 nests by beach and turtle. Fifteen hawksbills (8 tagged, 7 unidentified) laid 11,296 eggs, with a mean clutch size of 176.5 (± 26.6 eggs). Clutch sizes ranged from 116-224, with the median and mode being 176 and 178. Figure 22 shows that the most eggs were laid at Oneloa (35.7%), then Kealia (31.8%) followed by Kawililipoa (26.9%). Two nests were laid at Little Beach (3.2%), and only one at Kalepolepo and Koki for a total of 2.3% of all eggs laid.

Figure 23 shows the contribution of eggs to the total laid on Maui's nesting beaches by turtle. "Orion" laid 28.8% of them, followed by "Hokulele" (16.1%), "Hapa" (10.8%), "Sasha" (6.8%), "Kolohe" (6.4%), "Uhane Niniu" (6.0%), "Lele" (5.3%) and "Kulu" (4.5%) while the 7 untagged females totaled 15.2%. Table 5 lists the mean number of eggs laid by each female and the mean hatching and hatchling success per season (2000-2012). Figure 24 illustrates the number of eggs laid per nest across seasons in order of laying succession, which shows how much the different hawksbills' numbers of eggs changed. No consistent patterns of an increase or decrease in the number of eggs laid per nest through the course of the season, or across seasons through each turtle's nesting history were found (Figure 25).

Nest Success

Nest success varied widely by beach, from 0% to 99.4%. Specific egg development stage information was incomplete, with only 25 of the 71 nests being analyzed by NOAA-NMFS. Therefore, nest remains were analyzed in two ways using basic data from forty-three nests from 2000-2012 (the seasons with the most complete data): hatching success (# of empty egg shells/total # of eggs in the nest) and hatchling success (# of empty egg shells – dead hatchlings/total # of eggs in the nest) (Table 5). *Hatching success* = how many hatchlings successfully develop and hatch out of the egg, but any dead hatchlings were included (not subtracted) in this number. *Hatchling success* = how many hatchlings actually survive to make it to the ocean; therefore, hatchling success is usually lower than or equal to hatching success. These two categories may tell a very different story when it comes to nest site characteristics and threats and is useful information for management purposes. Figures 26 and 27 illustrate hatching versus hatchling success by season and by all turtles' nest succession by season (first nest through the last nest). The mean hatching success was 60.5 ± 0.4 (n=44) and the mean hatchling success was 51.9 ± 0.4 (n=44). Since hatchling success could only be figured from 2000-2012, it is known that 4,008 live hatchlings reached the ocean safely during these seasons.

Hatchling Emergence Times

The times of day and night when hatchlings emerge from their nests are highly variable. This is supposedly a sand temperature-dependent event in which hatchlings use the cool cue to emerge under the cover of darkness. Figures 28-31 show that at Oneloa in 2008, 2011 and 2012 plus at Kealia in 2009 there were both daytime (yellow bars) and nighttime (blue bars) emergences. These figures show how many times hatchlings emerged during each hour of the day. This does not cover the quantity of hatchlings, just the hour that they emerged from the nest. Combining these four years: 76.3% emerged at night and 23.7% emerged during the day (Figure 32).

Discussion

This long-term dataset, even with the data gaps and small sample sizes that trigger cautions of the analytical interpretations, is the second largest compilation of Hawaiian hawksbill nesting information. As this project continues, more information will be collected to further build upon this knowledge, and can be compared to Hawaiʻi Island data (Table 6). Compared to the Hawaiʻi Island, Maui has a very small nesting population, but it still warrants protection and our findings contribute to what is known about nesting Hawaiian hawksbills. During the last 17 nesting seasons, this Maui project has identified nesting and foraging/resting habitats, remigration intervals, nesting intervals, nesting re-attempt efforts, times and durations of nesting, insights into different individual nester's behavioral tendencies, nest characteristics and success, hatchling emergence times, and anthropogenic threats to the critically endangered hawksbill sea turtle on Maui.

When HWF began this project in 1996, the 3-week nesting interval in the literature was used as the standard to begin monitoring nests, but have since elucidated a mean nesting interval of 19.4 nights for Hawaiian hawksbills, with a range of 16-25 nights. In addition, nightly observations of nestings has determined the optimum time for observing nest laying and the duration, which suggests that night patrols to locate the nesters should essentially start at dark (18:00-19:00 depending on the month) and can stop after 04:00. Discovering that hatchlings have emerged from their nests regardless of the time of day/night has shown that daytime nest watches can save just as many hatchlings' lives as night monitoring, if not more. Not only do these insights help predict individual behaviors during the nesting and hatching season and therefore assist in gathering crucial information on nesting habitat usage patterns, but they can be used to assist in mitigating threats to hawksbills during these critical time periods.

Hatching versus Hatchling Success

The two most noticeable cases of these two differences in looking at nest success results happened in 2009 when two unknown, therefore unmonitored, nests' hatchlings emerged and were disoriented by lights. Approximately 75% of the hatchlings died from each of the nests at Kalepolepo and Kealia (by either being crushed on the nearby roads, or becoming dehydrated when entangled in the dune grasses). Oneloa's and Little Beach's problems that caused hatchling deaths were attributed to human trampling over two of the nests, compacting the sand so hatchlings weren't able to emerge. The reason for the low success of the 2012 Little Beach nest is unknown. Kawililipoa's dune vegetation seemed to cause a number of deaths (roots that grew over the top of the nest, entrapping hatchlings, as well as the hatchlings becoming entangled in the grasses upon daytime emergences and dying of dehydration). It is not well known how dune vegetation can change the dynamics of the nest environment, but of all beaches, Kawililipoa would be the most negatively affected due to the high density of vegetation throughout the nesting area. High temperatures may have caused some emerging hatchlings to die of heat exhaustion in the nest as high numbers of dead hatchlings have been found in Kawililipoa nests. Although not included in hatching success data, it should be noted that high temperatures may have negatively affected hatchling development, as high numbers of late-stage embryonic deaths were recorded at Kawililipoa. More temperature logger data need to be collected and analyzed to draw these conclusions.

Unsuccessful Nests at Kealia

The Kealia coastline was seriously altered during WWII, as dredging and coral reef blasting occurred to facilitate military training activities. These impacts, combined with the building of North Kihei Road in very close proximity to the shoreline, and Ma'alaea harbor being built at the north end of this beach, have seriously degraded this habitat. There is only a very small section along this stretch of beach that can support nests and the road presents an imminent danger to nesters and hatchlings. While nests on the southern-most, half mile section of this beach have been highly successful, those laid in the middle section, within half mile of the Kealia Pond mouth, have had little to no success (0 – 16%). There was a total failure in egg development in all nests from 1997 – 2008. There was notably high success in the 2009 season from two different hawksbills (one who had laid unsuccessful nests in previous seasons and one new nester), then none in 2010 by another two different hawksbills. Reproductive impairment or senescence issues are beyond the scope of this study and could be explanations, but those kinds of issues for four different turtles seems unlikely, especially when this issue has only occurred at Kealia.

Especially since hawksbills are critically endangered, infertility or the inability to find mates could be a reason for Kealia's non-developing egg issue.

Fertility testing of egg tissue was only begun in 2010. None of the 980 eggs laid at Kealia in 2010 produced any live hatchlings, and after waiting until approximately 72 days of development for each nest, they were excavated. All of the eggs, none of which were opened on Maui, were sent to George Balazs (NOAA-NMFS, Honolulu). Upon opening each egg from the first two nests, no obvious signs of developing embryos were seen. Some samples of egg matter were sent to Peter Dutton (NOAA-NMFS, SWFSC) for PCR analysis, and he found mtDNA in both clutches, meaning they had been fertilized. No results from the other three nests have been reported by these teams, but similar results are expected.

The only obvious difference between the nests that produced hatchlings and the unfruitful ones of the past are their general locations along that stretch of beach (Figures 33 and 34). The 2009 season's nests were laid southeast of all the other unproductive ones that have been found at Kealia (in the general location of the 2010 season's nests). Successful nest #6 of 2009 was laid close to where the 1996 nester was killed on the road (pre-fence). Also that year and very near nest #6, dead hatchlings were found on the road (having erupted from an unidentified nest) so it had apparently been a good incubation environment back then as well. The 1993 nester was killed closer to where the 2010 nests were laid.

Nests at Kealia have been laid in a variety of shady and sunny locations. Shaded vs. sunny nest sites did not appear to affect Kealia's nest success. The location of 2009's successful nest #3 allowed some direct sunlight, but the other three were laid in extremely shady locations. This noticeably slowed nest incubation, and likely contributed more males to the population than females since sex determination has been found to be linked to temperature in other populations, but we have no way of knowing whether it affected incubation success. Sand temperature loggers that HWF placed in and around nests in 2010 did not show any extreme temperatures.

Although sand color, shape, and grain size have not been analyzed, basic observations of the sand types were made. Two of the four 2009 nests (#2 and #4) were laid in a dirt/sand/kiawe mix, resembling the substrate of unsuccessful Kealia nests from the past. This didn't seem to influence development; as these nests had remarkable hatching success similar to the other two laid in predominately sand (2009's #3 and #6). However, the sandy dirt mixture and presence of a network of thin plant roots in all five 2010 nests may have played a negative role in allowing the eggs to receive the oxygen they needed for respiration. Roots can also affect moisture content, but sand samples were collected by USFWS and analyzed by NOAA-NMFS Honolulu, who found that there was sufficient moisture.

Habitat factors that may be influencing the lack of egg development at Kealia are based on what's known about a turtle egg's basic incubation environment needs: moisture, oxygen and heat. Whatever factors that are contributing to the very early, nearly immediate halt of embryonic development at Kealia must be extreme, because nests around the world are subject to a wide combination of environmental factors and most seem to incubate normally. Although more temperature and moisture tests need to be conducted, they don't seem to be what's causing this issue. The remaining options are oxygen and toxin analysis. Sources of potential pollutants at Kealia are the very nearby North Kihei Road, pond, sugar cane fields, and an electric company. The nests that didn't develop were all closest to the overflow mouth that drains the Kealia Pond. This pond receives runoff from thousands of acres of commercially farmed sugar cane and the fish that reside in this pond are considered too toxic for human consumption (K. Smith, USFWS, pers. com., 1997). Sand analysis for contaminants should be conducted in the areas near the pond where nesting has occurred and then compared to successful nest locations' results.

Radio and Satellite Telemetry

Six post-nesting hawksbill turtles were instrumented with satellite transmitters by HWF. Three out of seven known Maui hawksbill nesters forage off of the Hāmākua Coast of Hawai'i Island, one off O'ahu, one off of Moloka'i, and one off of Kaua'i then pelagic. Only two tagged Maui nesters have not been tracked: Kealia's "Kolohe" and "Kulu". Of the four Kealia tagged nesters, "Hapa" and "Lele" have been tracked post-nesting, and they both swam to nearby locations along the Hāmākua coast. None (that we've observed) of their nests have ever developed to produce live hatchlings. It's possible that something in their foraging environment has affected their reproductive abilities. The other Maui nester who was shown to forage along the Waipio Valley area (north of where "Hapa" and "Lele" reside) was the 1998 Kawililipoa nester, "Sasha", who laid five successful nests that season. None of the four Hawai'i Island nesters who have been tracked to the Hāmākua coast have laid failed nests either, so this doesn't seem to be the answer.

Management Recommendations

The USFWS Dawn Patrols need to be extended, starting May 15th instead of June 1st and ending on October 15th, instead of October 1st since nests have been documented during these dates. The Dawn Patrol component of this cooperative research and conservation program needs strengthening, understandably, since a volunteer-based program has its inherent limitations. Their critical role is to find the first nesting activity of the season, and then we set up our monitoring program. It was tragic when the first two nests of the season in 2009 were missed (one at patrolled Kealia, the other at unpatrolled Kalepolepo) and the majority of the hatchlings got killed on the road due to their misorientations. If HWF knew about these nests, these deaths would have been prevented by our nest monitoring efforts.

If the volunteers consistently show up on time and are attentive, tracks are usually easy to spot at all of the other beaches besides Kealia. Training volunteers to really be able to search correctly and recognize nesting activity at Kealia is the biggest challenge. Kealia is a highly eroded habitat with predominantly invasive dune vegetation. It's a noteworthy possibility that nests were missed due to the common difficulty in finding nesting evidence since windy conditions and high tides can obliterate tracks along many portions of Kealia. This may have happened again when we received reports of hatchlings in 2012, but we never located the nest(s) due to the witnesses not making careful notes of where they saw the hatchlings. If the nesting process isn't directly witnessed by HWF, then the egg chamber is very difficult to find, as the disturbed areas are very subtle and don't appear to be true nests when in fact they are. False crawls and nests tend to look very similar when laid amongst vegetation since the amount of thrown sand was limited.

Over the course of this project there have been multiple incidences at Kealia when unwitnessed crawls that didn't look like nests had to be assumed to be nests when the turtles didn't return to the monitored Kealia areas to lay their actual nests within the known nesting period. What likely happened was that the hawksbills traveled elsewhere to nest. Hawai'i Island hawksbills have switched nesting beaches within and among seasons, to beaches that were eleven miles apart (L. Katahira and W. Seitz, National Park Service, pers. comm. 2008).

Kealia nesters consistently have the highest number of false crawls and the lowest nest totals per season (1-3) compared to Kawililipoa (4-5) and Oneloa (2-5) nests. Although only observed for two seasons, Kalepolepo seems to have similar low site fidelity, with only one false crawl one year and one nest laid there in another year. One crawl was detected at Kealia in 2004, but no nest was apparently laid, and the hawksbill didn't return to Kealia all season therefore the female was not identified. There was a false crawl in late June of 2010, and then there was no other activity for nearly two months before 5 nests were laid by two hawksbills. It seems probable that Kealia turtles have a larger nesting range than the ~2.5 miles of this beach, and their other nests are going undetected.

The USFWS Dawn Patrol expanded coverage in 2010 to include the whole stretch of beach surrounding Kealia, from Ma'alaea to Kalepolepo by the Hawaiian Islands Humpback Whale National Marine Sanctuary. This is a positive step, as these are the nearest areas and therefore could be likely choices for Kealia females. Also in 2010, HWF organized a separate Dawn Patrol effort at Oneuli and Little Beach, which are near Oneloa. Since three Hana hawksbill nesting beaches have been identified, a community-based effort to organize patrol efforts needs to be initiated.

Knowing that development issues exist at Kealia demands that we become proactive in ensuring that no more clutches are wasted. If nests are laid at Kealia where egg development has been unsuccessful (all northern sites), the first nest should be left in situ as a control, then the rest should be immediately relocated to the 2009 southern, successful Kealia nest spots. Kawililipoa has not shown to be a better location to relocate them to, as was done procedurally well in 2005 and 2009, but without significant nest success (Table 5). Another idea is to test at least one clutch (after leaving a control in situ) in a controlled incubator environment, which can eliminate Kealia habitat issues altogether. Intensified testing of the habitat needs to be undertaken, especially for contaminants.

When the hatchlings were found on the road by Kalepolepo in 2009, DLNR-DAR and HWF found the nest and excavated it right away. During this process, two nearby Maui Lu Resort neighbors reported that approximately two months earlier, they happened upon who we assume was "Kulu" by their resort, which is across the busy South Kihei Road from Kalepolepo. "Kulu" must have been misoriented by the lights and crossed the road after she nested. Luckily, they guided her back across the road and directed her back to the ocean. Unfortunately, there are many well-lit roads that run very close to much of Maui's coastline, so if hawksbills (or any other turtle species) choose these areas to nest there is a real concern for their safety, their hatchlings' safety, as well as that of passing motorists. Although erecting turtle fences along every roadside beach is recommended, it is obviously impractical due to the resources involved. It's impossible to darken vehicle headlights, so solutions to these problems on a beach-by-beach basis should be considered before another valuable nesting turtle is killed.

The urgent and critical priority for the upcoming nesting season must be the completion of the Kealia fence replacement or repair to keep nesting hawksbills from being run over by passing vehicles on North Kihei Road. Only half of the permanent recycled plastic fence was installed in 2008 and even though funding for the rest of the fence was secured through the County of Maui, it expired before being used by The Kealia National Wildlife Refuge. Sections of the new fence are inadequate at stopping the turtles (they can crawl under or over it) so until the special posts are pounded in, extensions are built, and the rest of the fence is ordered and installed, HWF will have to continue to fix a large part of the dilapidated fenceline. This has unnecessarily cost HWF thousands of dollars and valuable time.

Not only does the whole fenceline need to be fully replaced with the recycled plastic fence material, it ideally should be relocated inland of the existing location of the sand fence, which is too close to the high tide line in some areas. This will increase the available nesting habitat as much as possible on this highly eroded beach. Unfortunately, this is Alexander and Baldwin land, and we can only presume the negotiations by The Kealia Pond National Wildlife Refuge will continue. The idea of rerouting North Kihei Road around the Kealia Refuge, obviously the best solution, should be proposed.

HWF has buried small temperature loggers in and around the nests at Kealia and Kawililipoa, all at ~15-20” depth, from 2009-2010. Information obtained from these loggers during incubation coupled with dead hatchling necropsies can approximate the sex ratio of hatchlings produced. Sex-determination is temperature-dependent, so if the egg’s temperature is over a certain degree the hatchling will be a female, and if it’s below it will develop to be a male. This pivotal temperature has not been determined for Hawaiian hawksbills. Predicting whether the majority of hatchlings are males or females would provide insight into the reproductive potential for the future population.

Threats to Nesting Habitats

All-night vigils to identify nest locations and protect nesting females and emerging hatchlings have been conducted by HWF for the last 15 years. These actions mitigate the threats identified below and are crucial for nesting female and hatchling survival. There are different and analogous threats at each of Maui’s nesting beaches. Table 7 categorizes 17 threats in the following categories:

1= serious threat (red)
2= threat present but not serious (orange)
3= potential but no cases (yellow)
4= no threat (green)

1) New/increased coastal development (directly impacting beach characteristics)
2) Light pollution (causing adult and hatchling misorientation events)
3) Vehicular beach traffic (smashing nests or striking nesters)
4) Human trampling (impacting nests)
5) Misorientation onto roadway (adult and hatchling mortalities)
6) Impacts by recreational users (camping, fishing, parties, etc)
7) Predation by feral or domestic animals (mongoose, rodents, cats, dogs)
8) Beach vegetation (limits available nesting areas, roots within the chamber potentially affecting development and entanglement upon hatchling emergence)
9) Invasive algae piles (blocks hatchlings’ access to the ocean)
10) Deep holes (sand type conducive to create deep footprints that hatchlings get stuck in and holes dug by beachgoers that both nesters and hatchlings get trapped in)
11) Egg development issues (failed nests)
12) Egg poaching (digging up eggs)

13) Nesting female poaching (killing nesting turtles)
14) Land-based and marine debris (buried in the sand)
15) Erosion (limiting sufficient nesting habitat)
16) Flooding (tidal, large waves or stream mouth)
17) Climate change (limiting available nesting habitat due to sea level rise)

The achievements of HWF's Hawksbill Recovery Project, a long-term research and conservation program, have been possible due to the overwhelming volunteer efforts and the collaborative nature of the resource management agencies charged with responsibility for this species: USFWS, NOAA/NMFS and DLNR. A tremendous effort is ongoing to understand and protect Maui's nesting hawksbills, and without it the survivorship of these turtles would certainly be jeopardized further. This community-based project has saved adults and hatchlings from a gauntlet of threats. The intensified monitoring of each nesting and hatching event has also greatly improved the dataset for these occurrences. As of yet, the actual numbers of nests on Maui are not increasing significantly. With a critically endangered species at such risk, more resources need to be funneled in this direction as there are many ways to increase survival. And, innovative research methodologies should be explored to further our knowledge of all aspects of this specie's life history to aid in its protection.

ACKNOWLEDGEMENTS

I am grateful for funding and collaboration opportunities with Dr. Kyle Van Houtan, George Balazs, Kim Maison, and Irene Kinan Kelley of the Pacific Islands Fisheries Science Center: NOAA Fisheries Marine Turtle Assessment Program and Marine Turtle Research Program of the Protected Resources Division and the Pacific Islands Regional Office. My deep appreciation goes out to all the hundreds of HWF volunteers who have contributed their valuable time and energy to protecting the hawksbills over the years, especially Norma Clothier whose positive attitude is always an inspiration. I couldn't have completed this research without guidance from Bill Gilmartin and Hannah Bernard of Hawai'i Wildlife Fund, Angie Hofmann's volunteer coordinating, and Jacob Freeman's project support. Mahalo!

HAWAI'I WILDLIFE FUND
HAWKSBILL RECOVERY PROJECT

Figure 1. Hawaiian Island Chain with Maui inset.

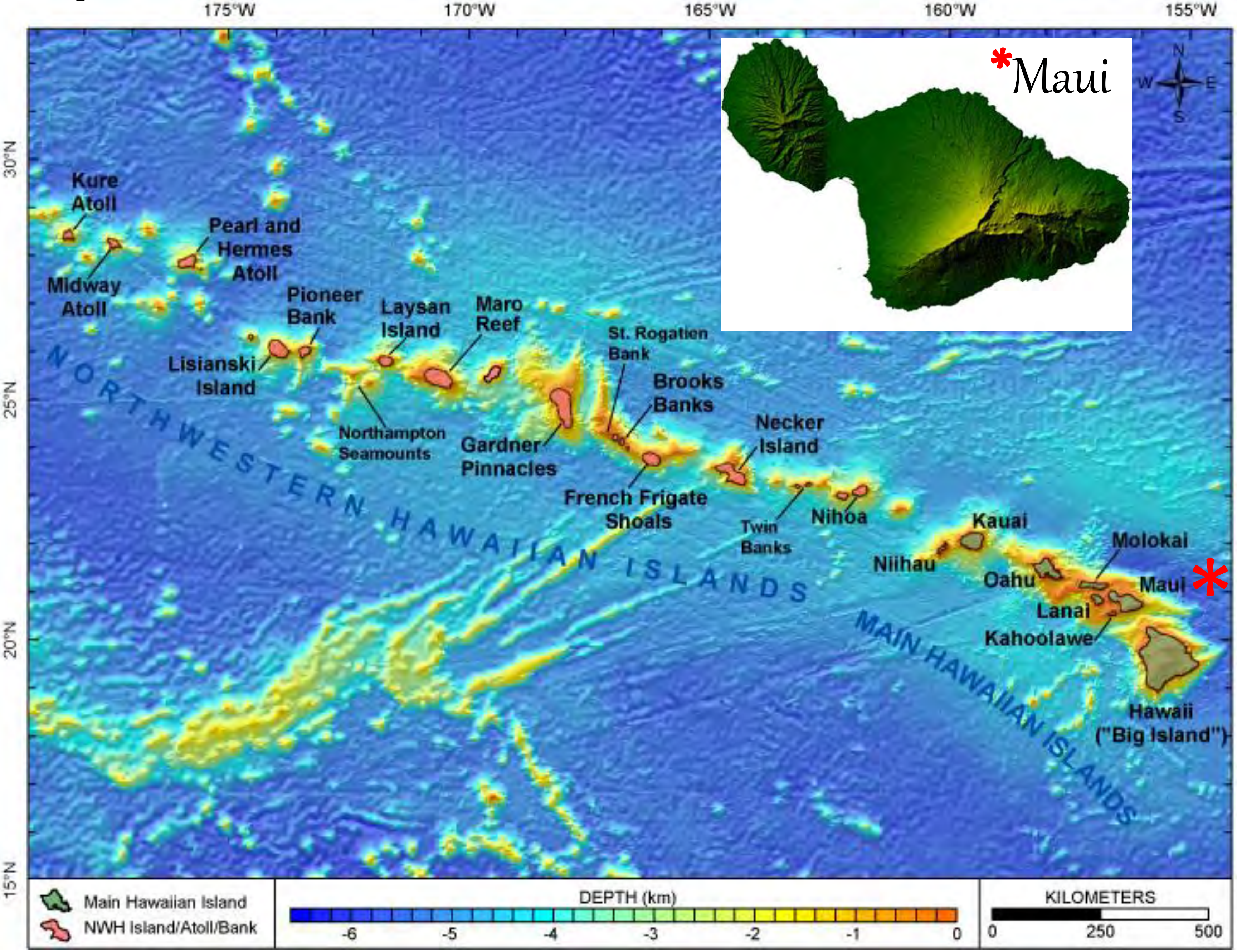
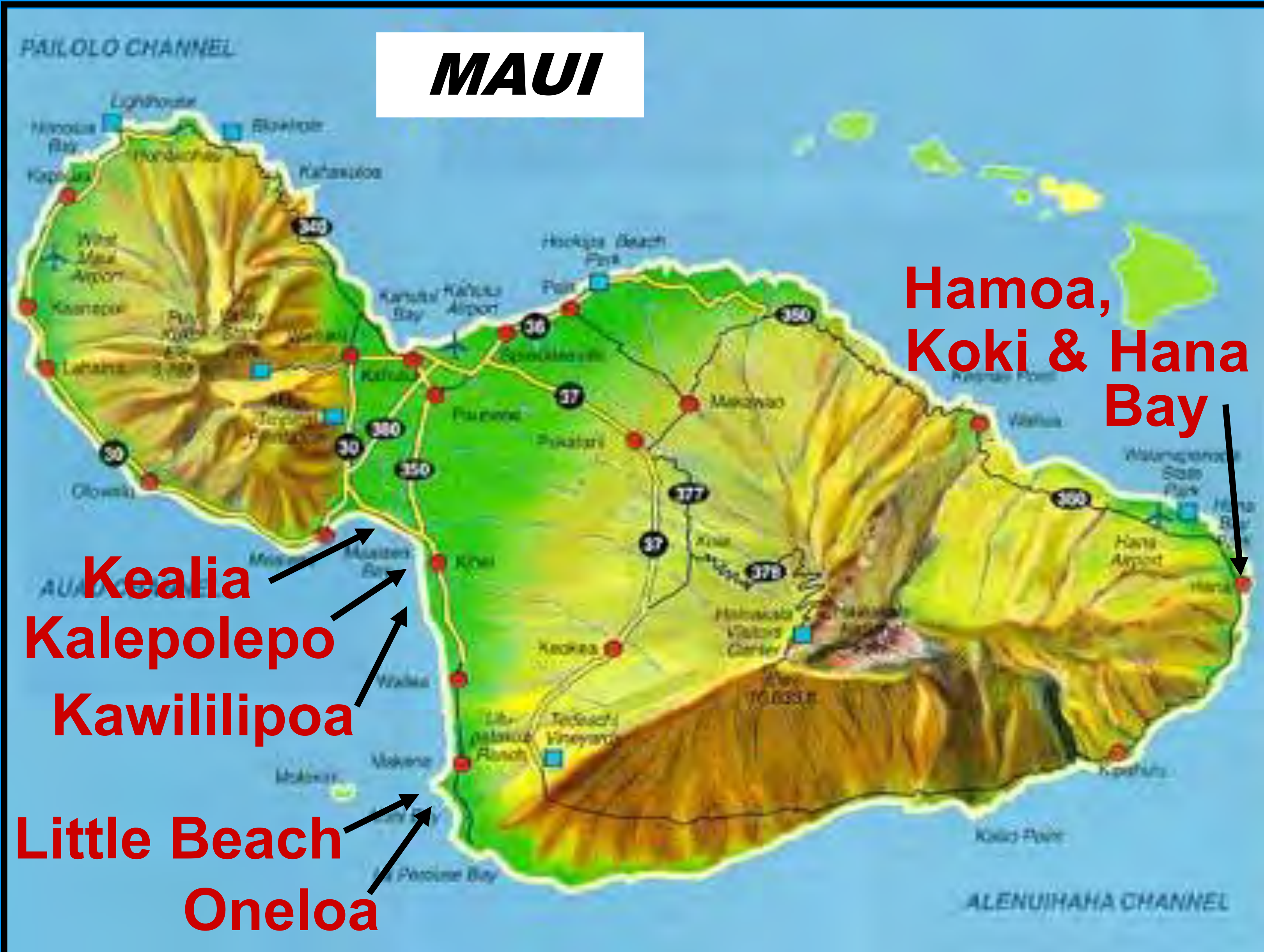
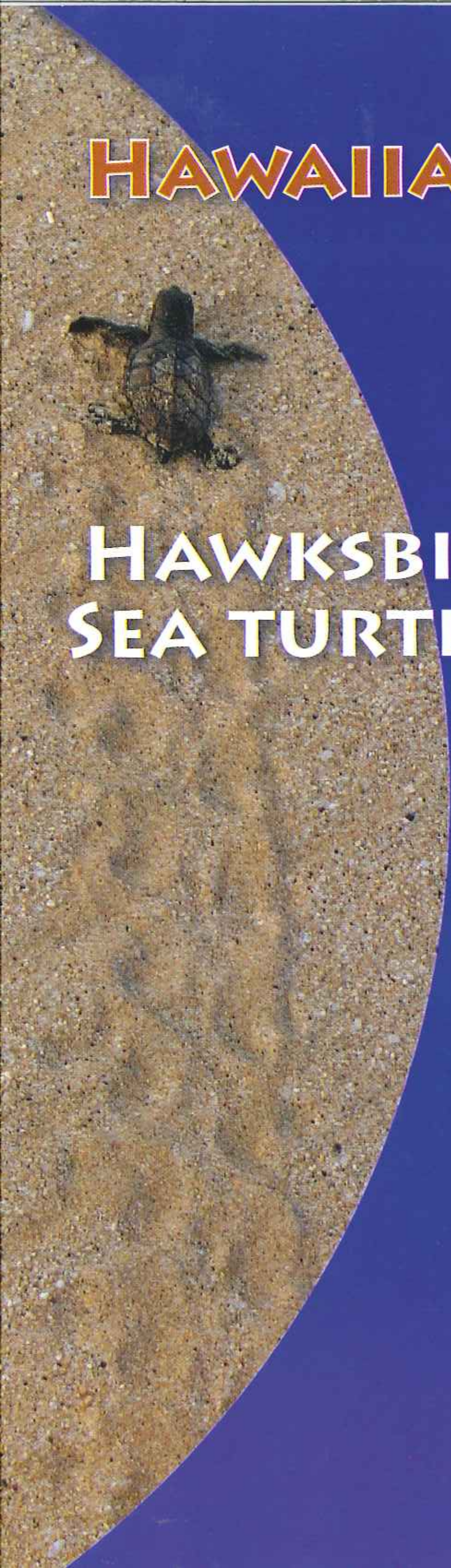


Figure 2. Locations of Reported Hawksbill Nests (1991-2010).



HAWAIIAN



HAWKSBILL SEA TURTLES

SEA TURTLES IN HAWAIIAN CULTURE

As indigenous species in Hawai`i, sea turtles have historically played an important role in Hawaiian culture. Honu (green turtle) and `ea (hawksbill turtle) are mentioned in the Kumulipo, the Hawaiian creation chant. Hawksbills are also called honu`ea in some parts of Hawai`i.

Sea turtles were utilized in traditional ceremonies, and their use was controlled by the kapu ('taboo' or prohibition) system.

Honu meat and eggs were consumed and oils were used for skin treatments. `Ea meat was also consumed, although it is sometimes poisonous because a hawksbill's diet can include toxic sponges. `Ea shells were prized for the making of fish hooks, tools, medicine, and jewelry ("tortoiseshell").

Sea turtles appear throughout Hawaiian lore and legend in hula, petroglyphs, chants, and tattoos. Some families highly revere sea turtles as their `aumākua, or personal gods.

Hawksbill Trivia

- Hawksbill sea turtles are listed as "Endangered" under the 1973 Endangered Species Act.
- Adults can be ~3 feet in carapace (shell) length and weigh ~250 lbs.
- Hawksbills feed on sponges, invertebrates, and algae in the crevices of coral reefs.
- Adult hawksbills can hold their breath for up to three hours while resting.
- Between 1989 and 2007, 86 individual nesting females have been tagged on the islands of Hawai`i and Maui through limited monitoring activities.
- Results from satellite tracking show that hawksbill foraging grounds are within the Main Hawaiian Islands, primarily off the northeastern side of the island of Hawai`i along the Hāmākua coast.

Hawksbill Nesting

- It may take anywhere from 15 to 40 years for a hawksbill to begin reproducing.
- Regular nesting occurs on Maui, Moloka`i, and Hawai`i. Over 90% of documented nests have occurred along the Ka`ū coast on the island of Hawai`i.
- Between 5 and 15 individuals nest each year in Hawai`i.
- Adult females return (to the same region where they hatched) to nest every 2 to 8 years.
- Each female can lay 1 to 6 nests in a season, approximately 18 to 22 days apart.
- Each clutch (group of eggs) contains an average of 180 eggs that will incubate for approximately two months.

Hatchlings (Keiki)

- Sex determination is temperature-related; cooler temperatures within the nest chamber produce males and warmer ones produce females.
- Hatchlings emerge from the nest when the sand is cool, usually at night.
- Hatchlings find the ocean by crawling toward the brighter, open horizon.
- Hatchlings face a variety of predators on their way to the sea like crabs, birds, mongooses, cats, dogs, pigs and others. Once they reach the ocean, sea creatures like fish and sharks also eat them.
- Although unknown, it is assumed that a very small percentage of hatchlings survive to adulthood.

"The Lost Years"

The first few years of a Hawaiian hawksbill's life are a mystery. Once they leave the nesting beach, their movement patterns, growth rates, and diet are unknown. Eventually, they navigate back to Hawaiian nearshore coral reef habitats as juveniles and continue to mature.

159°W 158°W 157°W 156°W

THREATS TO SURVIVAL

Because hawksbills and humans share the Hawaiian Islands, our actions affect their survival.

Coastal development and beach walls damage or reduce nesting habitat.

Fires and artificial lights visible from the beach or shoreline may scare away nesting females and disorient hatchlings.

Non-native predators like mongooses, cats, pigs, and rats are a threat to eggs and hatchlings.

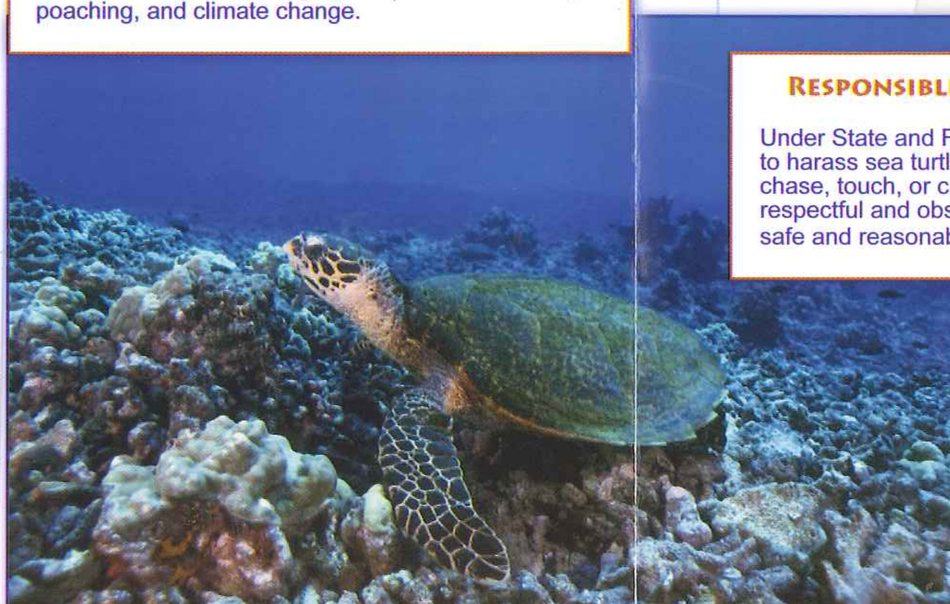
Some dune plants and grasses have thick roots that make nesting difficult. They also trap and entangle hatchlings.

Nighttime activity on nesting beaches can discourage nesting.

Beach driving can crush nests and creates tire ruts that trap hatchlings.

Trash or debris left on the beach can block hatchlings from reaching the sea.

Other threats include boat strikes, marine debris, urban run-off, invasive algae, fisheries interactions, poaching, and climate change.



RESPONSIBLE TURTLE VIEWING

Under State and Federal law, it is illegal to harass sea turtles. Please do not feed, chase, touch, or crowd them. Be respectful and observe sea turtles from a safe and reasonable distance.

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59°W 158°W 157°W 156°W

Hawaiian Hawksbills Need Your Kōkua!

Several agencies and organizations are collaborating in the on-going Hawaiian hawksbill research and recovery effort. Residents and visitors of all ages can get involved by volunteering or contributing in other ways. Mālama (protect) Hawaiian sea turtles by reporting tagged turtles, nesting activity, and in-water hawksbill sightings to the following.

Hawksbill Information Island Contacts:

O`ahu: NOAA's Pacific Islands Regional Office
808-944-2278, www.fpir.noaa.gov

Maui: Hawai`i State Division
of Aquatic Resources
808-243-5294,
http://www.hawaii.gov/dlnr/dar/index.html or
Hawai`i Wildlife Fund
808-385-5464, http://wildhawaii.org

Hawai`i: Hawai`i Hawksbill Turtle Recovery
Project 808-985-6090

To report stranded sea turtles please call the sea turtle stranding hotline: 808-983-5730

Report illegal or suspicious activity involving sea turtles to:

DOCARE: 808-643-3567 or

NOAA OLE: 1-800-853-1964

Hawksbill or Green?

How to tell the difference

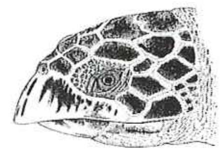
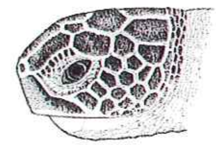
Hawksbill / `Ea / Honu`ea (*Eretmochelys imbricata*)	Green / Honu (*Chelonia mydas*)
	
• Narrow head and pointed beak • 4 pre-frontal scales (between eyes)	• Rounded head • 2 Pre-frontal scales (between eyes)
	
• Overlapping scutes on carapace (like shingles) • Carapace has serrated edges (juveniles) • Two claws per flipper	• Adjoining scutes on carapace (like tiles) • Carapace has smooth edges • One claw per flipper
	
• Hatchlings are all brown	• Hatchlings are dark gray with a white trim and underside.

Figure 4. South Maui nests by location with (the # of individual nesters/# of nests/ # of seasons).

Figure 5. East Maui nests by location with (the # of individual nesters/# of nests/ # of seasons).

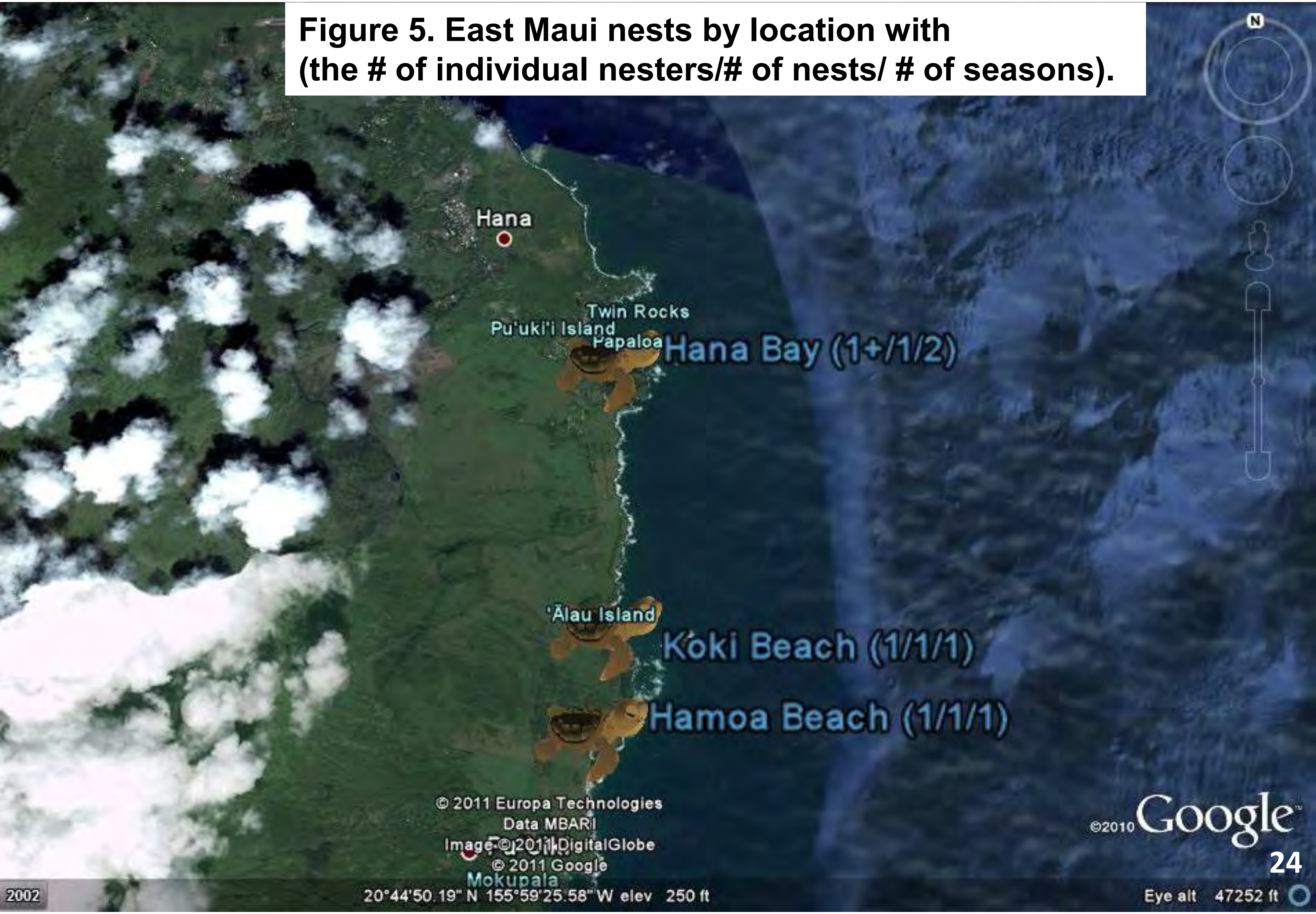


Figure 6. Summary of Maui's Hawksbill Nesting Activities (1991-2012).

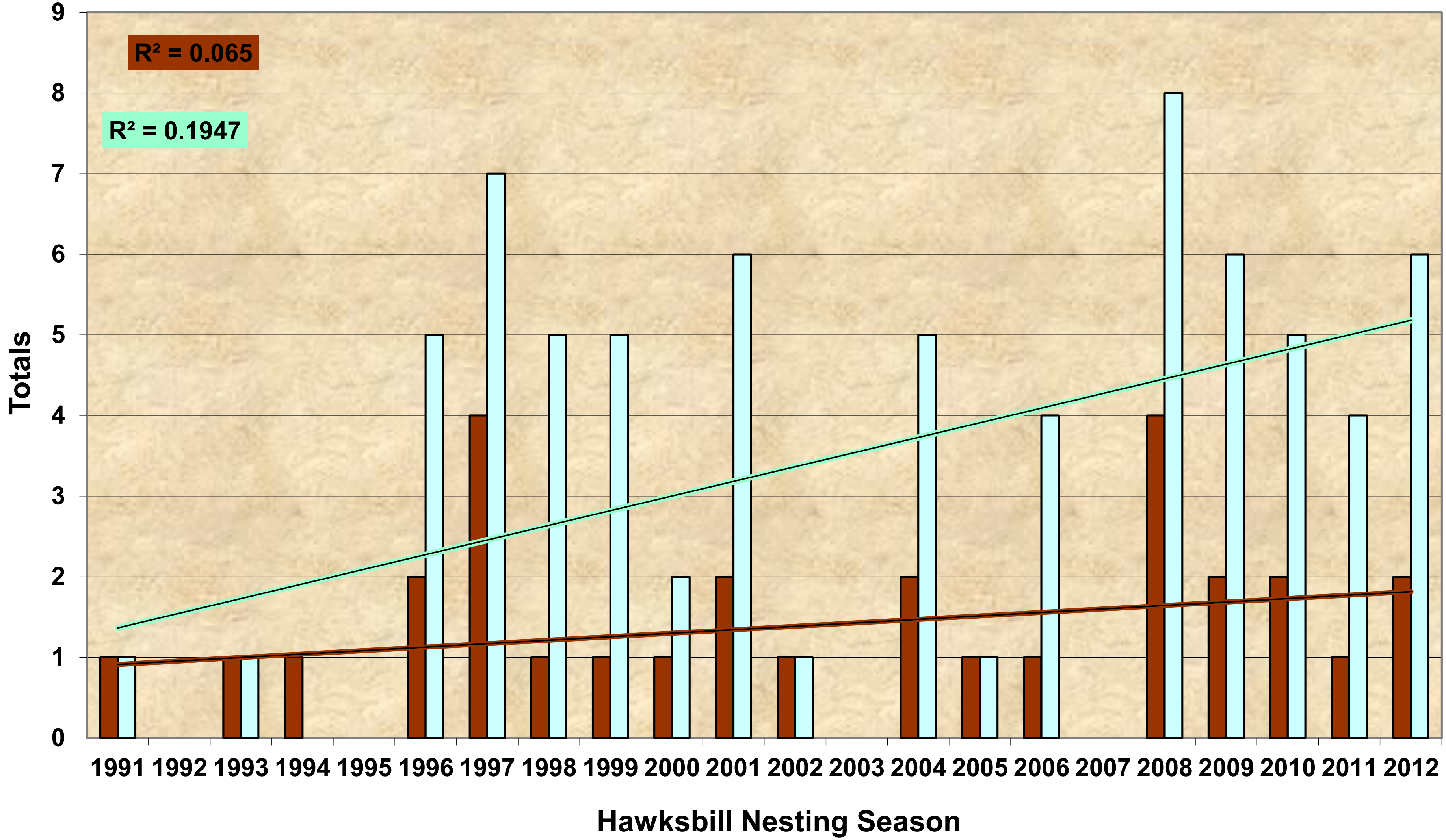


Figure 7. Annual Tagging Totals.

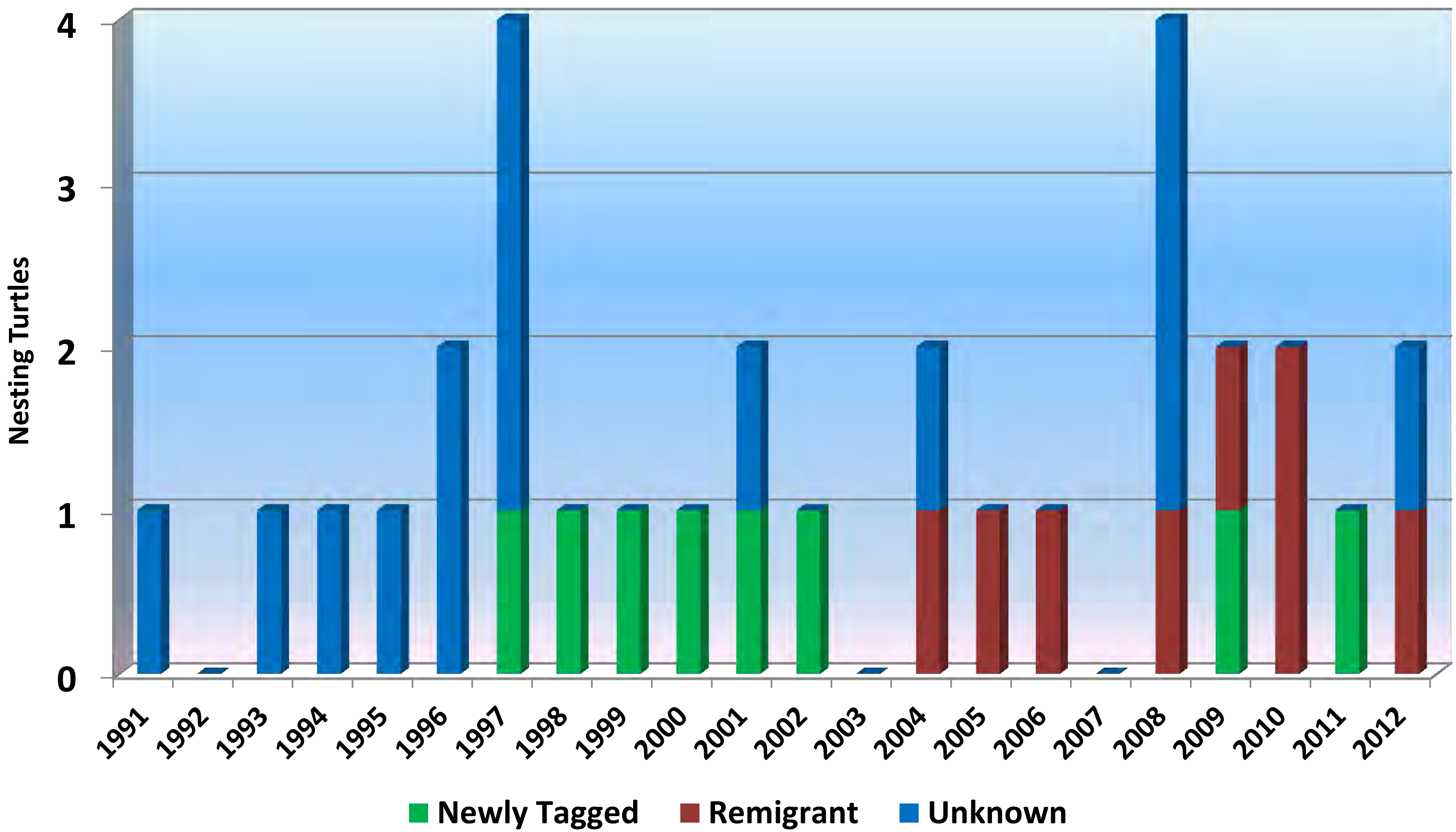


Figure 8. Tagging by Location (1997-2012).

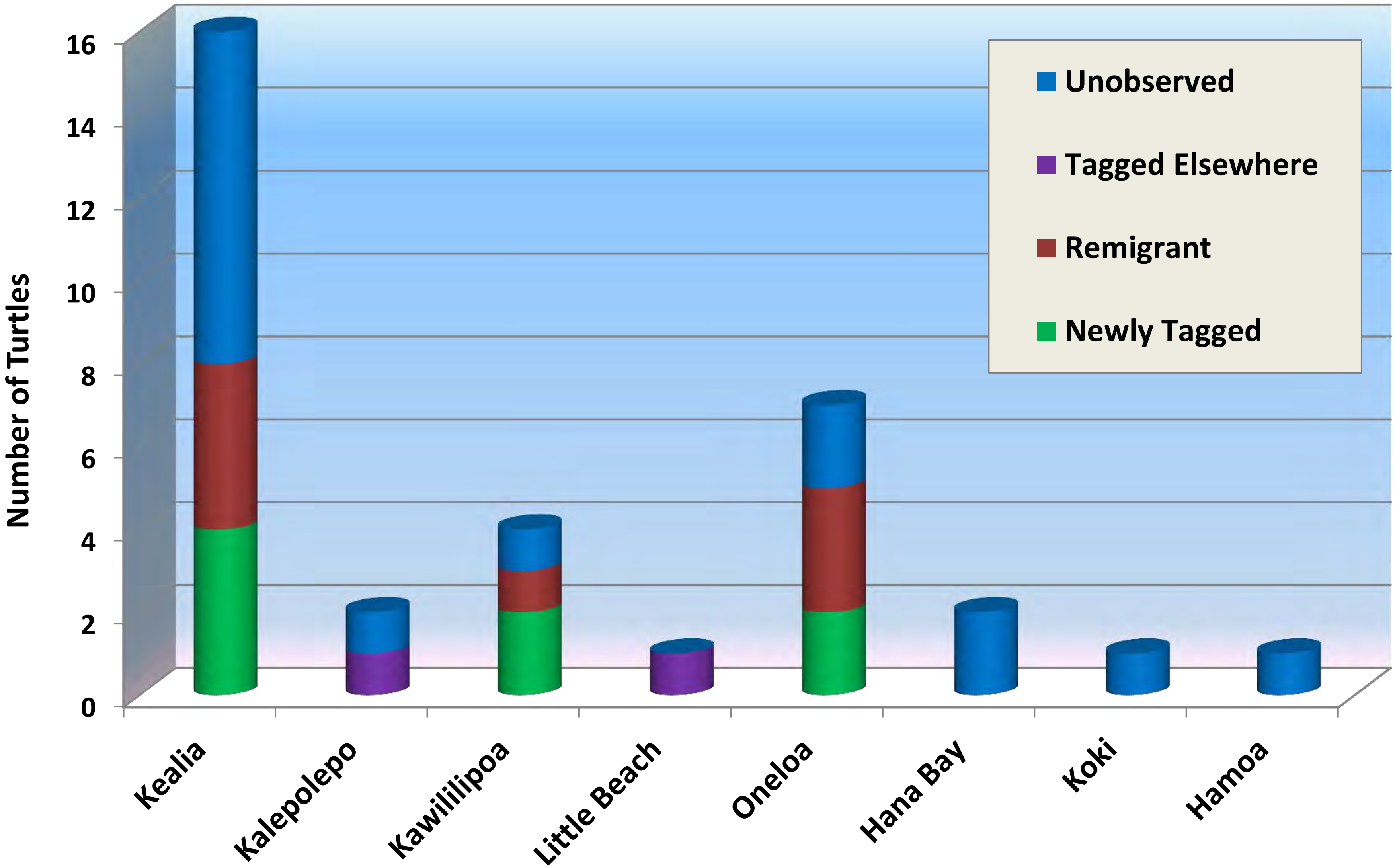
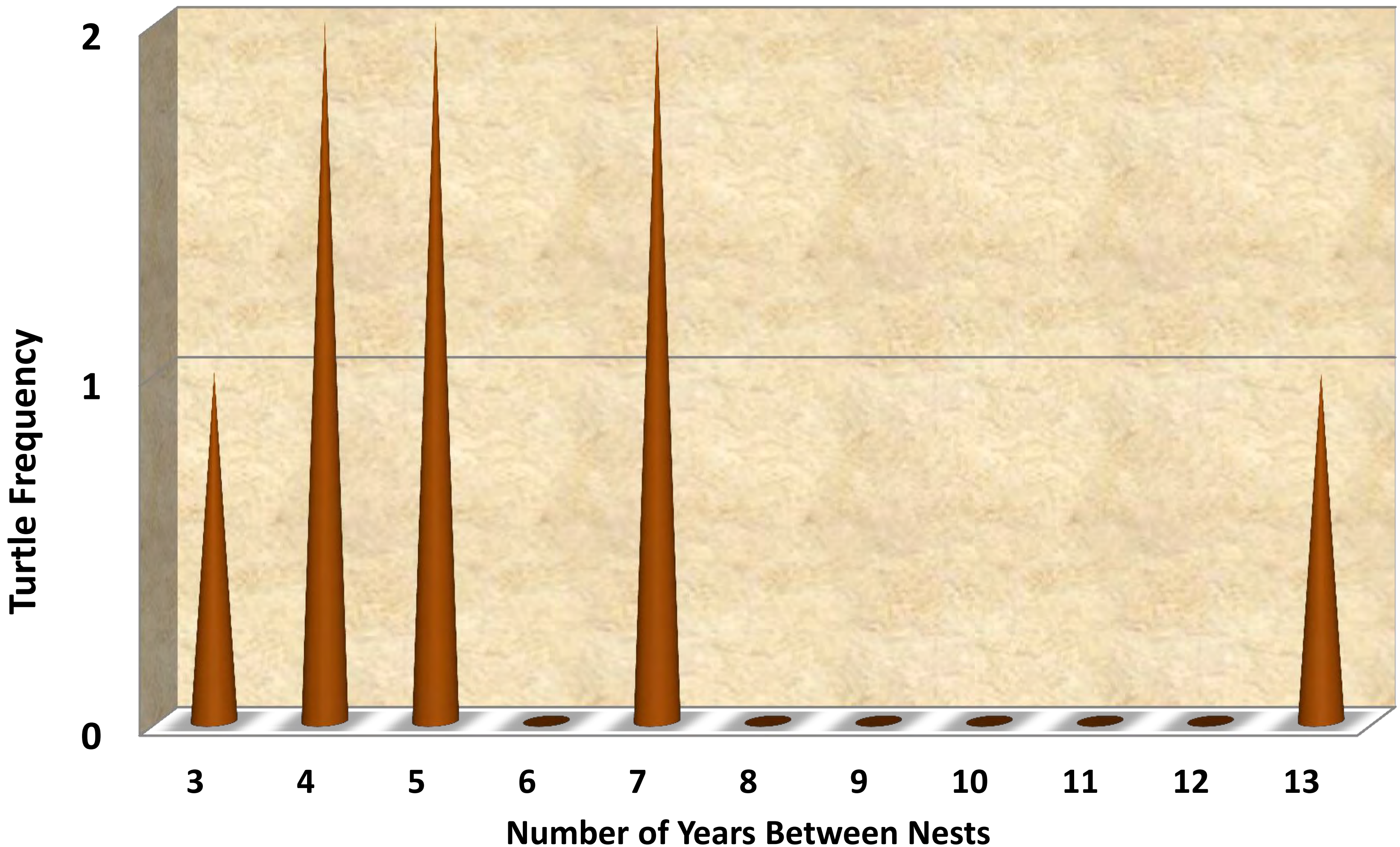


Figure 9. Nesting Remigration Interval.



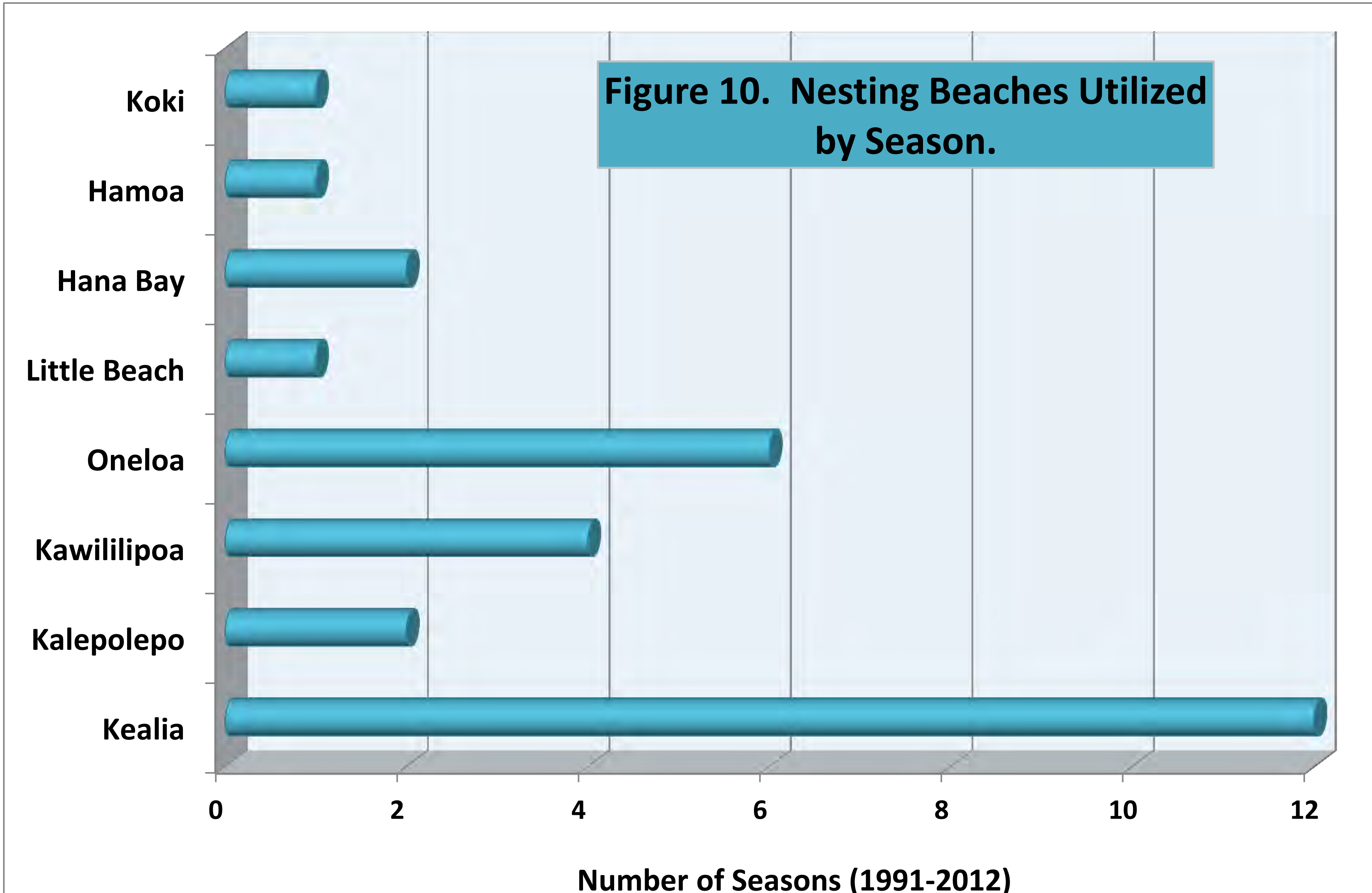
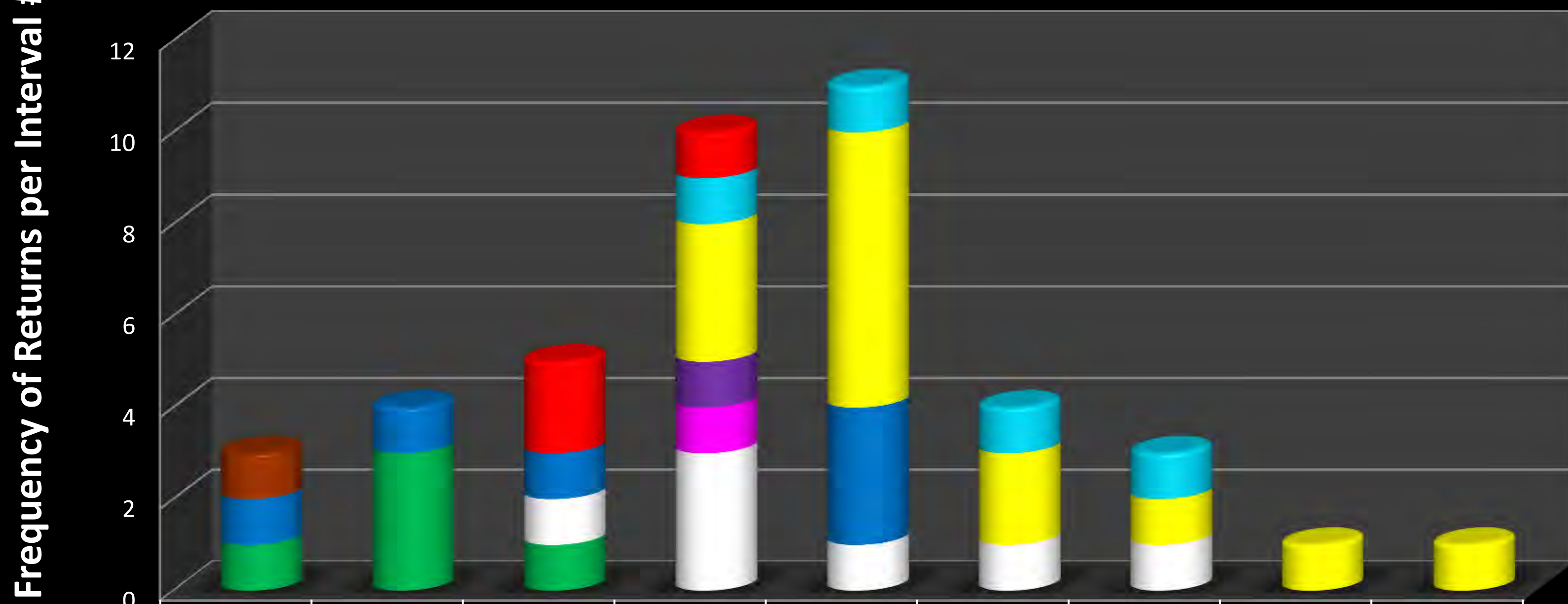


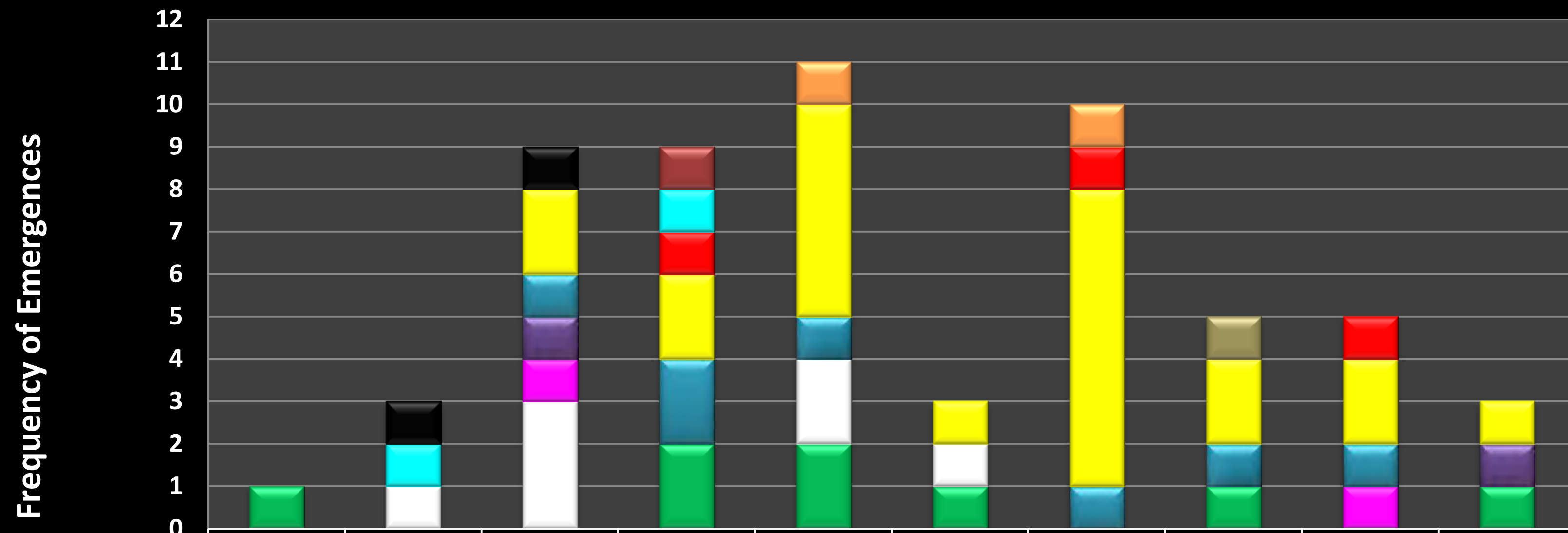
Figure 10. Nesting Beaches Utilized
by Season.
Koki
Hamoa
Hana Bay
Little Beach
Oneloa
Kawililipoa
Kalepolepo
Kealia
0
2
4
6
8
10
12
Number of Seasons (1991-2012)

Figure 11. 1997-2012 Remigration Intervals by Turtle (n=42).



# of nights	16	17	18	19	20	21	22	23	24
Uhane Niniu			2	1					
Sasha				1	1	1	1		
Orion				3	6	2	1	1	1
Oneloa X	1								
Lele	1	1	1		3				
Kulu				1					
Kolohe				1					
Hokulele			1	3	1	1	1		
Hapa	1	3	1						

Figure 12. 1994-2012 Ocean Emergence Times by Turtle (n=59).



times of emergence	18 to 19	19 to 20	20 to 21	21 to 22	22 to 23	23 to 24	24 to 1	1 to 2	2 to 3	3 to 4
Kealia '94 (n=2)					1		1			
Kealia '96 (n=1)								1		
Kawililipoa '97 (n=1)				1						
Hana Bay '08 (n=2)		1	1							
Sasha (n=2)		1		1						
Uhane Niniu (n=3)				1			1		1	
Orion (n=22)			2	2	5	1	7	2	2	1
Oneloa X (n=0)										
Lele (n=7)			1	2	1		1	1	1	
Kulu (n=2)			1							1
Kolohe (n=2)			1						1	
Hokulele (n=7)		1	3		2	1				
Hapa (n=8)	1			2	2	1		1		1

Figure 13. "Hapa's" 1997 Post-Nesting Migration to Hawai'i Island.

Figure 14. "Sasha's" 1998 Post-Nesting Migration to Hawai'i Island.

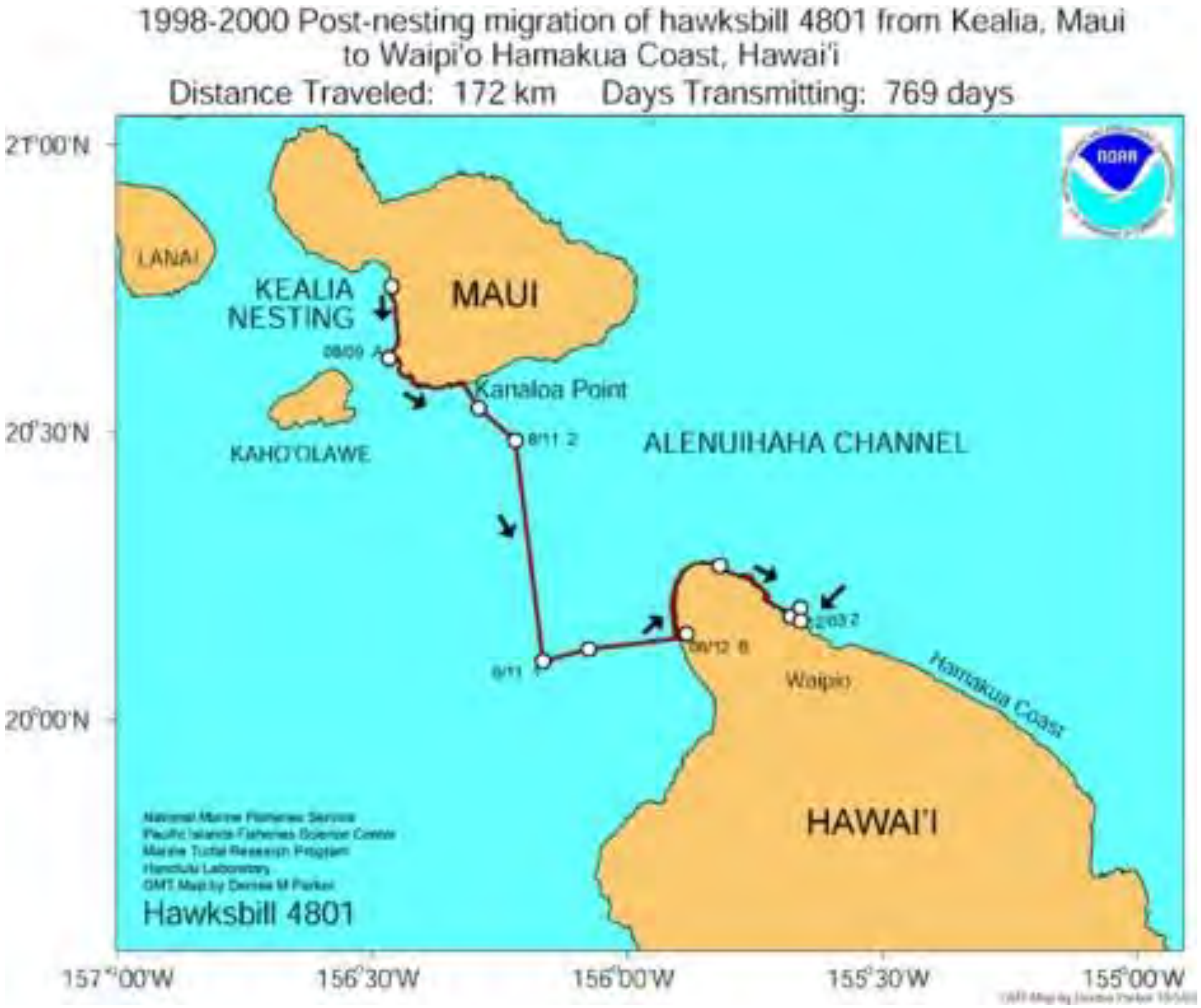


Figure 15. “Orion’s” 2004 Post-Nesting Migration to O‘ahu.

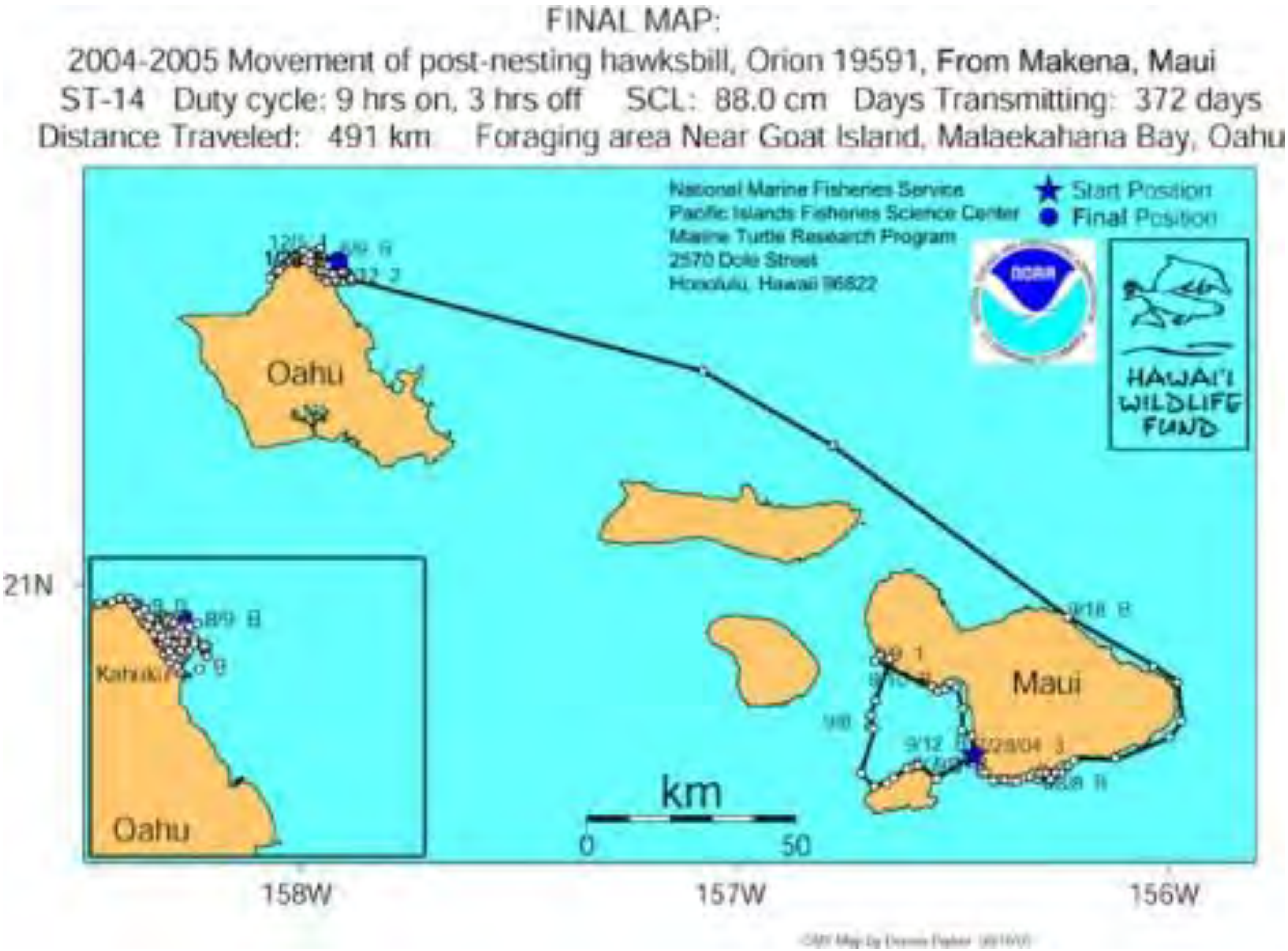


Figure 16. "Orion's" 2008 Post-Nesting Migration to O'ahu.

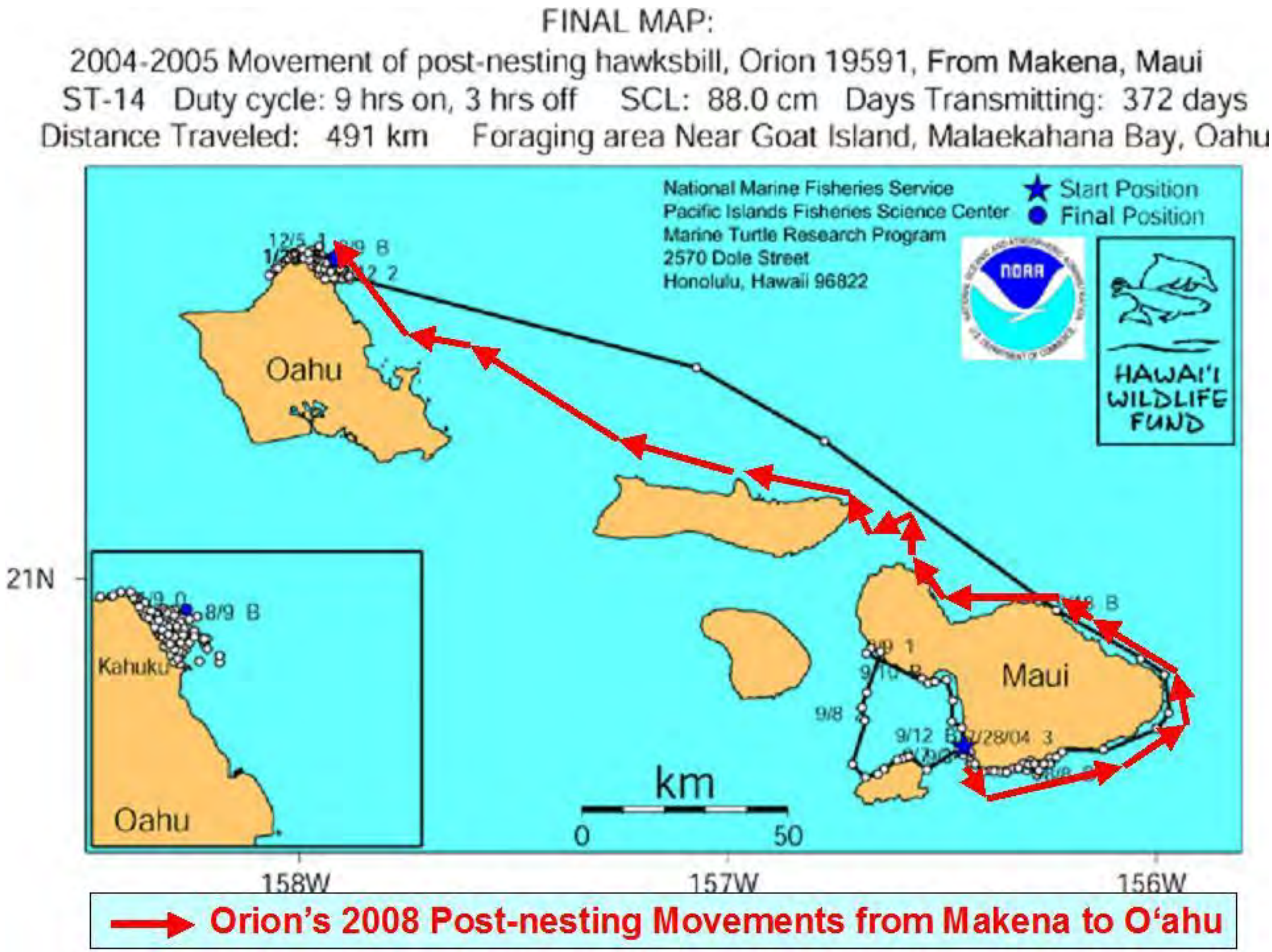


Figure 17. "Lele's" 2005 Post-Nesting Migration to Hawai'i Island.

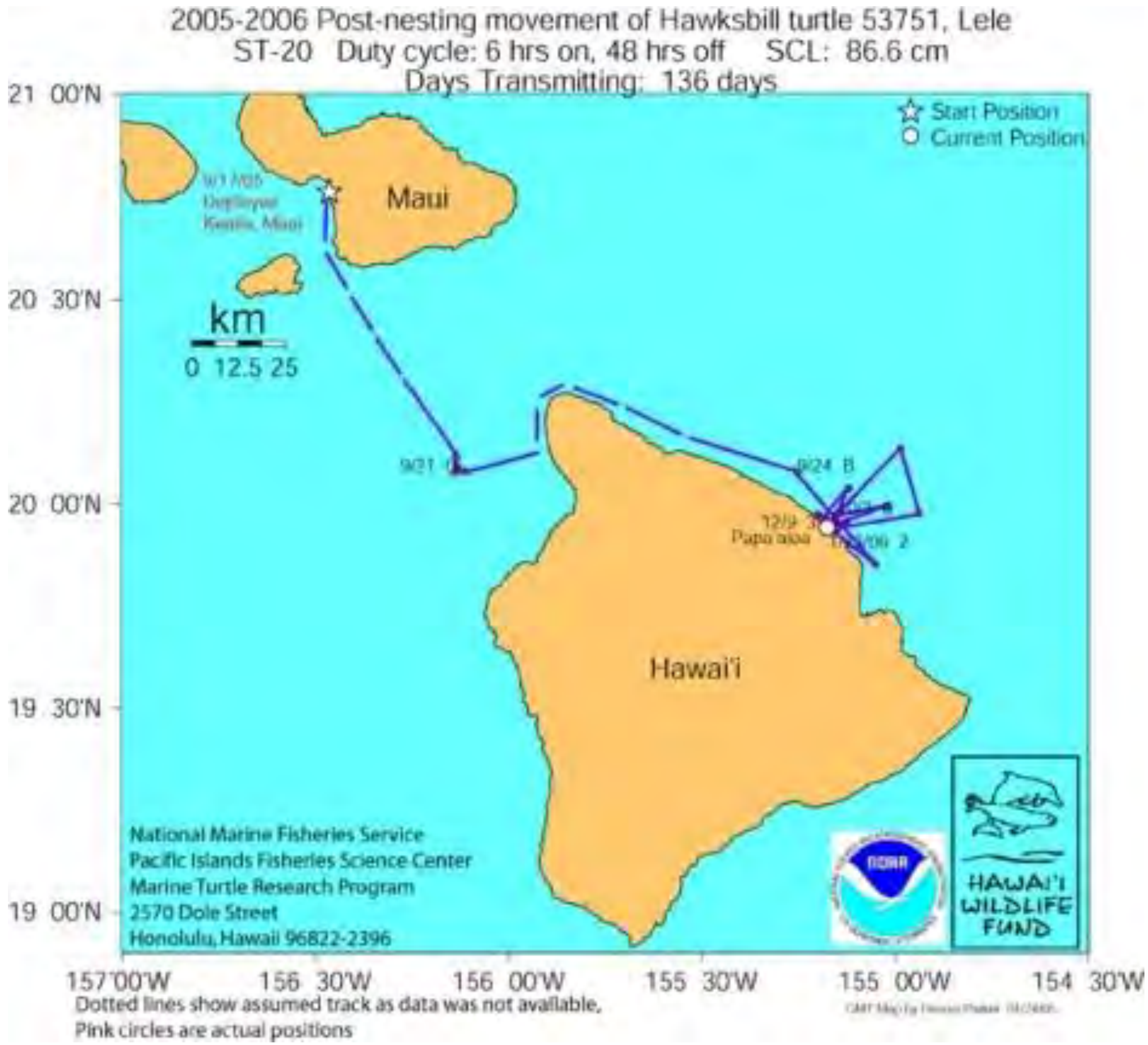


Figure 18. “Hokulele’s” 1999 Post-Nesting Migration to Moloka‘i.

Figure 19. "Uhane Niniu" 2011 Inter-Nesting Location.

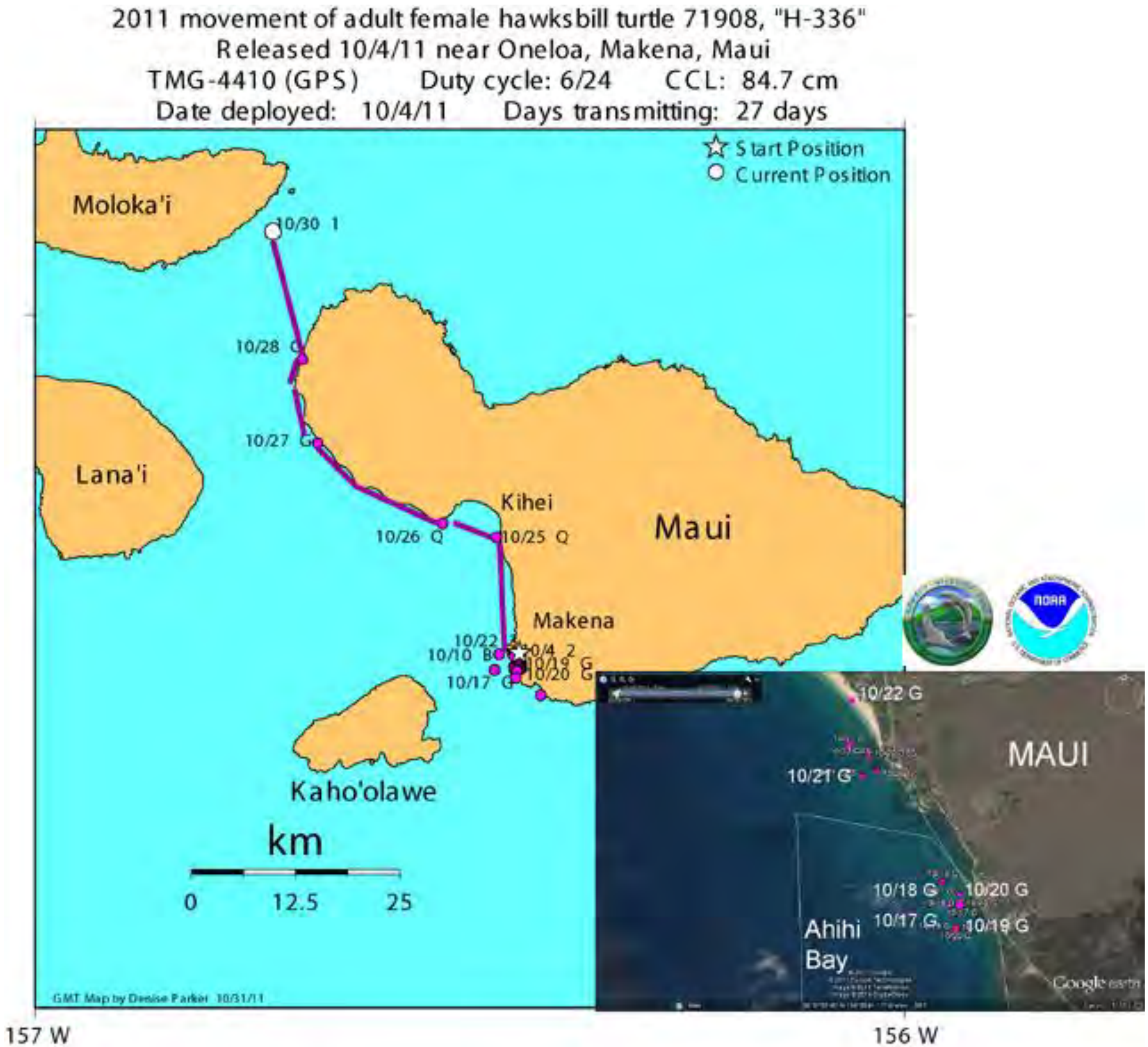


Figure 20. "Uhane Niniu" 2011 Post-Nesting Migration to Kaua'i & Pelagic.

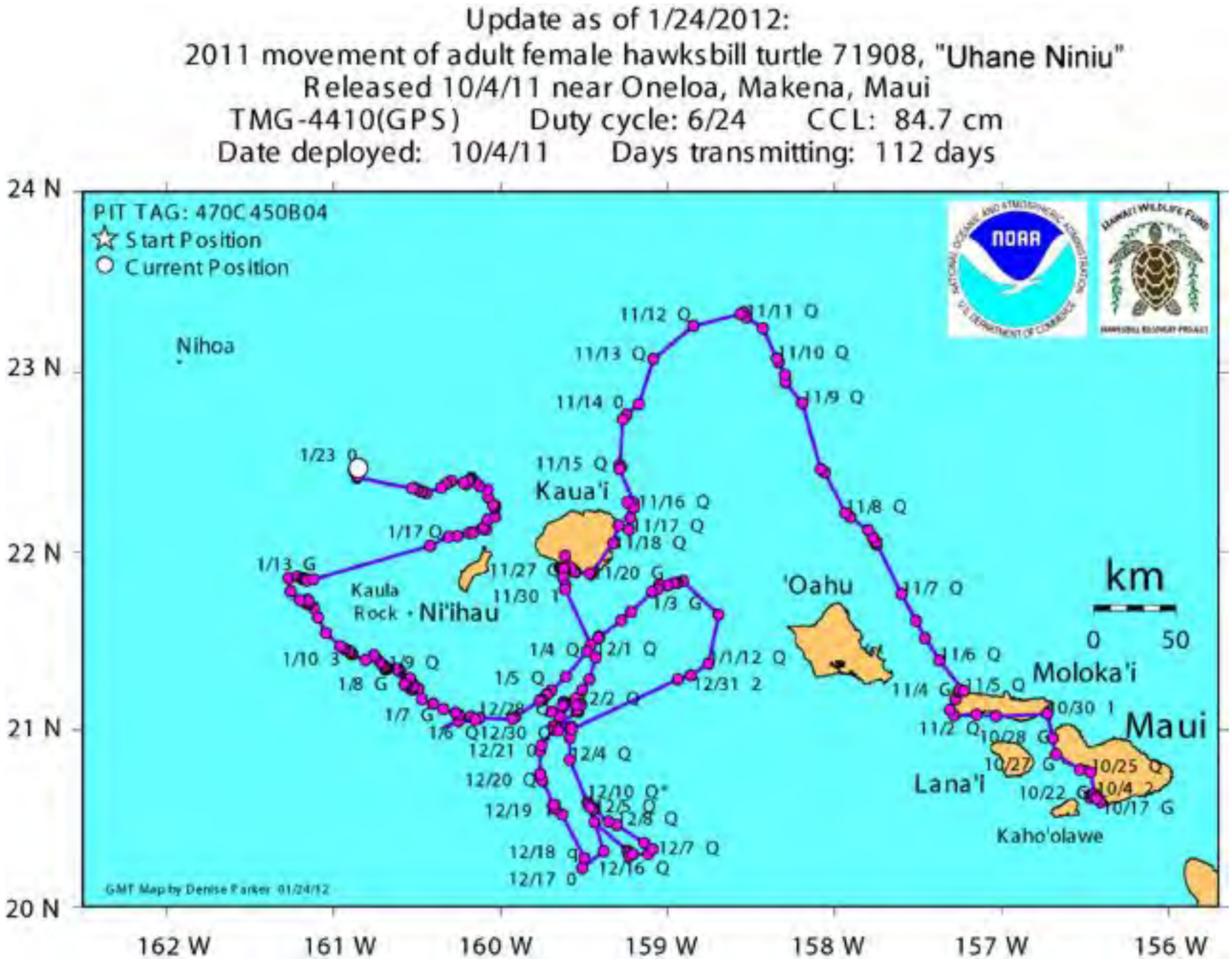
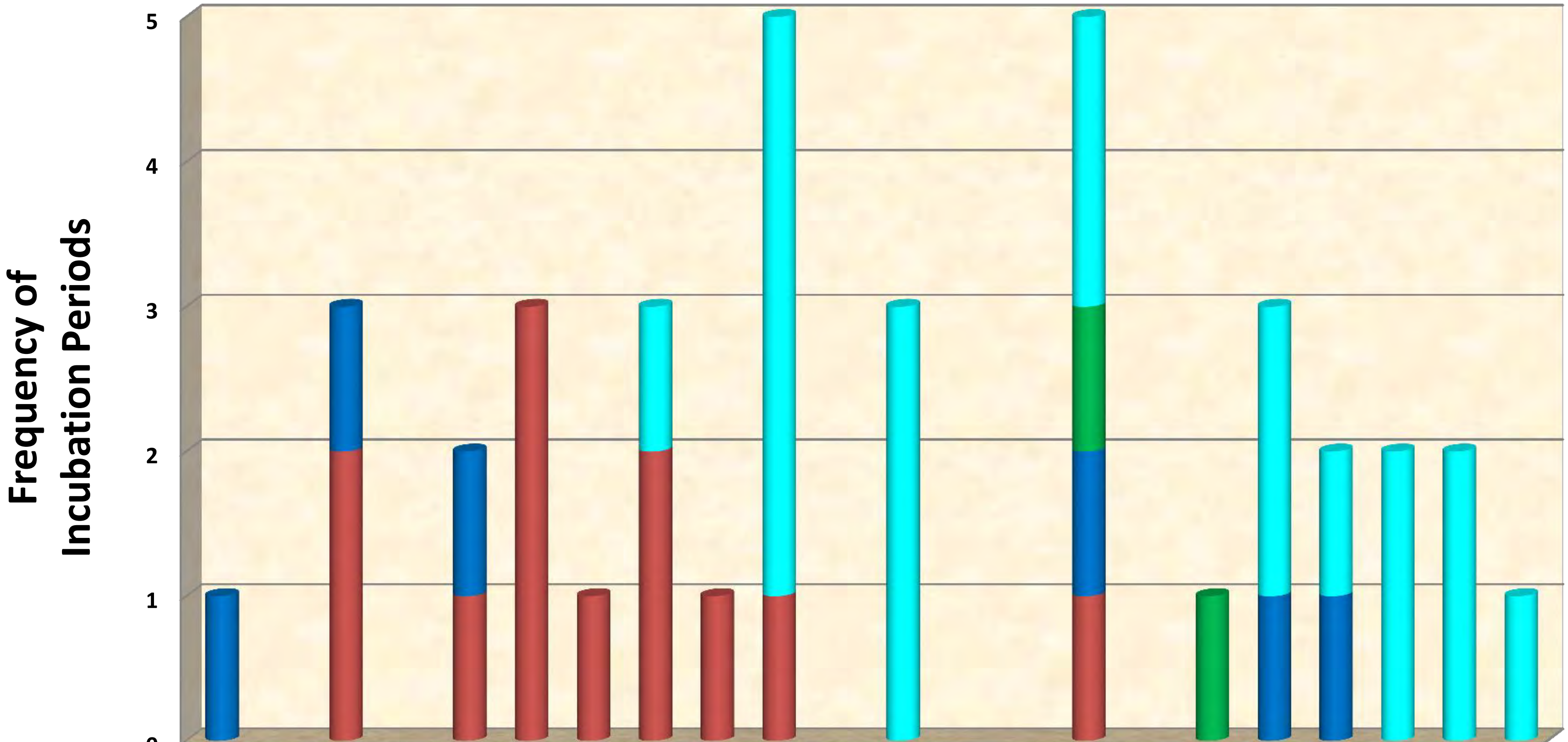


Figure 21. 1996-2012 Nest Incubation Periods by Beach (n=38).



# of nights	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	73
Oneloa								1		4		3			2			2	1	2	2	1
Little Beach															1		1					
Kealia	1		1		1										1			1	1			
Kawililipoa			2		1	3	1	2	1	1					1							

Figure 22. Total Eggs Laid by Beach (n=11,296).

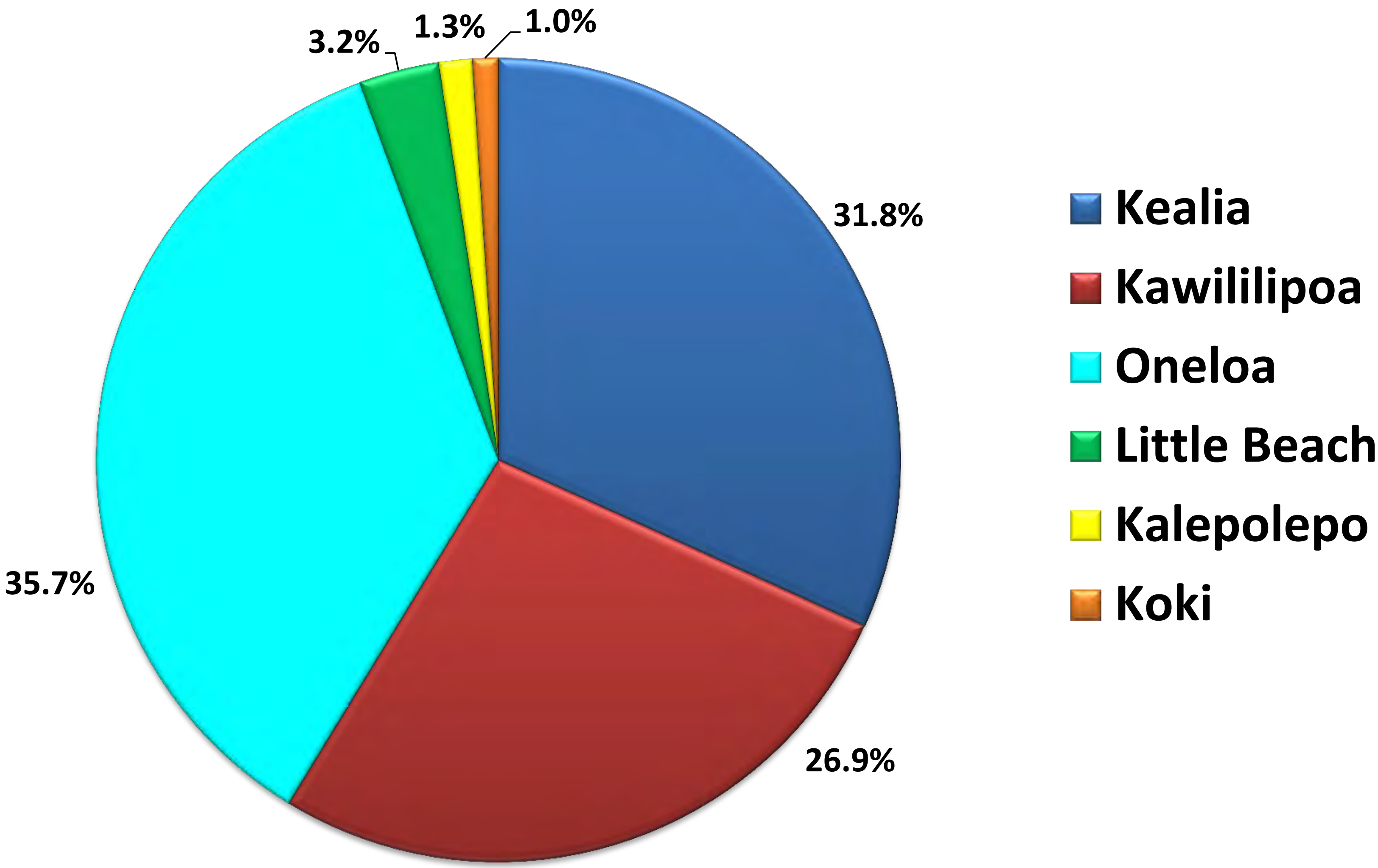
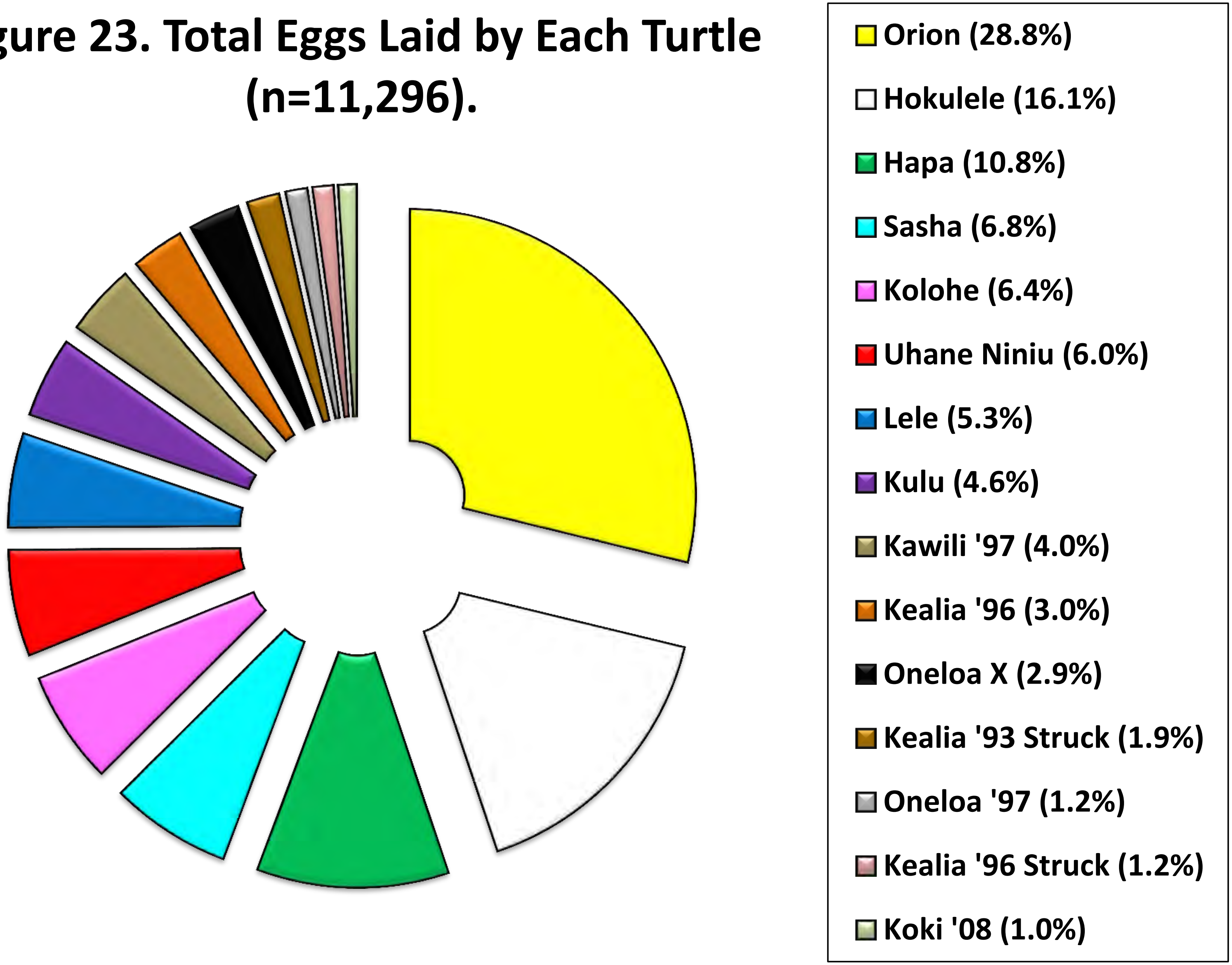


Figure 23. Total Eggs Laid by Each Turtle (n=11,296).



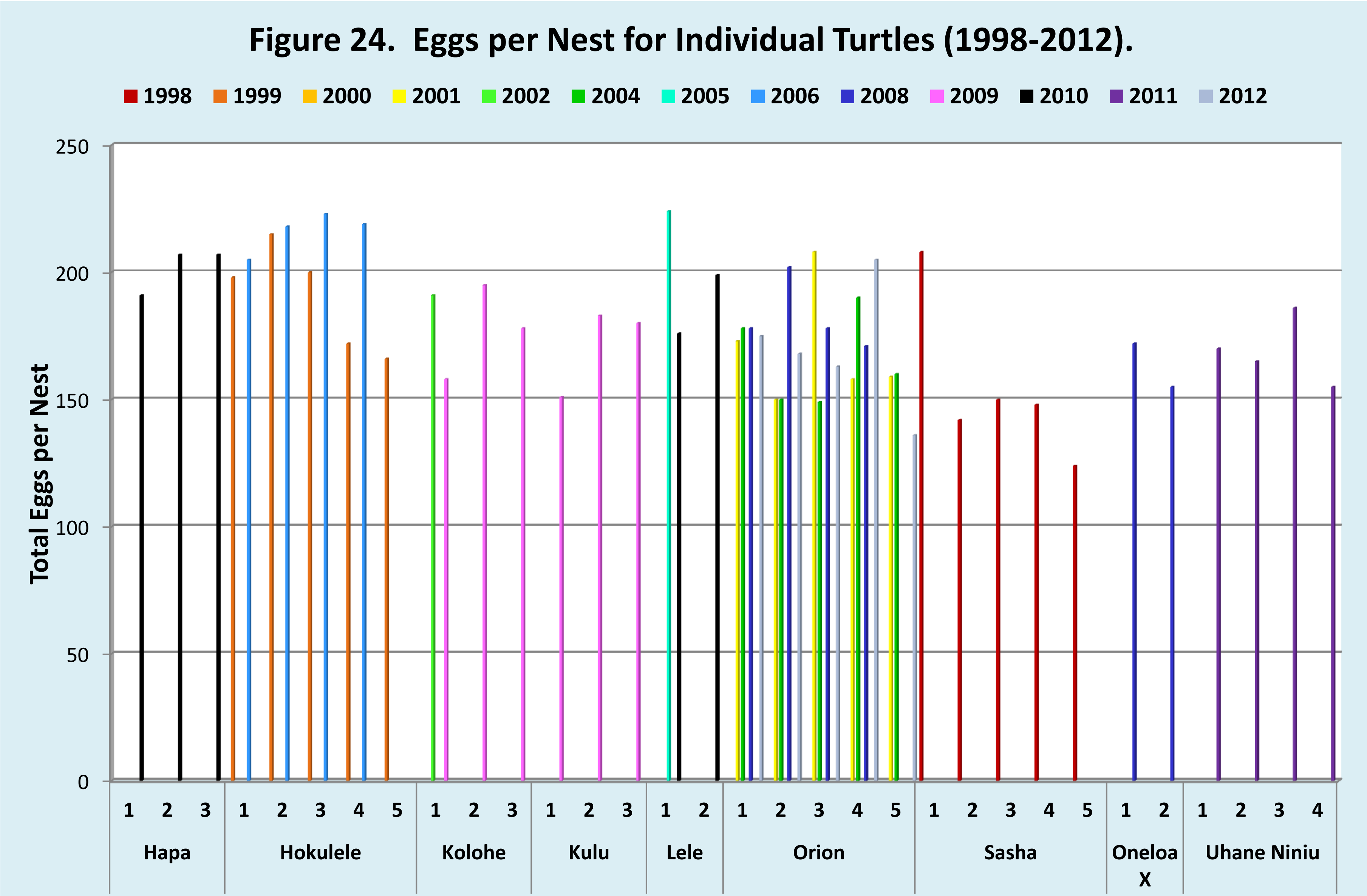


Figure 24. Eggs per Nest for Individual Turtles (1998-2012).
1998
1999
2000
2001
2002
2004
2005
2006
2008
2009
2010
2011
2012
Total Eggs per Nest
0
50
100
150
200
250
Hapa
Hokulele
Kolohe
Kulu
Lele
Orion
Sasha
Oneloa X
Uhane Niniu
Turtle and Nest Number by Season

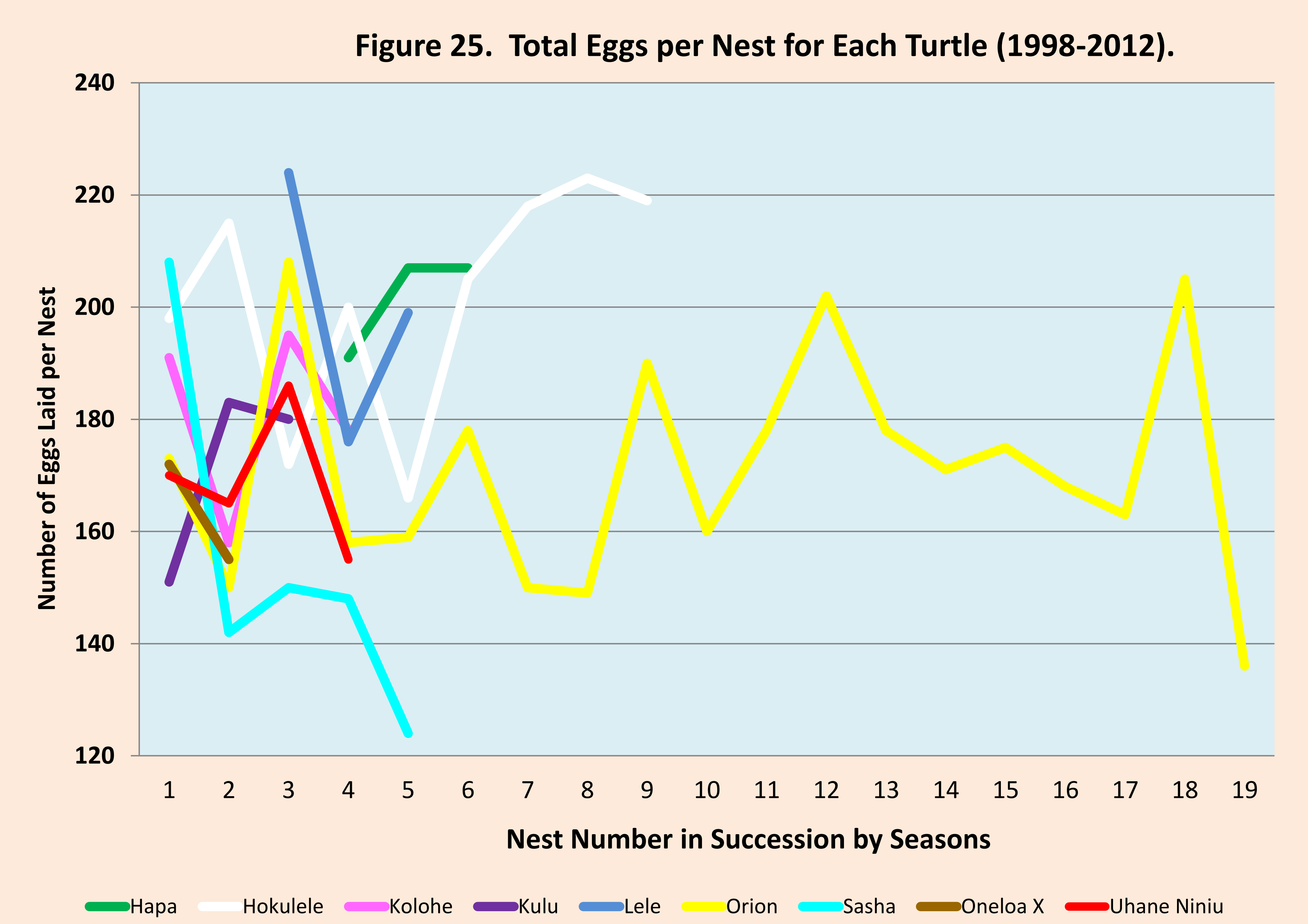


Figure 25. Total Eggs per Nest for Each Turtle (1998-2012).
Number of Eggs Laid per Nest
240
220
200
180
160
140
120
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
Nest Number in Succession by Seasons
Hapa
Hokulele
Kolohe
Kulu
Lele
Orion
Sasha
Oneloa X
Uhane Niniu

Figure 26. Hatching vs Hatchling Success by Season's Nest Number (2000-2012).

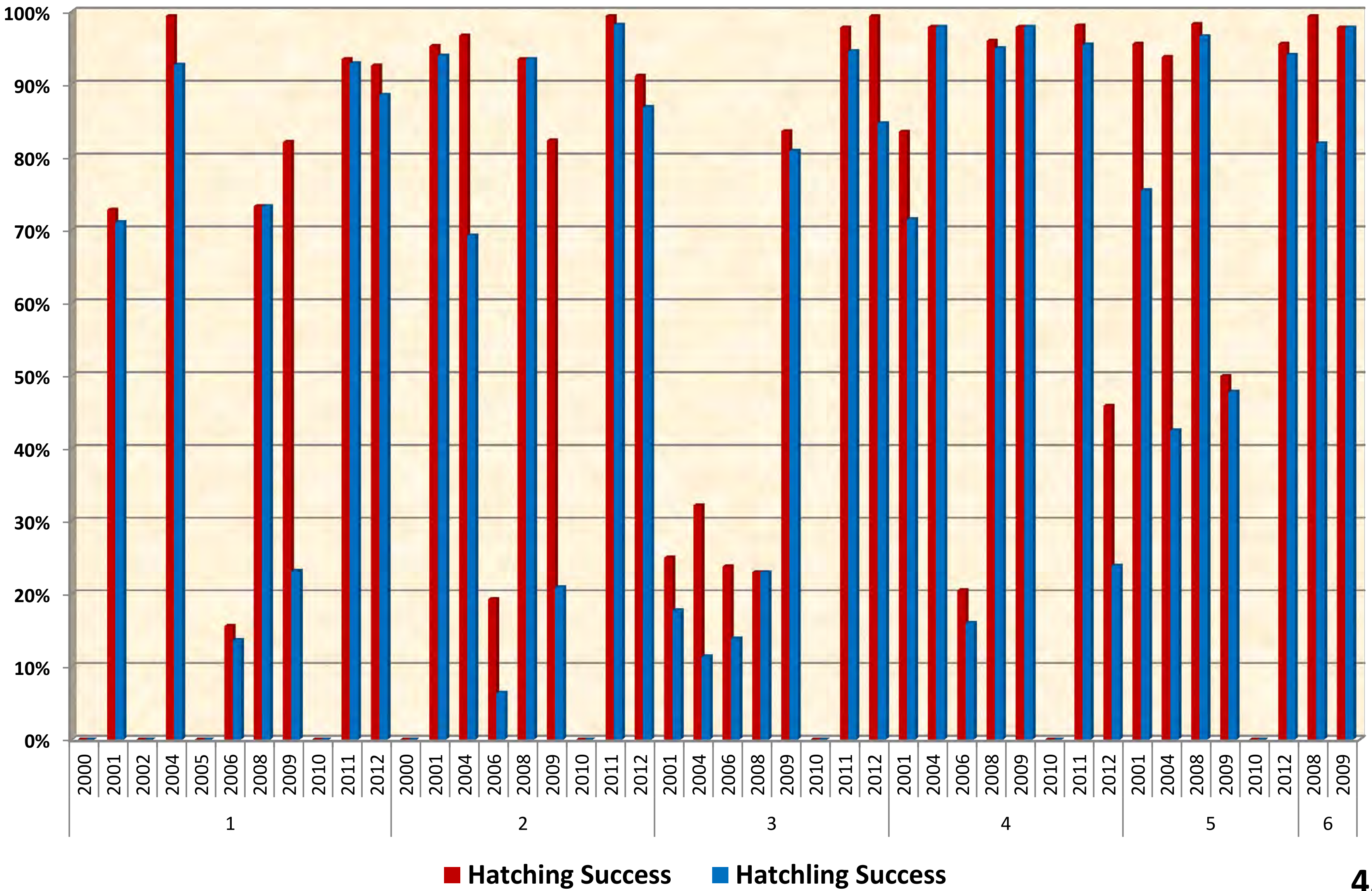


Figure 27. Hatching vs Hatchling Success for All Hawksbill Nests (2000-2012).

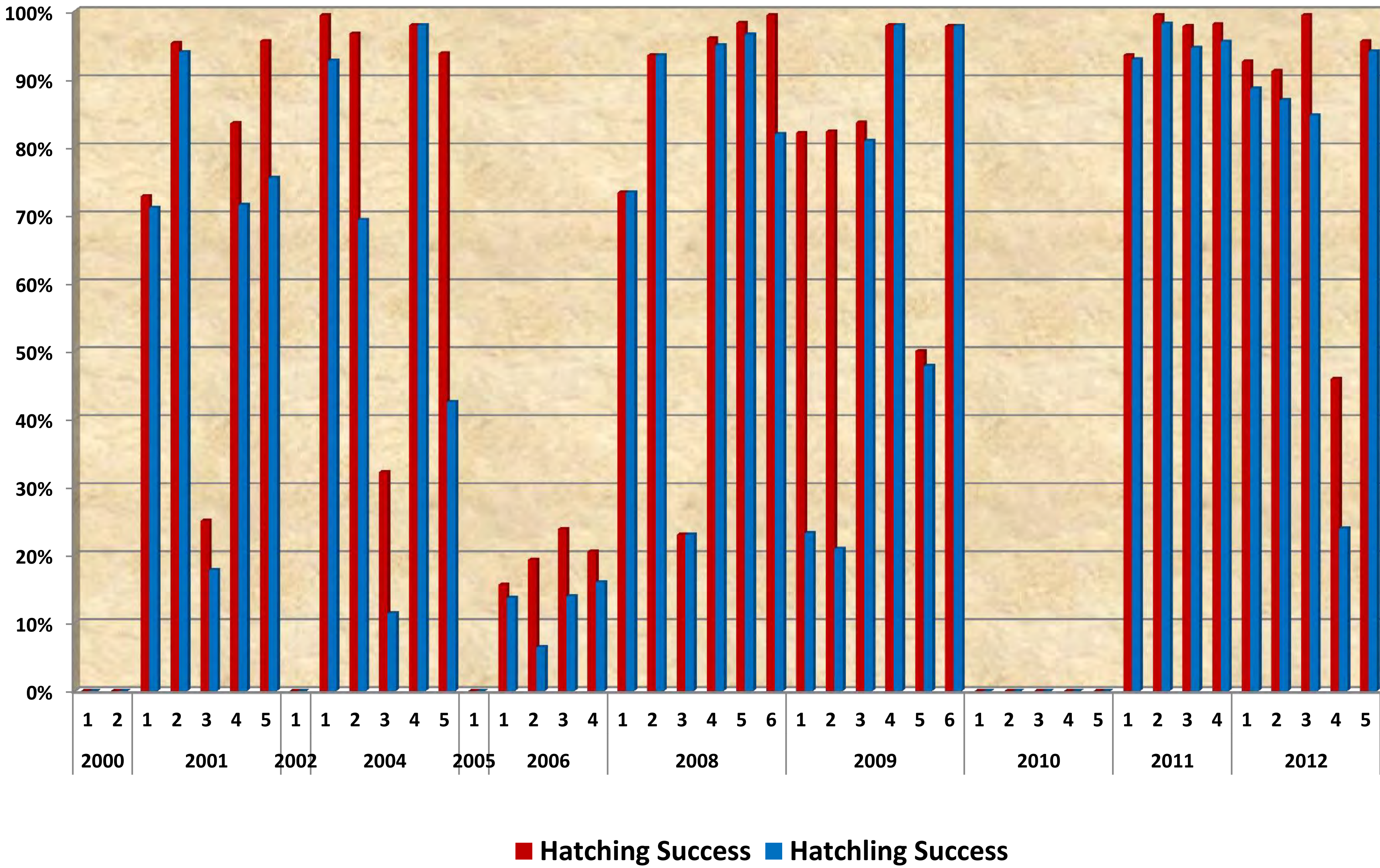


Figure 28. Frequency of Hatchling Emergences by Time at Oneloa in 2008 (Nests 1,3,5, & 6; n=38).

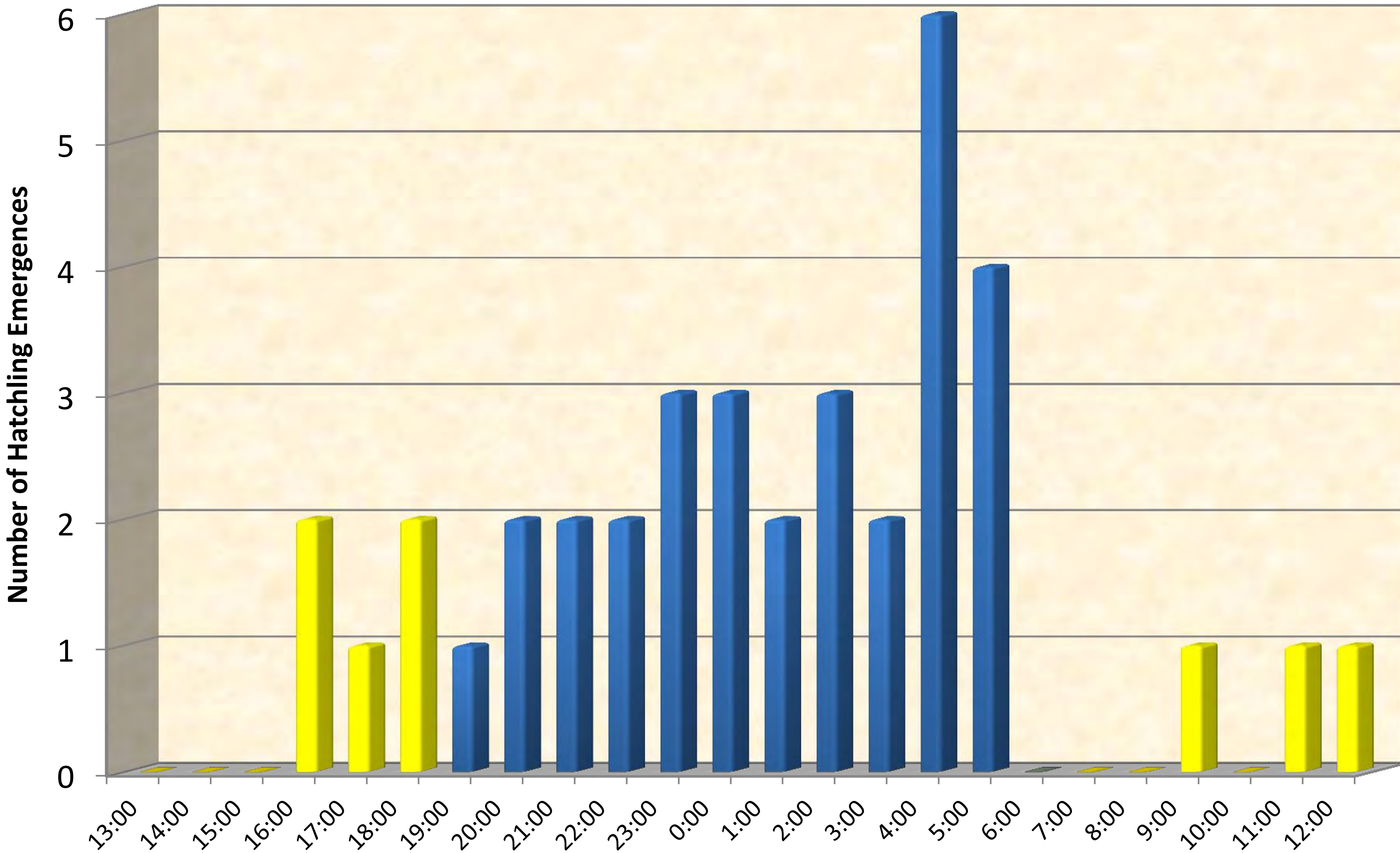


Figure 29. Frequency of Hatchling Emergences by Time at Kealia in 2009 (Nests 1, 3, 4, 5, & 6; n=27).

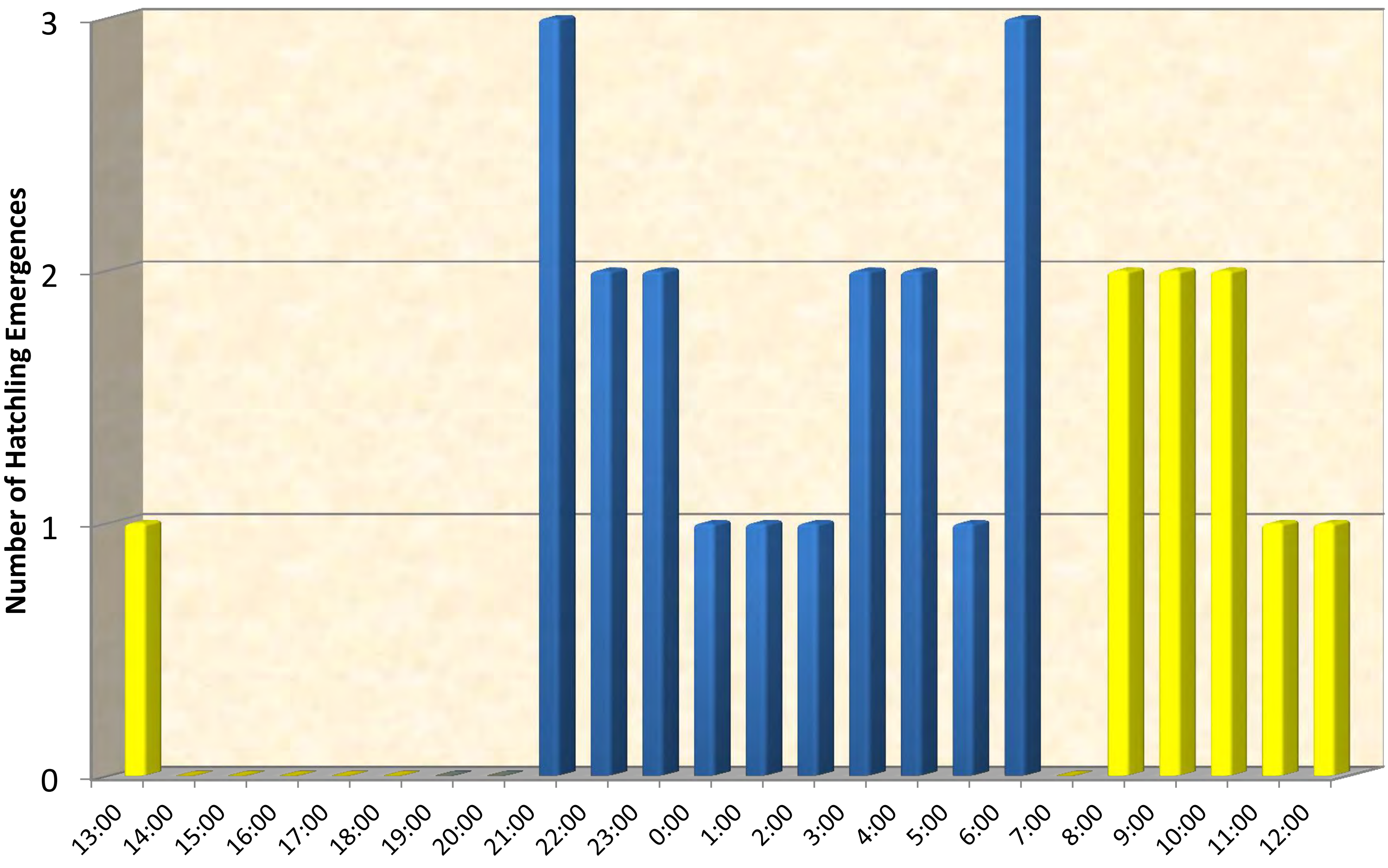


Figure 30. Frequency of Hatchling Emergences by Time in 2011 (Nests 2 & 4; n=17).

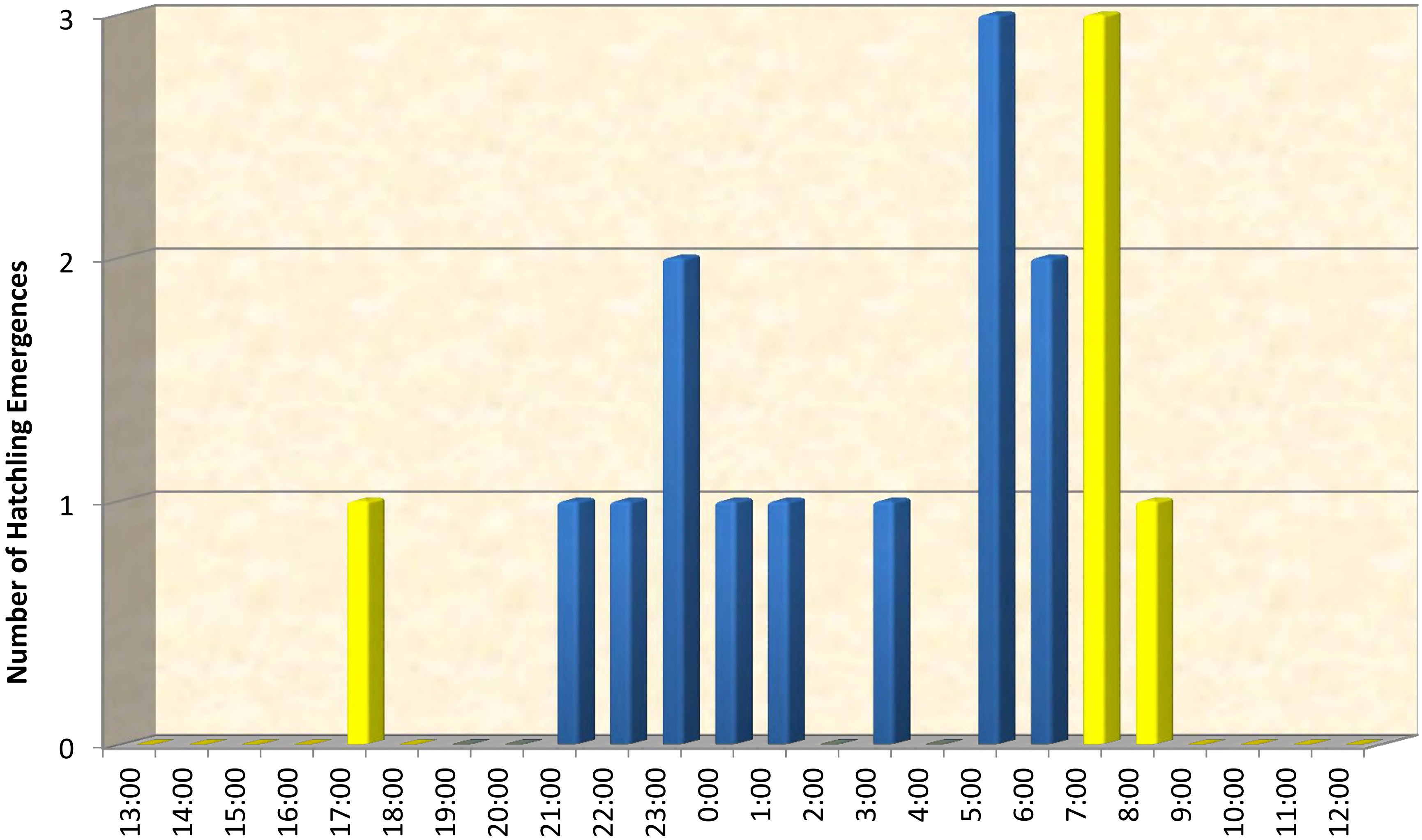


Figure 31. Frequency of Hatchling Emergences by Time in 2012 (Nests 1,2 & 3; n=32).

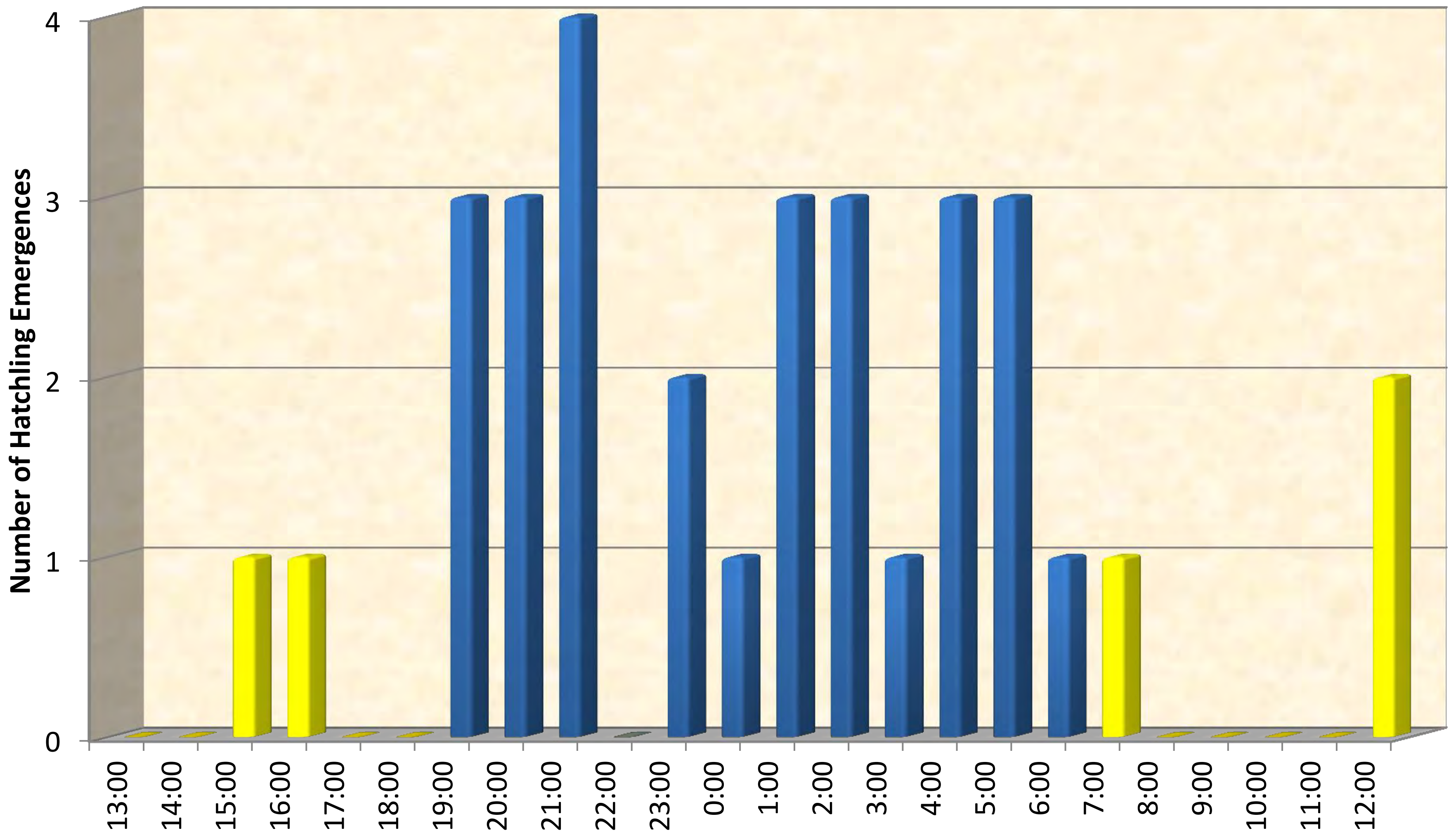


Figure 32. Frequency of Hatchling Emergences by Time in 2008, 2009, 2011, & 2012 (n=114).

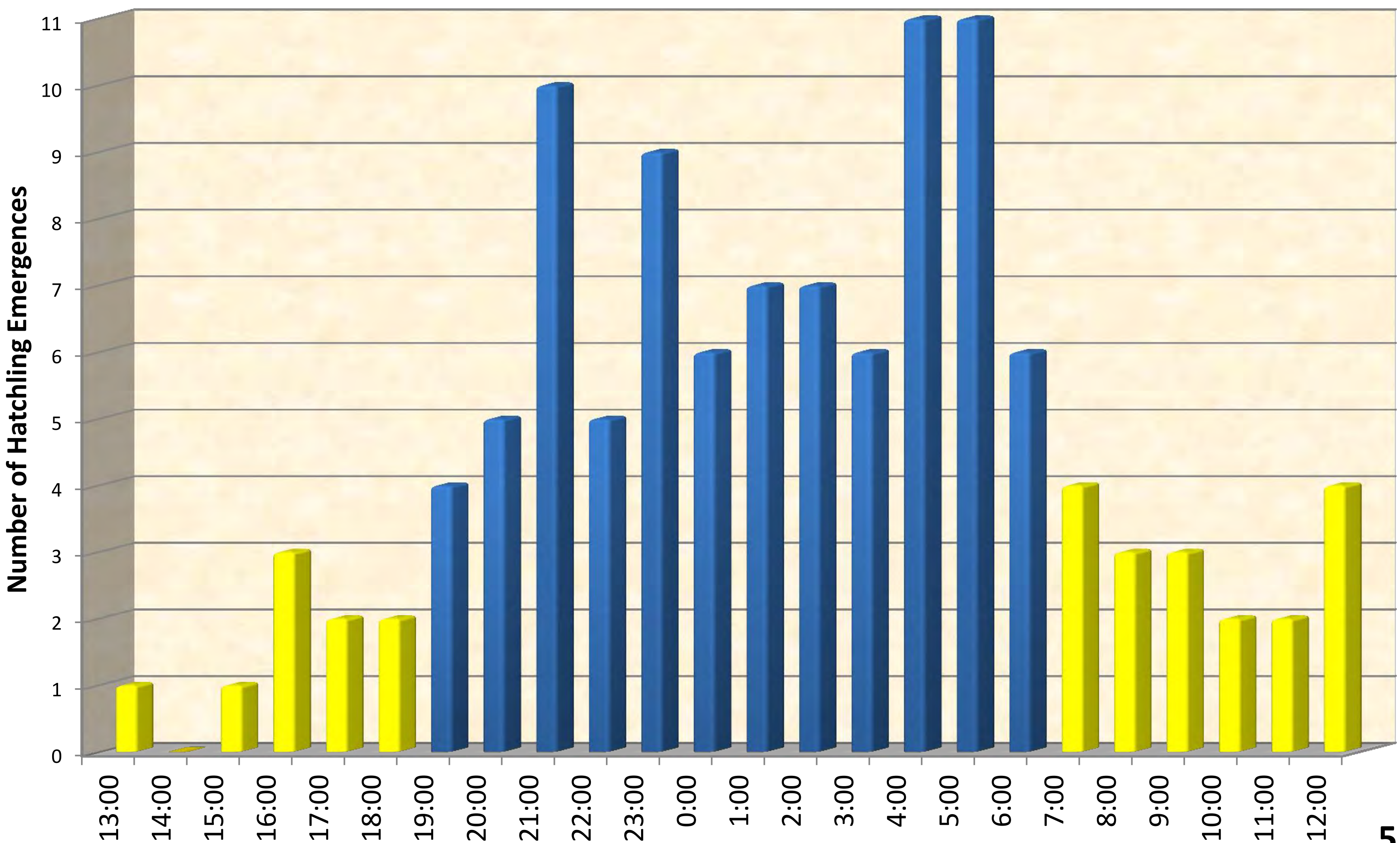


Figure 33. 2009 Nesting Activity at Kealia of Two Hawksbills: “Kulu” and “Kolohe”.

Figure 34. 2010 Nesting Activity at Kealia of Two Hawksbills: “Lele” and “Hapa”.

Figure 35. 2011 Nesting Activity at Oneloa: “Uhane Niniu”.

Figure 36. 2012 Nesting Activity at Oneloa and Little Beach: "Orion".

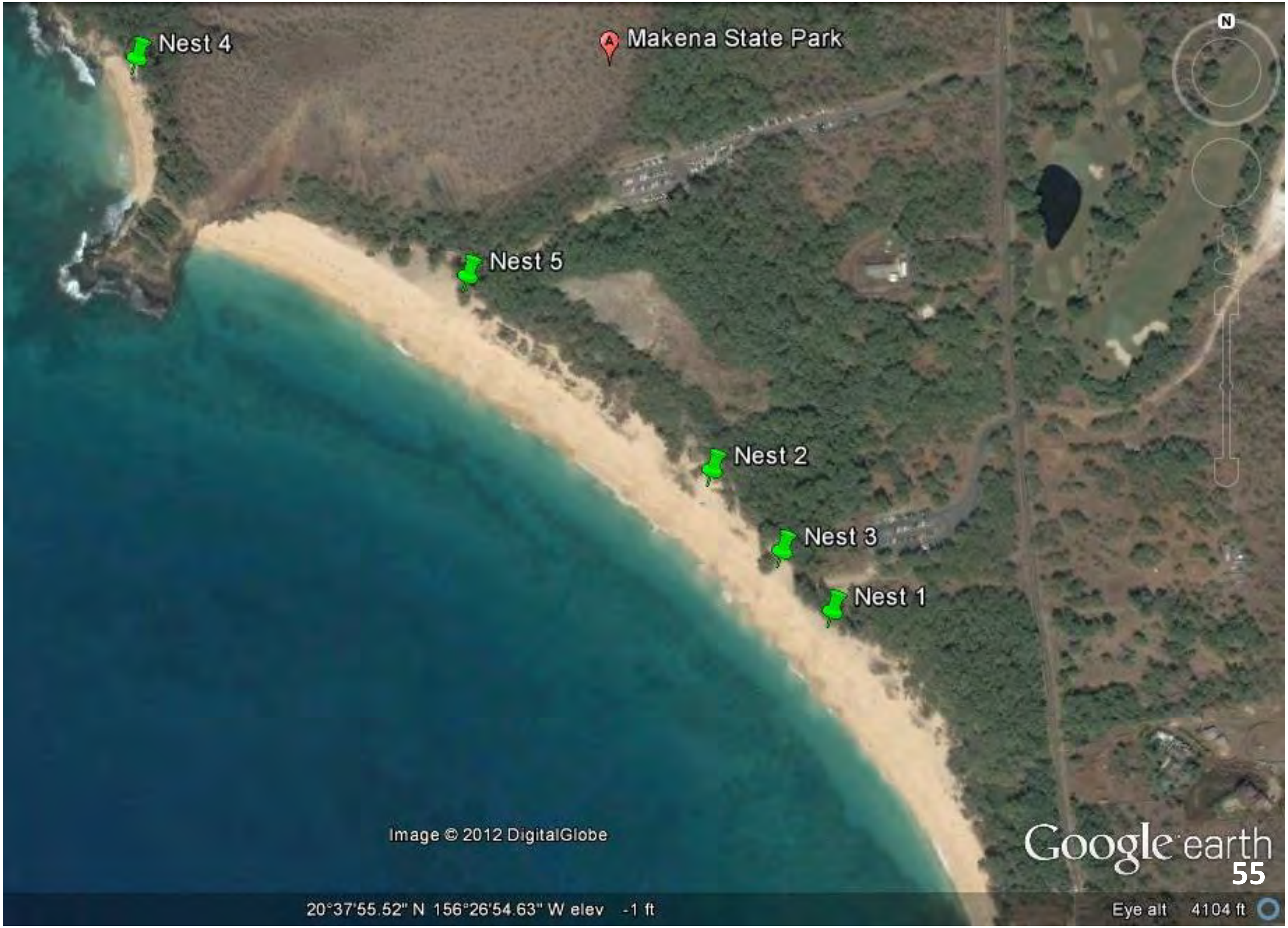


Table 1. Annual seasonal start and end dates by turtle since HWF monitoring began (1996-2012).

Season	Location	Turtle	# Nests	False Crawls	1st activity	Last Activity	Last Excavation
1996	**Kealia**	Kealia '96 Struck	5	n/a	7/24/96	8/30/96	10/20/96
1997	**Kealia**	Hapa	3	16	~7/31/97	10/11/97	n/a
1997	**Kawililipoa**	Unknown	3	0	n/a	n/a	n/a
1997	**Oneloa**	Unknown	1	0	n/a	n/a	n/a
1998	**Kawililipoa**	Sasha	5	1	**5/18/98**	8/8/98	10/7/98
1999	**Kawililipoa**	Hokulele	5	1	6/29/99	9/19/99	11/29/99
2000	**Kealia**	Lele	2	2	8/18/00	10/13/00	12/22/00
2001	**Oneloa**	Orion	5	3	~7/1/01	9/22/01	11/27/01
2001	**Hana Bay**	Unknown	1	0	n/a	n/a	n/a
2002	**Kealia**	Kolohe	1	2	9/14/02	9/14/02	11/23/02
2003	**none**						
2004	**Oneloa & Little Beach**	Orion	5	4	6/17/04	9/4/04	11/20/04
2004	**Kealia**	Unknown	0	1	9/23/04	9/23/04	12/4/04
2005	**Kealia**	Lele	1	5	8/8/05	9/16/05	11/27/05
2006	**Kawililipoa**	Hokulele	4	1	6/21/06	8/16/06	10/25/06
2007	**none**						
2008	**Oneloa**	Oneloa X	2	0	6/7/08	6/23/08	8/8/2008
2008	**Oneloa**	Orion	4	1	6/30/08	9/1/08	11/12/08
2008	**Kalepolepo**	Unknown	0	1	7/17/08	7/17/08	n/a
2008	**Hana Bay**	Unknown	0	2	6/29/08	6/29/08	n/a
2008	**Koki**	Unknown	1	0	8/3/08	8/3/08	10/20/08
2008	**Hamoa**	Unknown	1	0	n/a	n/a	n/a
2009	**Kalepolepo & Kealia**	Kulu	3	1	7/9/09	8/27/09	10/24/09
2009	**Kealia**	Kolohe	3	0	7/27/09	9/3/09	11/13/09
2010	**Kealia**	Unknown	0	3	6/27/10	6/27/10	9/7/10
2010	**Kealia**	Lele	2	2	8/28/10	9/17/10	11/26/10
2010	**Kealia**	Hapa	3	2	8/29/10	10/2/10	12/12/10
2011	**Oneloa**	Uhane Niniu	4	0	8/27/11	**10/21/11**	**1/2/12**
2012	**Oneloa & Little Beach**	Orion	5	5	6/17/12	9/17/12	11/23/12
2012	**Kealia**	Unknown	1+?	0	9/15/12	n/a	n/a

Table 2. Season, remigration interval, nesting beach, name, tag numbers, measurements, and growth.

Season	Remigration	Location	Name	LFF	RFF	CCL (cm growth)	CCW (cm growth)
1997	^	Kealia	Hapa	H326	H327	87.5	86
2010	13 yrs	Kealia	Hapa	H326	H327	n/a	n/a
1999	^	Kawili	Hokulele	H330	H331	89.0	82.7
2006	7 yrs	Kawili	Hokulele	H330	H331	90.7 (1.7)	84.3 (1.6)
2000	^	Kealia	Lele	H332	H333	91.0	82.0
2005	5 yrs	Kealia	Lele	H332	H333	94.1 (3.1)	80.7 (-1.3)
2010	5 yrs	Kealia	Lele	H332	H333	n/a	n/a
2001	^	Oneloa	Orion	H334	H335	93.3	84.5
2004	3 yrs	Oneloa & Little Bch	Orion	H334	H335	92.0 (-1.3)	85.1 (0.6)
2008	4 yrs	Oneloa	Orion	H334	H335	91.5 (-0.5)	86.0 (0.9)
2012	4 yrs	Oneloa & Little Bch	Orion	H334	H335	n/a	n/a
2002	^	Kealia	Kolohe	H340	H341&342	84.5	78.2
2009	7 yrs	Kealia	Kolohe	H340	H341&342	85.4 (0.9)	78.5 (0.3)

Table 3. Nesting details by season, location, turtle, flipper tags, measurements, and tracking information.

Season	Location	Name	LFFtag	RFFtag	CCL (cm)	CCW	Inter-nesting Location	Post-nesting Location
1994	Kealia	Kealia '94	^	^	65.0 SCL	n/a	n/a	n/a
1996	Kealia	Kealia '96 Struck	^	^	**96.0**	84.0	n/a	n/a
1997	Kealia	Hapa	H326	H327	87.5	86.0	Fishpond (~2 miles away)	Kuku Pt, Hamakua Coast
1998	Kawililipoa	Sasha	H329	H328	89.0	**87.0**	Keawakapu (~4 miles away)	Waipio, Hamakua Coast
1999	Kawililipoa	Hokulele	H330	H331	89.0	82.7	n/a	Pelekunu, Molokai
2000	Kealia	Lele	H332	H333	91.0	82.0	n/a	n/a
2001	Oneloa	Orion	H334	H335	93.3	84.5	n/a	n/a
2002	Kealia	Kolohe	H340	H341&342	84.5	78.2	n/a	n/a
2004	Oneloa & Little Bch	Orion	H334	H335	92.0	85.1	Nakaohu (~16 miles away)	Makaho'a Pt, O'ahu
2005	Kealia	Lele	H332	H333	94.1	80.7	Kealia Resort (~1 mile away)	Maulua Bay, Hamakua Coast
2006	Kawililipoa	Hokulele	H330	H331	90.7	84.3	n/a	n/a
2008	Oneloa	Orion	H334	H335	91.5	86.0	n/a	Kahuku area, O'ahu
2009	Kalepolepo & Kealia	Kulu	H343	H344	**83.5**	**76.5**	n/a	n/a
2009	Kealia	Kolohe	H340	H341&342	85.4	78.5	n/a	n/a
2010	Kealia	Lele	H332	H333	n/a	n/a	n/a	n/a
2010	Kealia	Hapa	H326	H327	n/a	n/a	n/a	n/a
2011	Oneloa	Uhane Niniu	H336	H337	84.7	81.5	Ahihi Bay (~2/3 mile away)	Kaua'i and pelagic
2012	Oneloa & Little Bch	Orion	H334	H335	n/a	n/a	n/a	n/a

Table 4. Nest clutch statistics by hawksbill and beach (1993-2012).

Beach	Turtle	Nests	Total Eggs	Mean of Eggs	StdDev of Eggs
Kalepolepo	**Kulu**	1	151	151.0	n/a
Kalepolepo Total		**1**	**151**	**151.0**	**n/a**
Kawililipoa	**Hokulele**	9	1816	201.8	20.6
	Kawili '97	3	456	152.0	10.5
	Sasha	5	772	154.4	31.7
Kawililipoa Total		**17**	**3044**	**179.1**	**33.1**
Kealia	**Hapa**	6	1224	204.0	8.8
	Kealia '93 Struck	1	209	209.0	n/a
	Kealia '96	2	339	169.5	30.4
	Kealia '96 Struck	1	134	134.0	n/a
	Kolohe	4	722	180.5	16.7
	Kulu	2	363	181.5	2.1
	Lele	3	599	199.7	24.0
Kealia Total		**19**	**3590**	**188.9**	**23.1**
Koki	**Koki '08**	1	116	116.0	n/a
Koki Total		**1**	**116**	**116.0**	**n/a**
Little Bch	**Orion**	2	365	182.5	31.8
Little Bch Total		**2**	**365**	**182.5**	**31.8**
Oneloa	**Oneloa '97**	1	141	141.0	n/a
	Oneloa X	2	327	163.5	12.0
	Orion	17	2886	169.8	19.1
	Uhane Niniu	4	676	169.0	12.9
Oneloa Total		**24**	**4030**	**167.9**	**17.8**
Grand Total		**64**	**11296**	**176.5**	**26.6**

Table 5. Maui Hawksbill Nesting Summary (1996 – 2012; n=70 nests).

Season	Location	# of Females	# of Nests	Mean # of eggs/ nest	Mean Hatching Success	Mean Hatchling Success
1996	Kealia	2?	5	157.7	n/a	16.0%
1997	Kealia	Hapa + 1?	3	206.5	n/a	0.0%
1997	Kawililipoa	1?	3	152	n/a	43.0%
1997	Oneloa	1?	1	141	n/a	23.0%
1998	Kawililipoa	Sasha	5	154	n/a	68.9%
1999	Kawililipoa	Hokulele	5	190.2	n/a	60.0%
2000	Kealia	Lele	2	232.3	0.1%	0.0%
2001	Oneloa	Orion	5	169.6	71.3%	63.0%
2001	Hana Bay	1?	1	n/a	n/a	n/a
2002	Kealia	Kolohe	1	191	0.0%	0.0%
2003	Ø	0	0	*	*	*
2004	Kealia	1?	0	false crawl	*	*
2004	Oneloa	Orion	4	166.8	83.4%	70.8%
2004	Little Beach	Orion	1	160	93.8%	42.5%
2005	Kealia»Kawili	Lele	1	224	0.0%	0.0%
2006	Kawililipoa	Hokulele	4	216.3	19.8%	11.9%
2007	Ø	0	0	*	*	*
2008	Oneloa	Orion	4	182	79.6%	74.8%
2008	Oneloa	1?	2	163.5	82.9%	82.9%
2008	Kalepolepo	1?	0	false crawl	*	*
2008	Koki	1?	1	116	71.6%	71.6%
2008	Hana Bay	1?	0	2 false crawls	*	*
2008	Hamoa	1?	1	washed out	0.0%	0.0%
2009	Kalepolepo	Kulu	1	151	82.1%	23.2%
2009	Kealia	Kolohe	3	177	93.6%	75.0%
2009	Kealia	Kulu	1	183	83.6%	80.9%
2009	Kealia»Kawili	Kulu	1	180	50.0%	47.8%
2010	Kealia	Lele	2	187.5	0.0%	0.0%
2010	Kealia	Hapa	3	201.7	0.0%	0.0%
2011	Oneloa	Uhane Niniu	4	169.0	97.2%	95.3%
2012	Oneloa	Orion	4	177.8	85.4%	79.7%
2012	Little Beach	Orion	1	205	45.9%	23.9%
2012	Kealia	1?	1	not found	*	*

Table 6. Data comparisons from Maui and Hawai'i Island.

	Maui 1991-2012	Hawai'i Island 1989-2009*
nesting season	May-January	April-February
# of nesting beaches	8 beaches	17 beaches
mean # of females/season	1.6 ± 1.1 (n=17)	11.6 ± 1.2 (n=18)
range of females/season	0-4 turtles	3-18 turtles
# of females tagged	8 turtles	100 turtles
# of females tracked	6 turtles	4 turtles
mean remigration interval	6.0 ± 3.2 (n=8)	3.5 ± 0.1 (n=106)
range of remigration interval	3-13 years	2-10 years
% of nesters using multiple beaches	25.0% (2 out of 8 tagged)	13.0% (n=unknown)
mean nest to false crawl interval	19.5 ± 2.2 (n=26)	18.6 ± 0.1 (n=276)
range of nest to false crawl interval	16-25 nights	13-24 nights
mean nest to nest interval	19.9 ± 2.0 (n=38)	20.0 ± 0.2 (n=277)
range of nest to nest interval	16-25 nights	13-30 nights
total # of nests	72 nests	742 nests
mean # of nests/season	4.1 ± 2.4 (n=17) (1996-2012)	35 ± 4.0 (n=21)
range of nests/season	0-8 nests	8-69 nests
mean # of nests/female	2.7 ± 1.5 (n=26)	3.3 ± 0.2 (n=20)
range of nests/female	1-5 nests	1-6 nests
mean clutch size	176.5 ± 26.6 eggs (n=64)	175.2 ± 1.5 (n=631)
range of clutch size	116-224 eggs	78-274 eggs
mean incubation period	60.9 ± 6.1 (n=38)	62.5 ± 0.4 (n=446)
range of incubation period	50-73 days	50-101 days
percentage of daylight emergences	23.7%	n/a
mean nest hatching success	60.5 ± 0.4 (n=44)	71.9 ± 1.0 (n=640)
range of nest hatching success	0-99.4%	0-100%
# of live hatchlings to the ocean	4,008 (2000-2012)	80,775 (1989-2009)

**Seitz, W.A., K.M. Kagimoto, B. Luehrs and L. Katahira. 2012. Twenty years of conservation and research findings of the Hawai'i Island Hawksbill Recovery Project, 1989-2009. Technical Report No. 178. The Hawai'i-Pacific Islands Cooperative Ecosystem Studies Unit & Pacific Cooperative Studies Unit, University of Hawai'i, Honolulu, HI. 177 pp.*

Table 7. Threats on Maui's Nesting Beaches.

	Kealia	Kalepolepo	Kawililipoa	Little Beach	Oneloa	Hana Bay	Koki	Hamoa
1) New/increased development	2	2	3	4	4	4	4	4
2) Light pollution	1	1	1	4	3	1	4	4
3) Vehicular beach traffic	1	1	4	4	2	3	4	4
4) Human trampling	2	2	3	1	1	1	1	1
5) Misorientation onto roadway	1	1	4	4	4	2	4	4
6) Impacts by recreational users	1	1	2	1	1	1	1	1
7) Predation by feral or domestic animals	2	2	2	2	1	2	2	2
8) Beach vegetation	1	2	1	3	2	4	4	4
9) Invasive algae piles	4	4	2	4	4	4	4	4
10) Deep holes	3	3	3	3	2	3	3	3
11) Egg development issues	1	3	2	3	3	3	3	3
12) Egg poaching	3	3	3	3	3	3	3	3
13) Nesting female poaching	3	3	3	3	3	3	3	3
14) Land-based and marine debris	2	2	3	4	4	4	4	4
15) Erosion	2	2	3	4	4	4	4	4
16) Flooding	1	2	4	3	2	3	3	3
17) Climate change	3	3	3	3	3	3	3	3

1= serious threat / 2= threat present but not serious /
3= potential but no cases / 4= no perceived threat