NOVA SOUTHEASTERN UNIVERSITY OCEANOGRAPHIC CENTER

AN ASSESSMENT OF SEA TURTLE RELATIVE ABUNDANCE, DISTRIBUTION, HABITAT, AND POPULATION CHARACTERISTICS WITHIN THE KAHO‘OLAWE ISLAND RESERVE, HAWAI‘I

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ABSTRACT

The sea turtle population utilizing habitats within the Kahoʻolawe Island Reserve (KIR) has gone practically unstudied. This baseline assessment (2002-2005) used a combination of aerial and in-water research methodologies designed in conjunction with recording all incidental sightings and opportunistic reports. In addition, cultural insight, previous studies, literature, and other references were reviewed totaling 708 sightings that provided the subsequent information on the occurrence of turtles within the reserve.

Overall, the different research assessment techniques produced similar results, suggesting the validity of the observations. All techniques had their separate merits and played significant roles due to the restrictions imposed on operations within a former military bombing range and the ongoing research activities of the Kahoʻolawe Island Reserve Commission (KIRC) Ocean Resources Management Program. The most superior methodology was the aerial survey for island-wide relative abundances and distributions, but in-water surveys were valuable in assessing turtle population characteristics, especially the fibropapilloma rate and site fidelity. Coastal surveys were done to search for signs of nesting or basking, but none were documented.

This study found turtles most commonly swimming individually in clear, shallow water (1-6m depth) coral reef habitats 5-20m from shore. Besides one female hawksbill (*Eretmochelys imbricata*), all were greens (*Chelonia mydas*) with no evidence of fibropapillomatosis. Immature turtles predominated and were fairly evenly distributed with some areas of higher density around Kahoʻolawe, namely in the Kākā, Hakioawa

and Kealaikahiki regions. Using photo-identification techniques, the strongest example of site fidelity was one particular turtle being resighted three times in the same location, with an 815-day interval between the first and last sighting. It was most common to find the turtles swimming as opposed to resting or foraging. The twenty foraging observations that were made occurred primarily in the Hakioawa and Kākā regions (depth mean=6m, SD=3.8m, range 1-11m). All were seen foraging on turf algae, as the abundance of macroalgae within the KIR was limited.

General turtle reactions to our presence were quantified roughly. With humans in the water the majority of the turtles kept a safe distance while exhibiting a slow departure from humans; unless approached closer (by free-diving) which typically caused them to flee. Near equal percentages exhibited flight responses versus toleration of our presence. Only one turtle displayed flipper swiping. During aerial surveys, our helicopter flew at ~31m which did not appear to alter turtle behavior as much as expected. As was the case of turtle reactions to our vessel *Hākilo*, disturbance was difficult to quantify unambiguously. Some turtles dove abruptly and others appeared to be unaffected by our presence, likely due to other variables unknown to us.

Abundance estimates were negatively biased due to availability biases (submerged turtles) and our detection limitations of naturally camouflaged, highly alert animals. Twenty-nine standardized aerial surveys averaged 7.2 turtles (SD=3.4, range 1-14, n=209) per ~60-minute circumnavigation survey yielding a mean density of 0.153 turtles per km (0.248/mile). Nineteen north coast surveys averaged 2.3 turtles (SD=1.76, range

0-6, n=43) per ~20 minute survey, resulting in a mean density of 0.131 turtles per km (0.209/mile). Sixty-seven nearly island-wide snorkel transects yielded a 1.31 turtles/hr mean (transect SD=1.8, range 0-8, n=82). Although effort varied widely, it was most common to incidentally witness one turtle at the surface per (~5-hour) day while different research activities within the reserve were conducted (1.29/day mean, SD=1.26, range 0-6, n=76 field days, n=98 turtles).

Exploratory analyses of correction factors for submerged turtles during aerial surveys and the collation of all sightings and references roughly estimate that fewer than 500 turtles inhabit the KIR (although these results should be used cautiously). KIR-specific turtle diving behaviors must be determined to enable reliable correction factors to be applied to density abundance estimates. Although these research results are not directly comparable to other studies within the rest of the Main Hawaiian Islands because this is the first island-wide study, these low numbers suggest a rather insignificant contribution to the extant population of Hawaiian sea turtles.

This baseline estimate allows for a) future comparisons using these standardized monitoring protocols, and b) the prioritization of restrictions to important KIR habitats, with implications for management on other islands. As the restoration and management of the KIR continues successfully, this reserve has great potential to host a healthy population of sea turtles that would be able to thrive in a non-anthropogenically stressed environment. Therefore this population and nearshore habitat should continue to be monitored and protected.

INTRODUCTION

Project Significance

"To really find out how turtle populations are doing we need to get into and above the water. We can then start to determine their relative abundance and gain insights into population trends when they are in the foraging grounds. After all, this is where they spend the vast majority of their lives and often when they are under the most threat" (Turtles in the Caribbean Overseas Territories (TCOT) Workshop, 2002).

The population of sea turtles around Kahoʻolawe, one of the eight Main Hawaiian Islands, has gone practically unstudied leaving a small void in Hawaiian sea turtle research. A variety of relatively undisturbed, natural habitats exist within the Kahoʻolawe Island Reserve (KIR), the largest contiguous marine reserve in the Main Hawaiian Islands. This reserve designation allows for aerial, in-water, and shore-based surveys to be uniquely implemented. This baseline study is the first island-wide sea turtle survey and monitoring effort of its kind to be implemented in the Hawaiian Islands. The main objectives of this study were to provide a summary of historical references and develop a comprehensive analysis of present-day sea turtle occurrence around Kahoʻolawe: species present, distribution and habitat use, size class and relative abundance, behavior, and fibropapillomatosis incidence. The results of these standardized survey methods will allow the most effective long-term monitoring of trends in numbers of turtles and use of habitats. Methodologies will become part of the Sea Turtle Management Plan for the Kahoʻolawe Island Reserve with statewide implication potential.

Background

Kaho'olawe Island Reserve, Hawai'i

The Hawaiian archipelago is the most isolated island chain in the world. This chain of 132 islands and reefs spans approximately 2,450 km and includes the remote, generally uninhabited Northwestern Hawaiian Islands (NWHI) as well as the populated Main Hawaiian Islands (Armstrong 1983). The Main Hawaiian Islands consist of Ni'ihau, Kaua'i, O'ahu, Moloka'i, Maui, Lāna'i, Kaho'olawe, and Hawai'i islands, with numerous other small islets (Figure 1).

Kaho'olawe (20°35'N 156°35'W) is the smallest of the eight Main Hawaiian Islands and is located approximately 10.8 km southwest of Maui and 28.7 km southeast of Lāna'i, and is considered a part of Maui Nui (Figure 2). Kaho'olawe's ~47 km shoreline is ~3.9% of the entire State's 1208 km of coastline. Kaho'olawe is 116.6 square km (28,800 acres) in total area and is 17.6 km long and 11.2 km wide at its broadest point. There is one small islet off the central southern coast called Pu'ukoa'e. The highest point of elevation, Luamakika, reaches 450 m above sea level (Armstrong 1983). Kaho'olawe receives less than 64 cm of rain annually and generally is a very dry and arid landscape. Alien vegetation, primarily kiawe (*Prosopis pallida*), dominates the coastal shrub and grasslands, but some rare native plants also exist there.

The ocean conditions surrounding Kaho'olawe are typically rough due to omnipresent wind and swell. The south and southeastern coasts are comprised of <240 m sea cliffs where the water depth quickly drops off past 60 fathoms (110 m) near shore (Figure 3). This shoreline is subjected to the prevailing strong easterly trade winds, currents, and swells (Figure 4). The island gradually slopes down to the north and northwestern facing shores where the 60-fathom depth is less than one km from shore. Along the western facing shore, this 60-fathom depth contour extends beyond the 2-mile (3.2 km) reserve boundary. This rocky coastline consists of four long calcareous sand beaches intermixed with coral rubble beaches (Figure 5). The northern facing shoreline is predominantly rocky with bays and small, detritus pocket beaches where gulches have formed (Figure 6). This shoreline is more sheltered than the other coastlines, but is still affected by northeasterly trade winds and winter swells. Surface currents run consistently to the southwest. Tide pool habitat and an extensive coral reef ecosystem thrive here, although some areas are heavily sedimented due to coastal runoff (Figure 7).

Historically, Kaho‘olawe was part of South Maui’s Honua‘ula district (Mākena area, directly across the Alalakeiki Channel) and was governed by the ali‘i (royalty) as such. Although details are scarce, it is thought that the whole island was divided into 12 ‘ilis (land sections). As a traditional form of land management, each ‘ili was taken care of by the people that inhabited it. Most resources were obtained from within these parcels, which stretched from the sea to the mountains, so these communities could live sustainably. The Kaho‘olawe Island Reserve Commission has slightly modified these twelve ‘ilis into ten divisions, which this study will utilize for distribution analyses (Figure 8).

Native Hawaiians likely inhabited Kahoʻolawe by 400 A.D. Traditionally Kahoʻolawe was revered as a wahi pana (sacred place) and a puʻuhonua (place of refuge), and is dedicated to Kanaloa, Hawaiian deity of the deep ocean. It was used as a training center for the navigation of voyaging canoes to and from the South Pacific. Several hundred semi-permanent residents utilized the island for agriculture and fishing. In 1500 Kahoʻolawe's population was estimated to be 725, but by 1750 it was only 72 (Hommon 1979). The 1800s brought missionary activities, a penal settlement (1826-1853) and ranching (sheep, cattle, goats) entrepreneurs. In 1981 Kahoʻolawe was listed as the "Kahoʻolawe Archaeological District" on the National Register for Historical Places, containing 544 archaeological and historic sites with over 2,000 features (Dames and Moore 1997).

Ranching persisted until the attack on Pearl Harbor in 1941. The island was then seized by the U.S. government for military training exercises and bombing rights. Nearly every type of ordnance known, except for chemical and nuclear, was exploded for training purposes. Torpedoes were launched at the coastline, ship-to-shore bombardments and landings were practiced, and aerial attacks were conducted. The island got the nickname "The Target Isle" as the explosions could be seen and felt on the surrounding islands. Three 500-ton TNT explosions in 1965 created a large crater along the southwestern coast called "Sailor's Hat" (Http://www.kahoolawe.hawaii.gov/history).

In the 1970s, grassroots protests over the abuse of the island manifested into illegal occupations to try to stop the bombing. The Protect Kahoʻolawe ʻOhana (PKO) was formed to challenge the U.S. Navy in litigation hearings. These protests were eventually successful and the bombing ceased after 50 years. In 1993 Congress mandated the U.S. Navy to remove the dangerous unexploded ordnance (UXO) and other debris that was left from the target range usage with a $400 million dollar budget. A two nautical mile radius boundary around the island was designated as the Kahoʻolawe Island Reserve (KIR). Unauthorized entry into KIR waters or on to the island is illegal. Commercial activities are prohibited. Formerly the Kahoʻolawe Island Conveyance Commission (KICC), a State agency called the Kahoʻolawe Island Reserve Commission (KIRC) was formed to manage the KIR and to oversee the Navy's cleanup project. In 2003, the cleanup project ended prematurely with only ~69% surface clearance and ~10% subsurface clearance of the island (KIRC 2002). None of the surrounding waters were cleared of UXO or debris, and these waters out to at least 120 ft are considered hazardous (Hutchinson et al. 1993).

The old military base camp barracks and galley remain on the west end of the island (Figure 9). These structures are still used by KIRC as the base of operations and although at least two personnel are always on the island, no one lives there permanently. Helicopter landing pads are maintained, as this is still the primary method of transportation to the island. The primary road runs uprange to Lua Makika, the region where the KIRC Restoration Program focuses their revegetation efforts. One rugged road leads to Keanakeiki and Kealaikahiki, and one to Sailor's Hat.

The KIRC controls access to Kahoʻolawe, continues to practice cultural, archaeological and environmental restoration, and is managing the KIR in trust for a future Native Hawaiian sovereign entity. This Native Hawaiian Cultural Reserve will once again become an important place where traditional Hawaiian practices will be renewed and passed on to future generations (Lauter 1992). The KIR approaches the management of its resources from a cultural perspective as well as a scientific one.

"The kino (physical manifestation) of Kanaloa is restored. Forests and shrublands of native plants and other biota clothe its slopes and valleys. Pristine ocean waters and healthy reef ecosystems are the foundation that supports and surround the island.

Nā poʻe Hawaiʻi (people of Hawaiʻi) care for the land in a manner which recognizes the island and ocean of Kanaloa as a living spiritual entity. Kanaloa is a puʻuhonua (refuge) and wahi pana (sacred place) where Native Hawaiian cultural practices flourish.

The piko of Kanaloa is the crossroads of past and future generations from which the Native Hawaiian lifestyle spreads throughout the islands."

Vision Statement
Kahoʻolawe Island Reserve Commission (2005)

Hawaiian Sea Turtles

Five of the world's seven species of sea turtles can be found in Hawaiian waters: leatherback (*Dermochelys coriacea*), olive Ridley (*Lepidochelys olivacea*), loggerhead (*Caretta caretta*), hawksbill (*Eretmochelys imbricata*), and green (*Chelonia mydas*). The threatened Hawaiian green sea turtle (*Chelonia mydas*) and critically endangered hawksbill sea turtle (*Eretmochelys imbricata*) are indigenous to Hawaiʻi and are most regularly found in the nearshore waters of the Hawaiian Archipelago. Leatherbacks, olive Ridleys, and loggerheads inhabit the pelagic Pacific (Ching 2001). This study focuses on the nearshore environment so green and hawksbill information will be emphasized (Figure 10).

In Hawaiian, the green and hawksbill are known as “honu” and “‘ea” or “honu‘ea”, respectively. Both honu and honu‘ea are featured in Hawaiian mythology, chants, and prayers (Emerson 1915; Fornander 1919-1920; Emory 1924; Beckwith 1970; Handy and Handy 1972; Johnson 1981). To some families, the sea turtle is their ‘aumakua, or guardian spirit. And, as it was common in so many other cultures where sea turtles are found, Hawaiians used them for their meat, skins, shells, and bones (Kaeppler 1978). Turtle was a favorite food of Pele, the famous volcano goddess (Fornander 1919-1920). Common women were not allowed to eat turtle, and this offense was punishable by death (Malo 1898). Hawksbill shell, particularly the laminae that is better known as “tortoiseshell”, was sought out for its medicinal purposes and to make implements such as fishhooks and jewelry (Balazs 1978; Kaeppler 1978; Reichel 1993). Although historical turtle abundance estimates are unknown, some uses of these products were monitored by a strict rule system, called kapu (taboo, prohibition). For example, it is thought that the honu‘ea shell was reserved for royalty (Eyre, unknown date).

Green sea turtles continued to be hunted for their meat and hawksbills for their shells until modern times. Although subsistence hunting had always occurred, the tourism market fueled a commercial industry that increased the demand. “The special market for the red meat is the principal feature of turtle exploitation in Hawai‘i. The market for polished shells is a casual one; calipee is not prepared, fat is discarded, and the hide is not saved for leather” (Hendrickson 1969). In the late 1960s a 200 lb. turtle would bring in at least $50 as restaurants paid $2.35 and more per pound of flesh (Hendrickson 1969).

Biologists recognized this issue and endorsed the State Division of Fish and Game’s Regulation 36, which made it unlawful to mutilate, injure, take, kill, or possess leatherbacks and hawksbills or their eggs. The maximum fine was set at $500 and was passed on May 30, 1974. This still allowed the home consumption of greens with a straight carapace length of $\geq$36” (although it was illegal to use nets to catch them) (Balazs 1976).

On July 3, 1975, George Balazs was quoted, “Although some subsistence taking of green turtles still occurs in Hawai‘i, I nevertheless must endorse the total ban of such activity, at least for the present time. As suggested (in the FEDERAL REGISTER notice) numerous alternate food sources are available from the sea and, based on my knowledge of the Hawaiian green turtle population, continued killing cannot be justified if viability is to be ensured” (Balazs 1976).

These species have since been completely protected by the U.S. Endangered Species Act of 1978 (NMFS and USFWS 1998), although restaurants were still illegally serving turtle products in the early 1980s (Balazs 1980a). Today, no restaurants are known to sell turtle, but poaching still occurs (Waite 2001; Monson 2003a and 2003b; pers. comm. Department of Conservation and Resources Enforcement 2005). In the current Hawai‘i economy, sea turtles are now believed to be worth more alive than dead. Sea turtles are a major tourist attraction, along with North Pacific humpback whales (*Megaptera novaeangliae*) and spinner dolphins (*Stenella longirostris*). They are heavily advertised in brochures and dominantly depicted in giftware and clothing. Sea turtles have become a symbol of Hawai‘i, quite a switch from being on the menu.

The National Marine Fisheries Service/National Oceanic and Atmospheric Association (NMFS/NOAA) is responsible for sea turtles when they are in the water, and the U.S. Fish and Wildlife Service (USFWS) has jurisdiction when they are on land (nesting and basking). NMFS/NOAA is carrying out numerous sea turtle research projects in Hawai‘i. There are at least 16 long-term research sites among the MHIs (Balazs et al. 2000). The Department of Land and Natural Resources (DLNR), numerous non-governmental organizations and other groups assist in the conservation of Hawai‘i's sea turtles. Current threats to Hawaiian sea turtles include poaching, marine and terrestrial habitat loss and degradation, invasive algae blooms, pollution, watercraft collisions, entanglement, and ingestion of marine debris and fishing gear, and harassment. Sharks, particularly tiger sharks (*Galeocerdo cuvier*), are their natural predators.

Eretmochelys imbricata

Hawksbills worldwide and Hawaiian hawksbills are categorized as a "critically endangered" species (IUCN 2004). Despite their protection it is still relatively rare to see a hawksbill while snorkeling or SCUBA diving the coral reefs in Hawai‘i. Population estimates and trend determination of the Hawaiian hawksbill are unavailable due to their scarcity and subsequent lack of research. Hendrickson (1969) stated that hawksbills were only encountered sporadically, with no known nesting. Hawksbills do not nest in the NWHIs like the honu, and are not known to occur there for other purposes (Kinan 2002). Jason Baker and Chad Yoshinaga disentangled a juvenile hawksbill from a net on 7/21/03 at Pearl and Hermes (S.E. Island) (J. Baker, pers. comm. 2005), seemingly the first report of a hawksbill in the NWHI. Balazs (1980b) reported infrequent hawksbill nesting on Hawai‘i Island and Moloka‘i. Hawksbill nests were first scientifically discovered on Maui in 1991 (Mangel et al. 2000). Hawksbills continue to nest at irregular intervals on the Main Hawaiian Islands of Moloka‘i, Maui, O‘ahu, and Hawai‘i, but hawksbill nest monitoring programs only occur on Maui and Hawai‘i (Mangel et al. 2000; Katahira et al. 1994; King et al. in press). Hawai‘i Island averages 13 nesting females per year, ~90% of the State’s known nesting hawksbill population (Katahira and Seitz 2002). From 1996-2003, Maui averaged 1.5 nesting females per year (King et al. in press). From 2004-2006, there was one nesting female on Maui each year (C. King, unpublished data).

Hawaiian hawksbills do not make long reproductive migrations, and haven’t been shown to leave the Main Hawaiian Islands. Satellite telemetry has revealed that some females utilize foraging and nesting areas that are simply on different sides of the same island (Hawai‘i Island) (Ellis et al. 2000). The majority of post-nesting females have been shown to travel to foraging grounds off of the Hamakua Coast of Hawai‘i Island. Other migrations have occurred from Maui to Hawai‘i Island, Moloka‘i, and O‘ahu, and from Hawai‘i Island to Maui (Figure 11) (Ellis et al. 2000; NMFS/NOAA and Hawai‘i Wildlife Fund, unpublished data).

Of 313 turtles caught for tagging purposes at Kiholo Bay on Hawai'i Island, only 3 were hawksbills (Balazs et al. 2000b). At some point they were recaptured in the same area, but details are unavailable from the publication. Individual hawksbills on Maui have been resighted in the same vicinities years later (C. King, unpublished data). Two individuals have exhibited site fidelity for a six-year period (P. Bennett and U. Keuper-Bennett, unpublished data).

Hawksbills worldwide are predominantly spongivores, but algae and invertebrates have been found in stomach contents (Witzell 1983; Meylan 1988; Limpus 1992; Lutz and Musick 1997; Diez and VanDam 2002; Spotila 2004). Little is known about the foraging habits of juvenile or adult Hawaiian hawksbills but their diets are thought to consist primarily of sponges (Balazs 1978a; NMFS and US FWS 1998). From the author's personal observations, they tend to be seen searching the crevices of finger coral (*Porites compressa*). Dr. Ralph C. DeFelice identified a forage species as *Chondrosia chucalla*, a possibly endemic sponge (U. Keuper-Bennett, pers. comm. email 2005). Ursula and Peter Bennett show a picture of a hawksbill eating an invasive algae species *Hypnea musciformis* and also cite the non-invasive algae *Melanamansia glomerata* as a forage species (http://www.turtles.org/limu/limu.htm). A hawksbill has been seen foraging in *Halimeda* spp beds, but it's uncertain whether it was targeting algae or invertebrates within the *Halimeda* (H. Spaulding, pers. comm. 2006), i.e. fireworms (*Eurythoe* spp.). SCUBA divers have reported seeing a juvenile hawksbill catching and eating octopus (*Octopus spp*.) (D. Bromwell and J. Svendson, pers. comm. 2006). Hawaiian hawksbills have been observed both foraging and resting during the day. Limited telemetry and time-depth recorder (TDR) research has shown that they do not forage at night or during inter-nesting periods (Hawai‘i Wildlife Fund, C. King and C. Littnan, unpublished data).

Chelonia mydas

Although in most regions green sea turtles are categorized as “endangered”, the Hawaiian honu is listed as a “threatened” species (IUCN 2004). Green turtles are now commonly found while snorkeling Hawaiian coral reefs. Over 90% of the Hawaiian green females nest every two to five years on the Northwestern Hawaiian Islands (namely the French Frigate Shoals) approximately 805 km (500 miles) northwest of O‘ahu (Niethammer et al. 1997). At least 50% of the nesting occurs on one island, East Island, and the females demonstrate very strong nest site fidelity to it (Balazs and Chaloupka 2004). Due to conservation efforts, the green population appears to be recovering. “It is now reasonable to conclude that the Hawaiian green turtle stock is well on the way to recovery after more than 25 years of protection of turtles and their nesting and foraging habitats in the Hawaiian Archipelago” (Balazs and Chaloupka 2004). The nesting female population of greens was estimated at approximately 1400 in the early 1990s (Balazs et al. 1993) and has been increasing in a step-wise fashion (Balazs and Chaloupka 2004).

“The early Hawaiians formed a relatively heavy population on the larger islands (Main Hawaiian Islands) and had a culture strongly directed toward heavy exploitation of the sea; and apparently most of the nesting aggregations on the larger islands had already been exploited to near-oblivion by the time of the coming of the white man” (Hendrickson 1969). In particular, a beach called Polihua (“eggs in bosom”) on the island of Lānaʻi was historically famous for its turtle nesting activities, which no longer occur on such a scale today, if at all (Emerson 1915; Emory 1924; Gay 1965; Balazs 1985). Clark (1980) mentioned that the last known green turtle nesting occurred here in 1954, but turtle tracks have been seen more recently (C. Venema, pers. comm. 2003). Just like Kahoʻolawe, Lānaʻi has not been systematically monitored. There have been 21st century green turtle nesting on Maui and Molokaʻi, but not on Hawaiʻi Island (Balazs et al. 2001; G. Balazs, unpublished data). From 2000-2006 there were at least 29 nests on 6 different Maui beaches (S. Hau and G. Nakai, unpublished data).

Hatchlings enter the sea from their nesting beaches, swim away from the nearshore reef and enter pelagic currents. This life history phase of unknown duration and biology is termed the "lost years" (Carr 1986; NMFS and USFWS 1998). Upon their return to Hawaiʻi, post-pelagic Hawaiian green sea turtles are still omnivorous but by adulthood they shift to a mostly vegetarian diet (Balazs 1980b; Balazs et al. 1987). Likely due to forage availability, Balazs (1979) reports an array of location-specific diets throughout the Hawaiian Archipelago, including 3 species of sea jellies in the NWHIs. A wide range of algae diet species include: *Pterocladia capillacea, Dictyospaeria cavernosa, Dictyota acuteloba, Gelidiopsis variabile, Gracilaria salicornia, Halimeda discoidea, Halimeda incrassata, Turbinaria ornata, Ulva reticulata, Ulva fasciata, Cladophora sericea, Acanthophora spicifera, Hypnea musciformis, Codium edule, Codium arabicum, Sargassum polyphyllum, Spyridia filamentosa, Melanamansia glomerata, Lyngbya majuscula, Gelidium pusillum, Caulerpa racemes,* and *Halophila hawaiiana* (endemic sea grass) (Balazs 1980b; Balazs et al. 1987; Balazs et al. 1993; Miya and Balazs 1993;

Landsberg et al. 1999; Russell and Balazs 2000; Balazs et al. 2000b; Gulko and Eckert 2003).

Juvenile and adult greens throughout the Main Hawaiian Islands have been observed resting and foraging together during the day and night, often inhabiting residential resting areas and foraging pastures (NMFS and USFWS 1998; Balazs et al. 2000b). Through tagging and photo-identification research, a very high degree of extended residency among coastal sites has been shown throughout the Hawaiian Islands (Balazs 1979; Balazs et al. 2000b; Bennett et al. 2000; Richardson et al. 2000). Resting places often consist of rock or coral reef ledges or man-made structures that turtles can wedge themselves into or hide under.

Depending on the individual turtles and their environments, they undertake a "daily commute" to their nearby shallow-water foraging habitats where limu (algae) grows on rocks along the shoreline, often with the help of fresh water and nutrient input. Miya and Balazs (1993) found that during late afternoon to early evening the number of turtles sighted from shore increased compared to morning and early afternoon. However, sonic-tagged turtles in Kiholo Bay on Hawai‘i Island rested at night, and then made their short commutes to forage in the early morning (Balazs et al. 2000b). Balazs (1996) recognized this switch in foraging behavior from night to day in the mid-1980s and attributed it to the reduction of hunting pressure from humans. In the past, turtles were not seen foraging so nonchalantly in such close proximity to shore and humans in the daylight.

Basking is a behavior almost exclusively unique to Hawaiian honu, both male and female juveniles and adults, in which they crawl out of the ocean and lie motionless for hours on the shoreline (beaches, rocks or man-made structures) at night or during the day. Honu might practice this behavior to rest, raise their body temperature, or to avoid predators or the harassment from mates (Whittow and Balazs 1982; Balazs 1996). This behavior has historically occurred on the Northwestern Hawaiian Islands, but has only been taking place in the last ten years on Hawai‘i Island, O‘ahu and Kaua‘i (Balazs 1996; Balazs et al. 2000b; C. King, pers. obs.).

Fibropapillomatosis

Honu, like other green sea turtles worldwide, are plagued with fibropapillomatosis (FP), an often deadly tumor-forming disease that was first discovered in Florida in 1938 and Hawai‘i in 1958 (Brill et al. 1995; Landsberg et al. 1999; Work and Balazs 1999). FP has since spread to loggerheads, olive ridleys (Aguirre 1998) flatbacks (*Natator depressus*) (Gulko and Eckert 2003), and hawksbills and leatherbacks (Spotila 2004). This disease has been documented on all of the MHIs, sometimes in epidemic proportions. The only known exception is the Kona/Kohala western coast of Hawai‘i Island where virtually no tumored turtles have been reported (Balazs et al. 2000b; Murakawa et al. 2000; Work et al. 2001). Kaho‘olawe was not included in any of these studies.

The tumors are benign, but tumored turtles have a depressed immune status (Work et al. 2001). The tumors, which resemble whitish gray cauliflower, can be very numerous and can grow larger than a grapefruit (Figure 12). If these tumors grow near a turtle’s eye, on its neck, throat, flippers, tail, or internal organs, this impairs its vision, swimming, breathing, feeding, and digestive abilities. Unexplainably, tumors in the oral cavity, which are very common in tumored honu, are not found in Florida's tumored greens (Balazs et al. 1997).

Although severe cases tend to be fatal, tumor regression has been shown, sometimes remarkably in less than 16 months (Balazs et al. 2000a; Bennett et al. 2000). In Hawai'i, this disease is significantly biased to females, and juveniles are the most susceptible and seem to be the most severely affected by this disease (Balazs et al. 1998; Murakawa et al. 2000; Bennett et al. 2000; Work et al. 2001). Turtles with severe cases grow significantly slower than those with less serious cases (Balazs et al. 2000a). Fibropapillomatosis is a major cause of dead and live strandings (Murakawa et al. 2000).

Despite worldwide research on this disease, its cause is still unknown (Morris and Balazs 1994; Murakawa et al. 1999; Davidson 2001; Spotila 2004). Landsberg et al (1999) hypothesizes that "the etiology of FP involves a tumor promoter such as okadaic acid that operates in conjunction with a tumor indicator such as a herpesvirus or retrovirus. The potential for dietary exposure to biotoxins cannot be underestimated and may be a dominant contributory factor to virus expression and FP in marine turtles." Among preferred forage species at high FP sites, a high abundance of toxic benthic dinoflagellates (*Prorocentrum* spp.) that are known to produce okadaic acid were found.

One possible method of FP transmission could be cleaner fish that move from turtle to turtle, becoming vectors. New recruits into the nearshore reef system from epipelagic waters are typically 35-45 cm and are recognizable by the complete absence of algae and barnacles (Losey et al. 1994). Older turtles do accumulate algae, barnacles and other epibionts on their shells and skin. These turtles tend to seek out certain species of fish that will graze on these algae and pick off these epibionts. Sites where this occurs are known as “cleaning stations”, and are often in semi-permanent locations that turtles return to routinely for this service.

Turtles actually pose during this process: “Swimming ceased and flippers were usually fully extended and drooped downward in a relaxed position. The neck was often fully extended and arched upward or downward. Approach and, especially, feeding bites by fishes on the skin produced seemingly cooperative responses in which the cleaning site was more fully exposed” (Losey et al. 1994). It is advantageous for them to be “cleaned” by fish to remain streamlined, and it is as mutually beneficial for the fish because the turtles deliver the food source. *Thallasoma duperrey* specializes in barnacle consumption, *Canthigaster jactator* picks at white spots (like tumors) in the head region, while *Acanthurus nigrofuscus, Zebrasoma flavescens, Ctenochaetus strigosus,* and *Scarus* spp. are shell cleaners (Losey et al. 1994; Gulko and Eckert 2003).

Sea Turtle Occurrence within the KIR

Historical Significance

The importance of taking into consideration what "used to be" when assessing populations and making management decisions has been emphasized in the shifting baseline phenomenon (Pauly 1995; Sheppard 1995). Kahoʻolawe has a rich cultural history, with close ties to the ocean and its creatures. Kanaloa, Hawaiian "God of the Deep Ocean", is thought to be physically manifested as the island of Kahoʻolawe, highlighting the island's sacredness and cultural importance. Undoubtedly, much information has been lost or altered throughout history, but available documents were reviewed for Kahoʻolawe-related sea turtle references.

Numerous organizations have completed archaeological surveys of Kahoʻolawe, with only one turtle-related finding recorded. Turtle shell fishhooks and pieces of hawksbill sea turtle carapaces were found in a shrine at Kamōhio Bay (McAllister 1933). The origins of these materials, whether they were from turtles caught on Kahoʻolawe or a neighbor island, are unknown.

Petroglyphs of varying representations are widespread throughout the Main Hawaiian Islands. Animal figures were much less abundant compared to human figures. "Other than a few turtles, crabs, and some other scarcely discernible sea creatures, sea life was largely neglected" (Cox 1970). At the time of this 1970 publication, Kahoʻolawe's petroglyphs were undiscovered, or unknown to the authors.

Patrick Ching (2001) compiled a photo album of Hawaiian honu petroglyphs (Figure 13). Four are found on Hawai‘i Island and one was from Lāna‘i. Kaho‘olawe is also fairly rich with petroglyphs, and two in particular resemble turtles. It should be stated that the recognition of these two Kaho‘olawe petroglyphs as being turtles is only a theory of the author, based solely on their appearances. One potential turtle petroglyph was found at Kaukaukapapa, although it is undescribed (Figures 14 and 15) (Community Development Pacific, Inc. 1994). Another is located inland at one of the oldest sites, near the top of a gulch that feeds Kanapou Bay (Figure 14 and 15). It is described as a “small triangle figure, phallic with curtailed legs and arms (11x12cm)” (Lee and Stasack 1993). The Kaho‘olawe petroglyphs share some features with the other turtle petroglyphs, but they are all unique in comparison.

The locations are also interesting, as Kaukaukapapa is the region where the large calcareous sand beaches exist, the most likely turtle nesting area (Figure 15). And Kanapou also has a large beach that could have been utilized by nesting turtles. However, the settings may not be a factor since one of the turtle petroglyphs on Lāna‘i is located even further from the coast than the one above Kanapou. And certainly other sea turtle-related activities or occurrences (possibly not even related to Kaho‘olawe) could have been what triggered these creations. “The Kaho‘olawe petroglyphs are purposeful and sincere, revealing the perceptivity of their makers… It seems evident that they possessed mana, or spiritual power” (Lee and Stasack 1993). Although it is quite doubtful that the truth will ever be known, these petroglyphs could be the result of Kaho‘olawe-related turtle observations.

Two turtle-related place names on Kaho‘olawe are associated with streams (Protect Kaho‘olawe Fund 1997). “Wai Honu Gulch” runs down the southwestern mountainside to the areas where the large sandy beaches are located. Wai means “water, river, stream”, and honu is the general name for turtle (Pukui et al. 1975). “Punawai Honu” is located on the south side of Kanapou Bay. Punawai means “water spring”. No history of the reasons, if any, behind these names have been found, and they are not labeled on all maps (Figure 15).

The most controversial place name on Kaho‘olawe happens to be the only other turtle-related name. A bay on the southwest coast of Kaho‘olawe apparently used to be called “Honukanaenae”. This was translated to “chant for the turtles” by Inez Ashdown, a woman who grew up on Kaho‘olawe on her father’s cattle ranch (Ashdown 1976; in Lindsey et al. 1997). She has stated that ranch workers had seen sea turtles nesting there, but details of these accounts have not been found (Balazs 1978). Ashdown wrote that two ko‘a (fishing shrines) were built by ‘Ai‘ai, son of Ku‘ula, the god of the fishermen. These were located here at Hanakanaia Bay (as she spelled it) for the “turtle or Honu-god which protects Kaho‘olawe” (in Reichel 1993). Ashdown says that ‘Ai‘ai also “blessed this area for the Honu (turtles) to lay their eggs, and for the koholā (whales) to be safe. Honu, the sacred turtle protects the cave also. Paniolo (cowboys) knew an oli (chant) about Ka nae nae and it was a prayer or Kāhea (call) to Ke Akua (God) and to ‘aumākua (ancestral spirits) whose form seen is the Honu. There also is a certain hula, Hula Honu done to this chant” (in Reeve 1993).

In yet another description, Ashdown (1979) states that “But my cowboys claimed that the proper name is Honu-kana‘i, meaning where the sacred turtle guards this land which will return to its heirs some day. Lae Ke-ala-i-kahiki is the tail and it points the way to the channel between Kaho‘olawe and Lāna‘i, and to the horizon, or Kahiki-ku”. These varying spellings and meanings are coupled with her apparent confusion of their exact locations, as she has labeled them in slightly different places over the course of her writings (in Reeve 1993). Although this has tarnished her credibility, her references can still be appreciated for what they are worth. There is a consistent mention of turtles (possibly nesting and/or basking) on the western coast of Kaho‘olawe.

Adding a hint of truth to Ashdown’s stories, during a videotaped interview with Native Hawaiian Harry Kunihi Mitchell, Mitchell mentioned, “A bay between Honakanai‘a and Kealaikahiki named Honukanaenae near Smuggler’s Bay, means ‘tired turtle’. This is where the turtles came to rest and to lay their eggs. It is not currently used as a nesting spot by turtles, perhaps because of the location of the military encampment in the vicinity” (Aluli and McGregor 1992). Smuggler’s Bay post-historically got its name because of its role as a drop-off location by opium traders sneaking this drug into Hawai‘i (Clark 1980).

Recent maps do not label Honukanaenae (Kaho‘olawe Island Reserve Commission 2002). There is still a beach there, which the KIRC Ocean Program has nicknamed “Seal Beach” due to common monk seal occurrences. Smuggler’s Cove is now labeled as

“Honokanai‘a”, which means “Bay of the dolphins” or “the dolphin harbor” (Aluli and McGregor 1992; Reeve 1993). This designation seems logical, because Hawaiian spinner dolphins visit this bay on a regular basis, but it is unknown if they did historically as this version of the name suggests. Ashdown also makes references to this effect (Reeve 1993). These two names are very similar, adding to the confusion of their meanings and designations. In some references both are included; Honukanaenae is located just north of Hanakanai‘a, also spelled Honokanai‘a (Figure 15) (Protect Kaho‘olawe Fund 1997).

The Kaho‘olawe Island Conveyance Commission (1993) compiled thirty-five different references for this area (from 1905-1984), most of which were similar. It no longer seems possible to further reconstruct these historical place names due to the loss of written and oral history over time. These names may have reflected a nesting or basking population of turtles, but further information, if it existed, seems to have been lost.

Recent Studies

Previous studies and reports of Kaho‘olawe’s resources, as well as Hawaiian sea turtle publications, were thoroughly reviewed for any Kaho‘olawe sea turtle sightings and references that may provide insight into Kaho‘olawe’s sea turtles at that particular time. Kaho‘olawe’s nearshore ecosystem has not been thoroughly studied by organizations outside the KIRC, which has just undertaken its monitoring within the past 10 years. Therefore there is a very limited written knowledge of the condition of Kaho‘olawe’s nearshore environment, and especially turtle populations, prior to KIRC's establishment and this study.

"Hawaiian lore points to nesting on some of the more isolated beaches and there are still occasional reports of single nestings, but there is no longer any significant pattern of nesting on any of the inhabited islands (Hawai'i, Maui, Moloka'i, O'ahu, Lāna'i, Kaua'i, and Ni'ihau)" (Hendrickson 1969). Kaho'olawe was not included here, but Balazs (1978b) did include Kaho'olawe in his statement that green nesting and basking are not known to occur on any of the eight MHIs. This is the only reference to Kaho'olawe from Hawaiian sea turtle scientific publications to date. A book titled "Kaho'olawe Nā Leo o Kanaloa" says, "Like the nai'a, the endangered honu (green sea turtle) is a kinolau of Kanaloa. Sea turtle populations have begun to reestablish themselves in the waters around Kaho'olawe, and recently honu have been seen laying eggs in the sands of the island's western beaches." ('Ai Pōhaku Press 1995). Details of the source for this reference have not been found.

Seven non-KIRC studies and reports (1972-1998) were found to contain 66 references to sea turtles, of which 54 provided location-specific information which allowed mapping (Figure 16) (Balazs 1978; Environmental Impact Study Corp. for the US Navy 1978; The Nature Conservancy 1990 survey in Gon et al. 1992; Department of Land and Natural Resources Division of Aquatic Resources 1993; Jokiel et al. University of Hawai'i, Hawai'i Institute of Marine Biology 1993; Kaho'olawe Island Conveyance Commission 1993; Protect Kaho'olawe Fund 1997). Sighting distributions are summarized in Table 1 and sightings are grouped by source type in Table 2. Four studies/reports did not yield any turtle sightings during their Kahoʻolawe research activities, although turtles were not a priority concern (State of Hawaiʻi, Division of Fish and Game 1972; US Dept. of Commerce 1991; Gon et al. The Nature Conservancy Hawaiʻi Heritage Program 1992; Coles et al. Bishop Museum 1998). One report provides herpetofauna restoration recommendations and a brief overview of Kahoʻolawe's sea turtle occurrence (Lindsey et al. US Geological Survey and Dept. of Agriculture 1997). Table 3 lists the reviewed studies and their survey efforts.

To date, the only sea turtle-specific study that has been undertaken was done in 1978 by George Balazs (National Marine Fisheries Service, NOAA Honolulu Lab). The investigation was considered preliminary, as he examined only 16.5% of the coastline. In these 4 days, 4 green turtles were documented while conducting a variety of aerial, coastal, and snorkel surveys (Balazs 1978c). This low number of sightings in comparison to what was typically seen around the other Main Hawaiian Islands at that time may be why Kahoʻolawe's sea turtle population has gone unstudied for so long, along with logistical difficulties of accessing the island. However, without a longer-term, systematic study such as this one, Kahoʻolawe's sea turtle population and subsequent habitat utilization cannot be fully characterized.

MATERIALS AND METHODS

Research Approach

As recognized in sea turtle recovery plans, certain research priorities are highlighted: "determine population size, status, and trends through long-term regular nesting beach and in-water censuses, and identify and protect primary nesting and foraging areas for the species…" (NMFS and USFWS 1998).

Due to the restrictive nature of accessing the Kaho'olawe Island Reserve because of Naval control (until Nov. 2003), the danger of unexploded ordnance, and the overall rough ocean conditions, studying many parts of the island was logistically difficult and expensive. Working with KIRC's available resources, the following field survey types were possible: aerial, in-water, vessel and shore-based. The KIRC Ocean Resources Management Program was fairly new, so the author was able to develop a combination of survey protocols from August 2002 to January 2003. The results of these trial/training surveys will be analyzed separately, along with all other previous turtle sightings and information the author compiled. Resources were made available and data collection was implemented once the author returned from taking courses at Nova Southeastern University in July 2003. Consistent data collection for this project lasted 2½ years, through December 2005.

Standardized assessment protocols were designed for each of these four survey types for ongoing assessment. These results can be compared to enable the most effective long-term monitoring of trends. Every effort to complete as many surveys as possible was made. We accessed the reserve an average of one day each week, typically two to three vessel days and one aerial survey each month. This project piggy-backed other KIRC Ocean Resources Management Program research monitoring of the coral reefs, ‘ilioholoikauaua, (Hawaiian monk seals, *Monachus schauinslandi*), nai‘a (Hawaiian spinner dolphins, *Stenella longirostris* and bottlenose, *Tursiops truncatus*), koholā (North Pacific humpback whales, *Megaptera novaeangliae*), manō (shark spp.) and other apex predators, and kai manu (seabird spp.).

These census surveys yielded such information as habitat usage, FP rates, overall health conditions, behavioral indexes, size class ratios, as well as density distributions and the relative estimation of population size (Hirth et al. 1992; Limpus 1992; Leon and Diez 1999; Kolinski et al. 2001). These former data aren’t available using aerial survey techniques but contribute to the “ground truthing” of aerial data. Background information, incidental, and opportunistic sightings were compared to these results.

Survey Design

Aerial Surveys

The KIRC Ocean Program first used helicopters for irregular surveying purposes in 2002, but the focus was on megafauna such as monk seals, dolphins, and whales, with turtles spotted very occasionally. During the first KIRC survey that the author participated in during October 2002, 12 turtles were spotted showing that these animals could also be recorded if an effort was made to do so. Turtles can be seen while they are breathing at the surface or swimming slightly subsurface. Since the coastline was being searched for monk seals, basking turtles, and any signs of nesting (tracks on the beach made by nesting females) were also included. Methodologies and personnel were standardized and monthly flights were scheduled.

Three different helicopters were used due to availability during the course of this 3-year survey, but they were all Bell 206 Longrangers: 993, 9RS, and 51H (Figure 17). Each helicopter could seat 6 people including the pilot, but for surveying purposes there were 3 primary observers. These three surveyors were nearly always the same experienced people (Cheryl King, Dean Tokishi, Charles Lindsey, and Alastair Hebard) in order to avoid observer bias when comparing survey results (Figure 17). Each surveyor wore polarized sunglasses and a hat to minimize sun glare. Although conducting aerial surveys closest to noon to avoid glare from the sun is recommended, this was not possible due to Kahoʻolawe's windy conditions that were characteristically present by mid-morning (Henwood and Epperly 1999; TCOT workshop 2002). The majority of the circumnavigations were flown in the morning between 8:00 and 11:00 am.

There were two coastal observers and one seaward observer on each survey. One observer (D. Tokishi) sat on the forward coastal side next to the pilot, who was on the seaward side. The other two observers faced forward, side-by-side, behind them. The seaward observer (A. Hebard/C. Lindsey) was strictly responsible for the seaward side of the flight path and did not look through to the coastal side of the helicopter. The rear coastal observer (C. King) was strictly responsible for the coastal side of the flight path and did not look through to the seaward side until a turtle sighting was made and the helicopter circled around. D. Tokishi was the master data recorder and retained operational power of the global positioning system (GPS) (Figure 18). C. King recorded turtle-specific information on a streamlined data sheet and had a digital camera (Olympus C-700 Ultra 27x Zoom) (Figure 19). A. Hebard/C. Lindsey did not have a data sheet or recording device due to being the sole seaward observer. During every circumnavigation, all side doors and windows were always removed from the helicopter so that maximum visibility could be maintained. This allowed for an unobstructed view in which the observers could search down, forward, and behind the helicopter, leaning out when necessary.

Two window seats faced backwards, opposite the rear coastal and seaward observers, and were used for silent, independent observers on occasion. A headset intercom system enabled full communication between observers except for these silent observers who could hear us but did not call out their sightings. They were instructed to record the times of their sightings. Since the observers could see each other, the silent observers' writings may have cued the primary observers' attention to a sighting that they may have missed otherwise. For this reason, the silent observer was instructed to write down "fake" sightings at random as well. Since the primary observers also knew these instructions, their inherent tendencies to be influenced by the silent observers were minimized.

We had nine different pilots (one for 45% and one for 21% of the flights), all of who were highly skilled and familiar with Kahoʻolawe's coastline. The standardized flight height was 30 m (100 ft), but there was some minor variability due to windy conditions.

This elevation was originally chosen primarily for the best monk seal sighting potential since they are quite cryptic when hauled out among the rocks and flying higher decreased their detection rate. A higher elevation also decreased the chances of distinguishing turtles from shallow coral reefs. Although flying higher would allow more area to be seen, the swath of vision from this ~30 m elevation allowed us to view the majority if not all of the nearshore and offshore reef areas of interest. The flight speed tended to range (25-60 knots) in different places around the island depending on the winds, but each circumnavigation took approximately 60 minutes (mean=63.9, range 49-80, SE=1.73). The total time of the flights increased with the number of animals (not just turtles) we saw, circled around to identify, and photograph. Recognizing the potential of additional sightings in proximity to the initial sighting the second time around, searching did not cease when the helicopter circled.

The flight patterns contoured the coastline less than 100 meters from shore, depending on topography, remaining consistent between surveys. This gave the coastal observers a swath of this amount of water plus the immediate coastline to investigate. The front coastal observer also searched through the front windshield and nose bubble window. This minimized the possibility of missing animals that were directly underneath the flight path. The seaward observer could not see the coastline. No effort was made to limit the viewing area so this methodology does not qualify as a strip transect. Quantifying the exact distance of each sighting from the helicopter (although the distance from the shoreline was recorded for turtles) was not practical; therefore this was not a true line-transect technique either. The survey results yielded an index of abundance with sighting rates (turtles/km) and (turtles/hour) (Bjorndal and Bolten 2000).

During each survey the total on-effort survey times, average speed, and altitude along with environmental conditions such as beaufort and sun glare were documented. A streamlined turtle data sheet was made to minimize transcribing time that could affect observations (Figure 19). Once a turtle was spotted the sighting was called out and the following data were recorded: time, GPS location, who made the sighting, the side of the helicopter the sighting was made from, distance from shore to the turtle (<5, 5-20, >20, or >40m), water clarity (clear or murky), marine habitat type (coral reef, sandy, rocky, or too deep/murky to tell), and behavior (foraging, breathing at the surface or swimming). Estimated size in carapace length was also recorded using the following categories: “small”= <2 ft, “medium”= 2 ft – 3 ft, and “large”= >3 ft. When unsure about size categories, overlapping categories such as “small-medium” or “medium-large” were recorded. Large turtles could potentially be sexed by viewing the tails. Adult males have elongated and thick tails that grow well beyond their carapace and hind flippers while females have short tails that don’t extend past their flippers. Positively distinguishing between species was not possible due to the similarities between greens and hawksbills. Any associations with marine debris (nets, rubbish) and detritus were documented.

The turtles’ reactions to the helicopter were recorded (no reaction or abrupt dive from surface). It is of course difficult to determine for sure if we had any effect or whether the turtle was already coincidentally diving when we passed. If the turtle stayed at the surface and wind conditions and time permitted it, we would circle back around to photograph it. Whether or not the turtle was re-located and its reaction to our second pass and/or hovering, were documented. If additional turtles or other animals were seen during this time, they were recorded as well.

Depending on fuel and time, overflights to and from Maui were utilized by surveying the north coast of Kahoʻolawe from Base Camp at Honokanaiʻa to Hakioawa/Oawawahie (17.6 km, 11 miles). The same data were taken, but circling animals usually wasn't done. The major difference with these flights was that the doors and windows were on, limiting the viewing capabilities slightly in comparison to the circumnavigations. Off-effort sightings made while conducting other projects were considered incidental and analyzed independently from the circumnavigation and north coast surveys. Also, during return flights to the heliport on Maui, opportunistic turtle counts were occasionally made along Maui's southeastern coastline within Maʻalaea Bay (Figure 20).

In-Water Surveys

The KIRC vessel *Hākilo* ("to observe closely, spy on, eavesdrop") is a 30' Almar Sounder with 2, 150 Yanmar engines with jet drive steering (Figure 21). It has a very shallow draft, allowing it to approach shore closely and navigate the shallow coral reef when necessary. A depth gauge aided in navigating and recording depth information for sightings near the vessel. We launched from the Kihei Boat Ramp, which was located on Maui's southern coastline within Maʻalaea Bay. The Alalakeiki Channel crossing typically took under an hour going, but over an hour on the return trip due to the typical increase in beaufort sea state in the afternoon.

The objective was to survey as much of the island as possible, but adverse conditions and conducting other research limited the amount and location of transects that could be completed. Each site was chosen randomly according to personnel availability, weather, visibility, and ocean conditions. Each in-water snorkel transect was ~60 minutes long and the start and end locations were recorded with a GPS so the coverage area could be quantified. Each survey involved 2-8 snorkelers swimming together at the surface in a single row perpendicular to and contouring the shoreline, focusing on the depth range of 1-40 ft (Leon and Diez 1999). The observers were arranged according to bathymetry, with the shoremost person remaining at ~5 ft depth making sure that the inshore area was visible. The seaward observer remained at ~40 ft while covering this area and seaward to ~50 ft. The other observers were spaced out between these two to complete the coverage. The purpose was to make a thorough “sweep” of the area, detecting the turtles that were in the region. While everyone swam at a constant speed (which varied according to currents and conditions), ledges and crevices that might have qualified as turtle resting areas were checked briefly by freediving.

Once a turtle was found, photographs were taken (both profiles, front flippers, fibropapilloma tumors, and any unique features) for individual identification purposes. Turtles have unique arrangements of scutes on both sides of their faces and flippers, and photographing them is a very nonobtrusive way of tracking them across time (Richardson et al. 1999; Bennett et al. 2000). This can be used as a mark-recapture method in the place of tagging (Gerrodette and Taylor 1999).

A specialized data sheet was created to collect the following data for each turtle: time, location, depth, distance from shore (<5, 5-20, >20, or >40m), habitat (coral reef, sandy, or rocky), size in carapace length (small= <2 ft, medium= 2 ft – 3 ft, large= >3 ft) (Parker 1991), sex if large size only (see previous description in aerial methodology), fibropapilloma (FP) score taking into account tumor size and number (0= no FP, 1= lightly afflicted, 2= moderately afflicted, and 3= heavily afflicted) (Work and Balazs 1999). Tags, injuries or other notable characteristics, as well as each turtle's initial behavior (swimming, resting, foraging, breathing, or posing at a cleaning station) were also recorded. Each turtle's behavioral reaction to human presence was also documented: tolerance (approaches or doesn't swim away), cautionary departure (swims slowly away and keeps its distance), or flight (rapid departure) (Figure 22). Sometimes there was a combination of reactions, such as to freediving. When a turtle brushes one of its front flippers across its face in a sweeping motion this is termed "flipper swiping", and could possibly be a display of displeasure (Davidson 2001). The occurrence of this behavior was documented as well.

Shore and Vessel-Based Surveys

Survey time and accessible locations were limited on Kaho'olawe. Shore-based surveys of the nearshore environment were useful for opportunistically searching areas while we were conducting other surveys, such as for monk seals. Observers were stationed at different places, preferably at elevated viewpoints, for various time intervals. Depending on the area, binoculars were used as necessary to scan the surface of the water. When a turtle was spotted, as many details of the sighting were recorded as possible (similar information to aerial and in-water surveys).

Shore-based surveys of the terrestrial environment included coastal hikes to assess potential nesting, basking, and foraging habitats. A majority of these hikes covered all the west end beaches from Kaukaukapapa to Honokanaiʻa (~5 km) (Figure 15). Most of these surveys took place opportunistically from June through November. This time period coincides with the nesting and hatching season for both greens and hawksbills allowing for the greatest possibility of discovering adult or hatchling tracks. Due to the perpetual risk of unexploded ordnance in this area, we had to be escorted by trained Navy Explosive Ordnance Disposal Technicians (EODs). This added expense to KIRC minimized the number of shore-based surveys that were undertaken.

Viewing these and the other pocket beaches from *Hākilo* (and from helicopters) was done whenever possible, although the detection of hatchling tracks was not realistic. Turtles breathing at the surface were searched for whenever traveling through the reserve. The author faced forward and searched the coastal side of the vessel, and the captain made sightings from the bow. Other passengers also contributed sightings, but were not dedicated observers. With such high variability in vessel speed, route, glare, and beaufort conditions, and therefore effort, all sightings made from *Hākilo* were considered incidental and analyzed on a per day basis.

Opportunistic Sightings and Anecdotal Interviews

Collecting opportunistic sightings and anecdotal information through "talk story" interviews has contributed to the depth of this study. There are many fascinating people that have spent valuable time on Kahoʻolawe, however the author could not locate and interview all of them. Therefore, some possible insights into the turtles of Kahoʻolawe were missed.

Three major groups that have ties to the island provided sighting information: KIRC employees/volunteers, the Protect Kahoʻolawe ʻOhana (the cultural group that was instrumental in ending the bombing of the island), and Parsons UXB employees (the trained explosive detonators and other personnel contracted by the Navy for the cleanup). This information was organized into two categories: anecdotal and opportunistic. Anecdotal information was exchanged when the casual chance to talk to someone about his or her Kahoʻolawe turtle encounters arose ("talk story" sessions as they are recognized in Hawaiʻi). No formal questionnaire was made, so responses weren't analyzed quantitatively, but all of this information was still compiled and mapped (Figures 23 and 24). Opportunistic sightings were those that got reported from numerous sources and that were obtained by reviewing old paperwork, emails, and field notebooks. Incidental documentation from old *Hākilo* logbooks was grouped and analyzed separately (Tables 1 and 2).

RESULTS

Survey Effort

Tables 4-8 present summaries of each survey type's research efforts. With the addition of past reports, anecdotal, and opportunistic sightings, a total of 708 turtle sightings and references were collated (Table 2). The compilation of all data collected yielded 671 location-specific data points, in which 157 (23.4%) were in the Hakioawa region (ʻili 6) (Tables 1 and 9, Figure 25). The second-most abundant region was Kealaikahiki (ʻili 1), followed by Kākā (ʻili 8), Honokoʻa (ʻili 2), and Ahupū (ʻili 3). There were only limited areas around the island in which no turtles were ever reported in the past or seen during the course of this project (Figure 26). Each survey type collected valuable information, and these results are explained below.

Aerial Surveys

Circumnavigations

A total of 245 turtle sightings were made during 39 circumnavigations (Table 10, Figure 27). Ten of these surveys were not standardized, therefore were analyzed as aerial incidentals (see below). During 29 standardized, monthly circumnavigation surveys from July 2003 through December 2005, 209 turtles were sighted (Table 11, Figure 28). Average number of turtles/survey varied annually: 10.6, 7.7 and 5.3 (2003, 2004 and 2005) (Table 4). The overall mean number of turtles observed per survey was 7.2 (SD=3.4, SE=0.64), ranging widely from 1 to 14 (Table 12). The totals from the 24 surveys in 2004 and 2005 were significantly different with a 95% confidence interval (2-way ANOVA: F=5.96, df=1, P=0.033).

Relative seasonal abundance for standardized circumnavigation surveys was analyzed and distributions were mapped by year (Figures 29-32). The monthly totals from the 24 surveys in 2004 and 2005 were not significantly different with a 95% confidence interval (2-way ANOVA: F=1.97, df=11, P=0.138). November had the highest overall mean of 11.5 turtles (n=2), and February had the lowest mean of 2.5 (n=3). Analyzing the means between nesting (April-September) and non-nesting (October-March) seasons yielded no significant difference between these two seasons (2-way ANOVA: F=0.14, df=1, P=0.744) (Figure 33). The higher overall mean was during non-nesting season. The seasonal differences were significantly different among years (2-way ANOVA: F=22.86, df=2, P=0.042), which were expected since the total means between years were shown to differ.

Using the ~47 km (29-mile) coastline value, the 7.2 turtle sightings/survey mean density equated to 0.153/km (0.248/mile) (Table 12). The minimum was 0.02/km (0.03/mile) for one turtle observed per circumnavigation, and the maximum was 0.30/km (0.48/mile) for 14 turtles observed per circumnavigation. The most common number of turtles sighted per survey was 5, 6, and 7 (during four surveys each) (Figure 34). Using the 63.9-minute average time of all standardized circumnavigations and the 7.2 turtle sightings/survey mean produced a 0.11/min (6.78/hr) mean sighting frequency. The maximum turtle sightings/minute for a survey was 0.29.

North Coast Surveys

A total of 43 turtle sightings were made during 19 standardized north coast flights (Figure 35). Turtle sightings per survey ranged between zero and six, with a mean of 2.3 (SD=1.76, SE=0.40) (Table 12). Average number of turtle sightings/survey/year was 2.8, 1.8, and 2.5 for 2003, 2004, and 2005 (Table 5). Using the ~18 km (11-mile) value for this section of coastline, the 2.3 turtle sightings/survey mean density equated to 0.131/km (0.209/mile). The minimum was zero turtles/km per survey, and the maximum of six was 0.33/km (0.55/mile). The most common number of turtles sighted per survey was one (during 5 surveys), for a 0.06/km (0.09/mile) density (Figure 36 and Table 12).

Using the 19.7-minute average time of all north coast surveys produced a 0.12/min mean sighting frequency (Table 12). The maximum turtle sightings/minute for a survey was 0.46. Relative seasonal abundance of turtle sightings was mapped, but not statistically analyzed due to the uneven effort among months and years (Figure 35). There were no obvious distribution trends.

Incidental Aerial Sightings

Information was collated for a total of 52 incidental aerial sightings from 2002-2005 (Figure 37). Independent observers made 7 of these sightings during one north coast survey (n=3) and two standardized circumnavigation surveys (n=4). When added to the 252 standardized survey sightings, these seven additional sightings constituted only 2.7% of the total. This was a small fraction when there were a total of 15 independent observers on 12 of the 29 circumnavigation flights and 7 independent observers on 5 of the 19 standardized north coast flights. Therefore, as was shown by the independent observers' low contribution of additional turtle sightings, this credits confidence to the primary observers' abilities to spot turtles and the quality of the data collected.

Also included in this incidental category were three non-turtle focused, nonstandardized aerial circumnavigations (which recorded a total of one turtle) that were completed in 2002 prior to this research project. Nineteen sightings were made during the two experimental design/training flights in October and December 2002. These twenty sightings plus sixteen that were made during five surveys (without the author and the other two primary observers) at the beginning of 2003 were considered incidental to avoid observer and effort biases. Figure 38 shows how including these surveys barely affected the monthly means. Also shown in this figure were the insignificant effects of the 4 total independent observer sightings (made on 2 different circumnavigation surveys, May and August 2005). These additional sightings were included with the incidental aerial results to avoid any observer and effort biases caused by the extra observer.

Relative Distribution

Standardized aerial circumnavigations were the most unbiased research method to assess total turtle observed distribution evenly in the KIR. Using this methodology determined that the highest overall relative turtle abundance occurred in the Kākā region of the KIR (‘ili 8, 23.4%) followed by the Hakioawa region (‘ili 6, 16.7%) (Tables 1 and 9, Figure 39). These two ‘ilis were the only two above the 95% confidence interval of the mean (20.9±9.76). The Kanapou region (‘ili 7) and Kealaikahiki region (‘ili 1) both had 27 sightings (12.9%). The other 6 ‘ilis had only 33.9% of the rest of the sightings. The Honoko‘a, Ahupū, and Pāpāka ‘ilis (2, 3, and 5 respectively) were below the 95% confidence interval of the mean (20.9±9.76).

Standardized north coast survey results (which surveyed ‘ilis 1-6 only for a total of 43 sightings) determined that most turtles sighted were found in the Hakioawa region (‘ili 6) followed by the Ahupū region (‘ili 3) and the Kealaikahiki region (‘ili 1) (32.6%, 23.3%, and 18.6% respectively). Tables 1 and 9, and Figure 40 show these comparisons. The other 3 ‘ilis had only 25.5% of the total sightings combined. The Hakioawa region was above, and the Honoko‘a region (‘ili 2) was below the 95% confidence interval of the mean (7.2±4.84). Extracting the north coast rankings from the aerial circumnavigation results yielded the top three ‘ilis as being Hakioawa, Kealaikahiki, and Kūheia (‘ili 4). Ahupū and Pāpāka (‘ili 5) ranked last, behind Honoko‘a.

Comparatively, the incidental sightings yielded slightly different ‘ili distribution patterns, which was expected due to the randomness of flights (Tables 1 and 9, Figure 41). Of these 69 sightings, 17.4% were seen in the Kealaikahiki region, followed by 14.5% both in the Hakioawa and Kanapou regions. The Pāpāka region (‘ili 5), which ranked last in the circumnavigations, ranked next with 13.0% of the sightings. The other 6 ‘ilis contributed the remaining 40.6%.

Overall, the top ‘ilis remained consistent. Comparing all of the 321 aerial sightings gave these top 4 rankings: Hakioawa, Kākā, Kealaikahiki, and Kanapou (18.4%, 17.1%, 14.6%, and 11.5%) (Table 13, Figure 42). Surprisingly since it was surveyed more, Honokoʻa (ʻili 2) ranked last, just below Kamōhio (ʻili 9) with only 4.7% of the sightings.

Clusters of Turtles

The term "cluster" is used here to describe a number of turtles that were in close proximity to each other at the time of the sightings. A total of 66 turtles in 27 clusters (ranging from 2 to 5 turtles per cluster) were documented from all aerial surveys and incidental aerial sightings (Figure 43). Two turtles per cluster was the most common occurrence (70.4%). Nearly one third, 29.6%, of all of these clusters were located in the Kanapou region (ʻili #7), followed by 22.2% in the Kuikui and Hakioawa regions (ʻili #6). Twenty-eight (48.3%) of the turtles sighted were classified as small in size and twenty (34.5%) were small-medium. Eight (13.8%) turtles were estimated to be medium-sized, and two were classified as medium-large (3.4%) (Figure 44).

Eight clusters, totaling 22 turtles, were associated with debris lines (Figure 43). These current-generated debris lines were all located on the eastern side of the island fairly close to shore, and were composed of rubbish (pieces of plastic and other floating materials) as well as terrestrial matter (sticks, sediment). It is unclear why these turtles were found with this debris. It is possible that they are attracted to these materials as possible sources of food, as floating objects generally attract a number of creatures. The turtles could be consuming the bits of plastic and other rubbish (Mascarenhas et al. 2004). Another possibility is that these turtles may have actually been floating with these materials pelagically and drifted in with the currents. If the latter were true, the turtles associated with these debris lines would likely be extra small or small in size, which was the case for 14 (66.7%) of the turtles that were estimated to be small. Six (28.6%) were small-medium and one was classified as medium (4.7%) (Figure 45). Interestingly, there were only 8 single turtles sighted aerially with debris lines. Sizes were recorded for six out of these eight, and four of these single turtles were estimated to be small and two were small-medium (Figure 46). The difference in the frequencies of small-sized turtles was significantly higher (P=0.13, percent test) in the debris lines compared to the total sightings of small-sized turtles.

Size Class Structure and Sex

Size estimations were made for the turtles in 260 sightings, but these results should be interpreted objectively knowing the limitations of aerial size assessments (Figure 47). Small turtles were sighted predominantly (38.8%, n=101) followed very closely by small-medium ones (37.7%, n=98). Sixty medium turtles were spotted (23.1%). One large and five medium-large turtles were seen (0.4% and 1.9%). Sex could not be determined for these six medium-large and large turtles.

Species Composition

With one possible exception, the aerial survey turtle sightings were not identified as greens or hawksbills because it was not thought to be possible to identify the differences from the air. The author made the one possible, unconfirmed hawksbill sighting. Leatherbacks would have been easily distinguishable, but none were seen.

Habitat

Marine habitat characteristics were recorded for 260 aerial sightings (from actual surveys and incidental sightings from the air). Turtles were most often found in habitat consisting of coral (50.4%, n=131) (Figure 48). Sixty (23.1%) of the sightings were made on portions of the south and southeast sides of the island where the nearshore depths inhibited the identification of the bathymetric composition (classified as "deep"). Forty-six (17.7%) of the sightings were classified into combinations of coral, sand, and rocky substrate. Only four sightings were made in sandy habitat, and nineteen in rocky habitat. Habitat characteristics did influence distribution, as there were significant differences between the number of sightings in each habitat ($X^2_{0.001,df=4}=187.2$).

Aerial surveys allowed for an unbiased view of water clarity conditions that these turtles were found in. There is an apparent preference for clear water over murky conditions. Out of 267 sightings that included observations of water clarity, 82.8% were in clear water (n=221) (Figure 49). A total of 35 turtles were seen from the air in murky water, and 11 in semi-murky water. Water clarity did not seem to affect researchers' detection abilities when the turtles were breathing at the surface, but would have influenced sighting capabilities if the turtles were swimming subsurface.

Distance from Shore

The compilation of all aerial distance from shore data yielded 286 data points (Table 14). These sightings were categorized by <5m, 5-20m, 21-40m, and >40m. The most common range was 5-20m with 46.2% of all sightings, followed by <5m with 34.3%.

The 21-40m and >40m each contained 14.3% and 5.2% of the sightings (Figure 50). Turtle distributions versus distance from shore were not random ($\chi^2_{0.001,df=4}$ =118.7).

Mauka/Makai (Landward or Seaward)

The positions in the helicopter of the initial observer for 266 turtle sightings were recorded. The sightings recorded from the two sides of the helicopter were not even ($\chi^2_{0.001,df=1}$ =33.2). The researchers facing the shoreline made the majority of the sightings (67.7%, n=180) compared to the seaward observer. This coincided with most of the sightings occurring closer to shore than offshore.

Behavior

Initial behavior data were taken for 285 sightings from all aerial observations (Figure 51). Eighty percent of the turtles were breathing at the surface when spotted, and 10.8% were swimming subsurface but still visible. Twenty-five (8.8%) were swimming and breathing as we watched them. One turtle was seen foraging off the rocks along the coastline. No shoreline basking was witnessed.

Perceived Reactions to Helicopters

Of the 268 observations that recorded our perceptions of the turtles' reactions to the helicopter, 66.4% exhibited no initial reaction to the first pass made by the helicopter. Upon maneuvering the helicopter to gain additional viewing time of the turtle, 106 resightings occurred: 60.4% did not react (stayed at the surface), while nine (8.5%) did not react initially, but eventually dove. Either in reaction to the helicopter or by coincidence, 31.1% dove. To summarize, Figure 52 shows the total reactions to the helicopters (n=374), both on the first and second passes: 64.7% did not react, 26.7% dove, and 8.6% did not react initially but eventually dove. In 30 instances, the turtle was not found again once we circled back to look for it.

South Maui Flights

In summary, more turtles were seen along the ~6 km (~10 mile) stretch of the South Maui coastline than were seen around the whole island of Kaho‘olawe. During the three surveys that started from Oneuli Beach (Black Sands) and ended at the southeast end of Kealia Beach we saw 34, 15, and 5 turtles (Figure 20). We saw 11 and 16 on the ~10 km surveys that started near the Grand Wailea and ended at the Kihei Canoe Club and Kealia Beach. Eighteen turtles were spotted in one 5-minute survey of a portion of this coastline. Another time, 12 were seen in a group offshore of the Hawaiian Islands Humpback Whale National Marine Sanctuary building (a definite “hot spot” as we’ve noticed them there prior to that as well but no formal counts were made). Although unquantified (as only numbers were recorded), the turtles were noticeably large compared to the KIR turtles, positively reinforcing our Kaho‘olawe size estimations. These turtles seem to have inhabited all ecosystem types from sand channels to rocky outcroppings, with varying distances from shore.

In-water, *Hākilo*, and Other Findings

Relative Abundance

A total of 62.7 in-water survey hours were completed during the course of this study (2002-2005). Although most transects were standardized at 60-minute durations, some lengths varied due to field conditions. Overall, the mean time of the 67 transects was 56 minutes. A total of 82 turtles were recorded on these transects, with a sighting frequency of 1.22 turtles/transect (SE=0.219, SD=1.791) (Table 6). This equates to a catch per unit effort (CPUE) of 1.31 turtles/hour. The sightings ranged from 0 to 8 turtles per survey, with zero turtles found during 34 (50.7%) of the transects. The total sighting frequencies decrease as the number of turtles per transect increases (Figure 53). The turtle sightings per transect among years remained consistent: 1.0, 1.2, 1.5, 1.1 from 2002-2005 respectively (Table 6). But as the distributions of the sites were picked randomly, these amounts reflect these survey site turtle sightings, not comparable annual trends around the whole island.

It was hypothesized that the number of snorkeling researchers per transect would increase the number of turtles sighted per transect due to the thinking that the more eyes in the water searching increased the odds of finding more turtles. This was investigated using only the 41 transects that were 55-65 minutes in duration (to eliminate the time variable) (mean=59.7 min, mode=60, SE=0.328, SD=2.10). Figure 54 displays these data, and Figure 55 is a scatter plot of this relationship. A positive correlation coefficient (r=0.114) and an r^2 value of 0.013 were obtained with linear regression analysis (SE=1.90). By definition, the number of turtles sighted increased with the number of researchers snorkeling per transect, but this relationship was very weak. No significant dependence of the number of turtles on the number of researchers was found (ANOVA: f test=0.512, $f_{(0.05)(2)(39)}$=5.43, P=0.478).

A typical survey day aboard *Hākilo* consisted of ~5 hours of observation time in the reserve, with a variety of research and other activities being performed during the course of the day. Although effort (route and distance traveled, number and effort of individual observers, etc.) combined with water conditions could not be analyzed due to the numerous factors and small numbers of sightings involved, a consistent observation effort was made daily by the author. From 2002-2005, a total of 98 turtles were seen during 76 survey days, with an overall mean of 1.29 turtles/day (SE=0.145, SD=1.26) (Table 7). The 2005 research year had the highest sighting frequency at 1.56 turtles/day. Sightings remained consistently low throughout this study period, ranging from 0 to 6 per day. It was most common to see one turtle per day (32.6%, n=24) with zero turtles per day being the second frequent occurrence (30.3%, n=23) (Figure 56).

Relative Distribution

Figure 57 shows the total sightings/transect and the areas of the KIR that were researched using the in-water survey techniques. The whole island was not surveyed equally, and approximately 18 km (11 miles) of coastline were not surveyed. Due to constantly murky conditions from Kaukamoku to Ahupū, this area was not surveyed. Consistent rough water conditions along the southern and eastern facing shores greatly limited surveys in these regions.

Figure 58 maps the distribution of all 58 in-water survey turtle sightings. In-water surveys (which did not research the whole island evenly, duplicating survey efforts in some regions and not surveying others) found that the highest overall turtle sightings occurred in the Hakioawa region (ʻili 6) of the KIR (50.0%, n=41) (Tables 1 and 9, Figure 59). The Honokoʻa and Ahupū regions (tied with 8 sightings each) ranked next, followed by the Pāpākā and Kākā regions (tied with 6 sightings each).

A total of 98 (one without location data recorded due to faulty GPS) incidental and visual sightings were made from *Hākilo*, with the Hakioawa and Kealaikahiki ʻilis having the highest relative abundances (29.9% and 21.7%) (Tables 1 and 9, Figure 60). Honokoʻa and Ahupū ʻilis followed with 11.3% each and 25.8% of the remaining turtles were in the other 6 ʻilis. These sightings are mapped by year in Figures 61, 62, and 63.

The compilation of the 55 location-specific *Hākilo* logbook recordings from 1997-2005 showed that the Hakioawa and Honokoʻa ʻilis both had 18.2% of the sightings, followed by Kealaikahiki (16.4%) (Tables 1 and 9, Figure 64). ʻIlis 8 and 9, Kākā and Kamōhio, both had 12.7% of the sightings. The other five ʻilis combined had 21.8% of the sightings. These sightings are mapped in Figure 65.

The 58 total opportunistic and anecdotal reports showed similar distribution patterns, with the Hakioawa, Kealaikahiki, and Kākā ʻilis ranking highest in sightings (25.9%, 22.4%, and 19.0%) (Tables 1 and 9, Figures 23, 24, and 66). The Honokoʻa and

Kanapou ‘ilis followed with 8.6% of the sightings each. Only 15.5% of the sightings were in the remaining 5 ‘ilis.

The past reports/studies were compiled to reveal a very different trend in ‘ili turtle sightings (Tables 1 and 9, Figures 16 and 67). Kealaikahiki, Honoko‘a, and Ahupū (31.5%, 22.2%, and 18.5%) were the top three, and the order followed down the north coast with Hakioawa being sixth. No sightings were reported in Kākā, with the south and southeast coasts only contributing 7.5% (n=4) of the sightings. These results likely reflect the minimal research effort that was attempted in these areas of the island.

Clusters of Turtles

The term “cluster” is used here to describe $\geq$2 turtles that were in close proximity to each other at the time of the sighting. A total of 82 turtles in 22 clusters were documented from all sources (except aerial surveys and sightings, which added 27 more clusters, see aerial survey section above) (Figure 68). Two turtles per cluster was the most common occurrence (68.2%). The majority of these clusters were sighted in the Hakioawa region (54.5%). Forty-six turtles were found in 18 clusters (ranging from 2 to 5 turtles per cluster) during in-water surveys and incidentally aboard *Hākilo.* Two clusters of 2 turtles each were recorded in the *Hākilo* logbook. One cluster of 2 turtles was opportunistically seen by a KIRC staff member. Joyce Kainoa, a Protect Kaho‘olawe Ohana member, made an anecdotal report of seeing 30 turtles in Kanapou Bay (she saw them as she was walking down the cliffs into Kanapou Bay proper in February 1978).

Photo-ID/Residency

Only one underwater photo of a turtle within the KIR was available before this project began. Although 82 turtles were seen on the snorkeling surveys and one incidentally while underwater, usable photos were not obtained from all sightings. Quality photos were often difficult to obtain due to the murkiness of the water and the tendency of the turtles to keep a distance from their observers. Sometimes it was only possible to acquire partial profile and flipper shot(s) before the turtle swam away. Another problem was the amount of sedimented algae coating portions of the turtles' flippers and heads, covering the scale patterns used to positively identify individual turtles. Since the right and left profiles and flippers have different scute arrangements, the right sides can only be compared to the right sides of other turtles, and the same with the left. If only one side of a turtle's ID was obtained, then these turtles couldn't be compared to others that had only the opposite sides photographed. Of the 41 individuals catalogued 23 were not matchable to every turtle in the collection, expanding the range of possible individuals to 64 if none of these 23 were found to match the other 41. This can be computed when more photos are taken in the future, and the photo-ID catalogue is expanded.

Ideally, the more parts (right and left profiles and flippers) of the turtles that can be compared the better, but as explained above, this was not always the case with some individuals' photographs. The possible resightings of 2 turtles from 4 sightings are based on just one front flipper scale arrangement, therefore should not be considered to be 100% confirmed. Turtle #21 was identified at Lae Paki in February 2004 and turtle #24 was seen at Ki‘i 37 days later (Figure 69). Upon close inspection of these turtles' right front flippers and a portion of the right profiles, these two sightings appear to be the same individual but no other comparisons can be made. The distance between these two sightings is approximately 5 km (3.1 miles). The other potential resight (from the comparison of the turtles' right front flippers) is of turtle #33 at Lae o Kākā and turtle #59 North of Hakioawa. These two sightings occurred 252 days apart, at a coastal distance of approximately 11 km (6.9 miles) (Figure 69).

There were only 5 positive resights of two individual turtles. These sightings were well within ¼ of a km from the original locations, all at Hakioawa. The greatest number of resightings of the same turtle was only three. Island-wide, this low number was predicted since Hakioawa was the most revisited site (surveyed five times). A higher number of resighted individuals was expected from Hakioawa, but there were inconsistent numbers of turtles seen during these repeated transects (ranging from 3-8, mean=5.6). For instance, the same transect was repeated within a few hours of one another, on the same day, with 6 turtles seen on the first transect but only 3 turtles on the second one. And only one turtle identified from the first transect was seen on the second, meaning at least two other turtles were in the area that were not seen on the first transect. And, 5 that were seen on the first survey were not visibly present for our observations the second time. Using the photo-ID method, 16 individual turtles were identified in the Hakioawa region during the course of this project.

The maximum time interval that a turtle was reobserved was 815 days (2.2 years) at Hakioawa. This turtle was spotted once more within this time interval as well, demonstrating a degree of residency to this location. Green turtles have a high residency rate (small home range) around the MHIs, likely coinciding with adequate foraging and shelter options. But since significant foraging grounds were not identified, more variability in the ranges of these turtles is probable. With a higher sample size, the degrees of immigration and emigration can be clarified with the future continuation of this work.

Species Composition

Only one confirmed hawksbill was seen during the course of this research (swimming quickly away from the author in 4.3 m deep coral reef habitat north of Hakioawa) (Figures 71). It was an adult female in mid-May 2005. There was one aerial sighting of a possible hawksbill by the author in mid-May 2004. It was sighted less than 1 km south of Oawawahie (~1.5 km to the south of where the 2005 hawksbill was seen), also in ʻili 6 (Figure 30). A report by the Protect Kahoʻolawe Fund called "Contemporary Subsistence Fishing Practices Around Kahoʻolawe" referenced a 15-20 lb hawksbill near Kūheia on 9/16/93 (Figures 16 and 71). "A friend told me about seeing some hawksbills somewhere on Kahoʻolawe" was conveyed in a talk story session with a Maui SCUBA diving store employee. All of the other sightings and references were greens or not identified to species.

Size Class Structure and Sex

The turtles were not measured and the observers could only visually estimate the size classifications from the boat, air, and shore. Therefore, these results unfortunately lack precision. The compilation of all turtle sightings from all surveys and sources yielded size approximations for 578 turtles (Table 15, Figure 70). The most frequent size class recorded (50.0%, n=289) was small (<2ft carapace or called "small" in anecdotes). In addition to this category, 20 (3.5%) turtles that were smaller than 18" or had notes referring to them being "new recruits", "extra small" or "tiny" were categorized as "x-small" (Figure 71). The smallest sighting recorded was estimated to be 6 inches, floating in a rubbish line in Kanapou Bay on 9/24/03 (by Kalei Tsuha, KIRC Cultural Program).

The second most frequent size class from all collated sightings (24.2%, n=140) was small-medium (when the differentiation between small and medium couldn't be distinguished accurately by the observers so this category was chosen). There were eighty-three (14.4%) medium sized turtles (2-3' carapace), and 60 out of the 83 were seen from the air. Only 7.9% of all turtles were large (>3'), with 30 of these 46 in one report (Joyce Kainoa, a Protect Kaho'olawe Ohana member, was walking down the cliffs into Kanapou Bay proper in February 1978 and she reported seeing ≥30 large turtles floating in the Bay) (Figures 24, 68, and 71). Although this sighting is questionable, it has been included. Five turtles seen from the air were described as "medium-large". Only three large turtles were seen during this research project. One was spotted while underway aboard *Hākilo*, one on an aerial survey, and one large female hawksbill was seen on an in-water transect (Figure 71). Since this latter female hawksbill was the only adult turtle that was seen underwater during the course of this project, she was the only one sexed.

The 96 in-water size assessments (82 from actual snorkel surveys, 14 incidental in-water sightings) should be considered the most reliable, and these results sighted small turtles at the highest frequency, 88.5% (Figure 72). Five (5.2%) were extra small and 4.2% were small-medium. As mentioned above, five medium-large turtles and one large one were seen.

Fibropapillomatosis

No evidence of fibropapillomatosis (FP) was detected during this project, and there were no references to its existence in all of the other sources of gathered information for Kahoʻolawe. Eighty-eight turtles in total were examined seemingly close enough to visually confirm that there were no obvious external tumors.

Injuries

Only minor injuries, some of which could have been birth defects, were witnessed on eight turtles that were observed underwater during this project. Two had small portions 'shaved off' the rear of their carapaces. One had an ~8 cm chunk out its left rear carapace. One had a ~2 cm plug missing in the tip of its right rear flipper, and another had a ~5 cm chunk out of its left rear flipper. One had a 'floppy' left rear flipper, which appeared to be broken parallel to the turtle's carapace. Two turtles' left front flipper tips (~5 cm) were missing. None of these injuries were fresh, or seemed to hinder the turtles' movements.

Eight turtles had varying degrees of white blotches on their heads (Figure 73). The blotches were not on any other parts of the turtles' bodies. All eight turtles had the splotches on the tops of their heads, and had varying degrees of affliction covering the rest of their heads. These turtles were all small in size, and one was resighted three times in the same location (Hakioawa, >2 year residency). The latter was the turtle with the most extreme case, having so many splotches covering its head that it appeared nearly all white. Interestingly, all of these individuals were seen in the Oawawahie-Hakioawa area, except for one at nearby Kuikui Point. It remains unclear why these turtles have this particular skin condition. On rare occasion, the author has seen turtles on Maui (adults that appeared healthy) with less severe conditions, but they have not been researched.

Epibionts

Besides thirteen turtles that were noted to have clean carapaces, an unknown species of algae resembling brown slime, coated most turtles' carapaces in varying degrees. This same algae/sediment frequently covers portions of the reef, mostly on the north and northeast sides of the island. Seventeen turtles that were seen at the surface were described as being "orange", likely due to algae growth coupled with sediment. No large barnacles or other epibionts were identified on any of the turtles' carapaces. Around the neck and shoulder skin regions another species of red algae (unidentified) was common.

Initial Behaviors and Reactions to Snorkelers

Of the 82 turtles that were observed during our in-water transects 9 were resting (11.0%), 8 were foraging (9.8%), and 63 were swimming (76.8%). Figure 74 shows these plus the

10 incidental sightings' behaviors). One turtle was found posing at a cleaning station, just south of Oawawahie (Figure 75). Only two came up for air while we were watching them underwater, suggesting a cautionary tone with us. Only one turtle performed any flipper swipes, the behavior that is interpreted as a conveyance of discontent. It was foraging at the time of the sighting, at Lae o Kākā. This behavior is seen quite commonly on Maui, by all size classes, when divers and snorkelers watch/approach turtles too closely. Two turtles displayed what was anthropomorphically considered "curiosity", or at least not fearful, as they swam right up to us in a "seemingly inquisitive manner".

Ninety-two reactions to snorkelers/divers were recorded over the course of this research (Figure 76). Among the categories of tolerance, slow departure, and flight, slow departure was most common (45.6%, n=42). Tolerance was the next prevalent response (18.5%, n=17), followed by flight (15.2%, n=14). Eleven (12.0%) turtles exhibited slow departure then flight, and seven (7.6%) were tolerant of our presence then slowly departed. Only one turtle's tolerance changed to a flight reaction. In this particular instance, the winding of a disposable camera seemed to trigger this response. Although not quantified here, the turtles tended to retreat when snorkelers free-dove to get closer for picture-taking purposes. This was observed early on in the research, and was not surprising as the turtles likely saw this as a threatening action on our parts. Consequently, photos were generally taken by the snorkelers at the surface to maximize the observation time and minimize potential stress to the animals.

Habitat

Habitat characteristics were recorded for 84 in-water sightings (from snorkel transects, incidental and opportunistic accounts). Turtles were most often found among habitat containing mostly coral (74.4%), followed by sand (14.9%) then rocks (10.7%), with thirty-four of these sightings consisting of a combination of habitats (Figure 77). Compared to 47 turtles that were found among predominately coral, only two turtles were spotted in just sand, and only one turtle was seen in a rocky habitat. And only one turtle was found in a combination sand/rock habitat. Even though these areas are not uncommon around Kahoʻolawe, coral reefs predominate. Since the coral reef sightings are much higher, it is likely that there is a preference for this habitat.

During hour-long snorkeling transects water visibilities often varied, so sampling both murky and clear conditions did happen. Although we were probably more likely to see a turtle in clear water, sightings in murky water were made as well. In addition to these sightings, three opportunistic sightings and one from the *Hākilo* logbook totaled ninety-one data points that assessed water visibility. Over 90% were in clear water. This number is likely higher since clear water was not as noteworthy compared to murky circumstances. Including thirty-five aerial sightings, a total of only forty-four turtles were sighted in murky water over the course of this project.

Depth

The compilation of all depth data yielded 136 data points (Table 16). The depths ranged from 1.5 to 31.1 m with an overall mean of 5.6 m (Median=4.5, Mode=3.0, SE=0.35, SD=4.1). Each survey method reflected their depth of coverage. In-water surveys yielded the shallowest mean (4.4 m), due to the abilities of snorkelers to access shallow water. Mean sightings from *Hākilo* were deeper (*Hākilo* logs=11.9 m, *Hākilo* incidental=6.5 m) because of the typical depth range of operations. Only the depths of the sightings near the boat could be accurately determined with the depth finder, when we were going slowly. Only one depth was reported opportunistically, at 5-6 m. There were eleven depths recorded in past reports from 1.4 m to 16.6 m, with a mean of 6.2 m.

The most common depth range, after categorizing them in intervals of 3 meters, was 1-3 m at 39.0% of the sightings (Table 16, Figure 78). The 4-6 m range closely followed with 37.5% of the sightings. The 7-9 m and the 10-12 m ranges followed with 12.5% and 7.4% of the sightings (n=17 and 10). There were only five sightings deeper than 12 m, two of which were recorded in past reports and three were sighted from *Hākilo.*

Distance from Shore

Including the 286 aerial survey sightings mentioned previously, the compilation of all distance from shore data yielded 438 data points (Table 14). The turtles' distances from shore ranged from a couple of feet from shore to the middle of the Alalakeiki Channel between Kahoʻolawe and Molokini. These sightings were categorized by <5 m, 5-20 m, 21-40 m, and >40 m groups (Figure 79). As with the aerial sightings exclusively, the most common range was 5-20 m with 45.4% of all sightings, followed by <5 m with 32.9%. The 21-40 m and >40 m each contained 11.2% and 10.5% of the sightings.

The 5-20 m range contained approximately 50% of the sightings from all aerial surveys, in-water surveys, and incidental sightings from *Hākilo*. The <5 m range had 26-34% of sightings from these survey types ranking second, except for the *Hākilo* incidentals in which there was one more sighting beyond 40m than in the <5 m range (Table 14). As with the depth ranges, the data reflect the survey methodologies and techniques (Figures 79-82). The most non-biased results are from the aerial surveys in which the whole survey area was being monitored equally from above, at the same time. From this viewpoint it's surprising that there were not more sightings beyond 40m (only 5.2%, n=15), which confirms that our survey types are correctly focusing on the nearshore area in which most sightings occur.

Foraging

Only sixteen instances of foraging were witnessed during the course of this project, and 4 were recorded in previous reports. These foraging behaviors were witnessed in the daytime from 09:12 to 13:40 with a mean time of 09:42. It should be noted that dawn/dusk or nighttime observations were not made on Kahoʻolawe and most fieldwork was done in the morning and early afternoon. The algae species could only be identified as silt-covered turf algae, composed of several species that had been grazed beyond recognition.

Only one turtle was observed foraging along the shoreline (SW of Kūheia), which happens commonly around the MHIs. The other turtles were foraging on the turf algae growing on the rocks on the seafloor. The mean foraging depth was 5.8 m (range 1.5 m to 10.7 m, SD=3.7, SE=1.2, median=4.4).

Figure 75 shows the distribution of the eighteen mapable foraging sightings. These limited observations suggest that preferred forage is fairly limited in distribution. The majority of foraging occurred in ‘ili 6 and 8 (33.3% and 27.8%). These ‘ilis had the highest number of turtle sightings during the aerial circumnavigation surveys. This high number in ‘ili 8 were actually all seen during one snorkel transect near Lae o Kākā, which is especially significant in that they were all foraging rather close together. The three sightings at Hakioawa were also foraging together. The foraging behavior at nearby Oawawahie was seen eight months later, which indicates regularity of foraging over time, in a different season, in that region.

Resting

Ten underwater sightings were made of resting turtles (lying motionless on the seafloor). The mean resting depth was 5.5 m (range 3.4 to 12.2 m, SD=2.7, SE=0.9, median=5.2). Figure 75 shows the distribution of these sightings, in which 50.0% occurred in ‘ili 6, and all occurred on the north-facing coastline.

Cleaning Stations

Only one turtle was observed briefly getting cleaned by unidentified species of fish just south of Oawawahie (Figure 75). The small turtle was in a clear water coral reef habitat, at a depth of 8 m, 5-20m offshore. The turtle displayed a slow departure reaction to our presence.

Reaction to Hākilo

Anecdotes were sometimes recorded concerning the turtles' reactions to *Hākilo* as we drove by. We did not normally veer off-course to approach the turtles with the vessel but sometimes this happened coincidentally with our operations. "Tolerance" distances between the turtles and us were not recorded. It was more common for turtles to dive, but only fourteen turtles were actually recorded as diving quickly due to what appeared to be the passing boat. Twenty-four turtles did not display a reaction (stayed at the surface to breathe seemingly unaffected by our presence) to the boat as we drove by.

Entanglements

One "fairly small" turtle at Oawawahie was entangled: "One had an eye of a net strapped around the left foreflipper and attached to the rock. Tried to capture to remove but could not catch." Marc Hodges recorded this notation in the *Hākilo* logbook on 9/19/97 (it's unclear why a turtle attached to a rock could not be caught…).

Strandings

One stranded (dead) turtle has been recorded on Kahoʻolawe. A "15-18 inch honu" was found washed ashore at Kanapou Bay (on 9/27/99), and was buried in a culturally sensitive manner at Honokanaiʻa. The author measured bones that resurfaced due to shifting sands, confirming this small size (Figure 83). Species could not be confirmed.

Basking

No basking was witnessed during the course of these research activities, but references were compiled (Figures 16, 24, and 71). As stated in the 1997 KIRC Ocean Management Plan, "Honu frequently rest on beaches in the Honokanaiʻa area, and may not be disturbed when resting" (Dames and Moore 1997). The only "proof" of this is a photo (taken by an unfamiliar person at an unknown location), which is also included in "Restoring a Cultural Treasure" (1993) (Figure 85). C. Lindsey has not seen basking here for 20 years (Pers. Comm. 2003). The "B/N" (basking or nesting) on Figure 24 depicts, "Uncle Harry Mitchell wrestled a large turtle that was on a beach north of Base Camp in October of 1980" (C. Lindsey, Pers. Comm. 2002). The Nature Conservancy report mentioned basking turtles at Kūheia in 1990 (Gon et al. 1992). The recent most occurrence was of a large turtle that went quickly back into the water when spotted at Keanakeiki around February 2002 (L. Abbott, Pers. Comm. 2004).

Nesting

Although the nesting searches were not nearly as frequent as needed to obtain 100% confirmation, no evidence of turtle nesting was found during the course of this project. And no one interviewed indicated any knowledge of such activities. The only references are from the 1995 book "Kahoʻolawe Nā Leo o Kanaloa" and Les Kuloloio's May 14th, 1995 observations of "the tracks and droppings of several turtles. Upon inspection found turtle eggs that had been laid in the sand" at Keanakeiki (Protect Kahoʻolawe Fund, 1997) (Figures 16 and 24).

DISCUSSION

KIR Habitat

Since currents deliver pelagic and inter-island marine debris to Kaho‘olawe’s eastern-facing coastlines, it is possible that this is how at least a portion of the turtles initially arrived to the island. Thirty turtles total (22 in 8 clusters, and 8 singly) were found among these debris lines near shore, with them occurring predominantly in Kanapou Bay (Figure 43). In the future, these debris lines could be examined offshore, with the attempt to find turtles within them. Keoneuli Beach within Kanapou Bay has the largest density of marine debris accumulation on the island (Figure 85) (KIRC Ocean Management Plan 1996). This is where the one stranding was found as well as the smallest sighting recorded (an estimated 6 inches), floating in a rubbish line. The highest numbers of “extra small” turtles were reported on this side of the island (Figure 71). These possible ‘new recruits’ then likely disperse from there around the island until they find suitable habitat. Clearly turtles also end up at the westernmost end of the island, as the Kealaikahiki ‘ili ranked high in sightings from all survey types and sources.

Once the residency patterns are better understood for the south coast region (and the entire island) by obtaining more photo-IDs and conducting satellite or VHF telemetry experiments, the quality of this coastline habitat for turtles will be elucidated. For instance, if it is found that turtles are residing in areas long-term, this will demonstrate that these habitats are adequate to support sea turtle survival, and these turtles aren’t just transiting through the area. The highest rate of residency (815 days) for an individual turtle was at Hakioawa, the region with the highest in-water relative turtle sightings and second highest aerial survey sightings. This is also where the only consistent replicate in-water transects have occurred, allowing for this resighting after a period of 2.2 years. No Hakioawa turtles have been sighted elsewhere. Since no turtles outside the Hakioawa region have been resighted throughout all the different locations that have been surveyed, this tends to suggest a degree of residency, at least in this region. Since the overall effort did not encompass all of the coastal waters, this topic needs further study.

Adequate resting and foraging locations are likely the two most important aspects that determine turtle distributions among habitats. Protected resting sites are seemingly plentiful on Kahoʻolawe, especially along the northern coast. Degrees of vertical relief have not been directly quantified for KIR's nearshore coral reef ecosystems, but is generally highest on the northern and northeastern shores, lowest along the southern shores where depth drops quickly just offshore (Figure 3). Past reports had identified these northern regions as likely turtle habitat, neglecting the southern shore's potential, so it was a surprise to have found as many turtles along the south shore as we did. Since shelter sites are uncommon, the primary reason why they may be occupying (if long-term and not simply transiting through) these southern areas would be forage availability. Yet the turtles that were seen foraging in this area (Lae o Kākā) were targeting sparse, unidentifiable turf algae (just like how they were typically doing on the northern coast).

Marine botanists have not examined the southern coastline due to the typically rough water conditions. Along the northern, accessible coastline, it has been found that Kahoʻolawe has a low abundance of algae, but high algal species richness (Cox 1993, Coles 1998). There is a definite lack of noticeable lush algae beds along the shoreline (likely due to insignificant freshwater and nutrient input by comparison to the developed MHIs). A limited study by Shultz (2004) found a significantly higher abundance of macroalgae on Maui than Kahoʻolawe, with Kahoʻolawe having less than 5% cover. Macroalgae was considered rare, with only half the species collected in spring and summer compared to winter. Sediment covered a good portion of the bottom and was embedded in much of the algae observed.

The most serious ecological consequence of the ranching and military occupation to the nearshore ecosystems has been recognized as the influx of sedimentation around the island during heavy rains. "It is estimated that 1.9 million tons of soil is deposited into the surrounding ocean each year as a result of erosion" (KIRC Puʻu Moaʻulanui Restoration Project 2005). Some areas remain pristine while at others the sedimentation lingers, choking out coral and algae life, affecting the dynamics of the reef system (Jokiel et al. 1995).

Turf algae, more resilient to sedimentation, was the dominant substrate across depths (over coral, crustose coralline algae, sand, and macroalgae) at up to 90% coverage (Shultz 2004). Species richness was similar to Maui. There is no shortage of species present that Hawaiian greens eat on Kahoʻolawe. Yet with the higher herbivorous fish populations and sedimentation effects, these algae are not thriving.

The author's observations around the island concur with Shultz's (2004) findings: "The majority of macroalgae found at Makaʻalae were collected in the intertidal in low relief features such as cracks in a reef. In the shallow subtidal, there were no macroalgae but there was a large number of scrape marks on the turf. The increase in the numbers of fish during high tide in the intertidal suggests increased grazing pressure is episodic and timed with high tide." Turtles are likely being out-competed by these herbivorous fish and forced to forage on turf algae. No health/energetics comparisons of turf algae to preferred species of forage have been made, but it is possible that turf algae is less beneficial especially considering its sediment load. Therefore these turtles may not make routine commutes from their resting spots, but instead may need to actively forage more often to obtain the quantity and nutritional content to survive.

The seemingly insufficient food sources could be the limiting factor of the size of this population, which favors small turtles. A distinctive aspect of this population is the near-total absence of adult-sized turtles. The KIR may be a developmental habitat, similar to what has been found in certain islands in the Southern Great Barrier Reef and the Caribbean (Limpus 1992; Leon and Diez 1999; Diez et al. 2003). "The preponderance of juveniles and subadults may be due to some developmental shift in habitat preference when turtles attain sexual maturity" (Seminoff et al. 2003). Once the turtles reach a certain size, the KIR may not be able to support them, causing them to leave the island altogether in search of better food sources. As a future project, turtles could be captured, tagged, and measured so that growth rates can be determined upon recapture.

On a positive note, survey teams have not found recent evidence of invasive algae species on Kaho‘olawe that are threatening reefs around the other MHIs (Coles 1998; UH Manoa

Botany Department and KIRC Ocean Program unpublished periodic, rapid assessments). Only one of the growing number of non-native species that have become nuisances around the populated MHIs has been found: *Acanthophora spicifera*, but only once at Maka‘alae (Cox 1993).

Hawksbills

No studies have addressed the presence, distribution or abundance of sponge species around Kaho‘olawe. Therefore, the quality of foraging habitat for hawksbills cannot be determined. One species was seen with frequency due to its easy identification, the black reef sponge (*Spongia oceania*). However, since diet preferences and requirements remain unknown for Hawaiian hawksbills, the benefit of the prevalence of this species is unknown.

Since the adult female hawksbill north of Hakioawa was found in mid-May (early nesting season) 2005, she may have been traveling through the area on a nesting migration and not be an island resident. She might have even been looking to nest on Kaho‘olawe, but no such evidence was found. A special effort should be made to replicate the transect in which she was found in an attempt to relocate her. The unconfirmed aerial sighting of a hawksbill by the author also occurred in mid-May, but in 2004. It was sighted less than 1 km south of Oawawahie (~1.5 km to the south of where the 2005 hawksbill was seen), which is also in ‘ili 6 (Figure 30). Only one green turtle was located during an in-water transect through this region (Figure 57). Interestingly, these island locations match with the orientation (northeastern facing shores) of the other MHIs in which adult female hawksbills have been found to forage (Figure 86).

Besides the literature sighting of a small hawksbill at Kūheia, the only other hawksbill know to exist within the KIR was an adult female (named "Orion") that was nesting in Mākena, on Maui in 2004. She was equipped with a satellite transmitter on Maui in order to locate her inter-nesting locations and post-nesting foraging grounds. Either right before or after her 5th nest of the season, she left the Mākena area and swam along the north coast of Kahoʻolawe, then eventually made her way back to the Mākena area (Figure 88). Since Orion's 5th nest was laid on a different beach than her first four and not discovered until hatchlings emerged, it's uncertain if she laid it before or after this journey. Due to the timing of these events, it is unlikely that she nested on Kahoʻolawe (although searching for nesting habitat seems like a "logical" reason for this journey since she didn't make any prior moves like this). While it has been shown that Hawaiian hawksbills don't always take the shortest route when returning to their foraging grounds after nesting, nesters are not known to swim to another island and then back again during this time, so this route was quite uncharacteristic of anything that is presently known about Hawaiian hawksbills (Hawaiʻi Wildlife Fund, NOAA/NMFS unpublished data).

Nesting

No nesting evidence, significant seasonal fluctuations, or noticeable influx of large sea turtles within the KIR during nesting season were found. Yet Kahoʻolawe's beaches seem to have good potential for hosting a successful nesting population of any Hawaiian sea turtle species. Besides the Northwestern Hawaiian Islands, they are the last remaining natural, minimally impacted beaches in Hawaiʻi. Since a nesting population is not presently utilizing Kaho‘olawe, establishing viable nesting grounds will essentially have to be done from scratch. Creating a nesting population in this way is a very long-term (100+ years) management strategy that will require close collaboration with State and Federal agencies to obtain the necessary permits and fine-tune the extensive protocols for bringing either eggs or hatchlings to the island. If it is found that this is something the KIRC and other government agencies would like to see happen and the benefits outweigh the monetary investment, efforts, and risks, then this venture should be attempted by all means.

Certain conservation management efforts need to be undertaken by KIRC to promote this nesting success. Although done on a small scale, the sand mining (from Base Camp beaches) for usage in road maintenance should be discontinued. The driving of trucks and all-terrain vehicles (ATV) on the beaches should not be practiced. No structures, permanent or semi-permanent, should be built on any of the beaches, and camping should be discouraged during nesting and hatching season (April-December).

Coastal lighting has been shown to discourage nesting female sea turtles from using lit beaches, and it also disrupts hatchlings’ seafinding abilities (Witherington and Martin 2000). The only beaches that are affected by lighting are the ones surrounding the Base Camp at Honokanai‘a. These lights can be easily shielded so that they are not visible from the beach and still achieve their purposes of providing safety lighting. Campfires should be discouraged during nesting and hatching season.

The feral cat population poses a threat to sea turtle hatchlings (and nesting sea birds, crab populations, etc) and should be removed using humane methods. The mouse outbreaks may also negatively affect hatchlings if the hatching and outbreaks coincide. Various rat species have only been occasionally found on Kaho‘olawe, but could be a threat to hatchlings. Fortunately, mongooses (*Herpestes auropunctatus*), a predator of hatchlings on other MHIs, are not known to inhabit Kaho‘olawe.

The only major beach restoration efforts would involve the removal of kiawe trees that line the beaches, and dominate the whole island. This species has the potential to negatively impact nests due to its thirst for fresh water and extensive root systems (Starr and Starr 2003). Besides buffel grass (*Cenchrus ciliaris*), two native plants, cressa (*Cressa truxillensis*), and ‘aki‘aki (*Sporobolus virginicus*), primarily occupy the dune systems, so there shouldn’t be a serious hatchling entanglement issue.

Fibropapillomatosis

No fibropapilloma tumors were detected on any of the 88 turtles observed in-water, and no indications from any other observations or sources to its presence on the KIR turtles were found. This is the most significant finding of this research. The small sized turtles found on Kaho‘olawe are the typical ‘victims’ of this disease on the populated MHIs. The low density of turtles reduces the possibility of their interacting with each other and spreading the disease if it is present in some individuals. And since there was only one observation of a turtle being cleaned by fish (another possible tumor-vector), this method of spreading the disease may not be occurring either. As written in Landsberg et al.

(1999), “Herbst and Klein (1995) discussed the fact that, ‘High FP prevalence is in affected nearshore habitats associated with agricultural, industrial, or urban development.’ Although they indicated that there did not appear to be a correlation with chemical contaminants, they suggested that nearshore habitats may contain other stressors that rendered turtles more susceptible to FP”. The absence of FP on Kaho‘olawe supports these views since there aren’t any agricultural practices or development.

Predators

According to legend, the Hawaiian shark god Kamohoali‘i (Pele’s brother) is thought to reside in a deep sea cave in Kanapou Bay. This bay and Kaho‘olawe in general have long been connected to shark-related legends and lore. Comparative studies show that the KIR has the highest top marine predator biomass of any of the MHIs suggesting an intact, healthy nearshore ecosystem (Maragos and Gulko 2002). The KIRC Ocean Program documented sharks and large predatory fish around the island during the course of this research (KIRC Ocean Program unpublished data). No large tiger sharks, which would be the biggest threat to turtles within the KIR, were observed.

No major injuries observed on any of the turtles suggest few, if any, predator interactions. Of course, the possibility that sharks may just be consuming the turtles, which are mostly small, outright definitely exists. No data on the frequency of turtle predation exist among the populated MHIs, although these interactions have been witnessed and turtles are occasionally seen with shark-related injuries. Sea turtles are resilient creatures and can survive the loss of a limb(s). More scarring or injuries would be expected from seemingly less-deadly interactions with predatory fish, but those were not observed either suggesting that sort of predator interaction is not common.

Behaviors

The presence of divers, helicopters or vessels makes it impossible to study ocean animals in a way that doesn't affect their behaviors. The helicopters and *Hākilo* both operate very loudly, and since these were our primary vehicles for assessment it is quite likely that the turtles could hear us approaching. How that affected their behaviors is not possible for us to determine or quantify since the turtles likely reacted differently depending on the situation. Since helicopters have been used frequently around Kaho‘olawe for decades it is possible that some turtles have become accustomed to them since no real hazard accompanies them.

Meadows (2004) found that of the 105 Hawaiian green sea turtles he watched during 5 min focal-animal activity budget observations, both in the presence and absence of recreational snorkelers (besides himself) on Maui, the majority of time was spent in an inactive state on the sea floor (over 50%). The five other behavior categories that were ranked after resting were: swimming (~35-40%), being cleaned (~5-10%), breathing (~5%), being bottom active (<5%), and foraging (<3%). None of these behavior categories differed significantly with snorkeler presence, and size, sex and fibropapilloma score did not seem to be factors. Although these observations were made in areas where turtles are highly accustomed to people, they still provide an interesting comparison.

For the majority of the KIR turtles to have been swimming (and not breathing at the surface, resting, foraging or getting cleaned) when we saw them on in-water transects brings up some possibilities that should be addressed. They could have been on their way to the surface to breathe when they saw us, and then grew cautious about doing so (although this doesn't seem to intimidate the green sea turtles on Maui, where many have grown accustomed to the presence of people and surface within arms' length of snorkelers). These turtles, being highly alert animals, may have seen us approaching on our transects before we saw them and left their resting spots, or changed behaviors from foraging or posing at cleaning stations. Or, our detection abilities were limited in that we could only locate the ones that were swimming (the others had good hiding places). And we might have only actually spotted a fraction of these swimmers as many may have eluded us altogether, especially in semi-murky water. The turtles always swam away as opposed to trying to hide in crevices, under ledges, etc. There were too many variables involved (our proximity to the turtles and the bathymetric escape routes available) to discern a typical choice of swimming to deeper water as opposed to shallow, but the former tended to be what occurred.

The turtles that currently populate Kahoʻolawe are fortunate in that they aren't affected by fibropapillomatosis and other anthropogenic stresses such as the ones around the populated MHIs are experiencing. And due to the fact that it is illegal to enter the reserve's nearshore waters and no commercial activities are allowed, human presence is nearly nonexistent except for the KIRC and Protect Kahoʻolawe Oʻhana (PKO) accesses.

Therefore, most of these turtles had likely never been in contact with humans before. For these reasons, their reactions to us were of interest. For the highest density of turtles to have been found in the Hakioawa region, the place where the PKO has been conducting their cultural accesses for years, is noteworthy. This is the only area on the island that has a semi-regular human presence, as snorkelers (and spear fishermen gathering for on-island subsistence) explore the reef here. It is possible that the turtles in this location have grown accustomed to humans from these activities, therefore were not scared away and were counted easily on our transects. Another aspect to the PKO's activities that may be affecting the reef ecosystem in that area is the subsistence harvesting of fish. These extractions may allow for more macroalgae (food for the turtles) to grow, resulting in a higher abundance of turtles in this area. This possible correlation has not been examined.

Survey Bias

Aerial surveys for sea turtles and other animals have been conducted in many different places, but helicopters have been used predominately for nesting beach surveys, and small, fixed-wing aircraft typically conduct in-water surveys that cover vast areas (Slay 1991; Thompson and Huang 1993; Epperly et al. 1994; Carson 2000; Garmestani et al. 2001). While sometimes providing the only means of determining relative distribution and abundance of species in remote locations, the data need to be interpreted with caution. Numerous problems can be associated with this type of survey including: observer bias, species and size error, weather/visibility variables, inconsistency of flight paths, effort grade, and "invisible" turtles. Correction factors and statistical methods to eliminate these factors have been used, and calculations for submerged turtles can be figured so that density distributions and other results can be more accurately compared (Bayliss 1986; Marsh and Saalfeld 1989; Musick et al. 1994; Preem et al. 1997).

Observer Bias

Although the KIRC survey team was comprised of experienced observers, it is probable that turtles were missed due to difficult sighting conditions and complex habitat types, the distraction of other sightings, or fatigue. Although the actual circumnavigation survey time was only approximately an hour, it required intense effort to deal with the windy, sunny conditions and remain focused. To address this observer bias issue, 1-2 silent observers accompanied the survey team on 35.4% of the flights (n=17), in which only seven extra sightings were made (2.7% of the total standardized survey sightings). All seven of these extra sightings were made from the seaward side of the helicopter, where only one researcher sat, behind the pilot (two were on the coastal side). This is a low number, but shows that the surveyors did not achieve 100% accuracy.

Overall, only 32.3% of the sightings were made by the seaward observer compared to the coastal side's 67.7%, but researcher ineptitude is not thought to be the cause of this. It is challenging for the solo spotter, but no more so than the coastal spotters which also had the shoreline to check. These differences in numbers likely reflected actual locations of where the turtles most commonly were (closer to shore), which is why the seaward side of the helicopter logged more sightings.

Perception Bias

Rough water conditions could have increased the magnitude of perception bias during each of the surveys. The question of whether sea state affected turtle sightings was investigated. Sea state was recorded using the standard beaufort sea state for 3 portions of the island's waters during each circumnavigation: the north coast, south coast and the east coast. These three scores, ranging from 0 to 3-4 (mean 1.5), were then averaged to figure a total-survey rating (range 0.5 to 2.8). The 2004 and 2005 scores were graphed with their respective number of turtles sighted during that survey (Figures 88 and 89). 2004 and 2005 had weak correlation values (r) of -0.0278 and 0.222 respectively. Figure 90 is a scatter plot of the average beaufort sea state and total sightings per survey. A positive correlation coefficient (r=0.200) and an r^2 value of 0.0437 were obtained with linear regression analysis (SE=3.11). By definition, the number of turtles sighted increased with the increase in beaufort sea state, but this relationship was not very strong. No significant dependence of the number of turtles on beaufort was found (ANOVA: f test= 0.959, $f_{(0.05)(2)(22)}$=5.79, P=0.339).

Availability Bias

Due to the natural behaviors of sea turtles spending only a portion of their time near or at the surface of the water, unknown numbers of turtles were unavailable for sighting during these surveys. Attempting to understand the relationship between surface and dive interval durations relative to environmental conditions and behaviors is a multifaceted undertaking. Sea turtles must surface to breathe, and their behaviors and activity levels are correlated to their dive rates and surface durations. If the turtle is exerting a lot of energy swimming or foraging (in rough water conditions, for instance) then it will need to come to the surface to breathe more often than when it is simply resting. And as would be expected, the larger the turtle is in size the more oxygen it can store therefore increasing its possible submergence durations. Size also influences the time that turtles spend at the surface replenishing their oxygen supplies, with smaller turtles having shorter surface intervals (Renaud et al. 1993). Daily behavior (resting and foraging) patterns also need to be determined so that the percentage of submergence and surface times can be figured accordingly. Only then can these data be more confidently applied as correction factors to observed densities to calibrate population estimates.

Population Estimate

The KIRC Ocean Resources Management Program will be conducting VHF radio telemetry and time-depth recorder (TDR) research on turtles in the future. This research will lead to a better understanding of dive behaviors and activity levels and allow for reliable correction factors to counting methods to obtain KIR turtle abundance estimates. Because these data are not currently available and because Hawaiian research on this subject is limited, worldwide studies of diving behaviors were examined. Fifteen studies provided a range (n=109) of surface and dive durations, which yielded the percent of time these different turtle species spent submerged (Table 17). These dive durations typically ranged in the nineties from 91.2-98.6% (with two extremely low values of 71.0% and 80.8%) depending on species, age, behaviors, time of day, tidal influences, and other environmental variables (Mendonca and Pritchard 1986; Byles 1988; Byles 1989; Balazs 1993; Renaud et al. 1993; Renaud and Carpenter 1994; Renaud et al. 1994; Renaud 1995;

Gritschlag 1996; VanDam and Diez 1996; Renaud and Williams 1997; Morreale and Standora 1998; Schmid et al. 2002). Although it is not possible to directly relate these figures to the KIR turtles, they serve as examples of likely possibilities and provide a dependable framework.

From these borrowed data and techniques, correction factors were calculated from the aerial circumnavigation densities, and the probable minimum and maximum abundance estimates were predicted (Tables 18 and 19). "Since only turtles at the surface of the water are observed on aerial surveys, a correction factor can be used to account for submerged turtles. If the amount of time a turtle spends at the surface is known, an adjustment factor can be calculated as the inverse of the proportion of time spent at the surface. By multiplying this factor by the relative density accounts for the submerged turtles, an estimate of population density may be obtained" (Musick et al. 1994).

Using the Musick et al. (1994) calculations and the range of worldwide turtle diving behaviors, the Kahoʻolawe-wide mean range equated to 36 to 719 turtles, with a 70 to 1400 turtle maximum depending on the surface intervals adopted. This is quite a wide range, but it provides an upper estimate of the KIR population at 1400 turtles. The actual number is speculated to be somewhere in the middle of this range, under 500. One figure or equation will not encompass the complexities of sea turtle behavior; therefore these rough estimates should be interpreted with a lot of caution. A population modeling exercise taking into account as many variables as are available should be considered in the future to provide a more accurate figure.

In-water sightings were likely negatively biased, and the whole island was not surveyed completely or equally, which brings any population estimates using only these methods under scrutiny. Not taking into account habitat differences, if the 1.22 mean number of turtles spotted during the ~½ mile (0.8 km) in-water surveys is converted to an island-wide density the result would be 70.8 turtles in the reserve. If this same broad assumption is made for island-wide distribution using the maximum of 8 turtles witnessed during one in-water survey, then the population estimate increases greatly to 464 turtles. This merely shows that these figures are at least in the range of the aerial estimates (and possibly influence the opinion towards the lower estimates), but of course should also be interpreted with a lot of caution.

The only other published in-water census in Hawaiʻi was done with SCUBA along the Kaʻu coastline of the island of Hawaiʻi, resulting in "the sighting of approximately three turtles during each hour of diving time" (Balazs 1980). This is more than our 1.31 mean CPUE, but no further details from this study are available for comparison. Leon and Diez (1999) used our same in-water methodology in the Caribbean and found a mean of 1.67 turtles/hr (0.08-3.43 range). On the Southern Great Barrier Reef, Limpus (1992) had the same 0.02 turtle/minute finding as we did, although they practiced boat-based rodeo technique methodologies, with a maximum of 1.29 turtle/hr.

No population estimates are available for any of the other MHIs, but they all likely significantly exceed 500 turtles, which is not a surprise due to habitat availability. In

1979 as few as 50 greens inhabited Kane‘ohe Bay on O‘ahu compared to at least 500 mostly immature greens in 1989. Kaneohe Bay is the largest bay in the MHIs, 13 km long and 4 km wide (Balazs et al. 1993; Losey et al. 1994). When asked about the total population estimate of Hawaiian greens in a personal communication with the author, George Balazs responded, “several 10s of thousands”. This statement provides perspective to Kaho‘olawe’s small contribution to the Hawaiian sea turtle population, but doesn’t lessen its significance as an endangered species habitat.

CLOSING

The results of this study provide a baseline for future comparisons and assessments of the turtle population utilizing Kaho‘olawe’s waters. I recommend that the Kaho‘olawe Island Reserve Commission’s Ocean Resources Management Program continue and expand these studies, using all of these methodologies when possible. As with any dynamic population, only then can sound conservation management decisions be made. Kaho‘olawe is still recovering from the overgrazing by feral ungulates, ranching activities, and fifty years of live-fire military exercises and training. It is not possible to realistically determine the negative effects the bombing had on the sea turtle population of the past. However, the future looks bright for the Kaho‘olawe Island Reserve as restoration endeavors are underway and tremendous effort and care is being put back into the island. Kaho‘olawe undoubtedly deserves it, as it is an amazing place.

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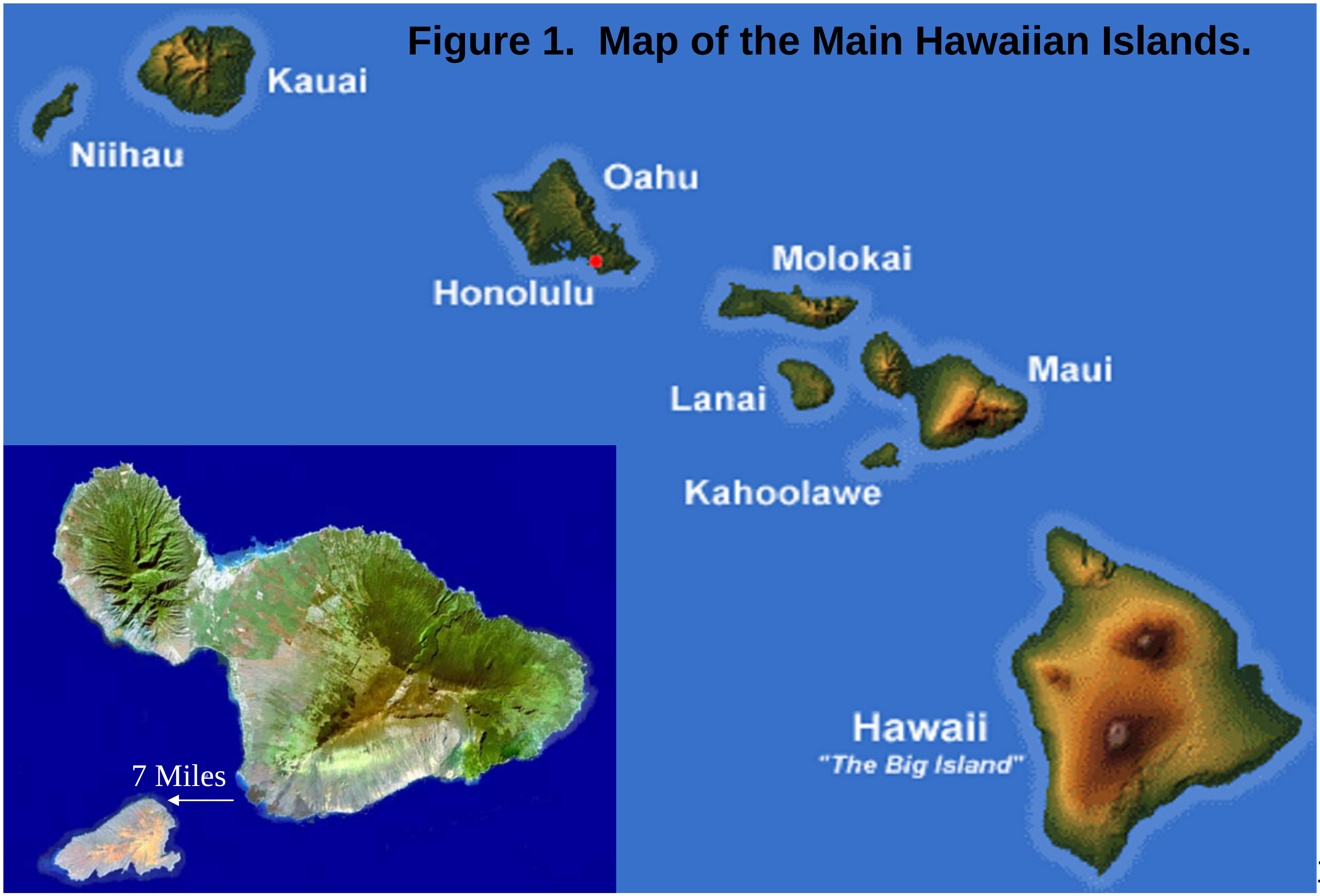


Figure 1. Map of the Main Hawaiian Islands.

Figure 2. Map of Maui Nui (Molokaʻi, Lānaʻi, Maui, and Kahoʻolawe).

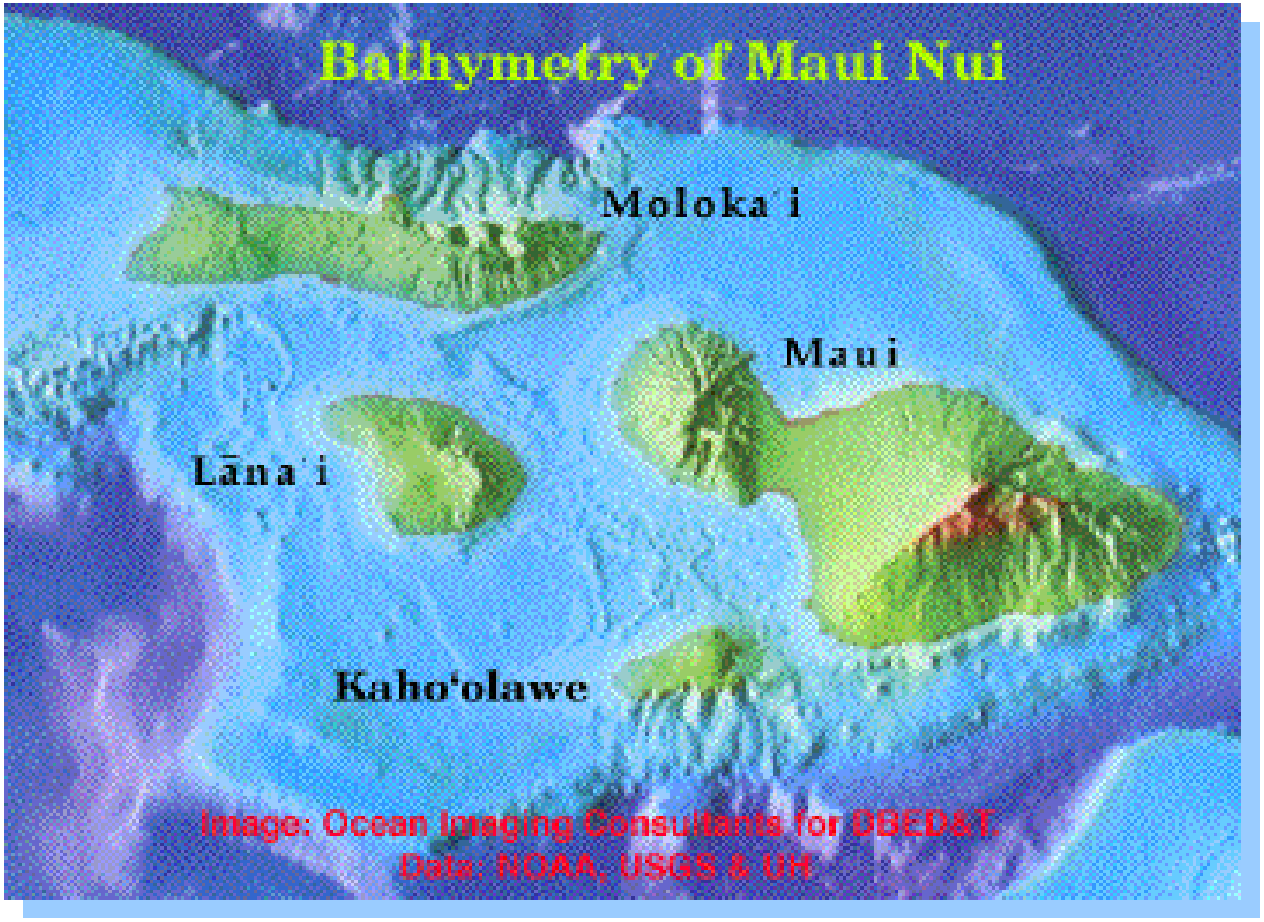


Figure 3. Bathymetry Map of the Waters Surrounding Kaho‘olawe.

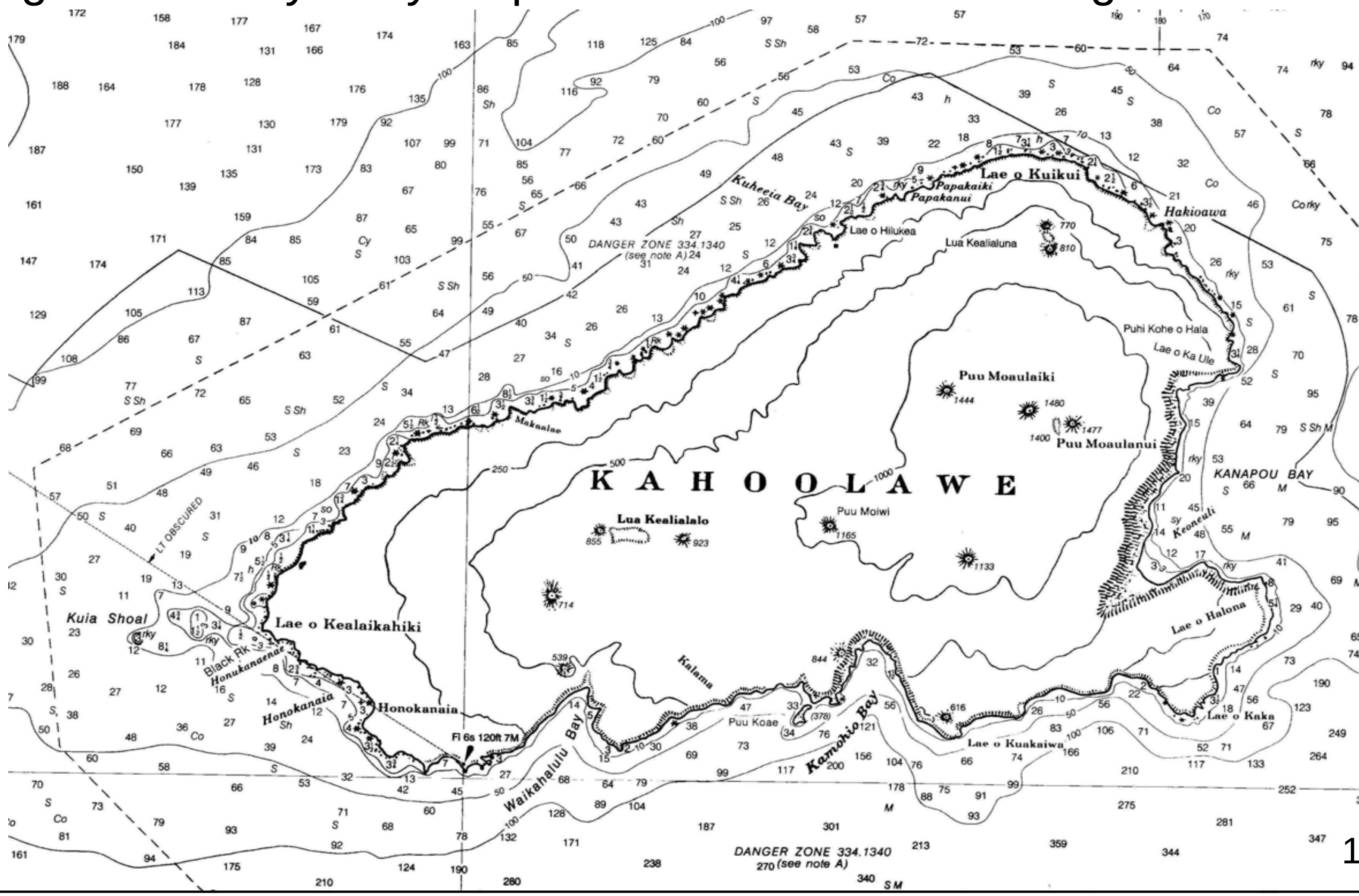


Figure 4. Aerial Photograph of Kaho‘olawe’s Southern Coastline.

Figure 5. Aerial Photograph of Kaho‘olawe’s Western Beaches.

Figure 6. Aerial Photograph of Kaho‘olawe’s Northern Coastline.

Figure 7. Aerial Photograph of Sediment Runoff.

Figure 8. Map of Kaho'olawe with 'Ili and UTM Delineations.

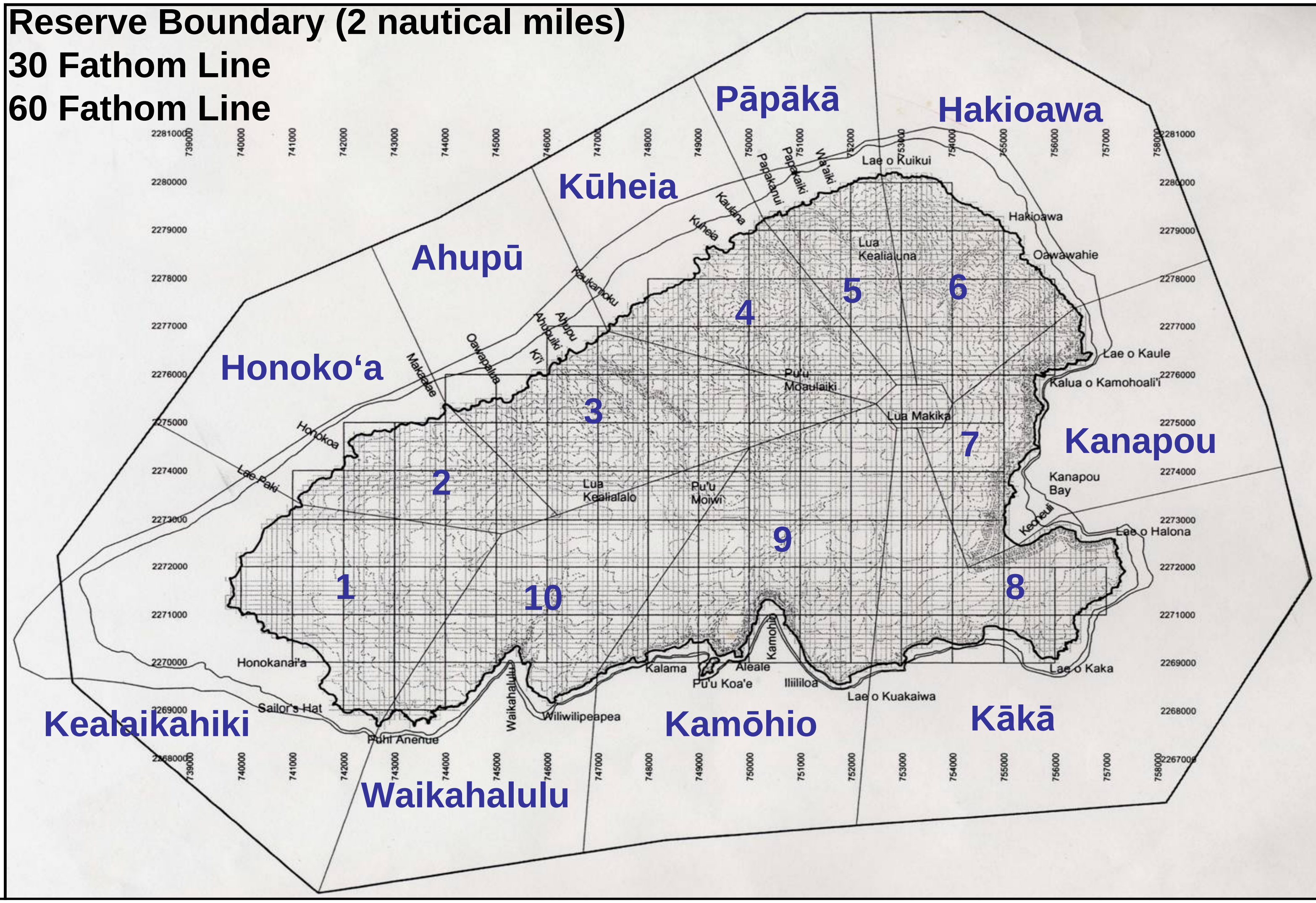


Figure 9. Aerial View of the Base Camp Facilities at Honokanai'a.

Figure 10. Photographs of Hawaiian Green (*Chelonia mydas)* and Hawksbill (*Eretmochelys imbricata)*.

Honu

'Ea

Figure 11. Satellite Map Summary of 7 Hawksbills' Post-Nesting Migrations.

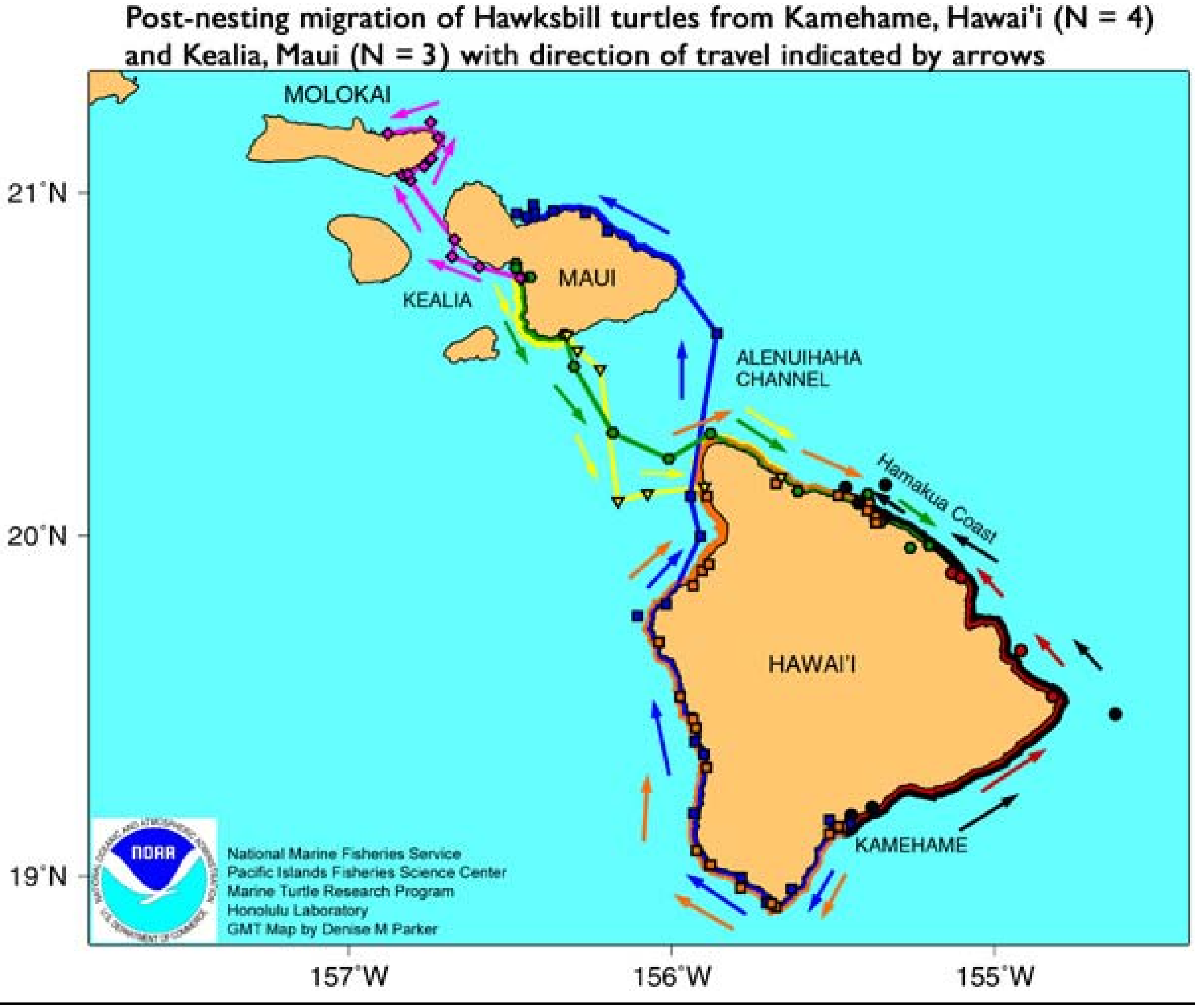
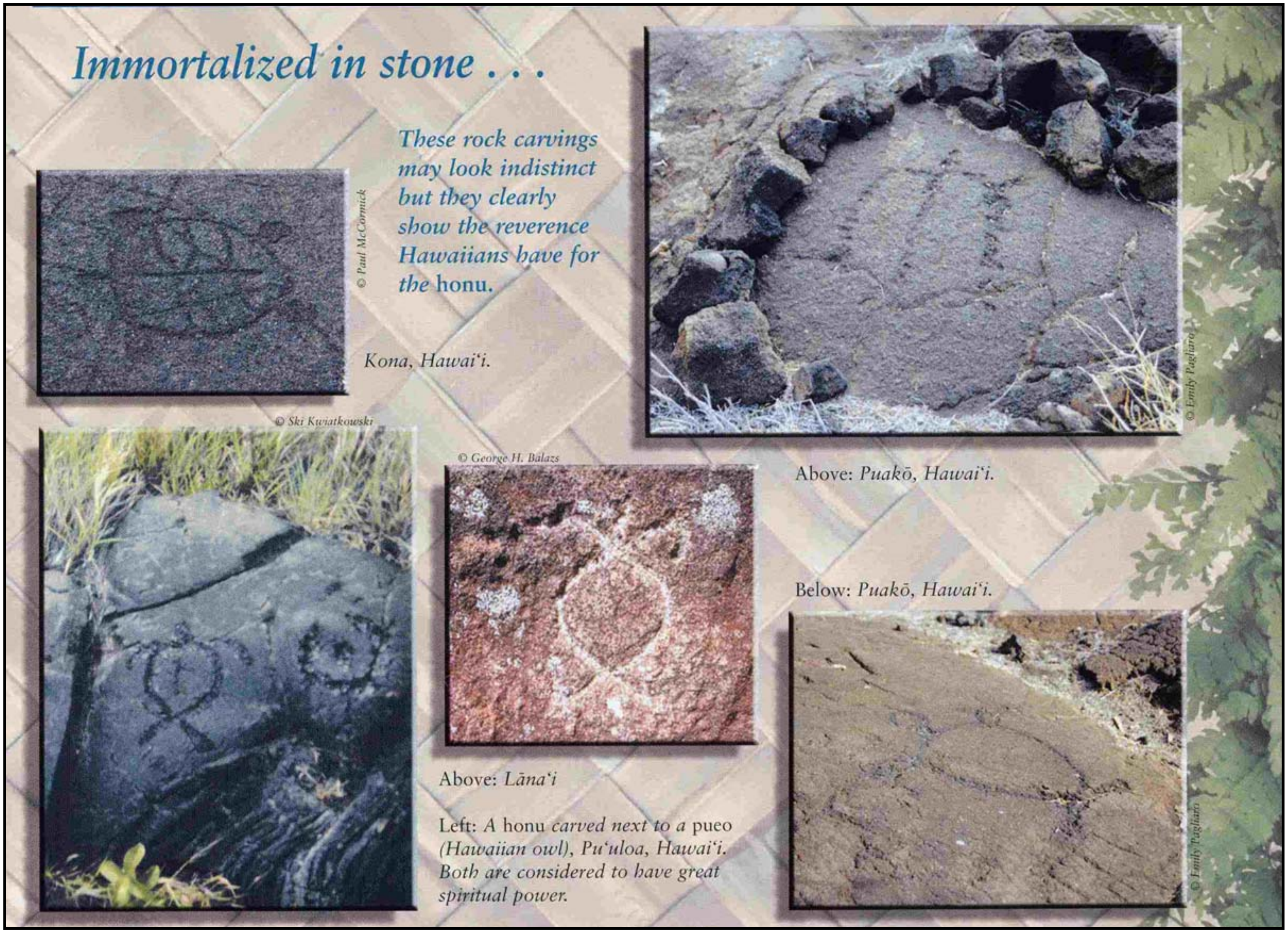


Figure 12. Photograph of *Chelonia mydas* with Fibropapilloma Tumors.

Figure 13. Photographs of Hawaiian Turtle Petroglyphs.



Immortalized in stone . . .

These rock carvings may look indistinct but they clearly show the reverence Hawaiians have for the honu.

© Paul McCormick

Kona, Hawai'i.

© Emily Pagliaro

Above: *Puakō, Hawai'i.*

© Ski Kwiatkowski

© George H. Balazs

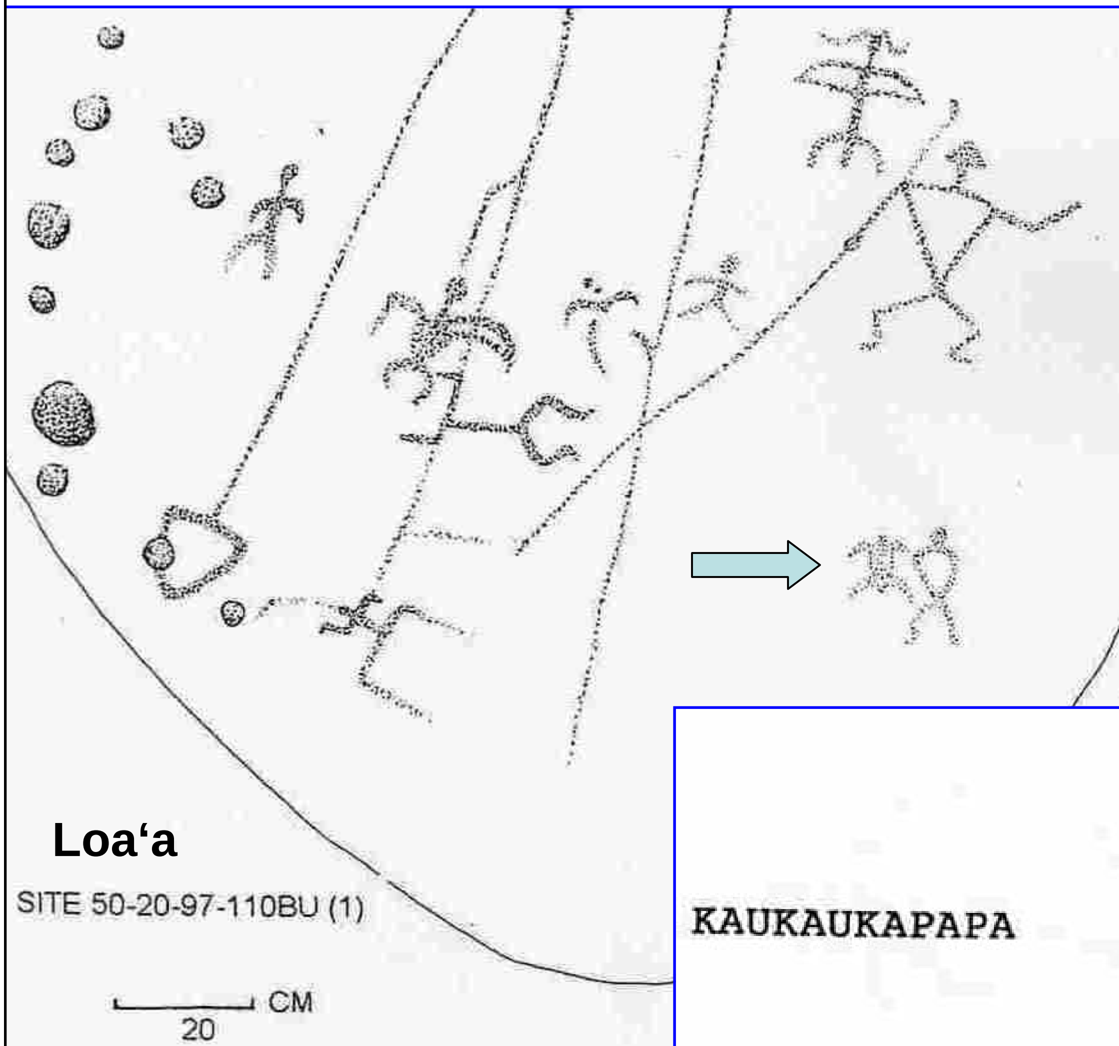
Below: *Puakō, Hawai'i.*

© Emily Pagliaro

Above: *Lāna'i*

Left: *A* honu *carved next to a* pueo *(Hawaiian owl), Pu'uloa, Hawai'i. Both are considered to have great spiritual power.*

Figure 14. Kaukaukapapa and Loa‘a Possible Turtle Petroglyphs.



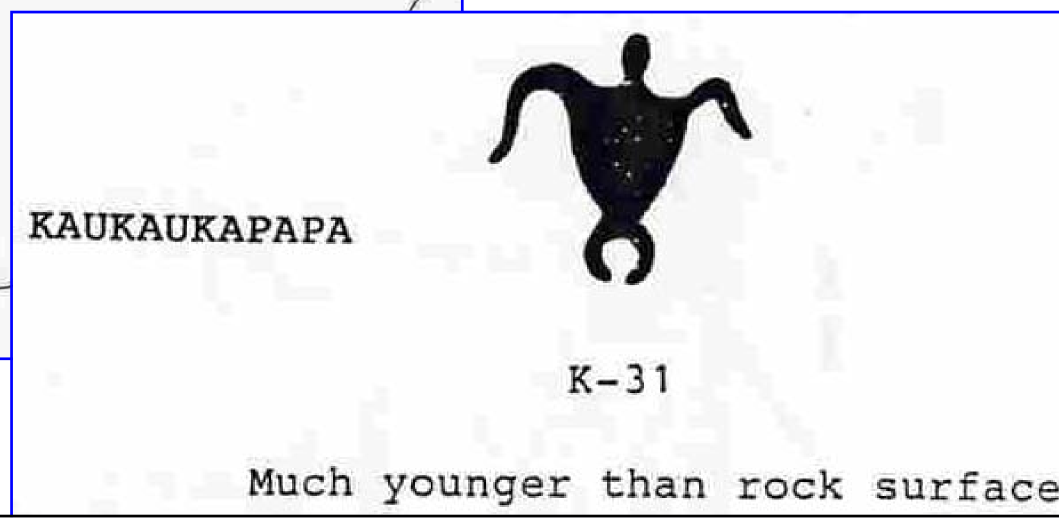
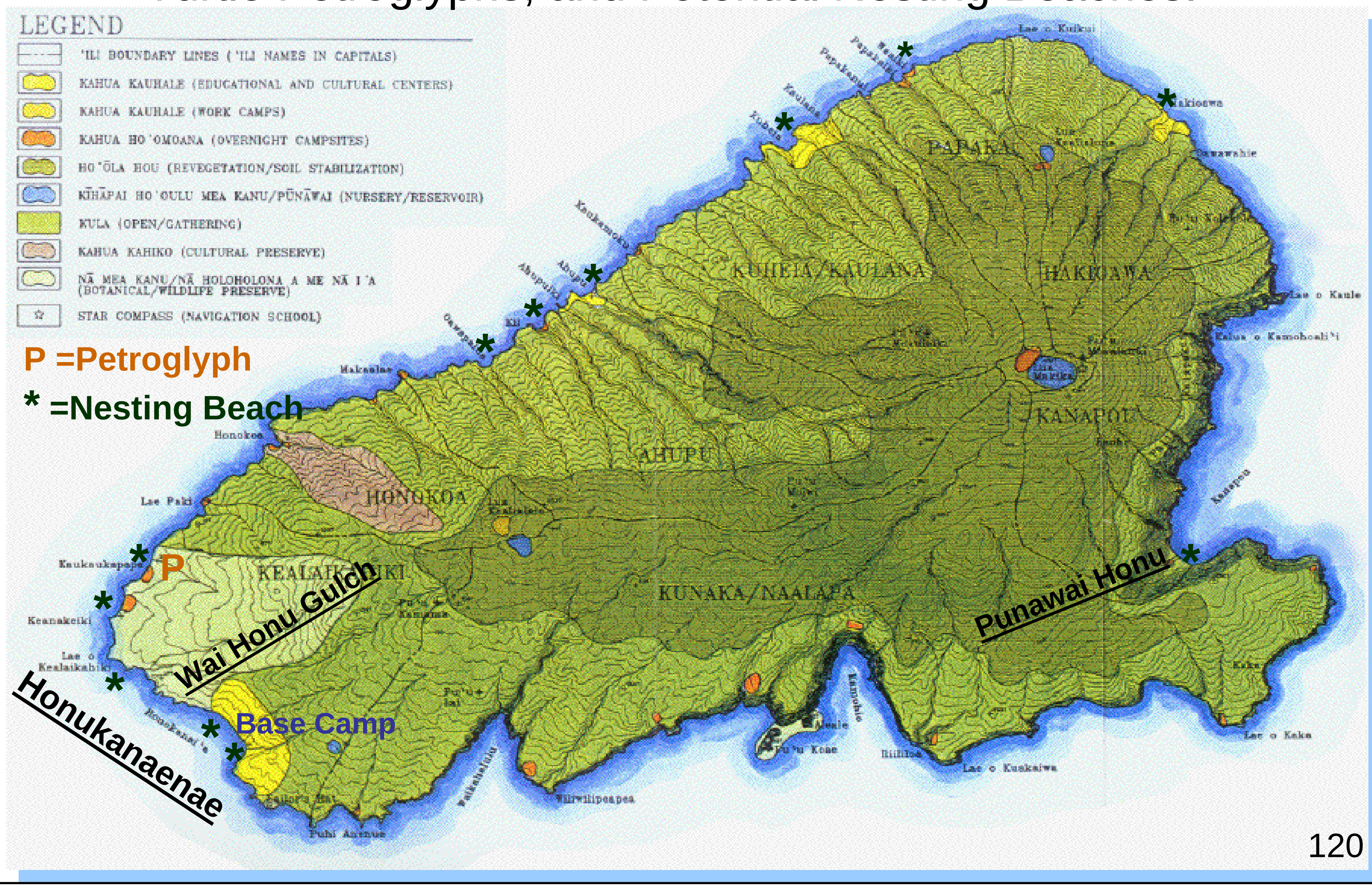


Figure 15. Map of Kaho‘olawe with Honu Place Names, Possible Turtle Petroglyphs, and Potential Nesting Beaches.



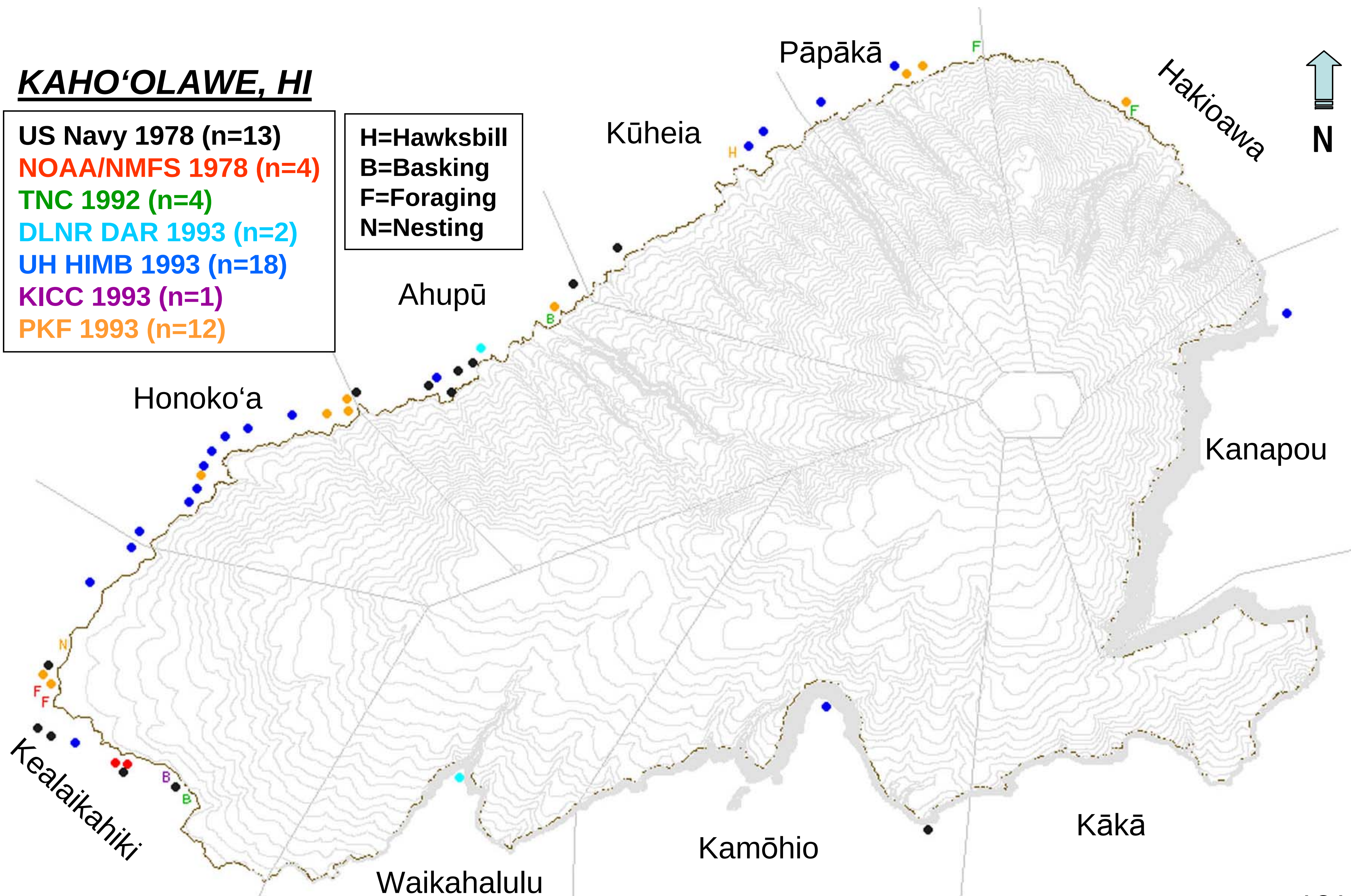


Figure 16. Distribution Map of Turtle Sightings from Past Reports/Literature.

Figure 17. Photographs of Aerial Survey Pilot, Researchers, and Helicopters.

Figure 18. Aerial Survey Data Sheet for All Sightings.

Kaho'olawe Coastal Aerial Survey

KIRC Oceans Resources Management Program
dtokishi@kirc.hawaii.gov
Phone: 243-5889 Fax: 243-5885

Date: ____________ Bird: ________
CIRC. or N.Coast Pilot: ________
CW or CCW Doors ON or OFF
Surveyors: ____________________
(Circle Data Recorder)

Start Location:			Start Time:
End Location:			End Time:

Time	Waypt.	Seen by	Number / Species	Descriptive Info. (size, scars, etc.)	Behavioral or Other Notes	Pictures

Start HOBs:			End HOBs:
	Beaufort	Avg. Ground Speed	Avg. Altitude
South Coast			
Kanapou			
North Coast			

Survey Notes:

page____of____

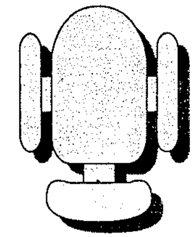
Figure 19. Aerial Survey Data Sheet for Turtles.

Kaho'olawe Honu Survey: AERIAL

Oceans Resources Management Program, KIRC

Phone: 243-5889 Fax: 243-5885

Date:	Bird: Pilot:
Start Time:	Location:
End Time:	Location:
Route:	
Effort:	Doors: on off
Team:	Label→
Honu data recorder:	



N. Coast:	
Kanapou:	
S. Coast:	

Hobbs	
Avg alt.	
Avg spd.	

Turtle #	TIME	WAY POINT	BEAUF	GLARE	METERS OFFSHORE	WATER CLARITY	HABITAT	SPS	SIZE	BEHAVIOR	RXN FLY-BY	↷	RXN HOVER	PHOTOs
			0 1 2 3 4 5	☼ ©	<5 5-20 >20 >40	Clear Murky	CR S R	*Cm* ? *Ei*	S M ? L ♂ ♀	Breathing Swimming	Ø ↓ shore ↔ off	Y N ⃠	Ø ↓ shore ↔ off	
COMMENTS:														
			0 1 2 3 4 5	☼ ©	<5 5-20 >20 >40	Clear Murky	CR S R	*Cm* ? *Ei*	S M ? L ♂ ♀	Breathing Swimming	Ø ↓ shore ↔ off	Y N ⃠	Ø ↓ shore ↔ off	
COMMENTS:														
			0 1 2 3 4 5	☼ ©	<5 5-20 >20 >40	Clear Murky	CR S R	*Cm* ? *Ei*	S M ? L ♂ ♀	Breathing Swimming	Ø ↓ shore ↔ off	Y N ⃠	Ø ↓ shore ↔ off	
COMMENTS:														
			0 1 2 3 4 5	☼ ©	<5 5-20 >20 >40	Clear Murky	CR S R	*Cm* ? *Ei*	S M ? L ♂ ♀	Breathing Swimming	Ø ↓ shore ↔ off	Y N ⃠	Ø ↓ shore ↔ off	
COMMENTS:														
			0 1 2 3 4 5	☼ ©	<5 5-20 >20 >40	Clear Murky	CR S R	*Cm* ? *Ei*	S M ? L ♂ ♀	Breathing Swimming	Ø ↓ shore ↔ off	Y N ⃠	Ø ↓ shore ↔ off	
COMMENTS:														
			0 1 2 3 4 5	☼ ©	<5 5-20 >20 >40	Clear Murky	CR S R	*Cm* ? *Ei*	S M ? L ♂ ♀	Breathing Swimming	Ø ↓ shore ↔ off	Y N ⃠	Ø ↓ shore ↔ off	
COMMENTS:														
			0 1 2 3 4 5	☼ ©	<5 5-20 >20 >40	Clear Murky	CR S R	*Cm* ? *Ei*	S M ? L ♂ ♀	Breathing Swimming	Ø ↓ shore ↔ off	Y N ⃠	Ø ↓ shore ↔ off	
COMMENTS:														
			0 1 2 3 4 5	☼ ©	<5 5-20 >20 >40	Clear Murky	CR S R	*Cm* ? *Ei*	S M ? L ♂ ♀	Breathing Swimming	Ø ↓ shore ↔ off	Y N ⃠	Ø ↓ shore ↔ off	
COMMENTS:														
0=mirror 1= light ripples	2=small waves 3=large waves (breaking)	4= some wt caps	5= many wt caps	glare ☼ ©cloudy	5m= ~15ft 20m= ~60ft 40m= ~120ft		CR=C.Reef S=Sandy R=Rocky	*Cm*: green *Ei*: hawksbill	S=<2' M=2-3' L=>3' ♂ long tail		Ø = no rxn ↓=abrupt dive ↔=direction change: swim towards shore or offshore	⃠ not found again (AFTER U-turn)	same as FLY-BY	

PAGE #_____of_____

Figure 20. Map of South Maui's Aerial Survey Routes.

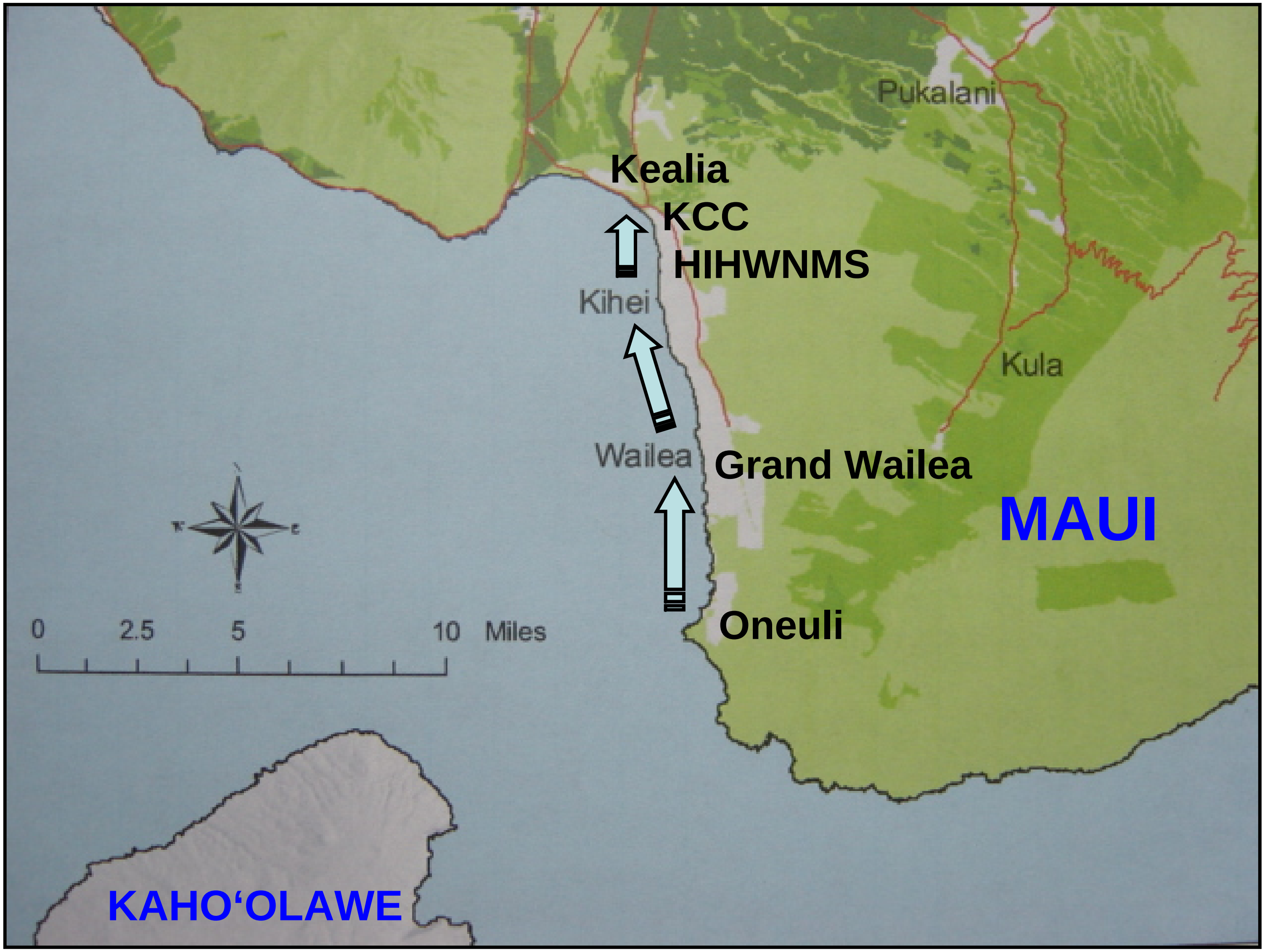


Figure 21. KIRC's Vessel *Hākilo*.

Figure 22. In-water Survey Data Sheet.

Kaho'olawe Honu Survey- Dive/Snorkel

Oceans Resources Management Program, KIRC

Phone: 243-5889 Fax: 243-5885

Date: ____________ Vessel: ____________ Captain: __________

Start Location: ______________________________

Start Dive Time: ______________ GPS: ______________

End Location: ______________________________

End Dive Time: ______________ GPS: ______________

Weather: ____________ Beauf: ____ Visibility: ____________

Current direction: Current strength:

Divers: Start Frame:

Photographer: Camera: End Frame:

Turtle#	Time	Depth(ft)	Habitat	Size/Sex	FP	Behavior	RXN	Tags/Injuries/etc.	Seen by: / Distance offshore / NOTES	Blank
			C.Reef Sandy Rocky	Small Med. Large ♂ ♀	0 1 2 3	SW BR R F P	Tolerance Slow Departure FS Flight			
			C.Reef Sandy Rocky	Small Med. Large ♂ ♀	0 1 2 3	SW BR R F P	Tolerance Slow Departure FS Flight			
			C.Reef Sandy Rocky	Small Med. Large ♂ ♀	0 1 2 3	SW BR R F P	Tolerance Slow Departure FS Flight			
			C.Reef Sandy Rocky	Small Med. Large ♂ ♀	0 1 2 3	SW BR R F P	Tolerance Slow Departure FS Flight			
			C.Reef Sandy Rocky	Small Med. Large ♂ ♀	0 1 2 3	SW BR R F P	Tolerance Slow Departure FS Flight			
			C.Reef Sandy Rocky	Small Med. Large ♂ ♀	0 1 2 3	SW BR R F P	Tolerance Slow Departure FS Flight			
			C.Reef Sandy Rocky	Small Med. Large ♂ ♀	0 1 2 3	SW BR R F P	Tolerance Slow Departure FS Flight			
			C.Reef Sandy Rocky	Small Med. Large ♂ ♀	0 1 2 3	SW BR R F P	Tolerance Slow Departure FS Flight			
			C.Reef Sandy Rocky	Small Med. Large ♂ ♀	0 1 2 3	SW BR R F P	Tolerance Slow Departure FS Flight			
				S= <2' M= 2'-3' L= >3' ♂: long tail ♀: short tail	0=no FP 1=light 2= moderate 3=heavy	SWimming BReathing Resting Foraging Posing (@ cl. Station)	FS= FlipperSwipe			

Survey Notes:

Map of area and route taken:
(Mark # for each honu sighting)

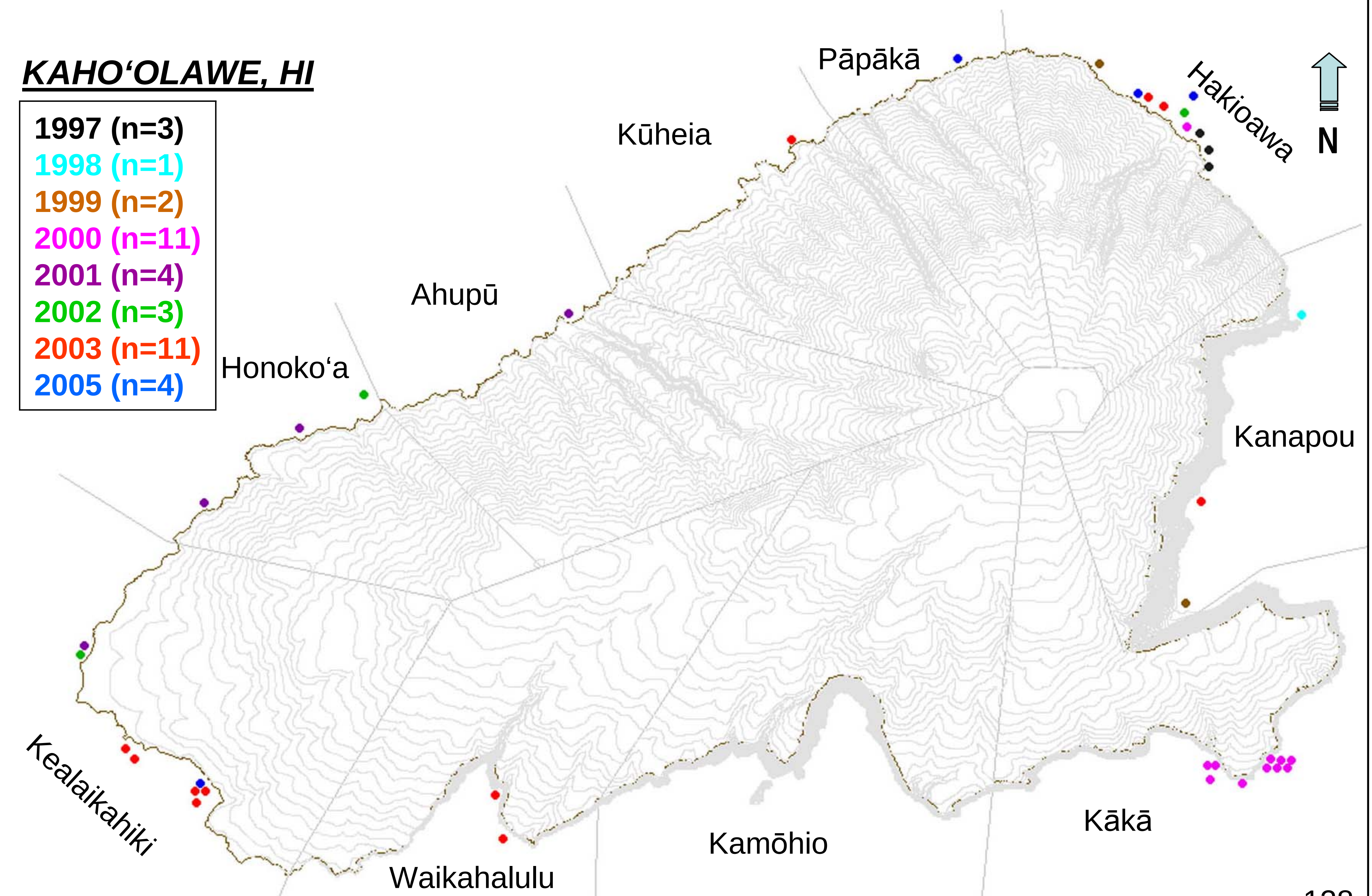


Figure 23. Distribution Map of Opportunistic Turtle Sightings (n=39).

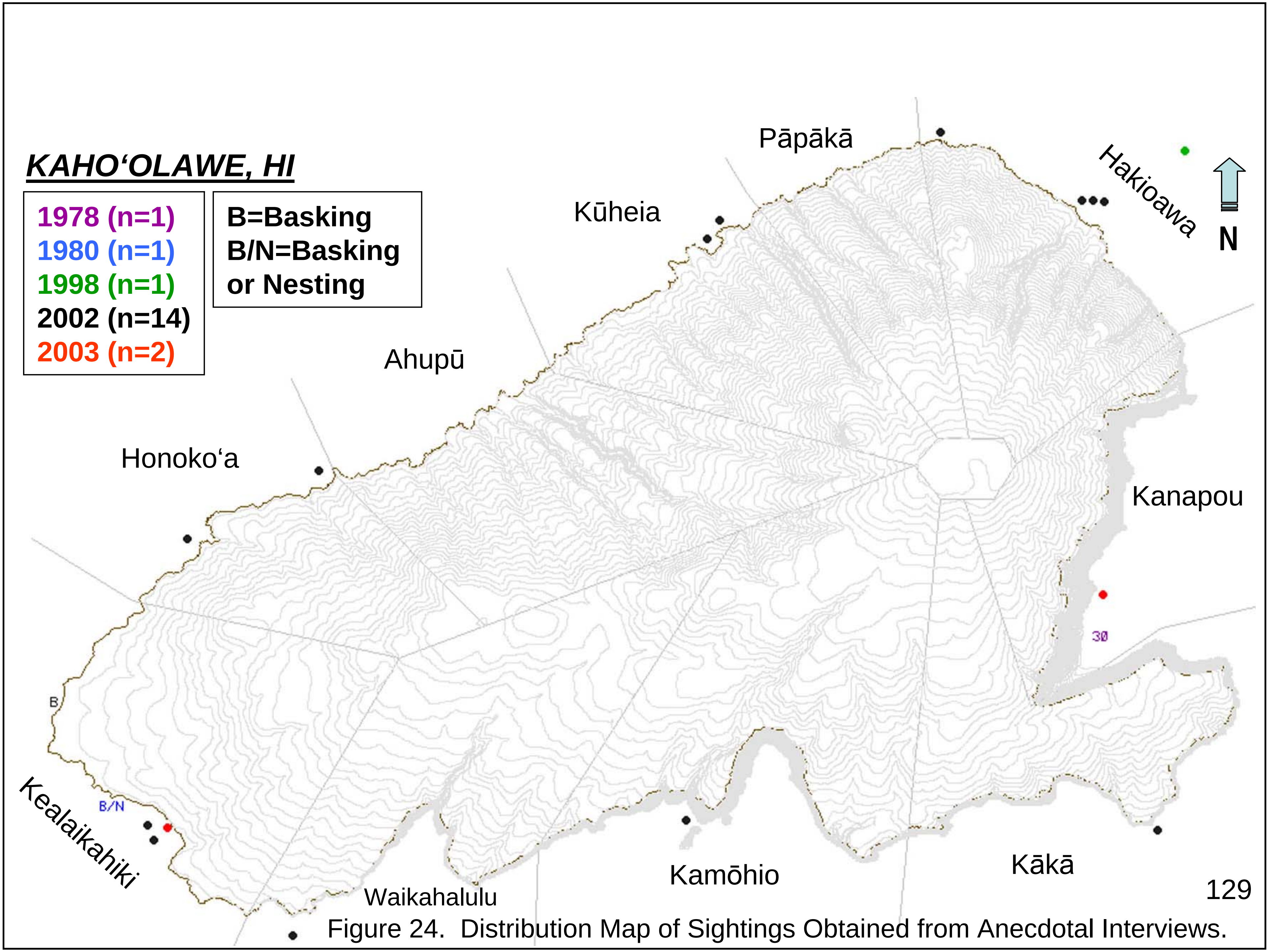
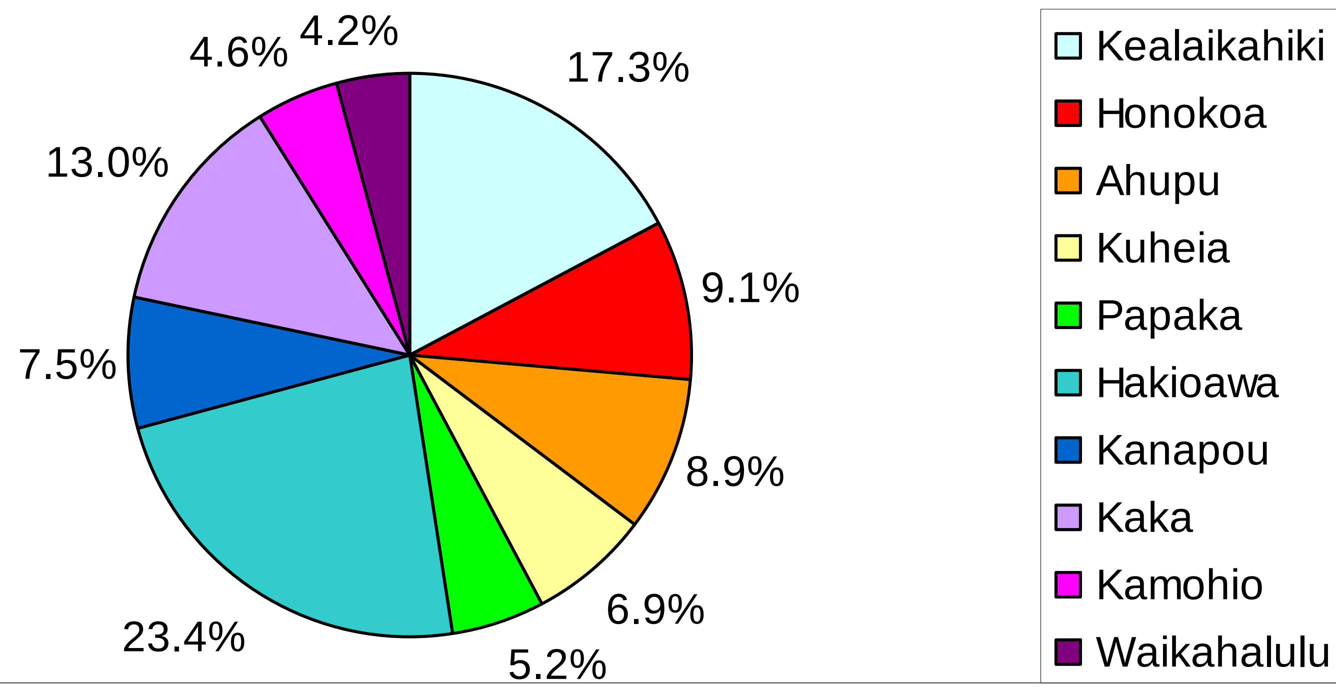


Figure 24. Distribution Map of Sightings Obtained from Anecdotal Interviews.

Figure 25. Distribution Totals by 'Ili for All Survey Types and Sources (n=671).



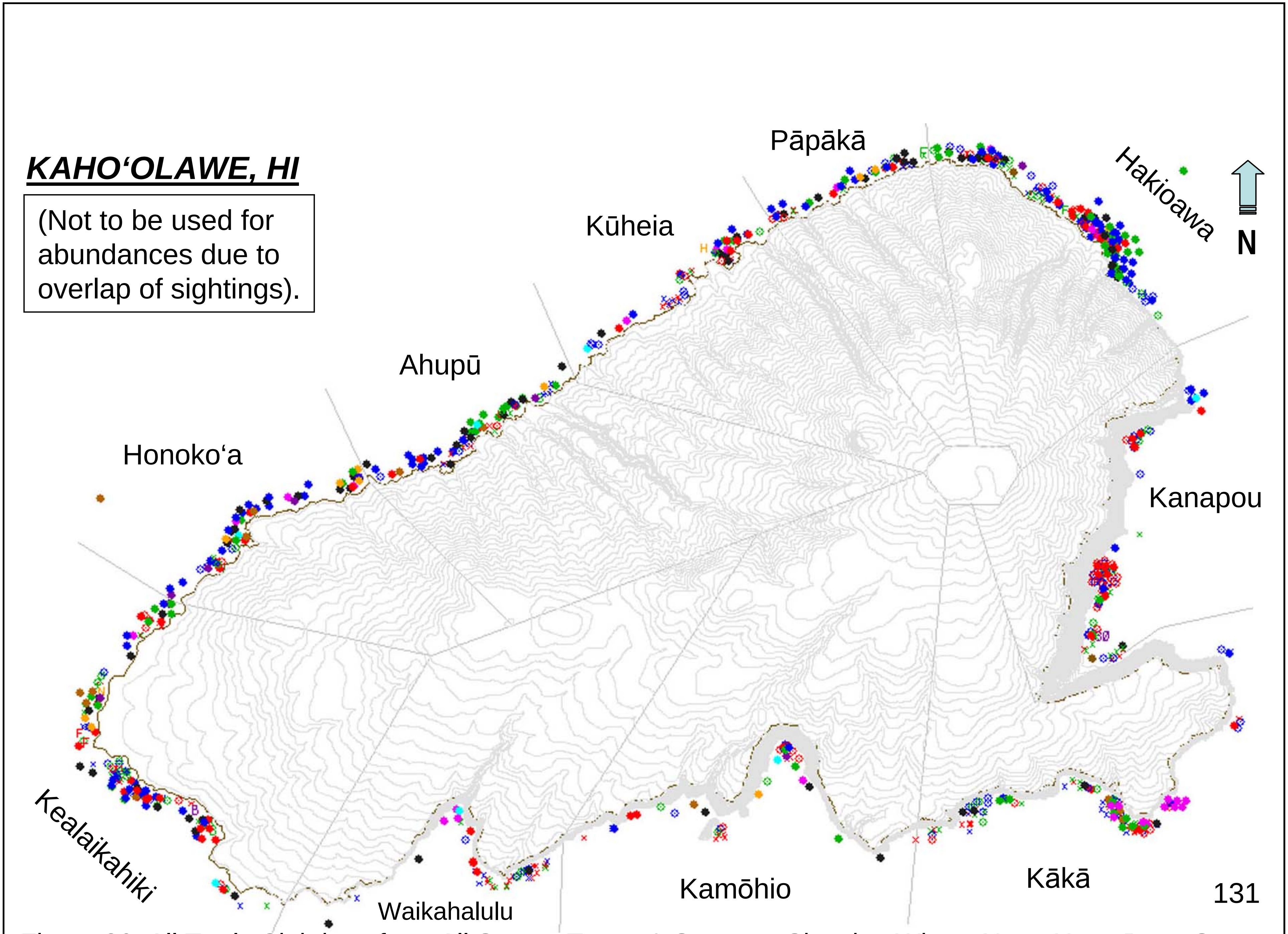


Figure 26. All Turtle Sightings from All Survey Types & Sources, Showing Where None Have Been Seen.

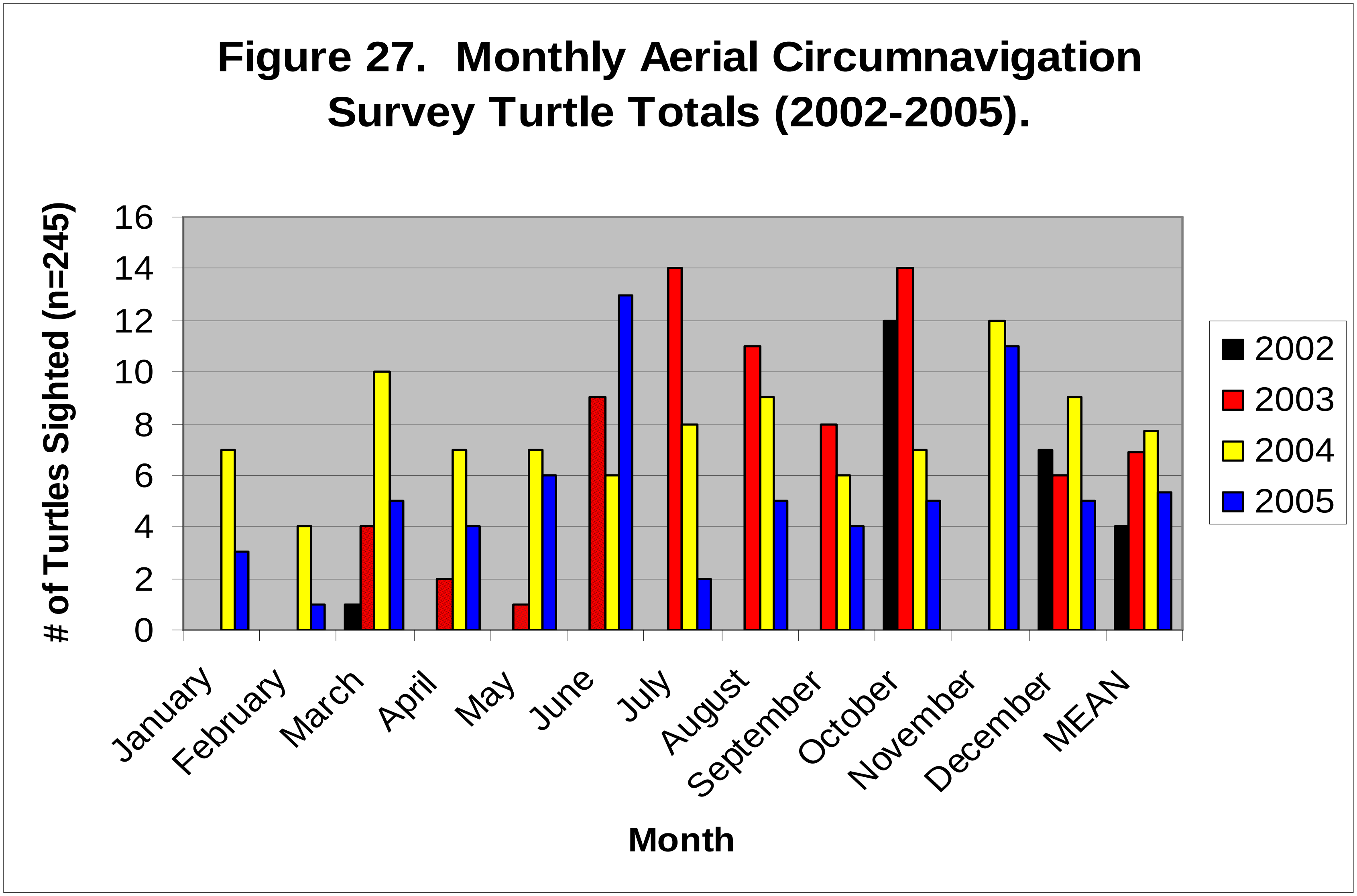
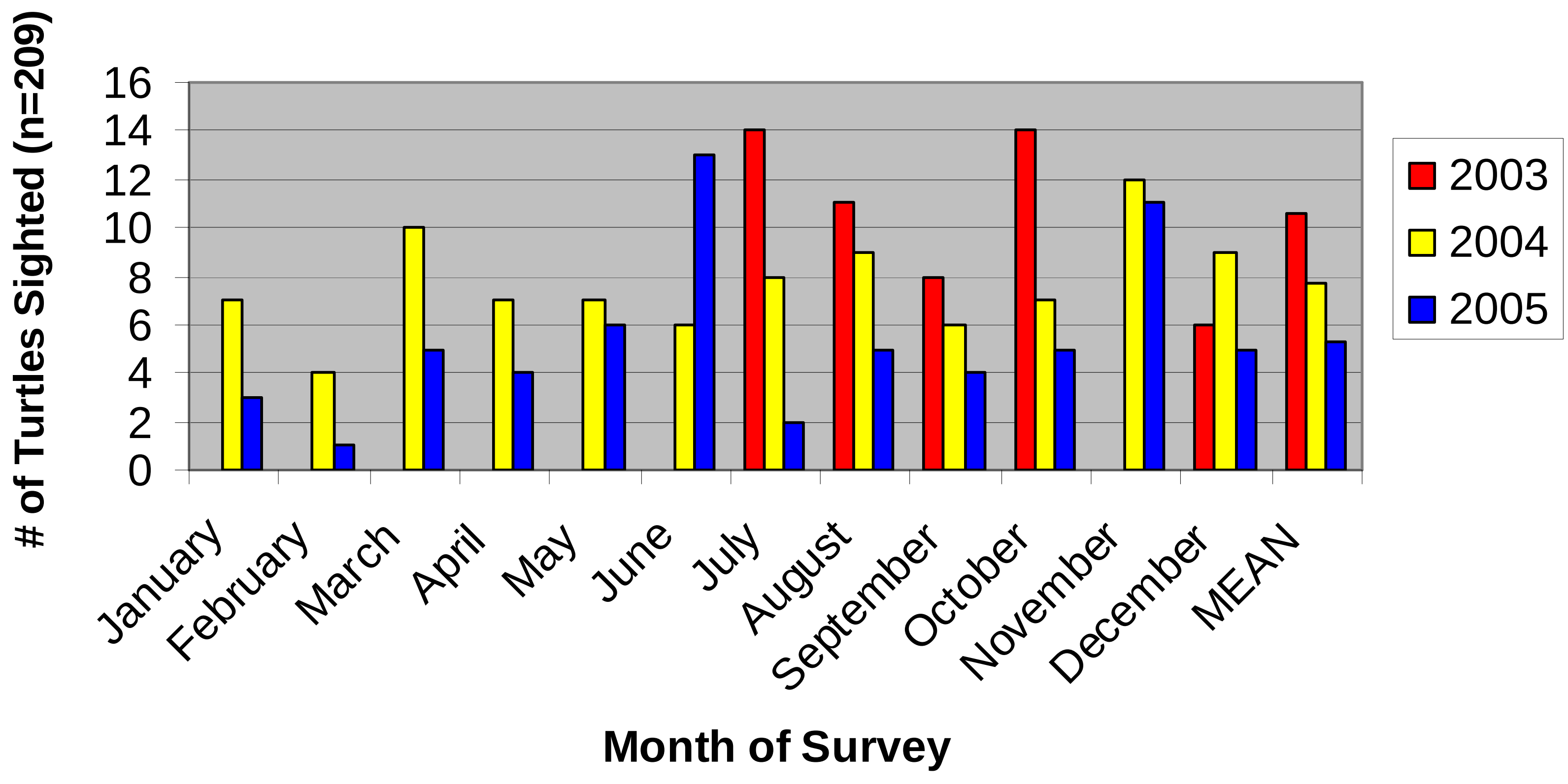


Figure 27. Monthly Aerial Circumnavigation Survey Turtle Totals (2002-2005).
# of Turtles Sighted (n=245)
16
14
12
10
8
6
4
2
0
January
February
March
April
May
June
July
August
September
October
November
December
MEAN
Month
2002
2003
2004
2005

Figure 28. Standardized Monthly Aerial Circumnavigation Survey Turtle Totals (2003-2005).



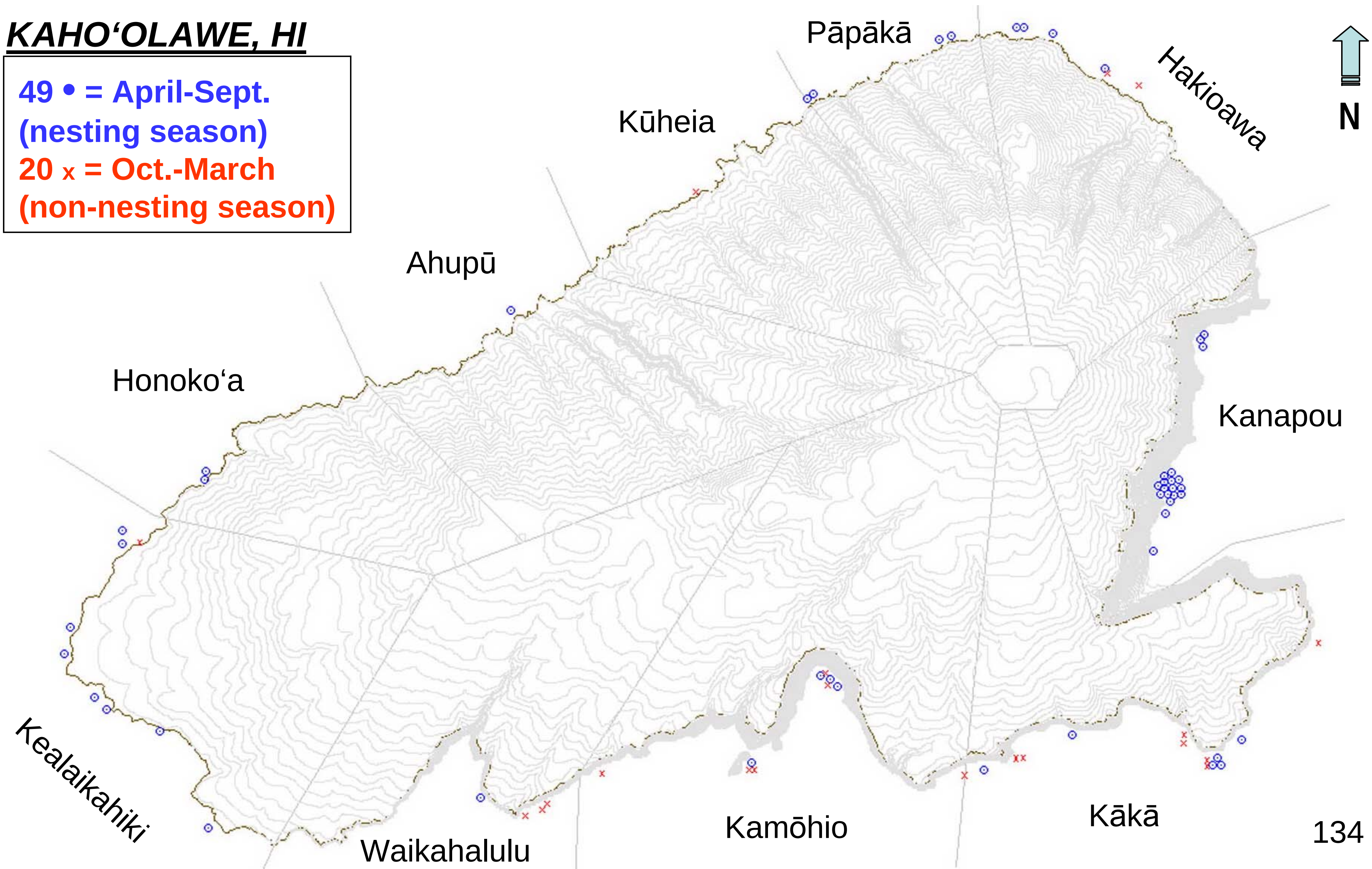


Figure 29. Seasonal Distributions of 69 Turtle Sightings from 10 Aerial Circumnavigation Surveys, 2003.

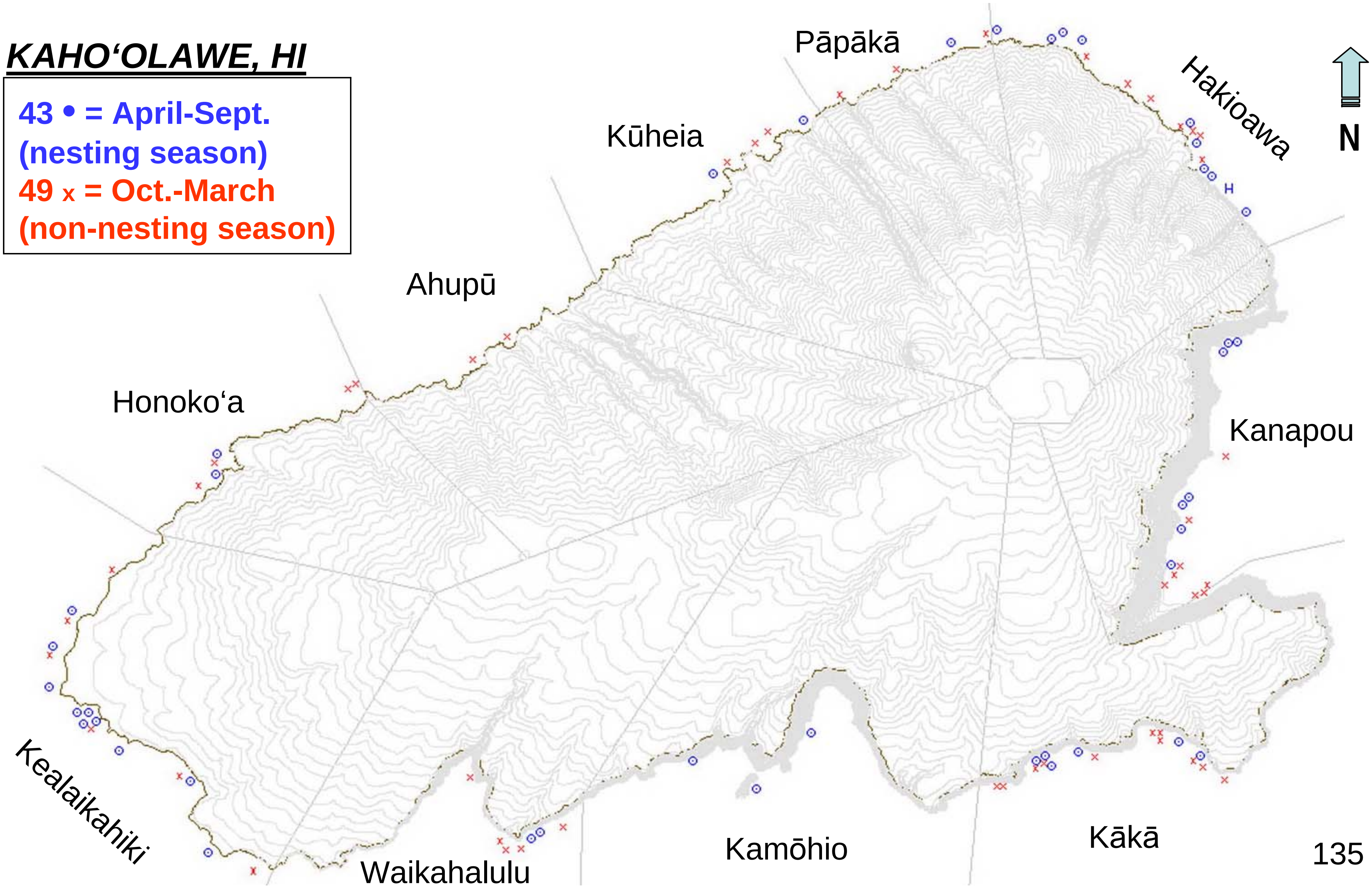


Figure 30. Seasonal Distributions of 92 Turtle Sightings from 12 Aerial Circumnavigation Surveys, 2004.

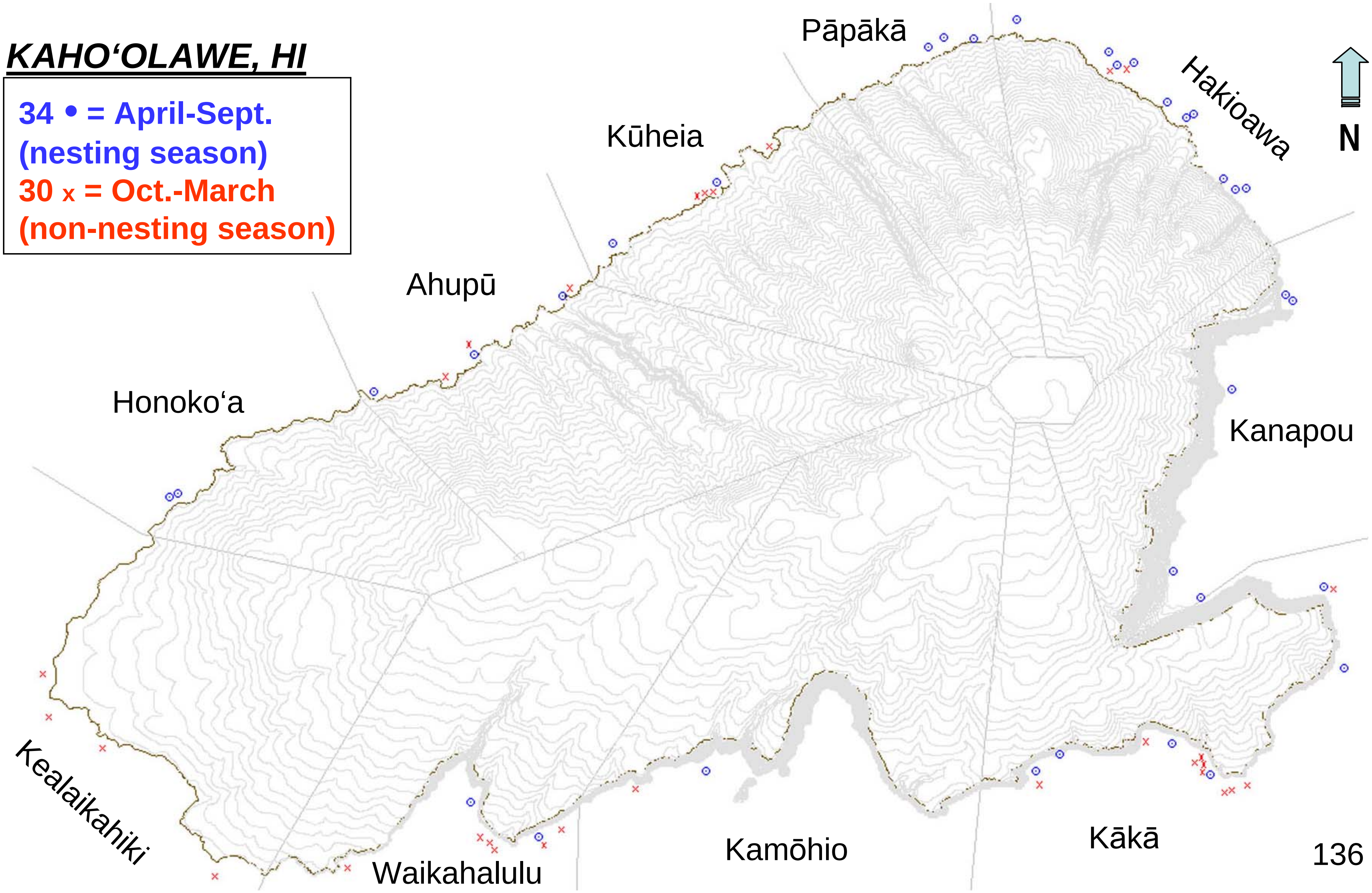


Figure 31. Seasonal Distributions of 64 Turtle Sightings from 12 Aerial Circumnavigation Surveys, 2005.

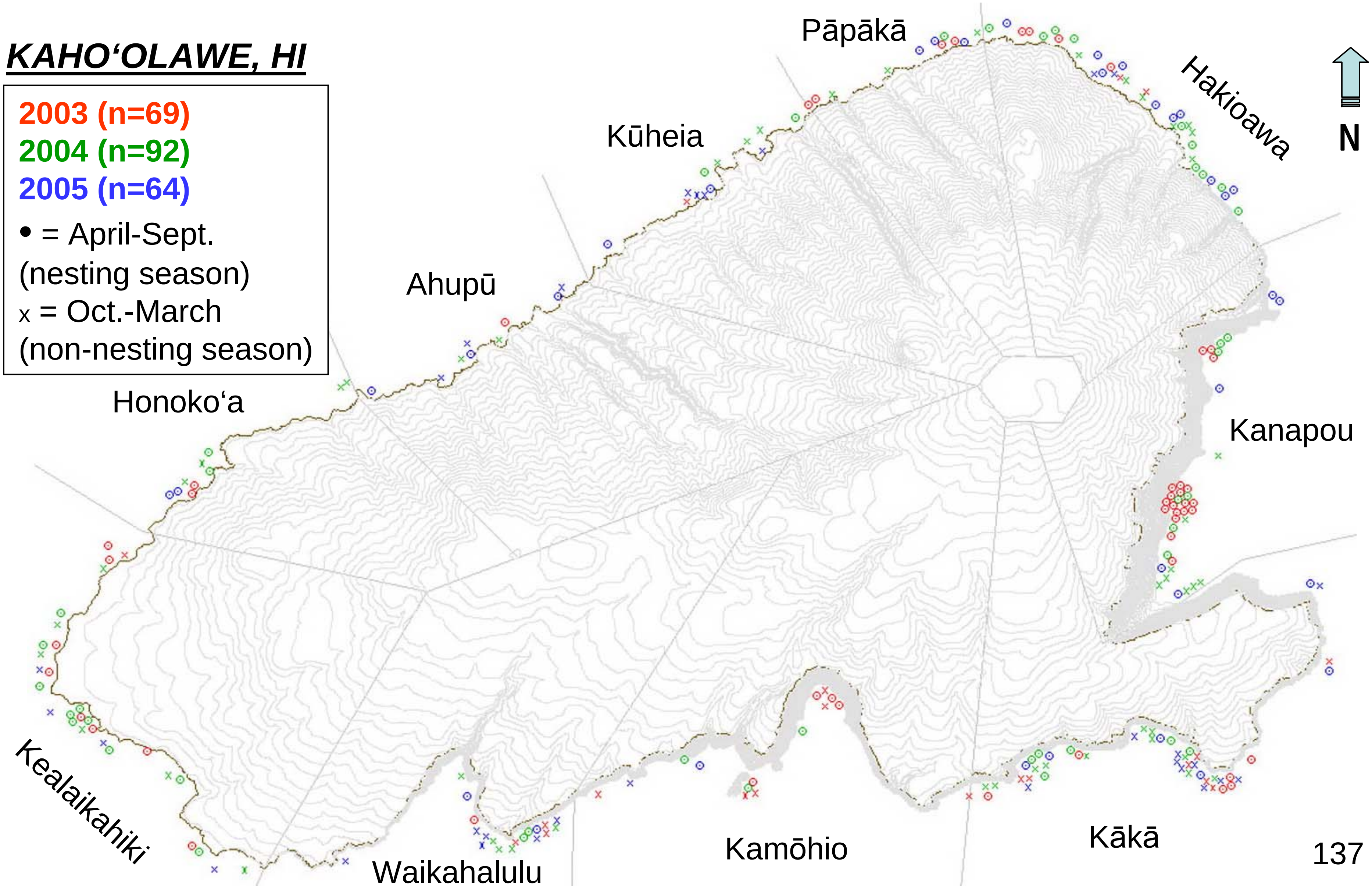


Figure 32. Seasonal Distributions of 225 Turtle Sightings from 34 Aerial Circumnav. Surveys, 2003-2005.

Figure 33. Relative Seasonal Abundances (Nesting Vs. Non-nesting) from 29 Standardized Aerial Circumnavigation Surveys (2003-2005).

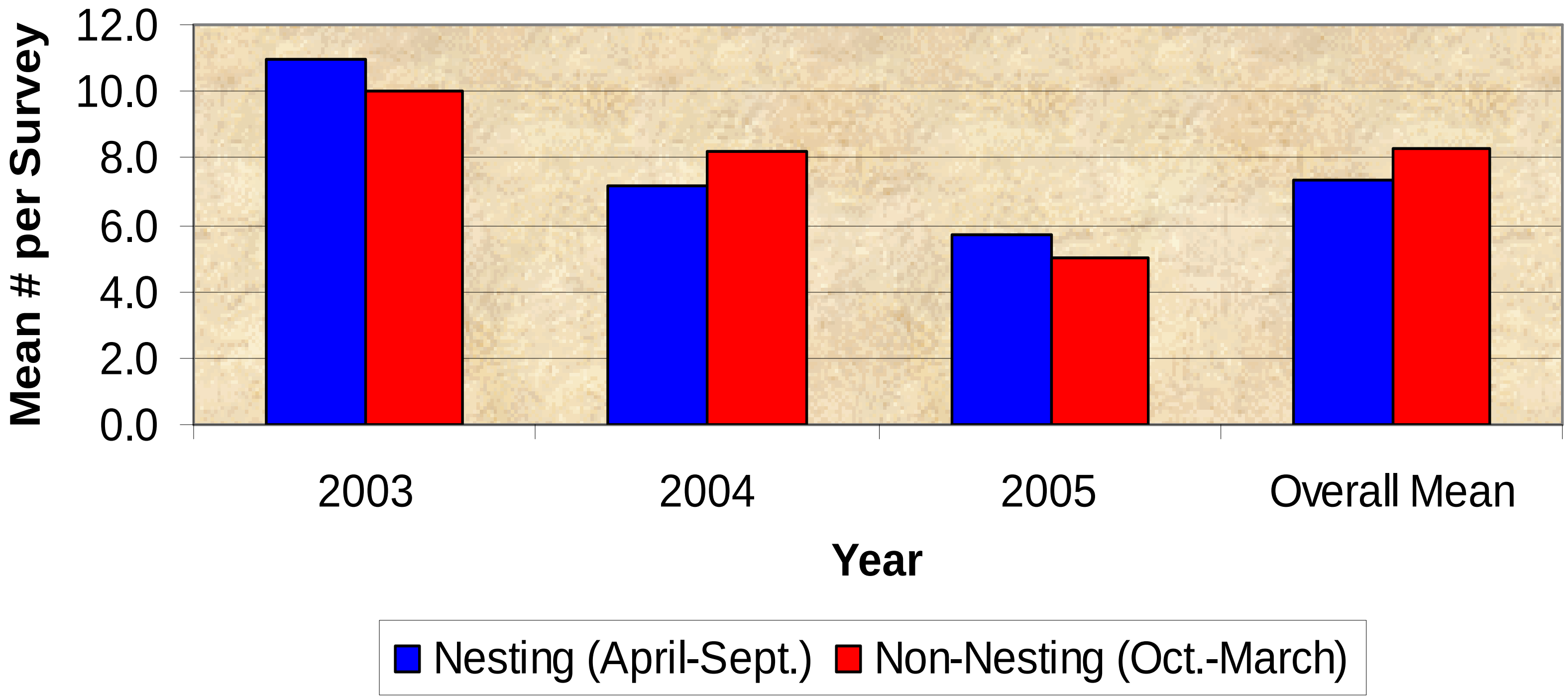
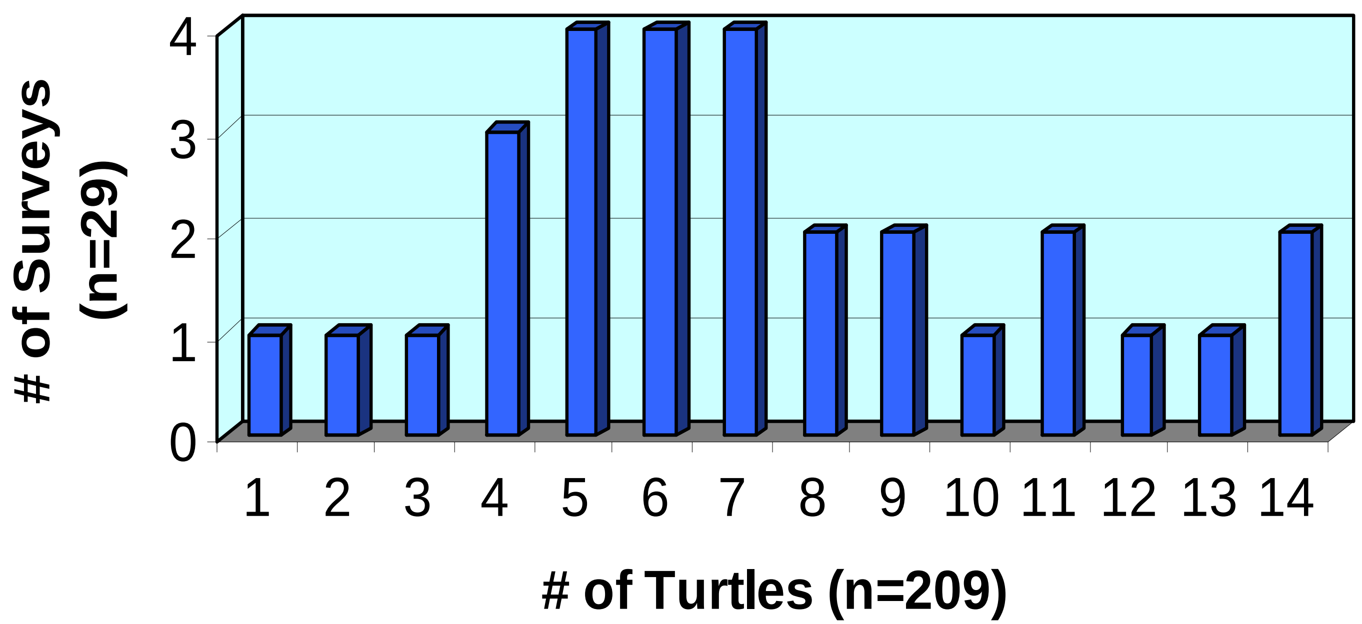


Figure 34. Frequency of Turtle Sightings per Standardized Aerial Circumnavigation Survey (2003-2005).



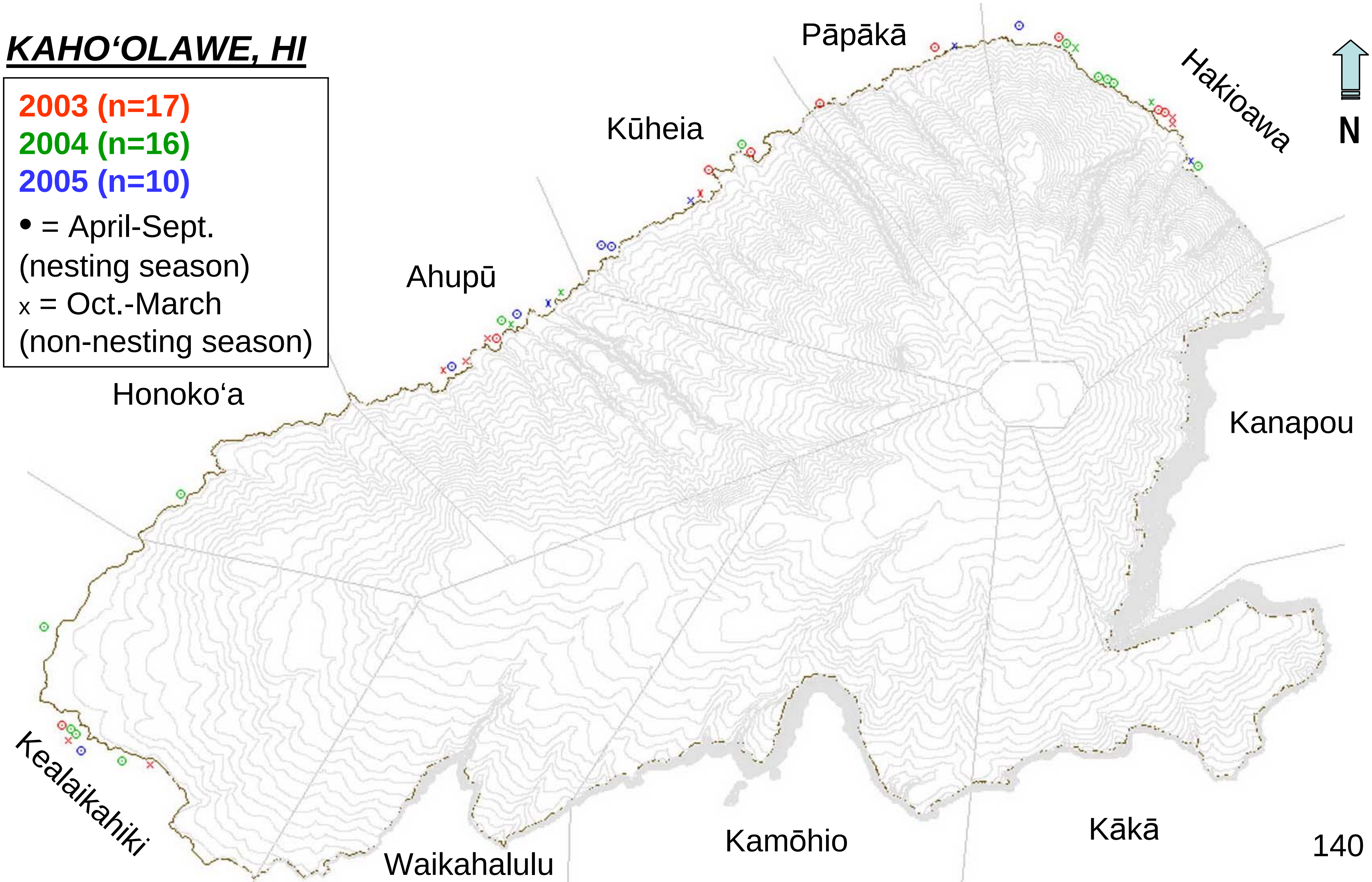
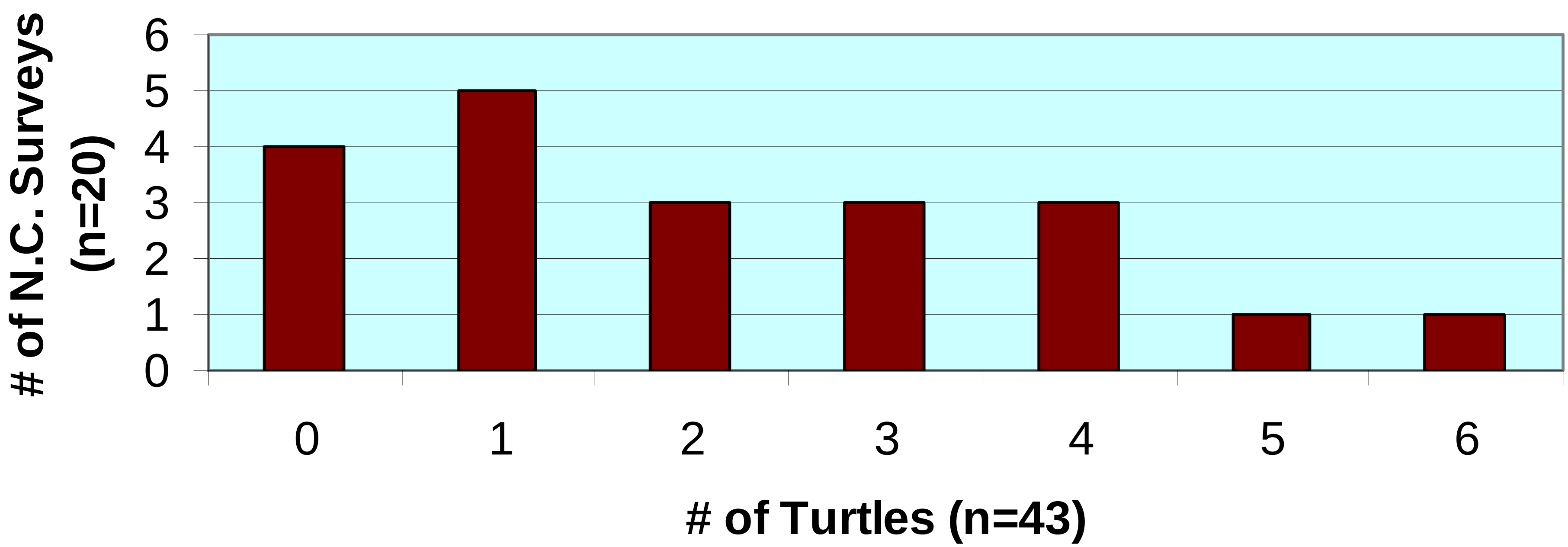


Figure 35. Distributions of 43 Turtle Sightings from 19 Standardized North Coast Aerials (2003-2005).

Figure 36. Frequency of Turtle Sightings per Standardized North Coast Aerial Survey (2003-2005).



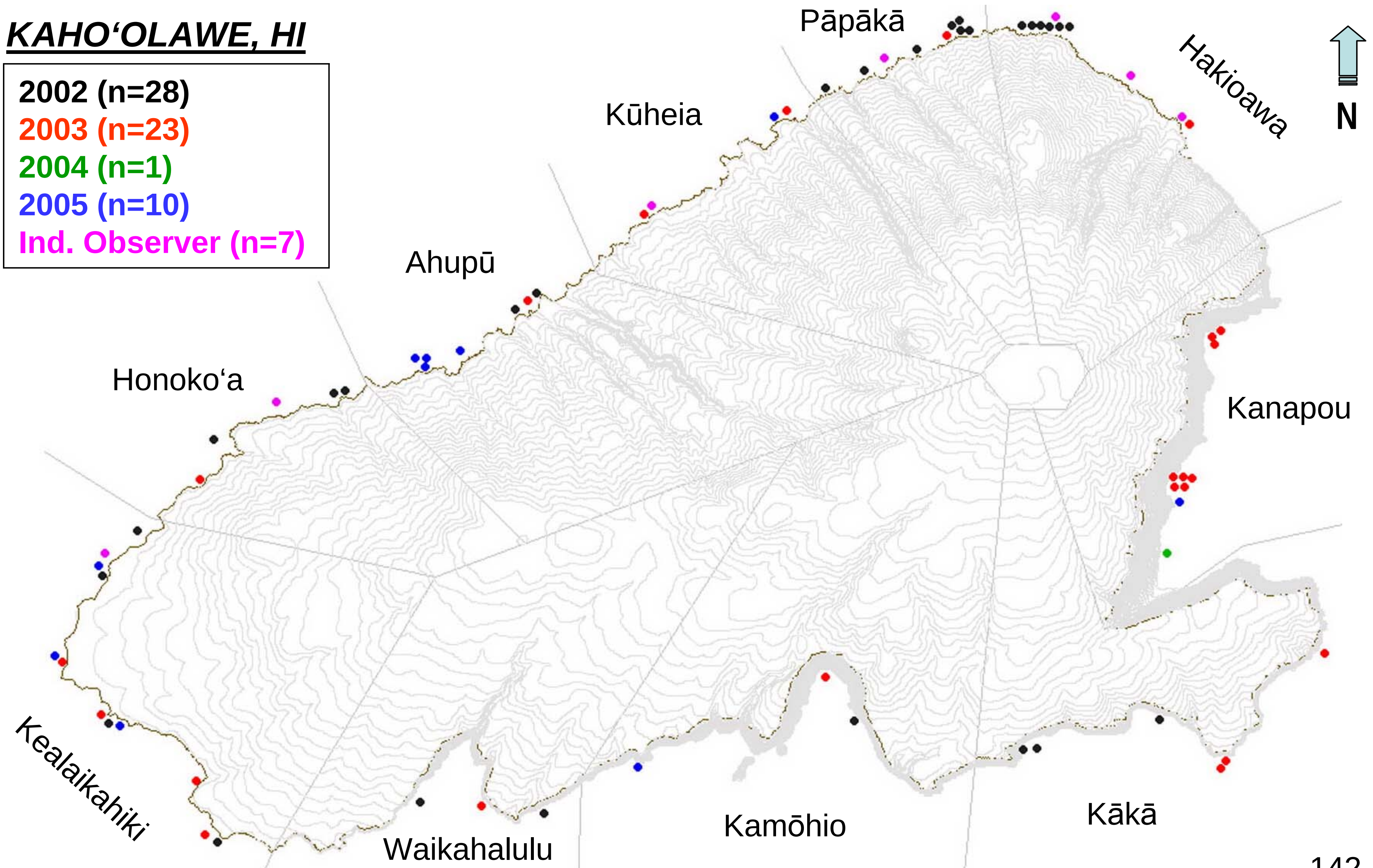


Figure 37. Incidental (n=62) and Independent Observer (n=7) Aerial Turtle Sightings (2002-2005).

Figure 38. Standardized Vs. Non-standardized and Independent Observer Monthly Totals from Aerial Circumnavigation Surveys.

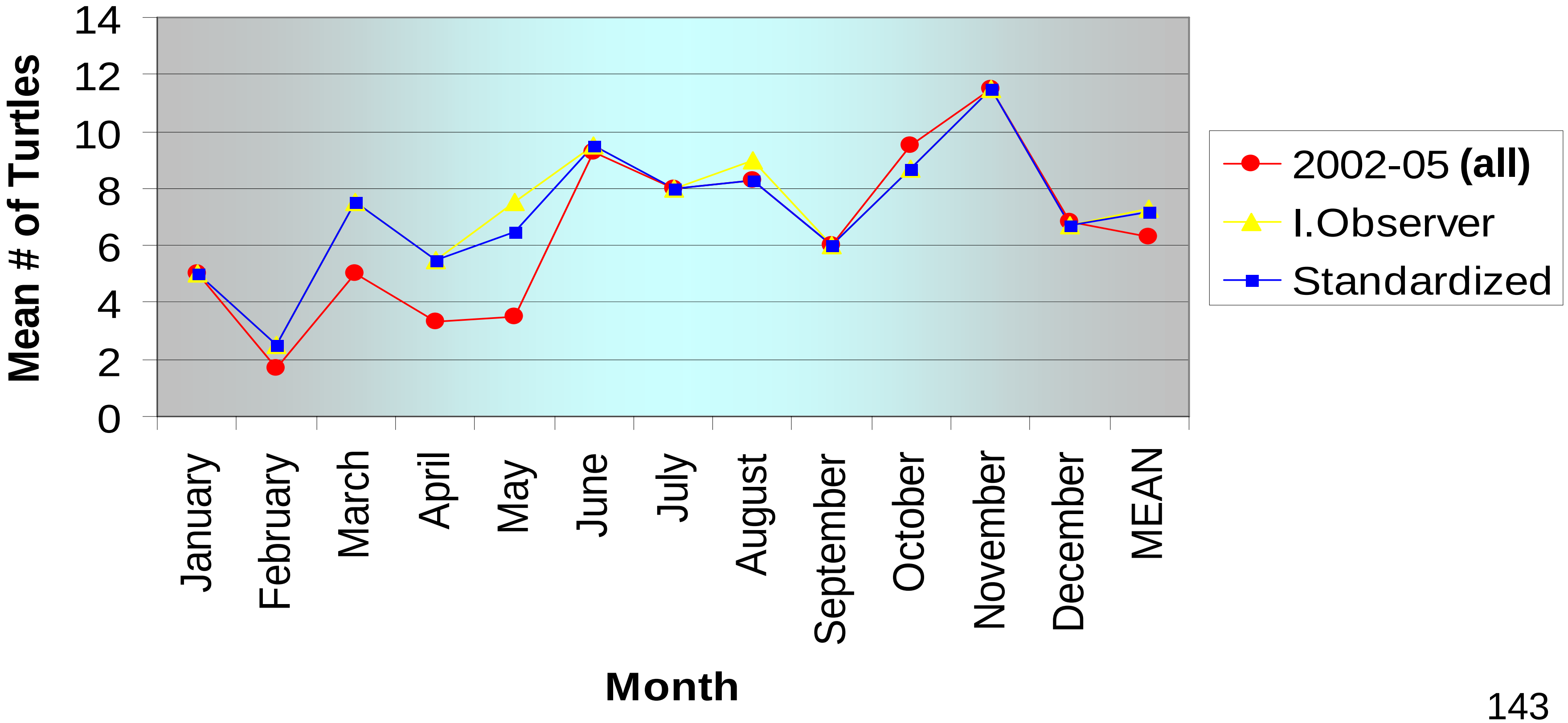


Figure 39. Aerial Circumnavigation Sighting Distributions by 'Ili (Compared to Total Sightings).

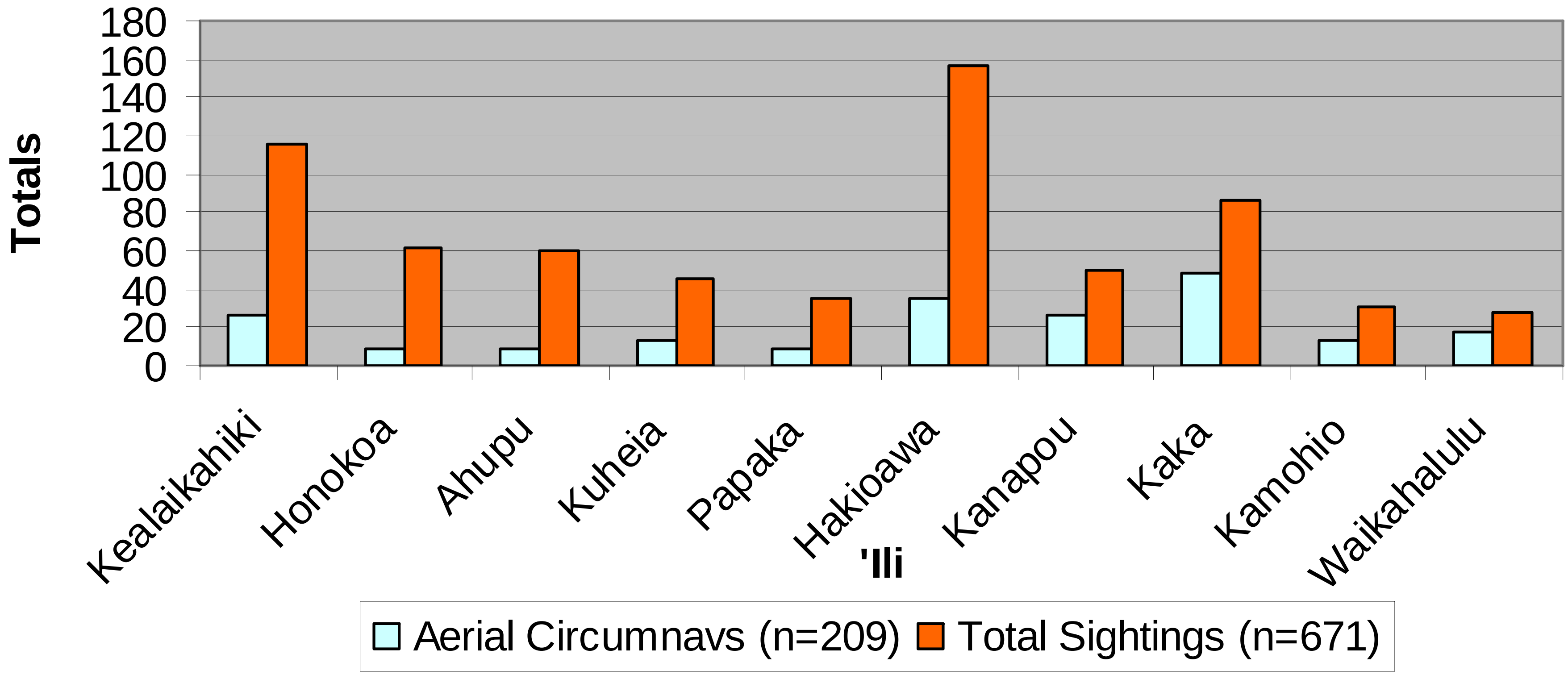
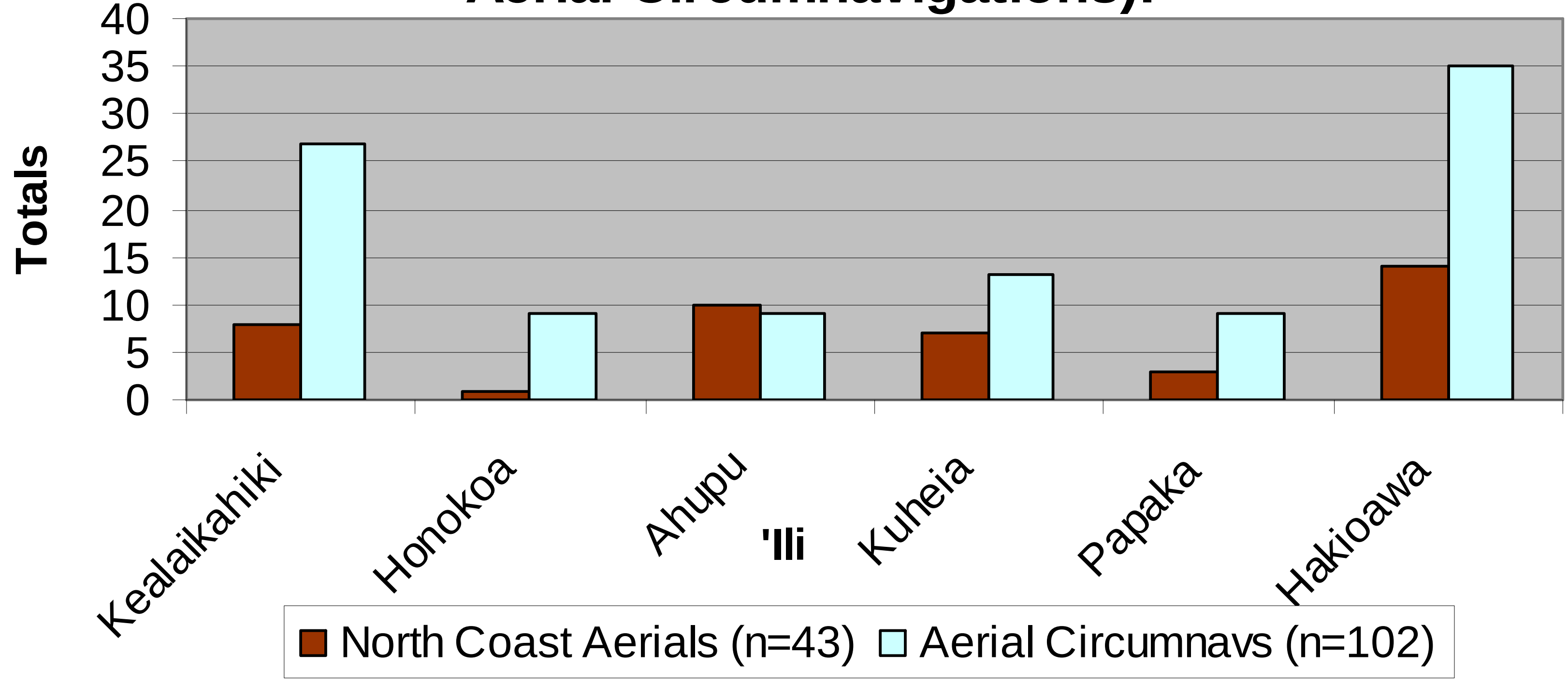


Figure 40. North Coast Aerial Sighting Distributions by 'Ili (Compared to Standardized Aerial Circumnavigations).



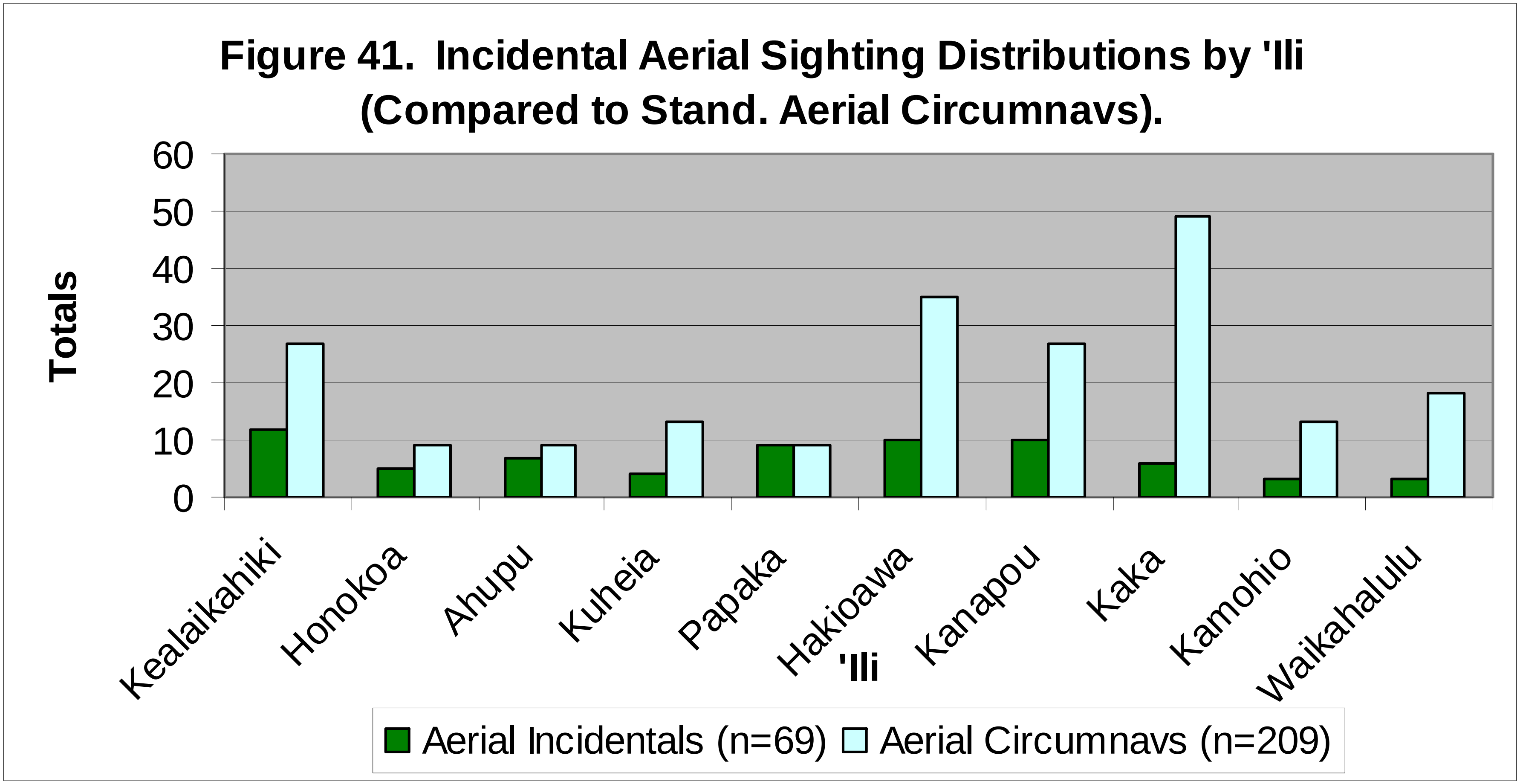


Figure 41. Incidental Aerial Sighting Distributions by 'Ili
(Compared to Stand. Aerial Circumnavs).
Totals
60
50
40
30
20
10
0
Kealaikahiki
Honokoa
Ahupu
Kuheia
Papaka
Hakioawa
Kanapou
Kaka
Kamohio
Waikahalulu
'Ili
Aerial Incidentals (n=69)
Aerial Circumnavs (n=209)

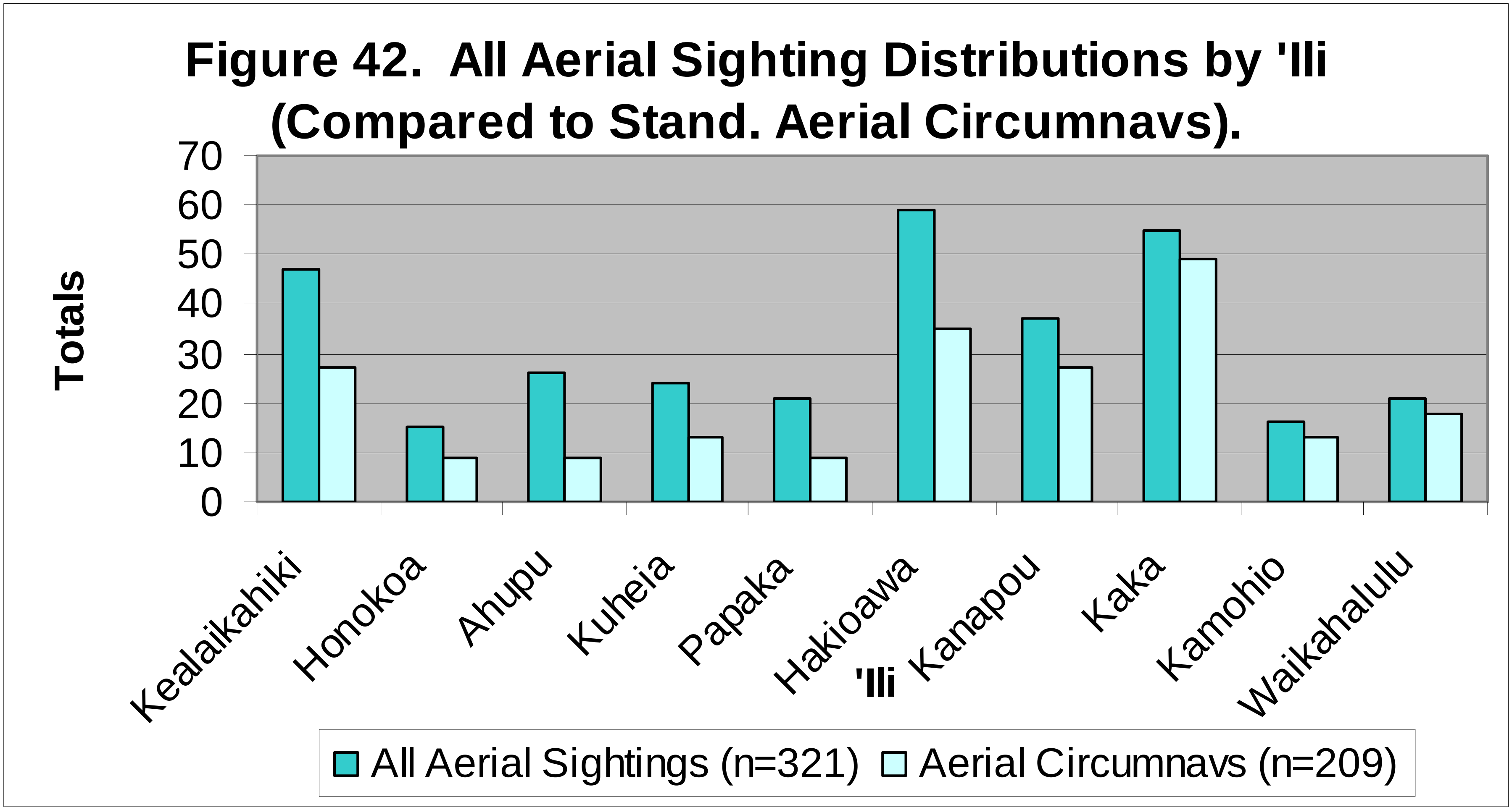


Figure 42. All Aerial Sighting Distributions by 'Ili
(Compared to Stand. Aerial Circumnavs).
Totals
70
60
50
40
30
20
10
0
Kealaikahiki
Honokoa
Ahupu
Kuheia
Papaka
Hakioawa
Kanapou
Kaka
Kamohio
Waikahalulu
'Ili
All Aerial Sightings (n=321)
Aerial Circumnavs (n=209)

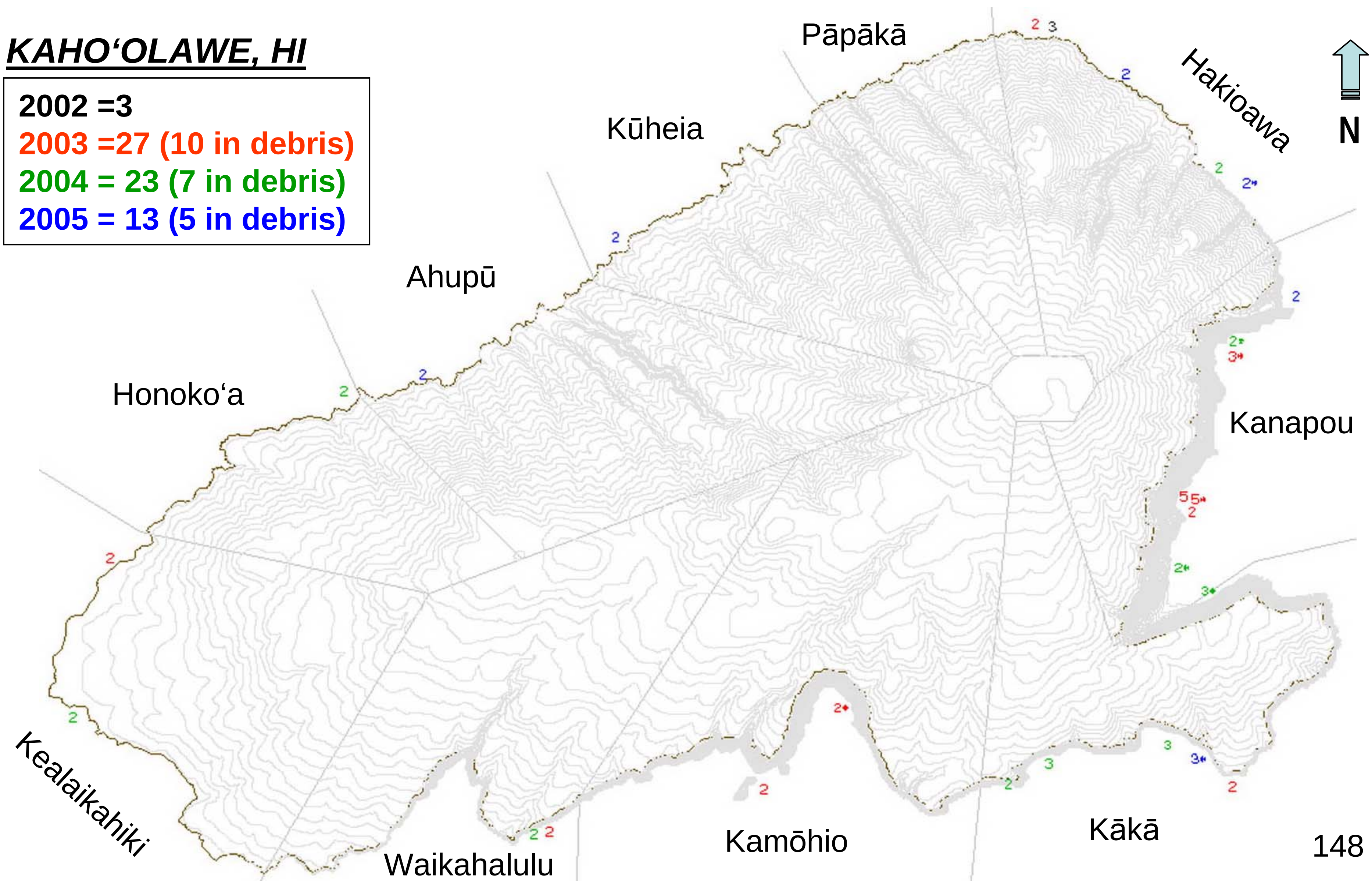


Figure 43. Clusters of Turtles and Their Associations with Debris Lines (Aerial Sightings 2002-2005).

Figure 44. Size Classes of Turtle Clusters Sighted Aerially (n=58).

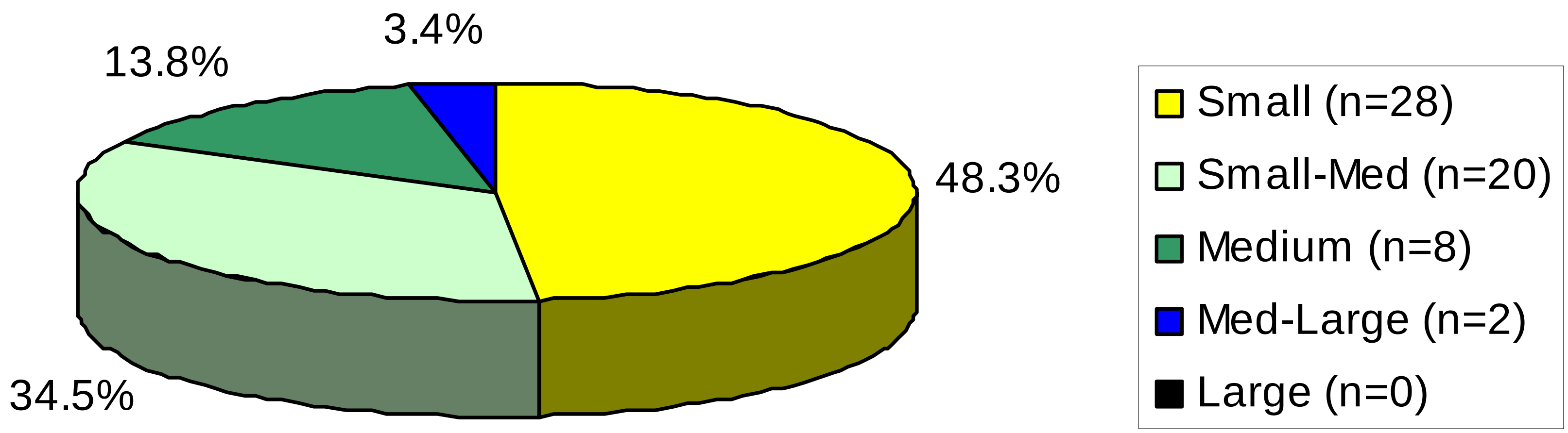


Figure 45. Size Classes of Turtle Clusters Sighted Aerially within Debris Lines (n=21).

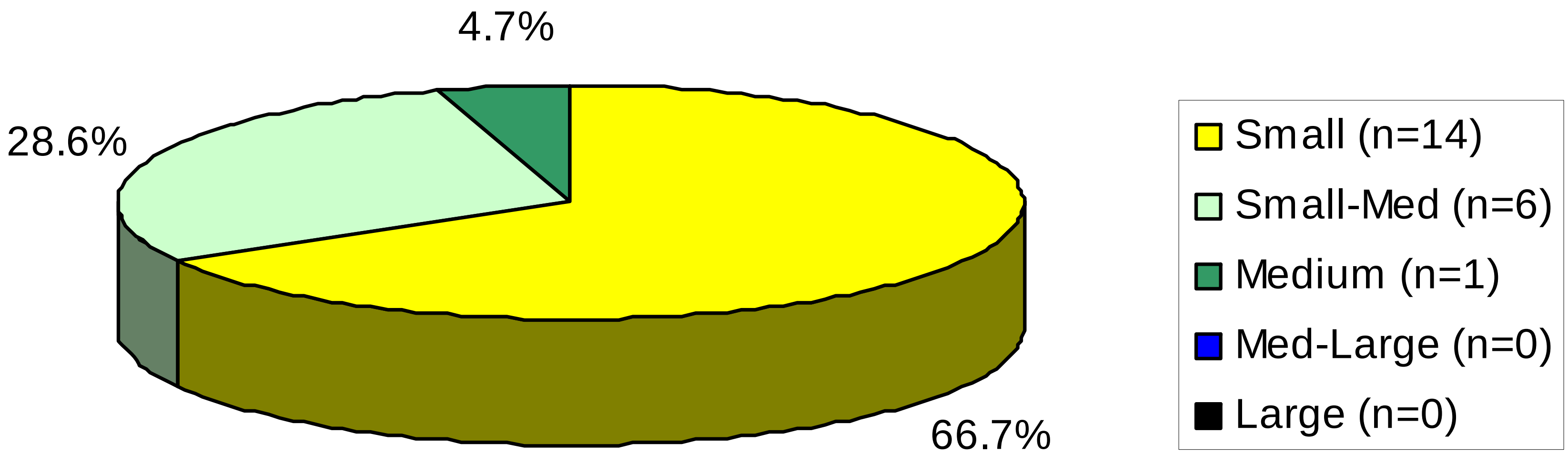


Figure 46. Size Classes of Turtles Sighted Aerially within Debris Lines (n=27).

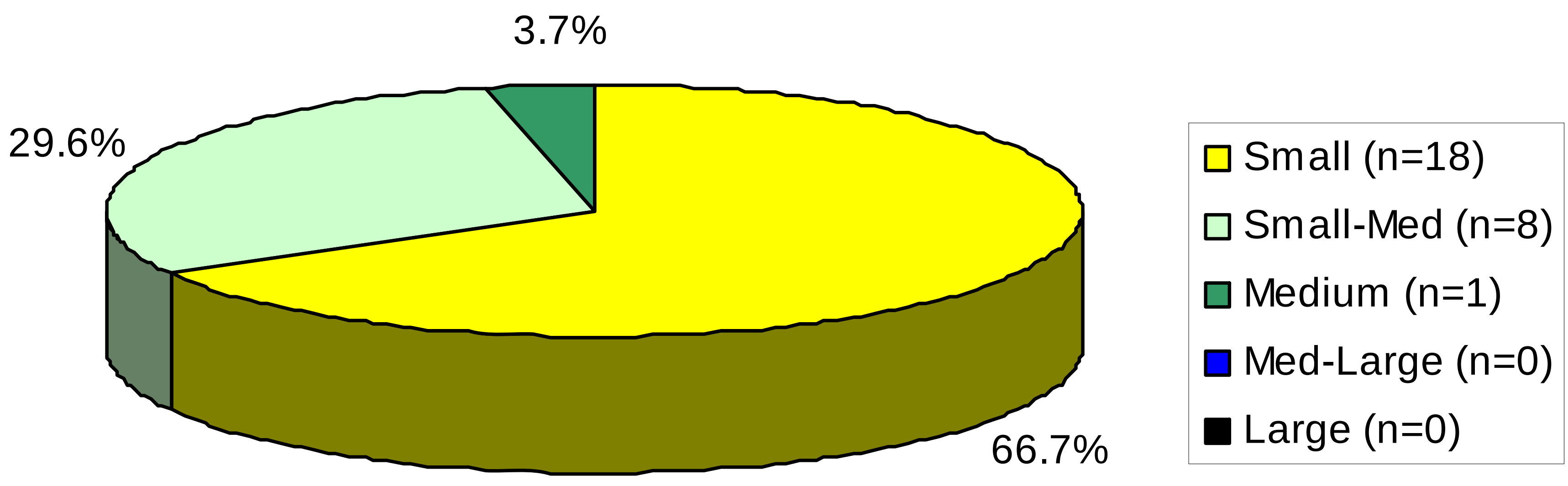


Figure 47. Size Classes of All Aerial Turtle Sightings (n=260).

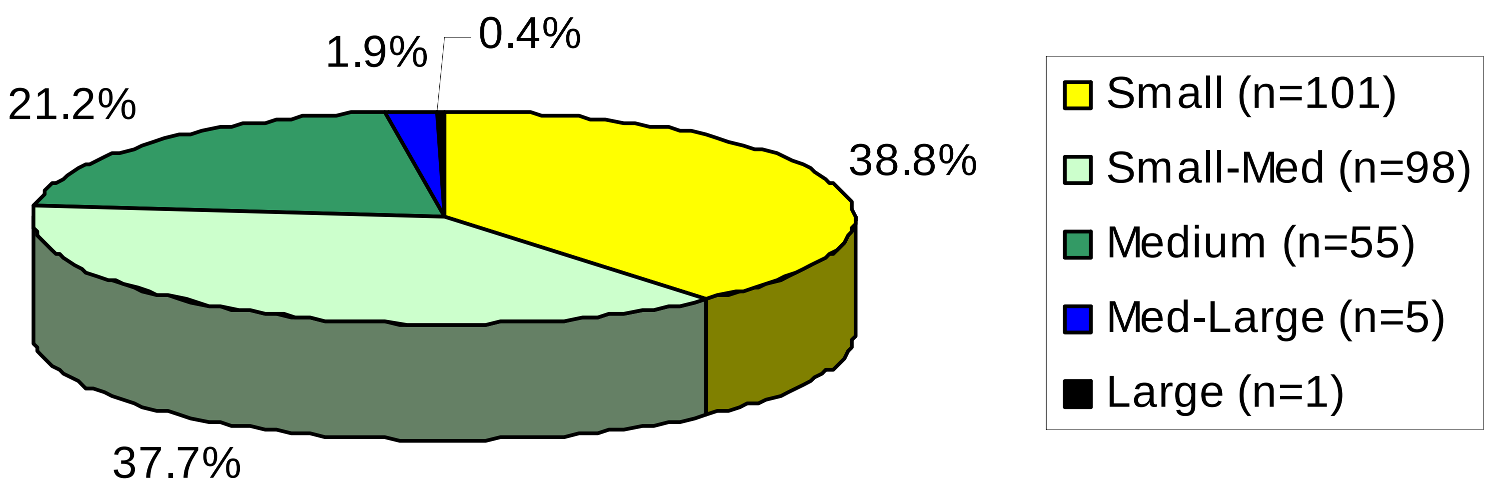


Figure 48. Habitat Characteristics of Aerial Turtle Sightings.

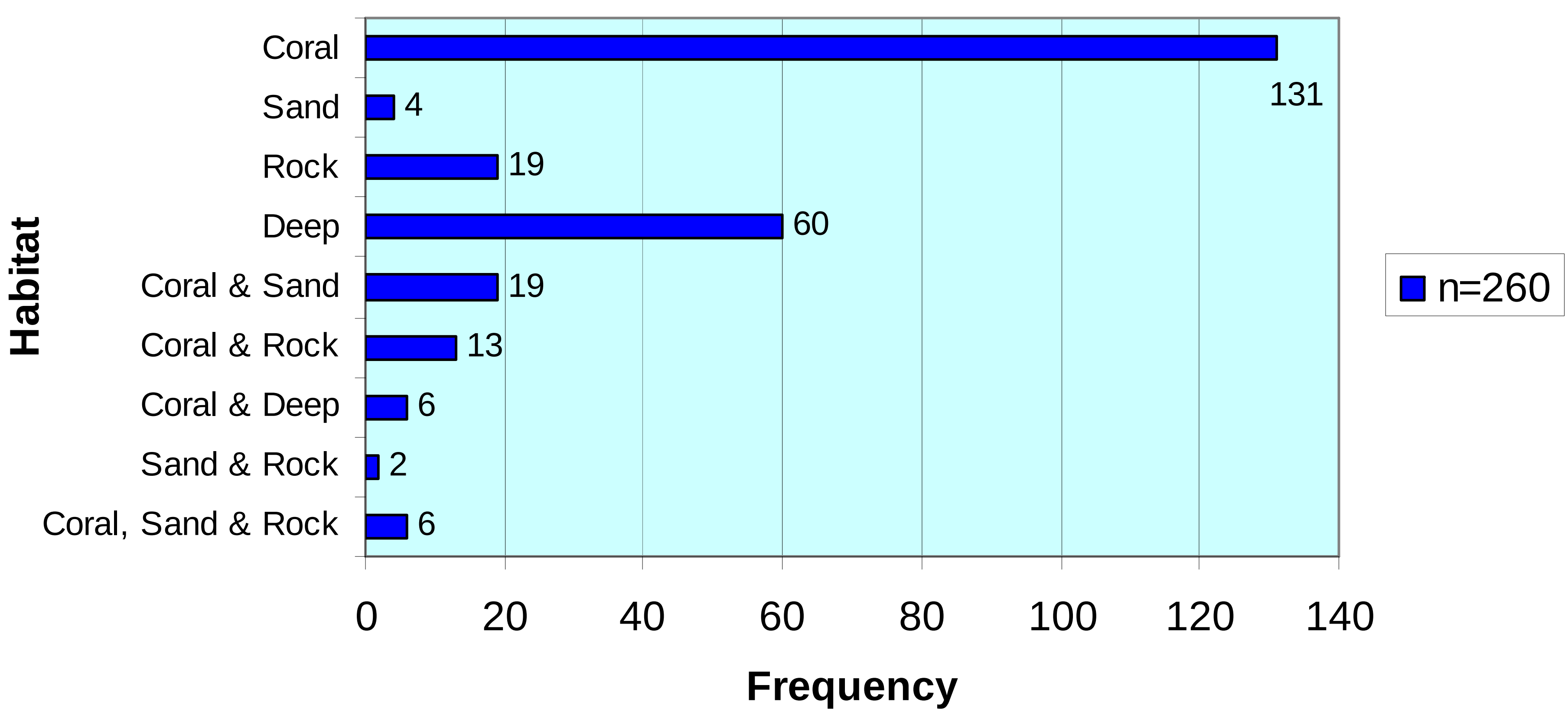


Figure 49. Water Clarity Associated with Aerial Turtle Sightings (n=267).

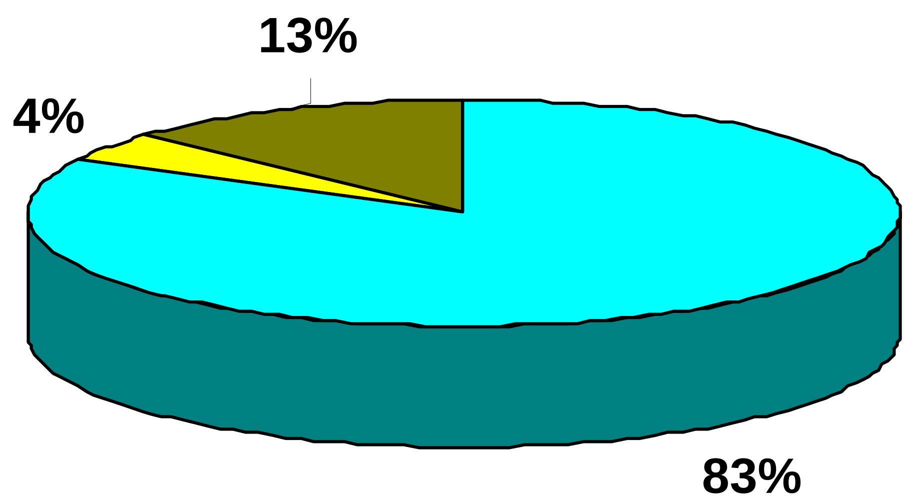


Figure 50. Relative Distances from Shore (from Aerial Sightings, n=286).

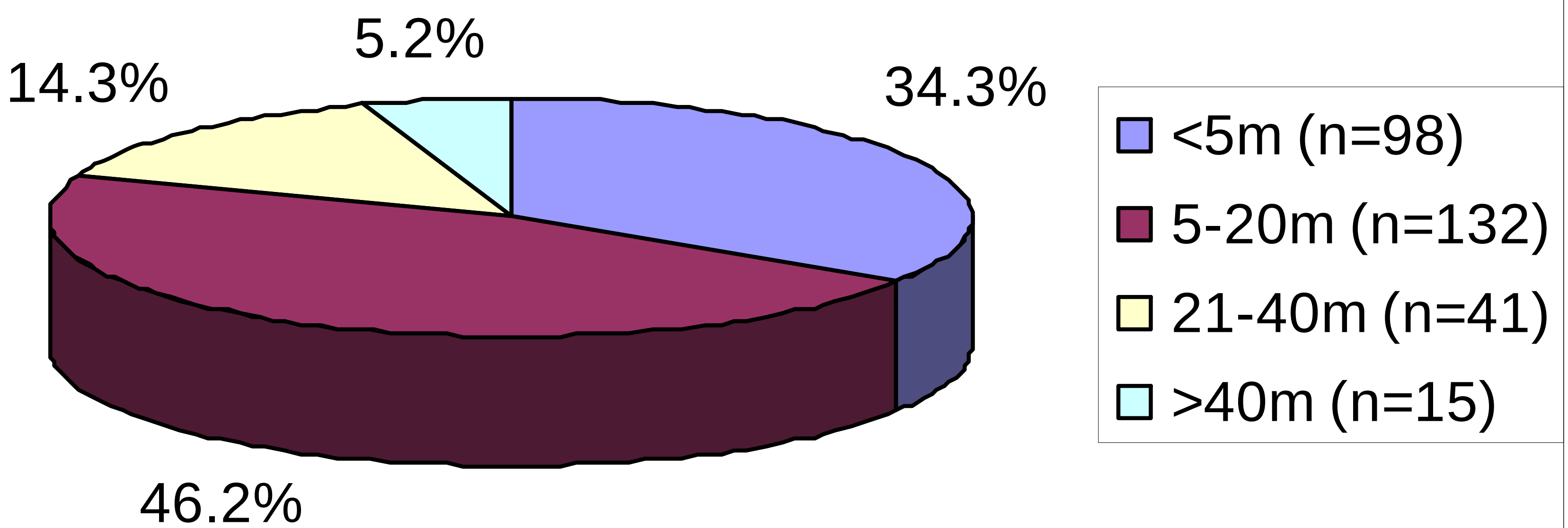


Figure 51. Behaviors of Turtles Sighted Aerially (n=285).

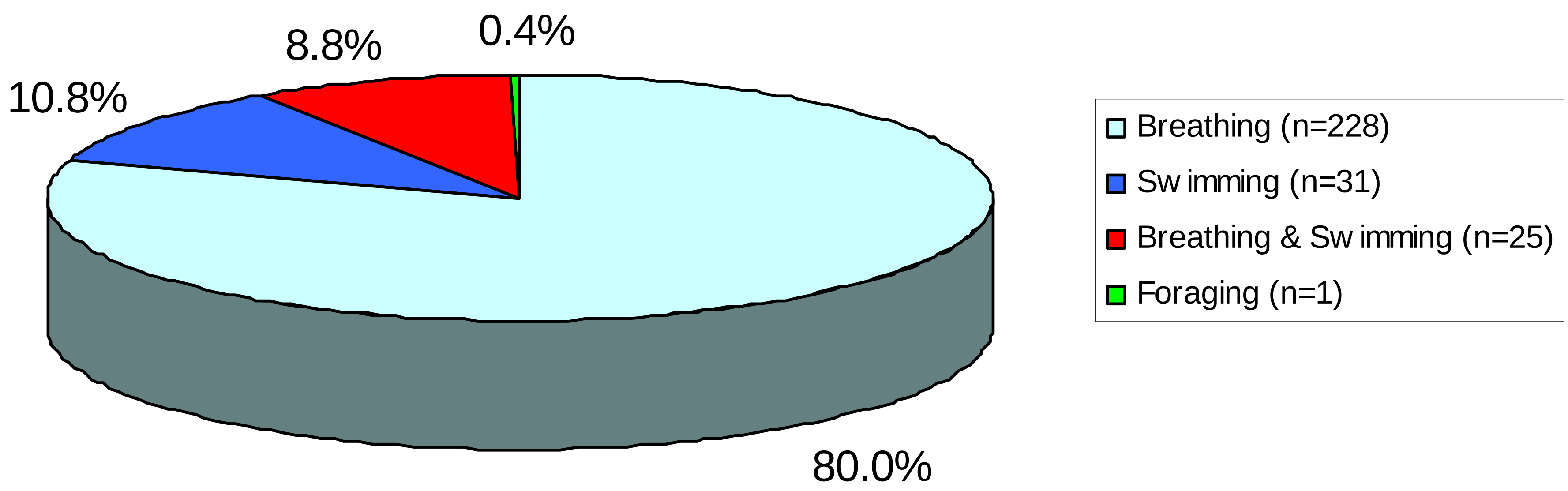
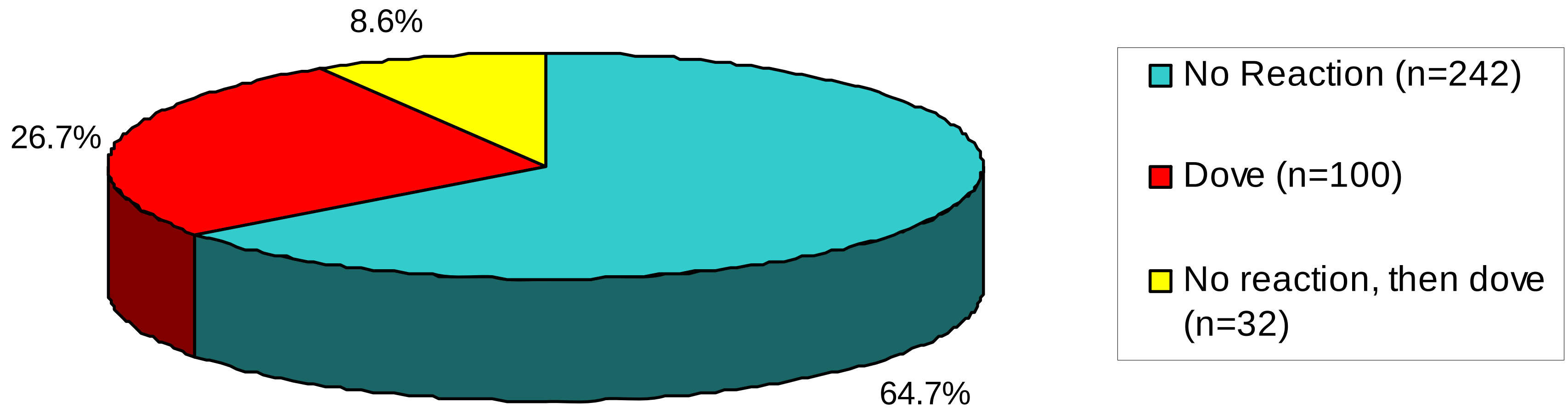


Figure 52. Summary of Perceived Turtle Reactions in Response to Helicopter Presence During 1st and 2nd Passes (n=374).



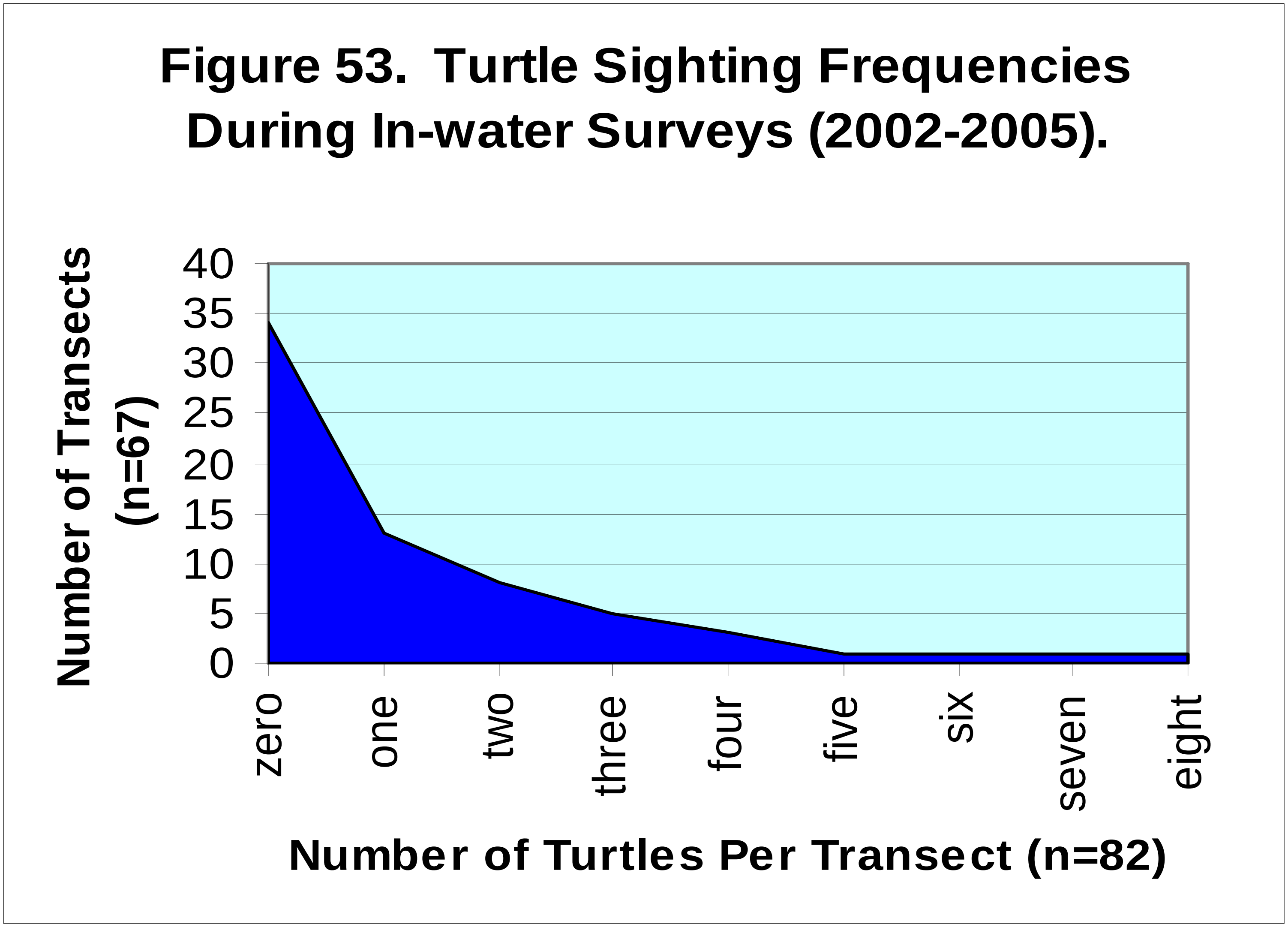


Figure 53. Turtle Sighting Frequencies
During In-water Surveys (2002-2005).
Number of Transects
(n=67)
40
35
30
25
20
15
10
5
0
zero
one
two
three
four
five
six
seven
eight
Number of Turtles Per Transect (n=82)

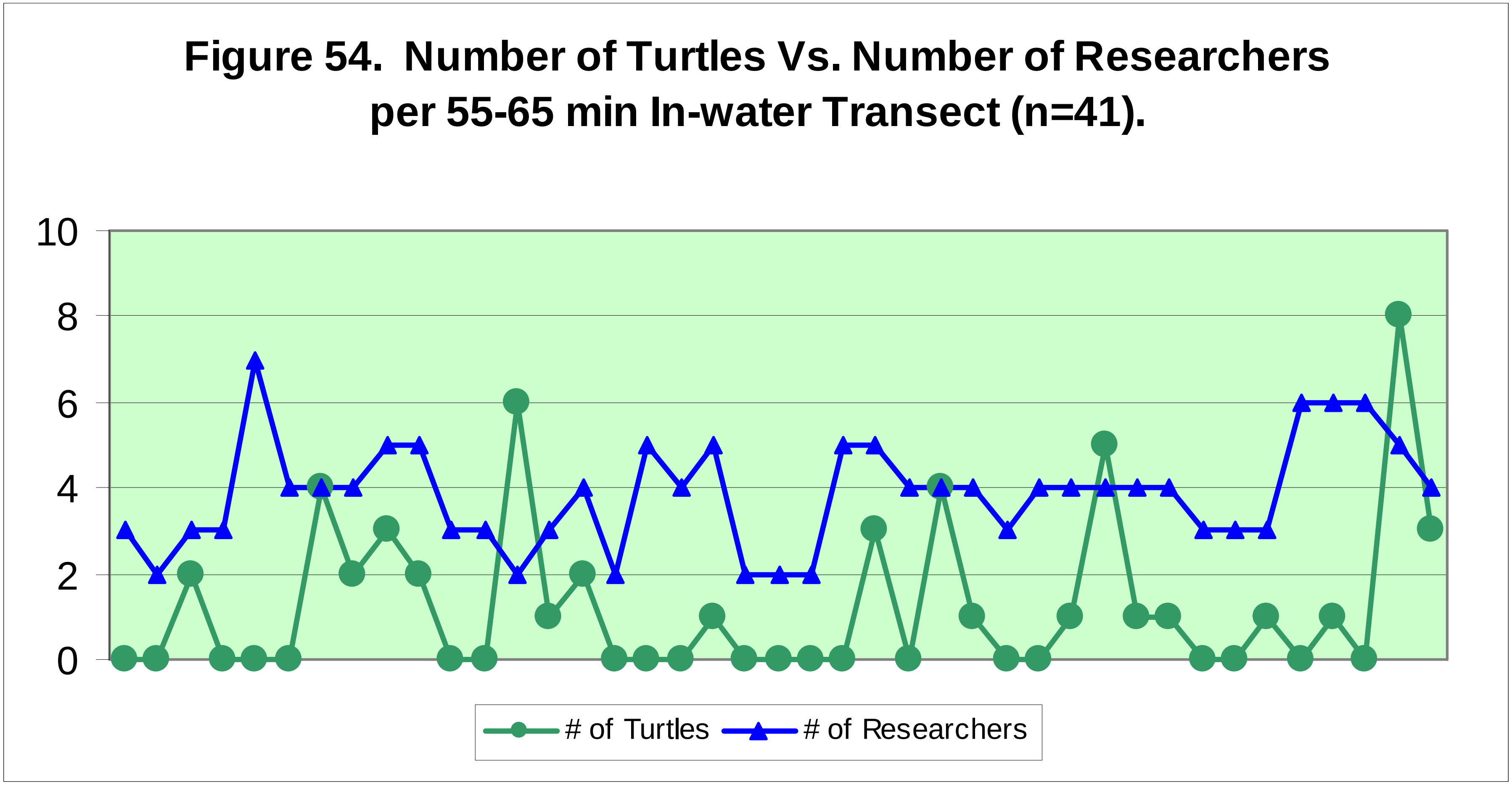


Figure 54. Number of Turtles Vs. Number of Researchers
per 55-65 min In-water Transect (n=41).
10
8
6
4
2
0
# of Turtles
# of Researchers

Figure 55. Scatter Plot of the Number of Turtles and the Number of Researchers per 55-65 min In-water Transect (n=41).

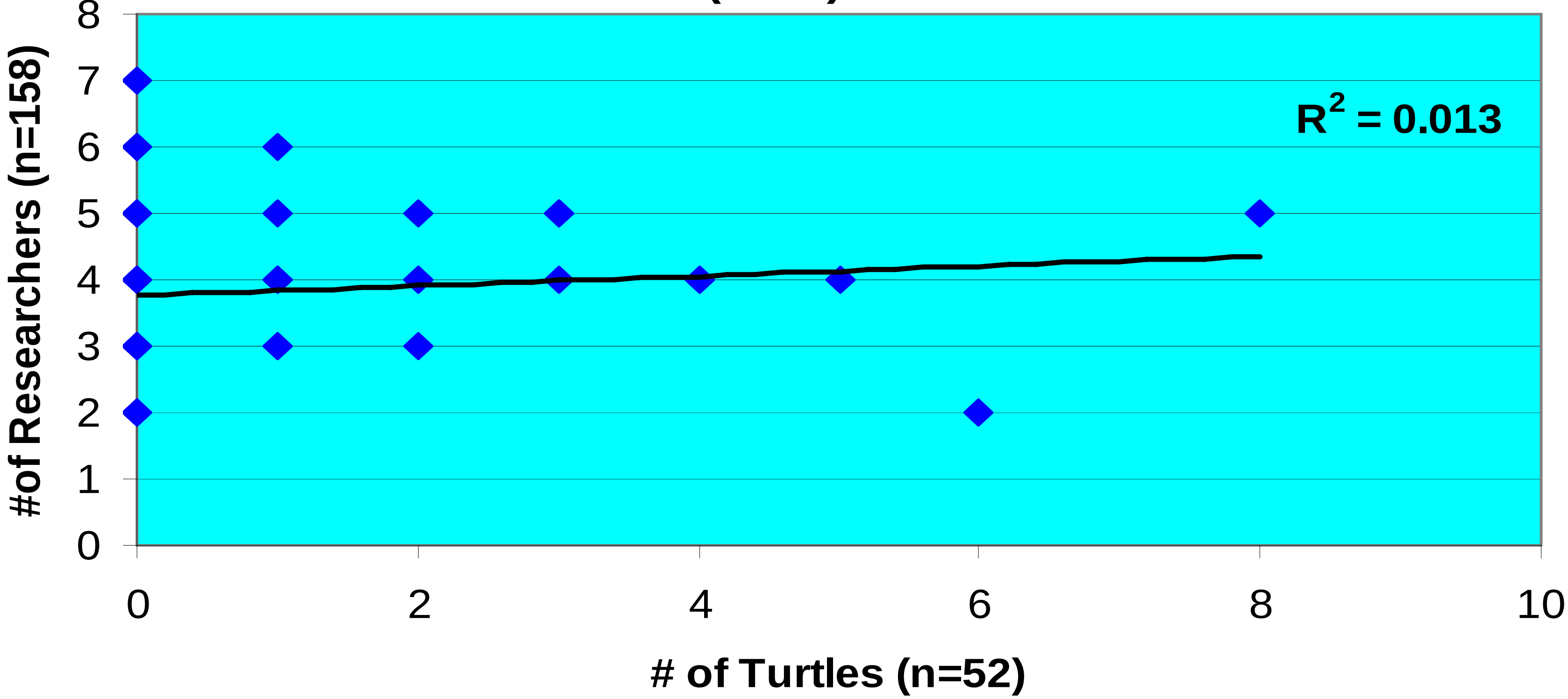
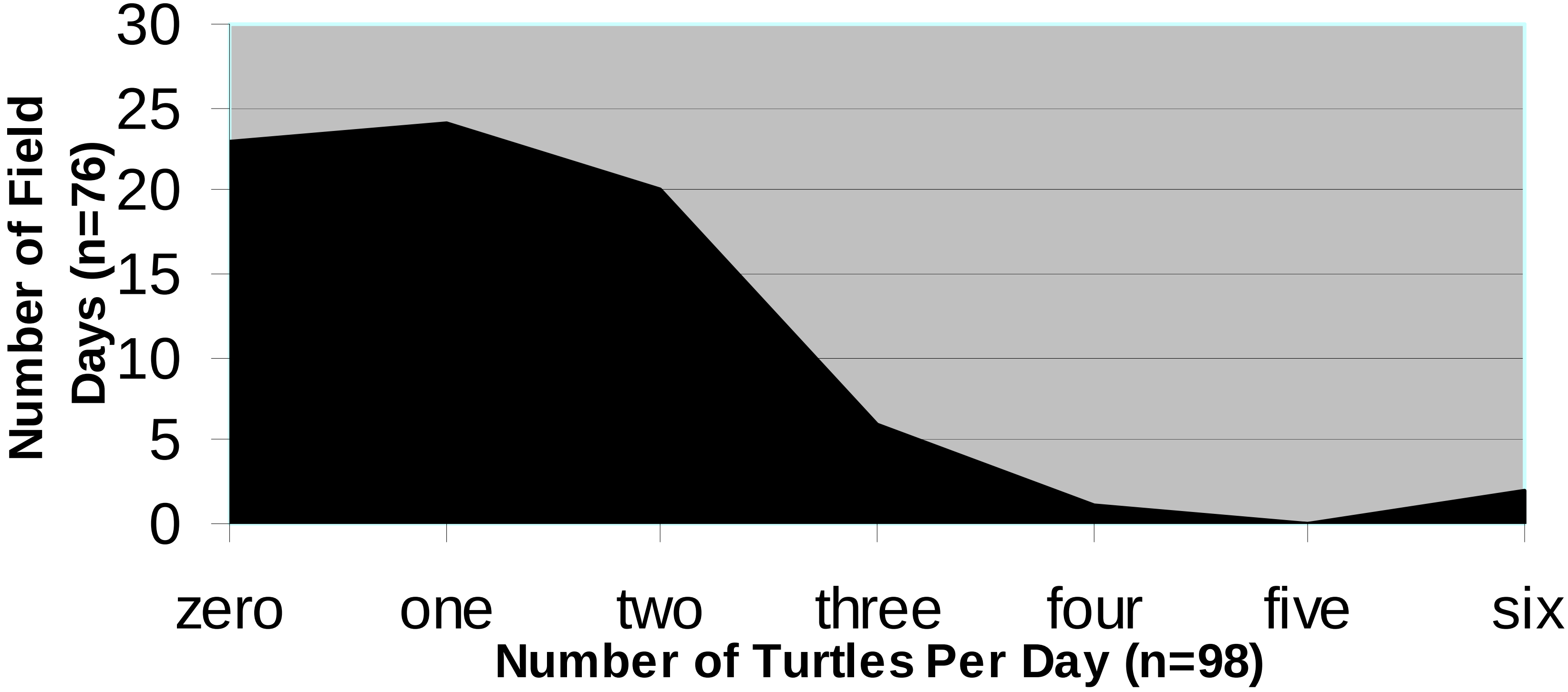


Figure 56. Incidental Turtle Sighting Frequencies During Field Days Aboard *Hākilo* (2002-2005).



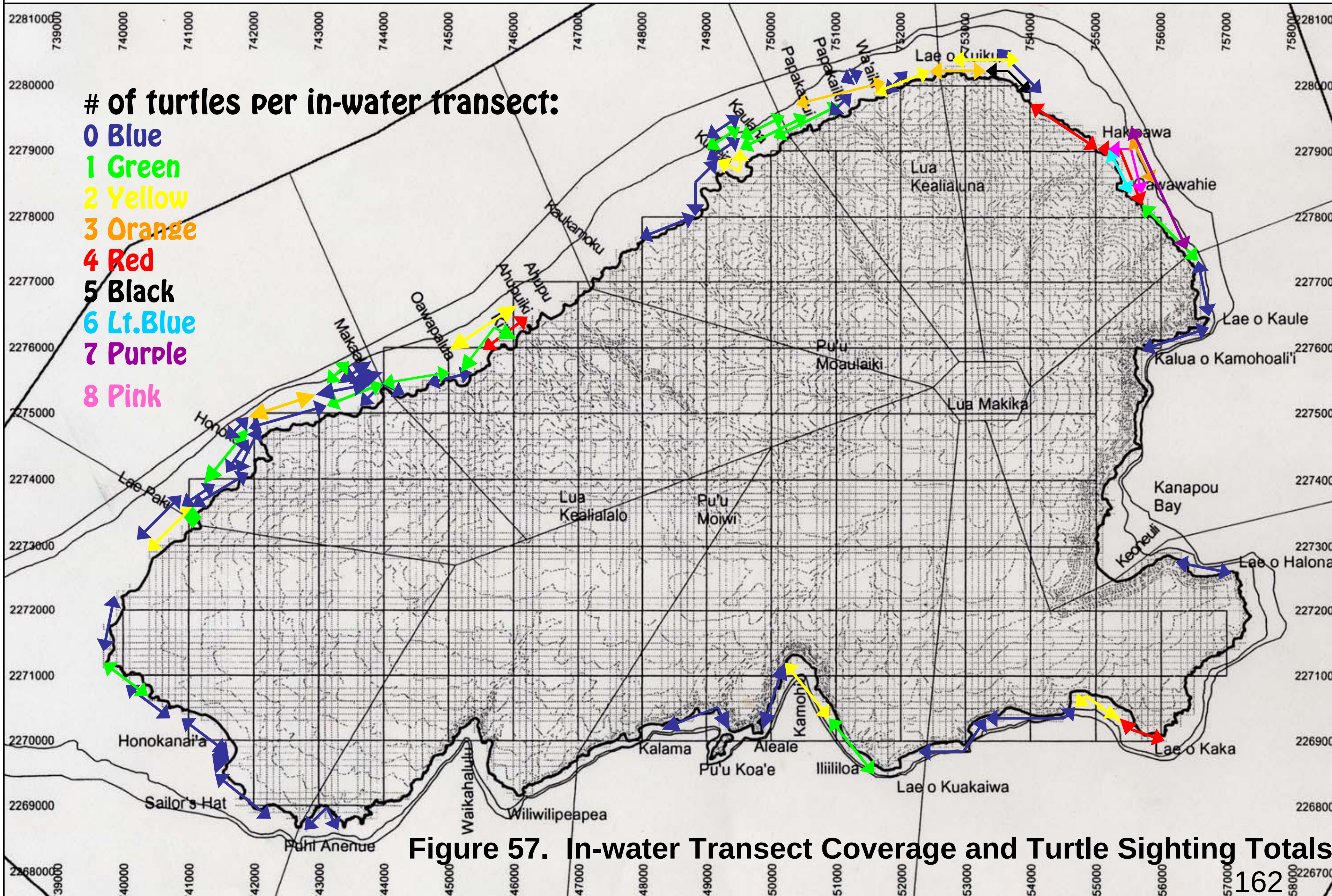


Figure 57. In-water Transect Coverage and Turtle Sighting Totals.

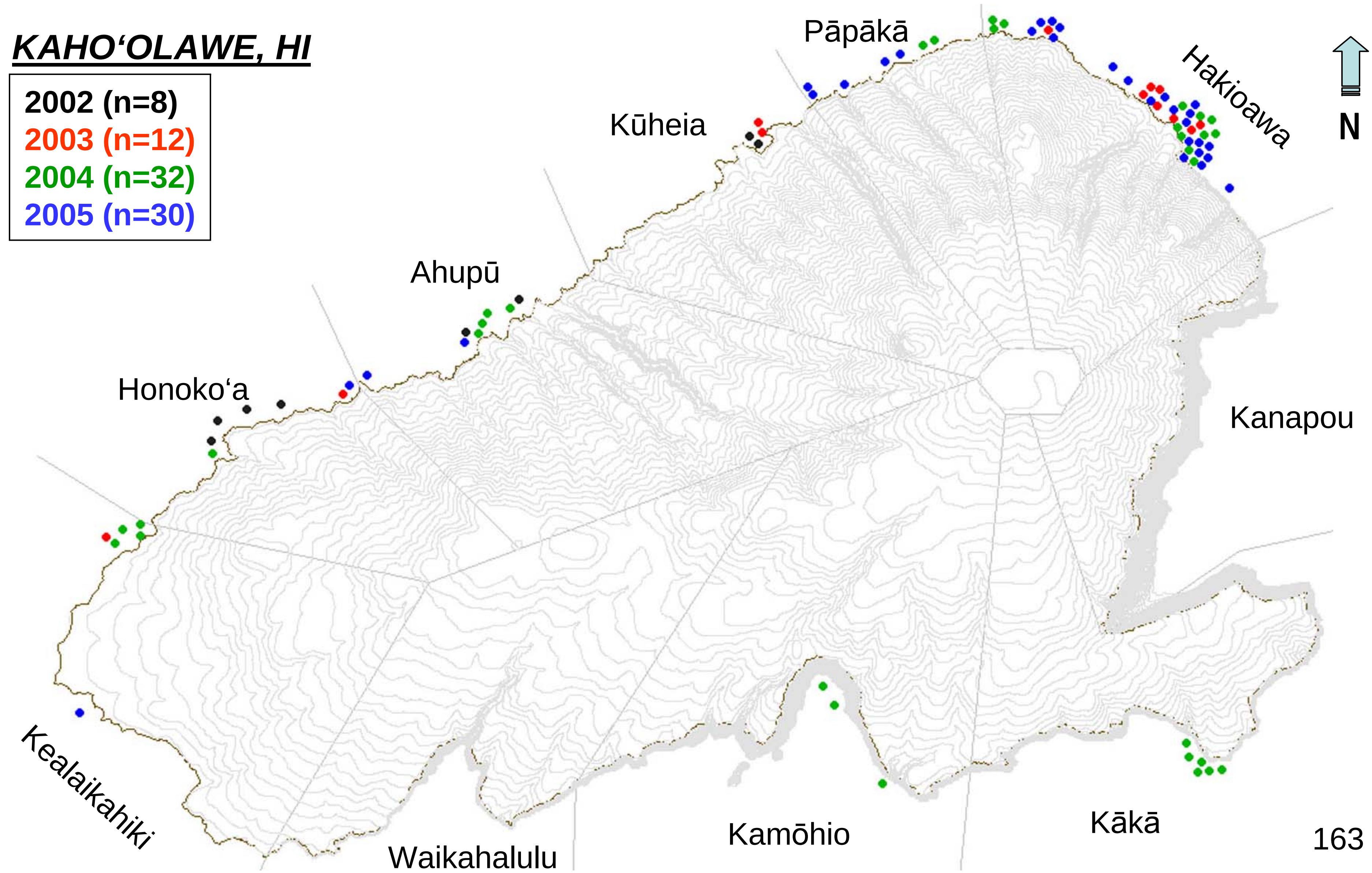


Figure 58. Distribution Map of In-water Turtle Sightings (2002-2005).

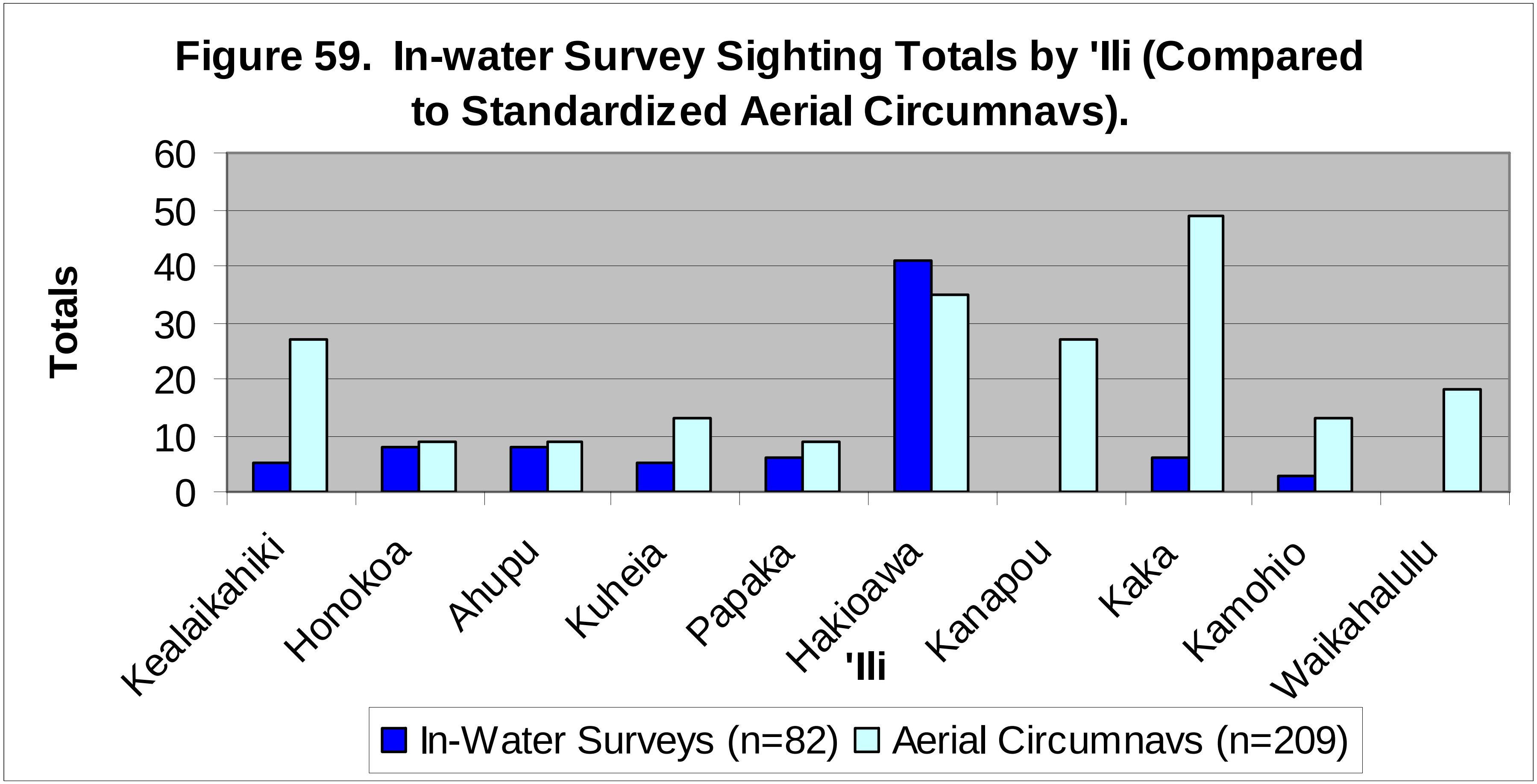
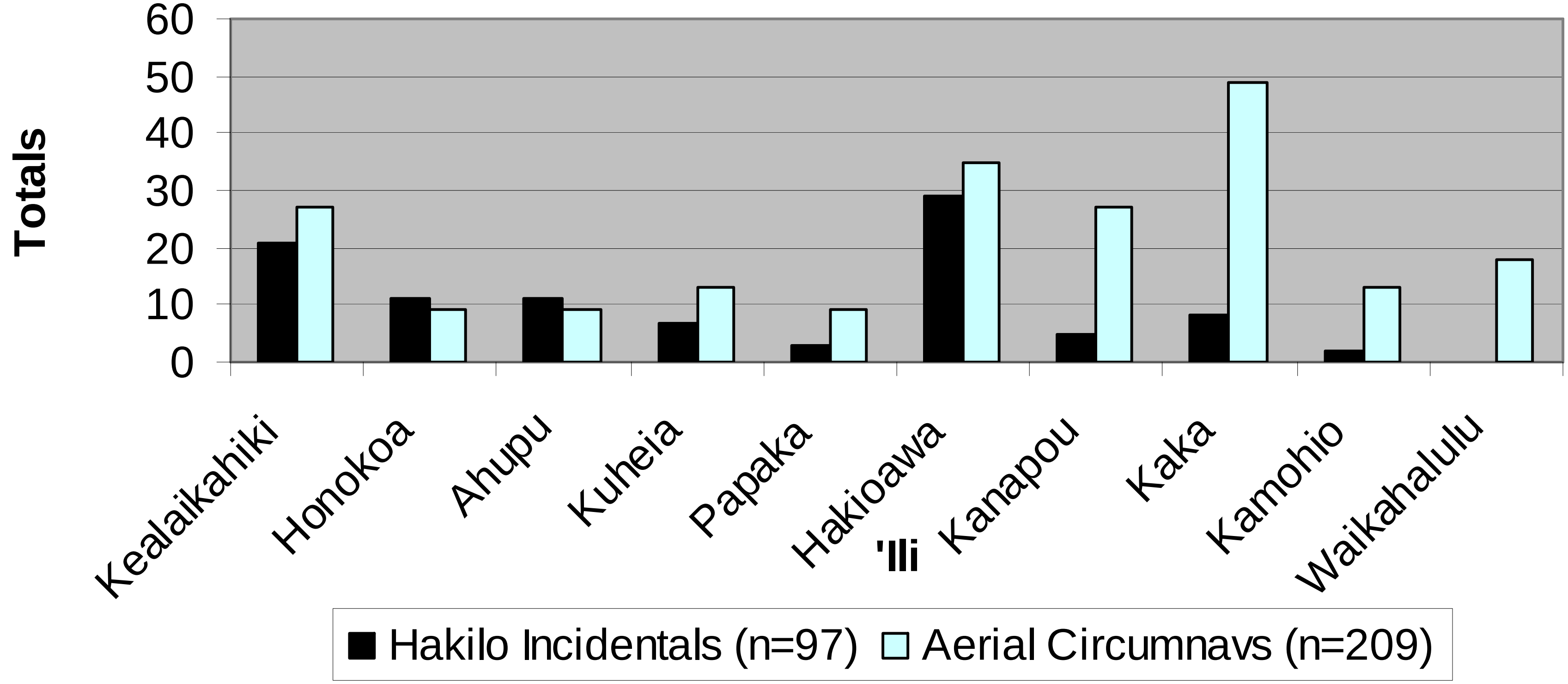


Figure 59. In-water Survey Sighting Totals by 'Ili (Compared to Standardized Aerial Circumnavs).
Totals
60
50
40
30
20
10
0
Kealaikahiki
Honokoa
Ahupu
Kuheia
Papaka
Hakioawa
Kanapou
Kaka
Kamohio
Waikahalulu
'Ili
In-Water Surveys (n=82)
Aerial Circumnavs (n=209)

Figure 60. *Hākilo* Incidental Sighting Totals by 'Ili (Compared to Stand. Aerial Circumnavs).



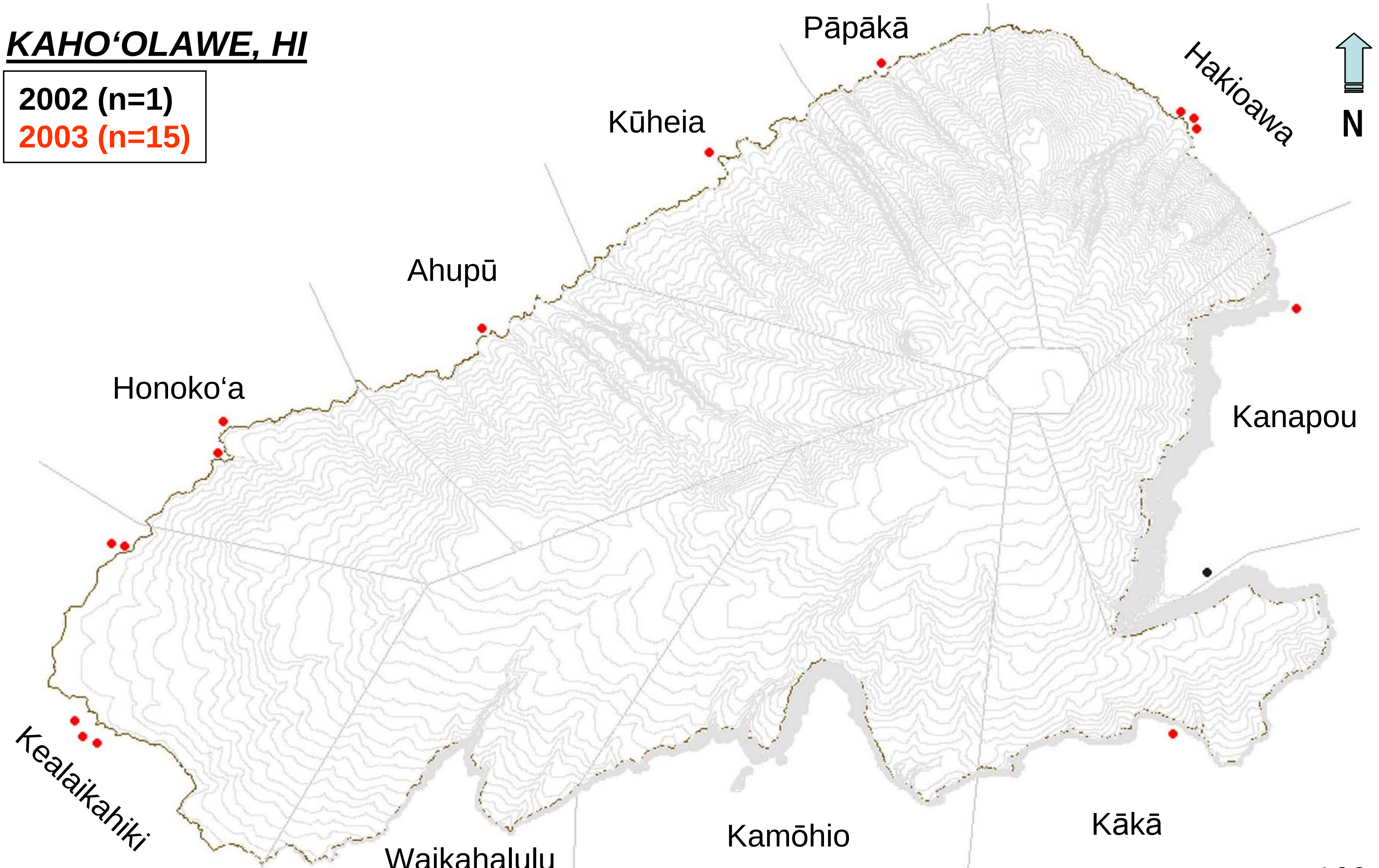


Figure 61. Distribution Map of 2002 and 2003 *Hākilo* Incidental Turtle Sightings (n=16).

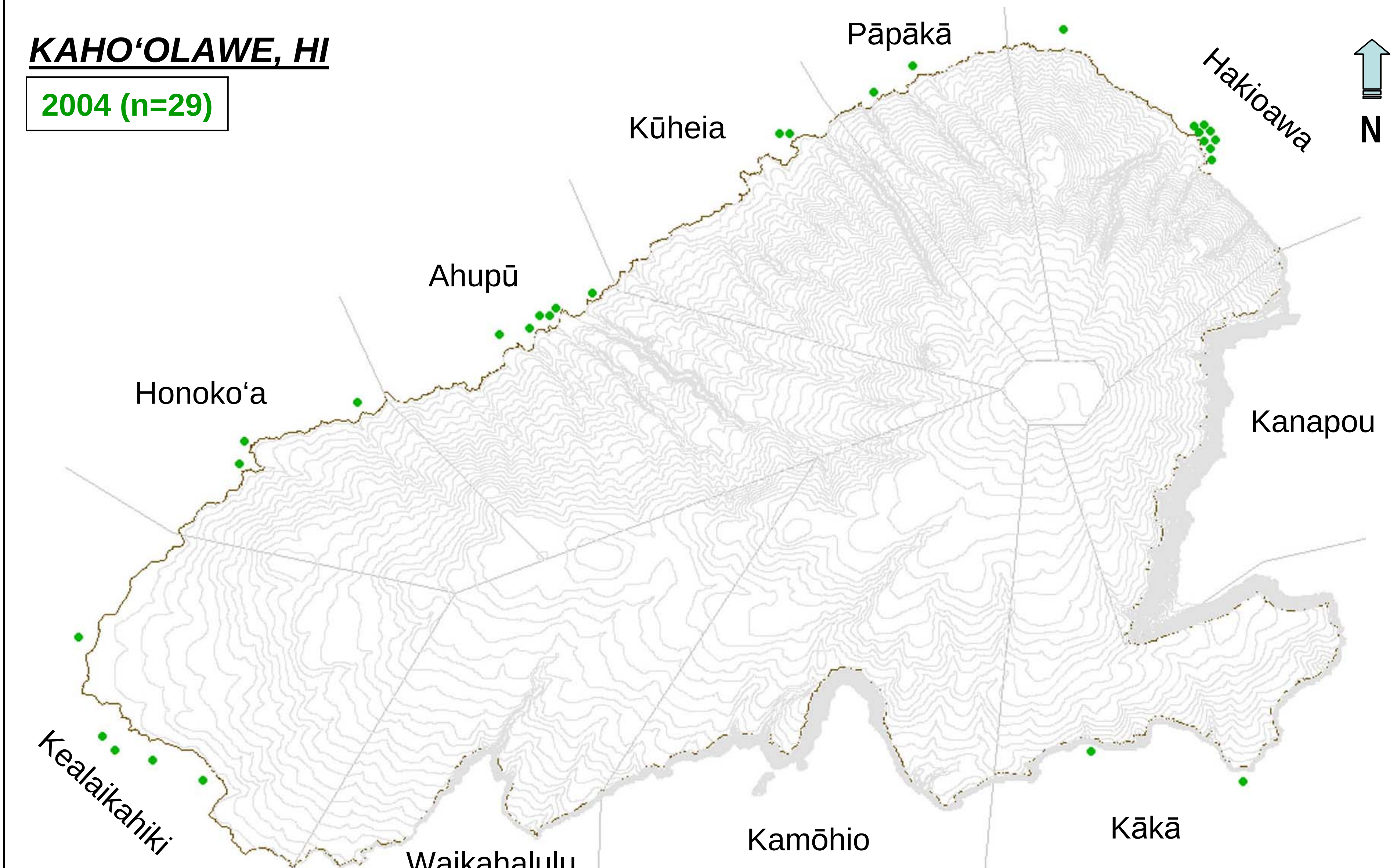


Figure 62. Distribution Map of 2004 *Hākilo* Incidental Turtle Sightings (n=29).

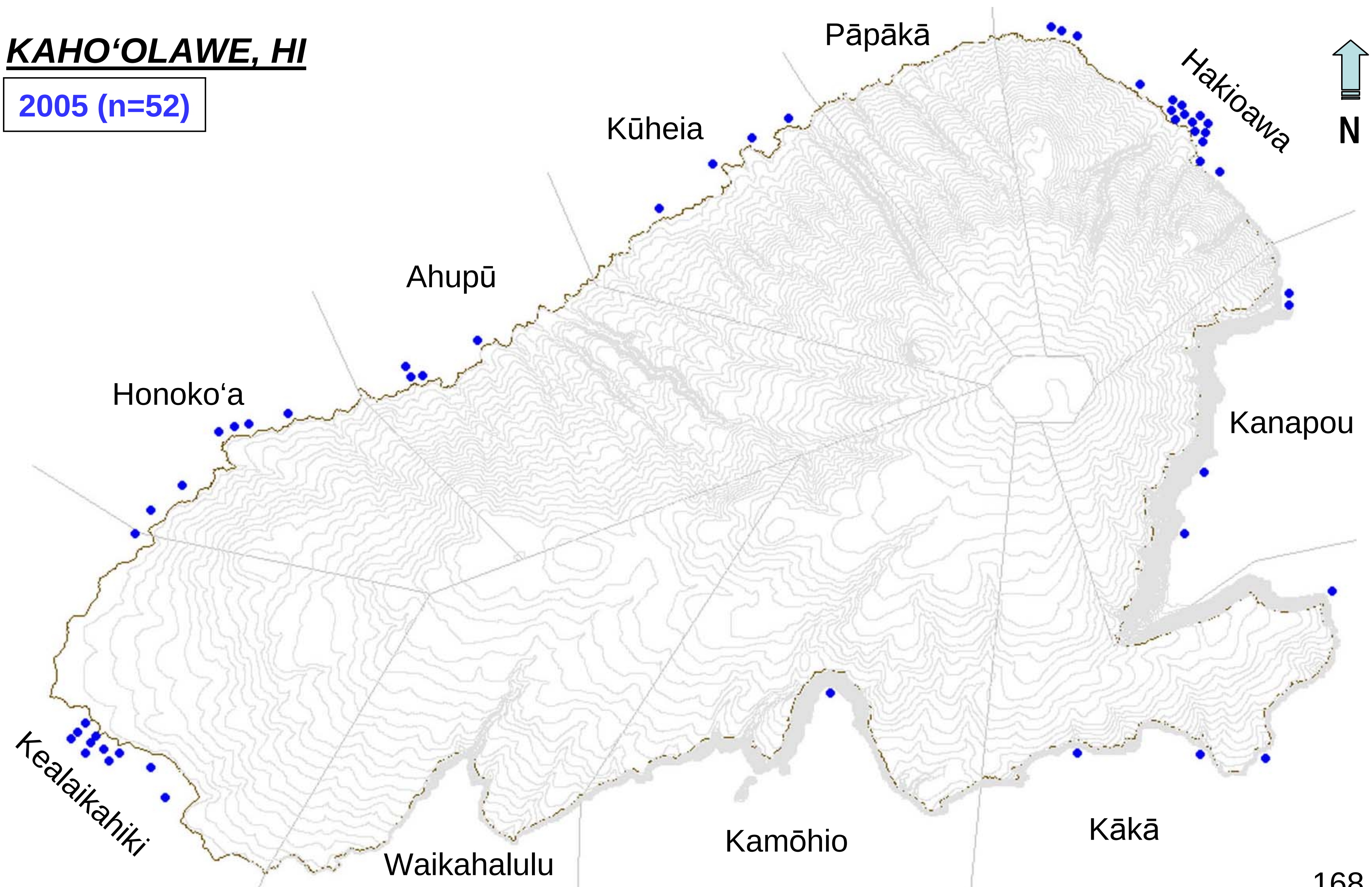
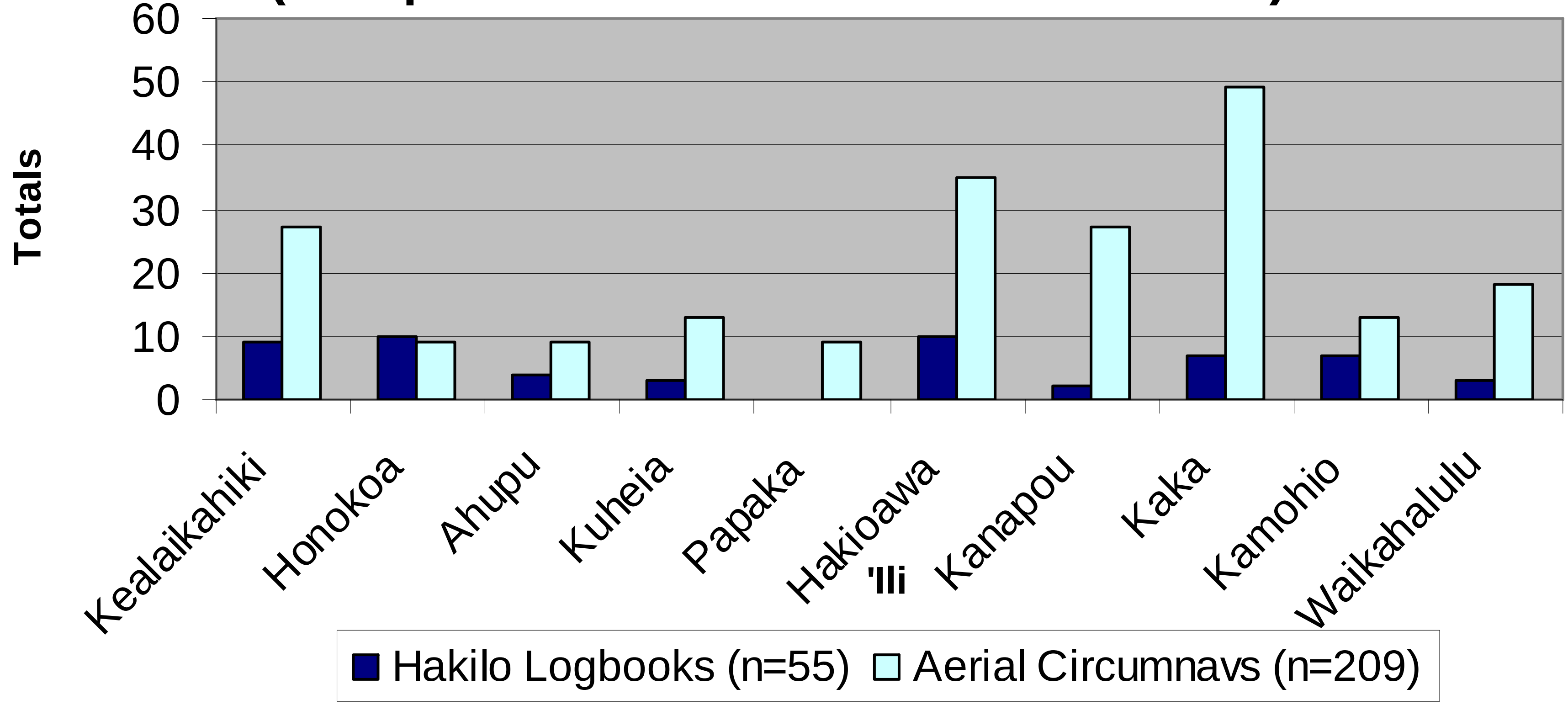


Figure 63. Distribution Map of 2005 *Hākilo* Incidental Turtle Sightings (n=52).

Figure 64. *Hākilo* Logbook Totals by 'Ili (Compared to Stand. Aerial Circumnavs).



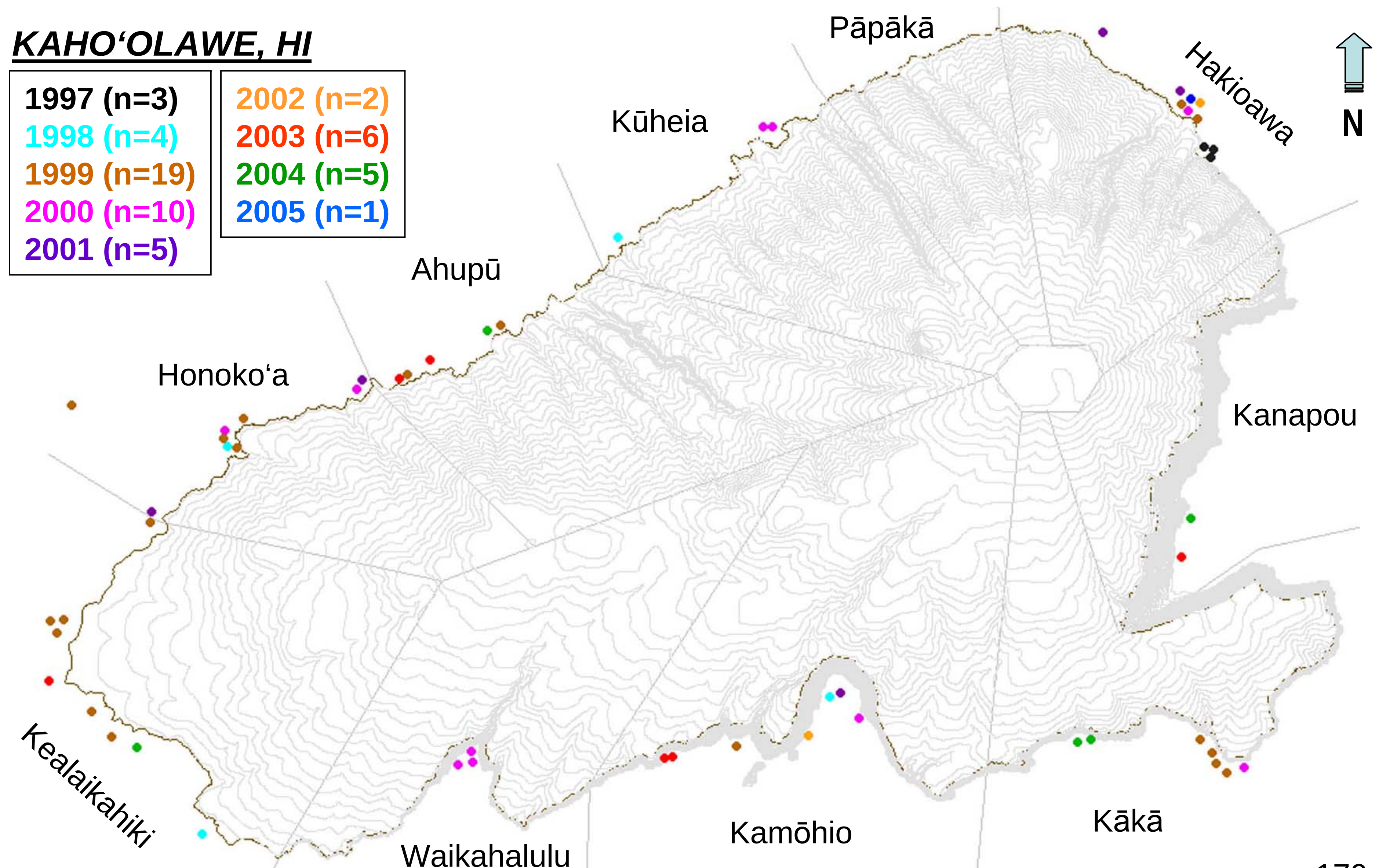
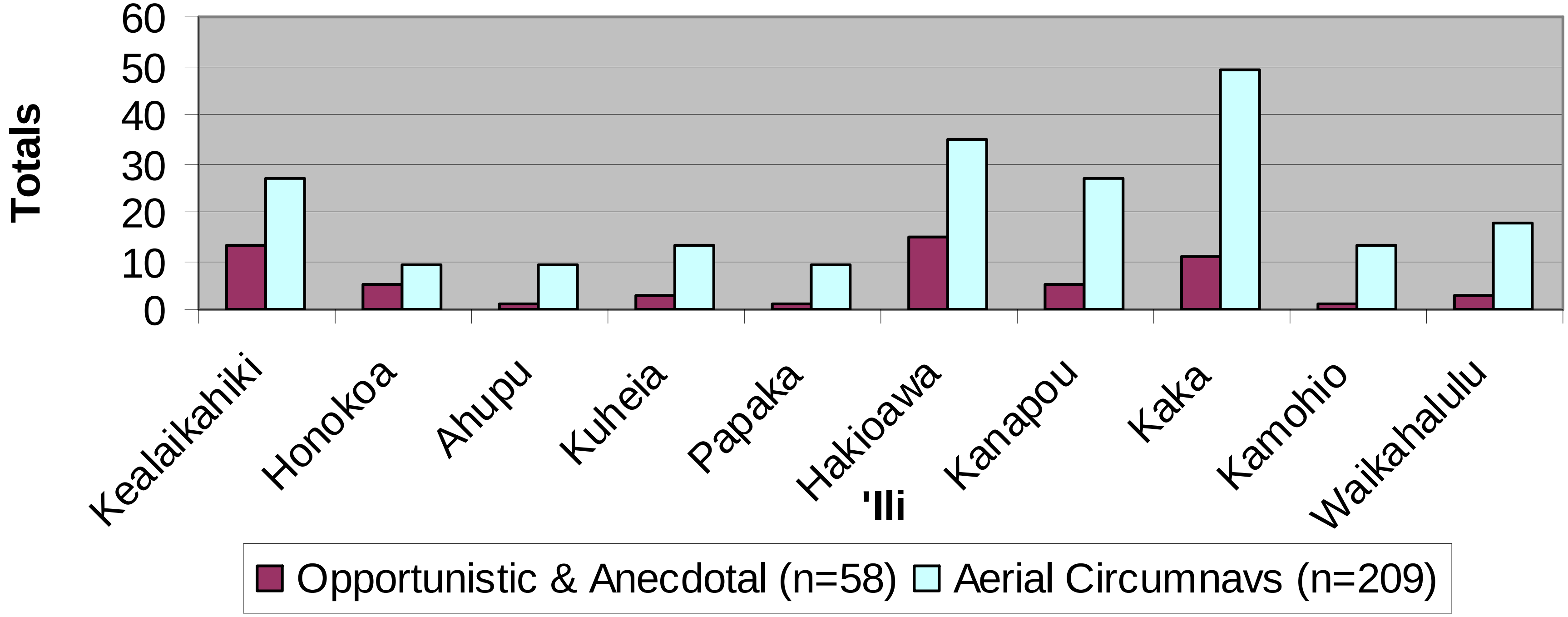


Figure 65. Distribution Map of 55 *Hākilo* Logbook Sightings (1997-2005).

Figure 66. Opportunistic and Anecdotal Sighting Totals by 'Ili (Compared to Standardized Aerial Circumnavigations).



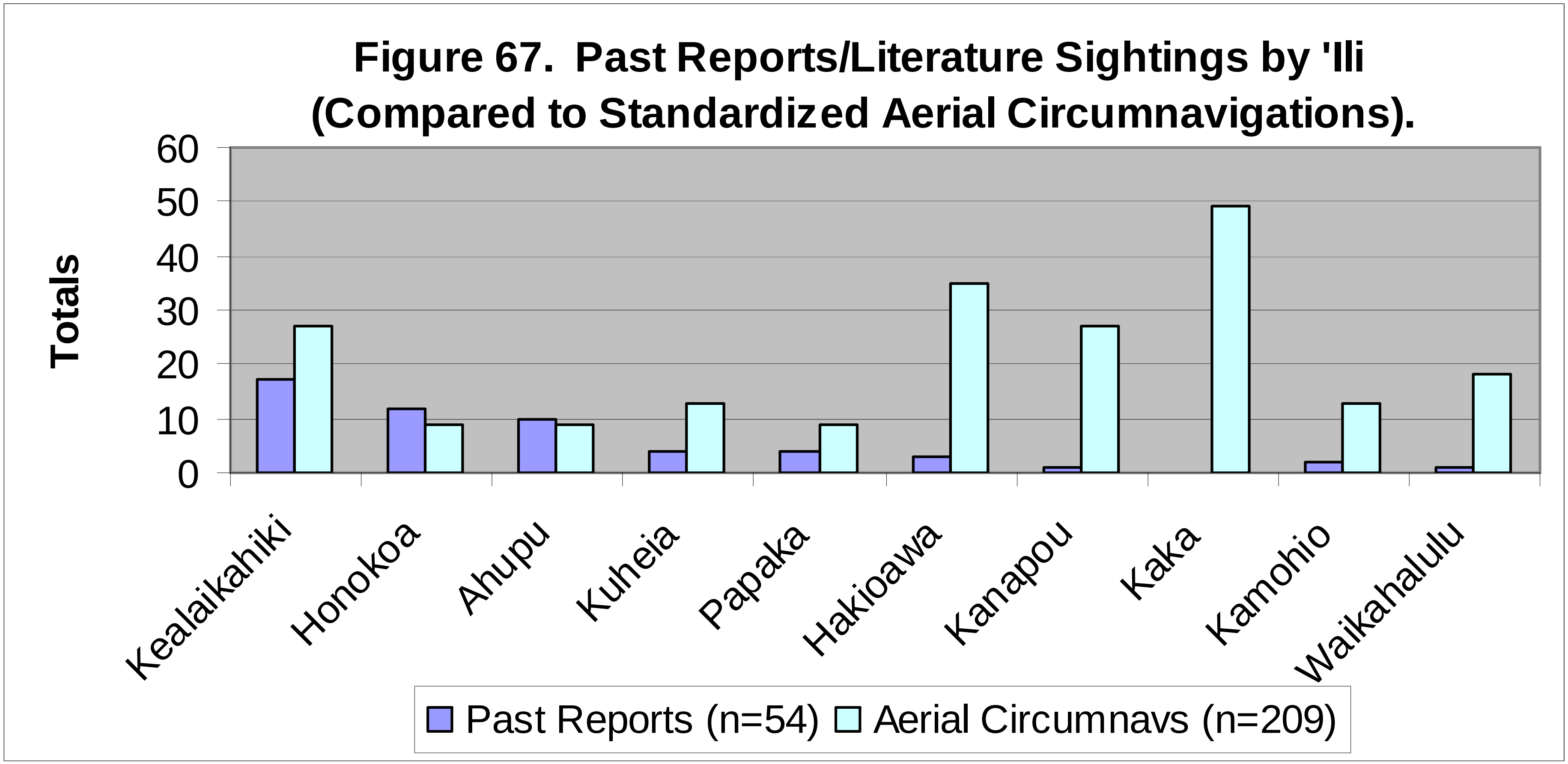


Figure 67. Past Reports/Literature Sightings by 'Ili
(Compared to Standardized Aerial Circumnavigations).
Totals
60
50
40
30
20
10
0
Kealaikahiki
Honokoa
Ahupu
Kuheia
Papaka
Hakioawa
Kanapou
Kaka
Kamohio
Waikahalulu
Past Reports (n=54)
Aerial Circumnavs (n=209)

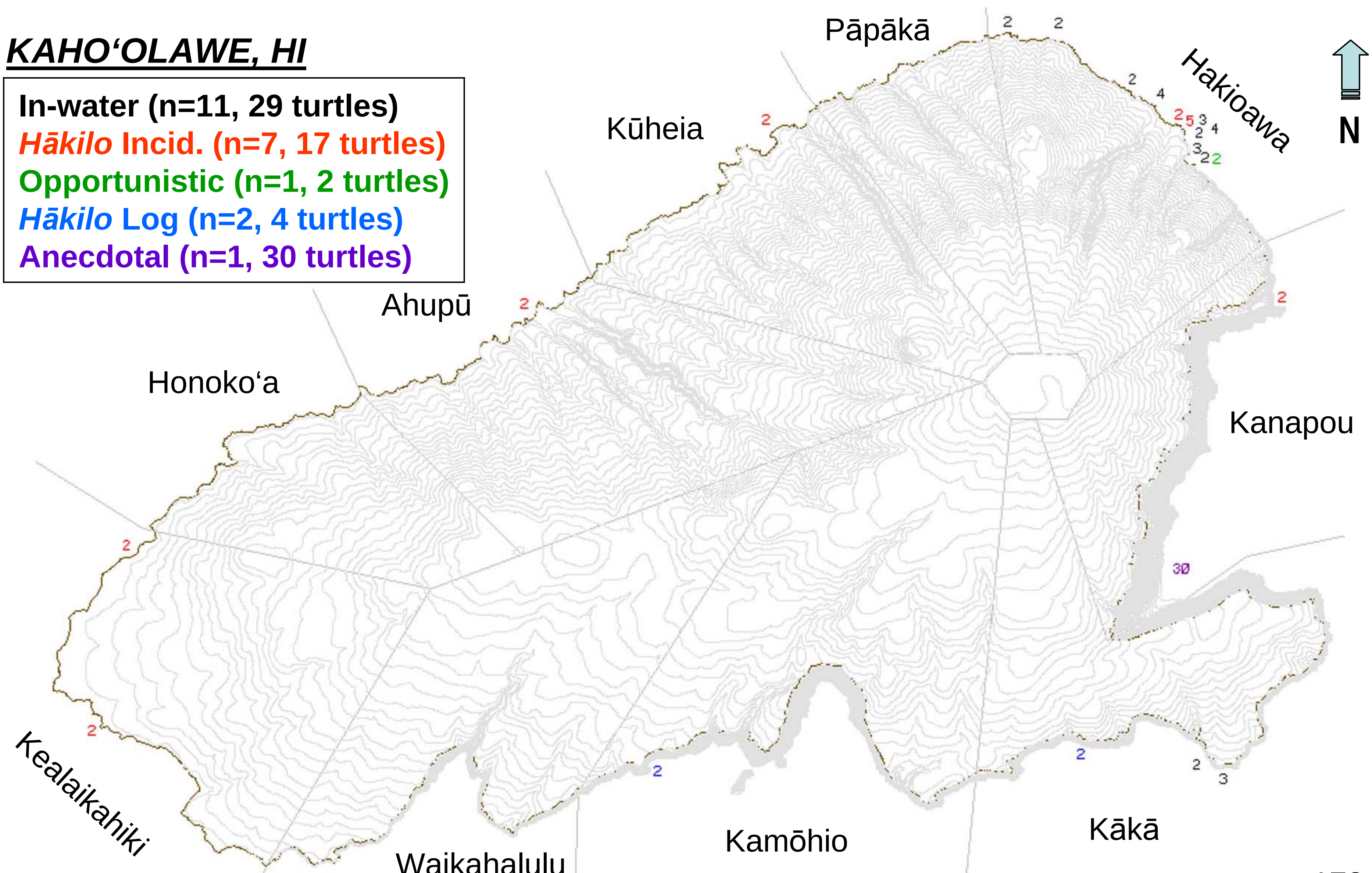


Figure 68. Distribution Map of Turtle Clusters from All Sources Except Aerial Surveys.

Figure 69. Possible Individual Turtle Resightings.

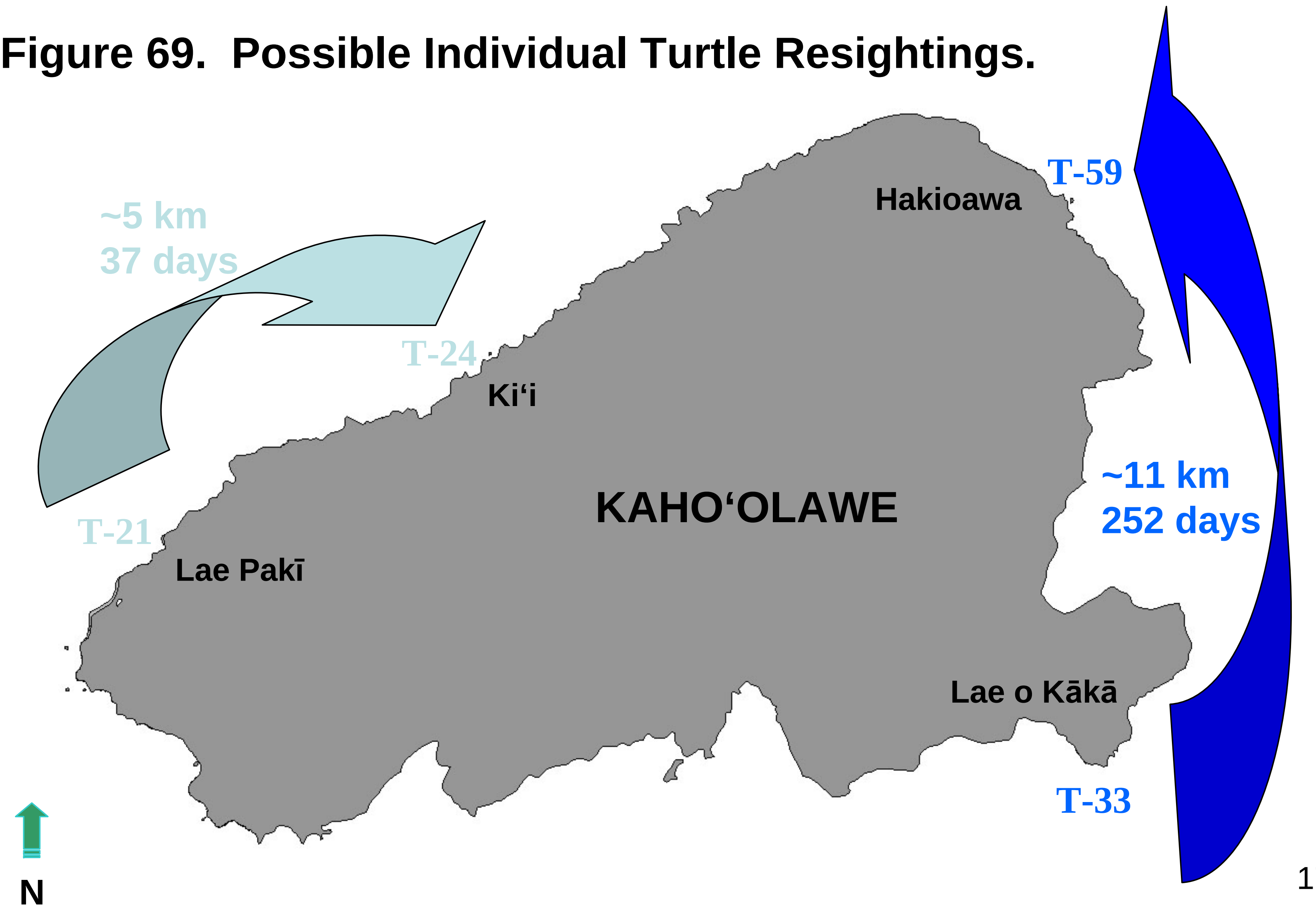
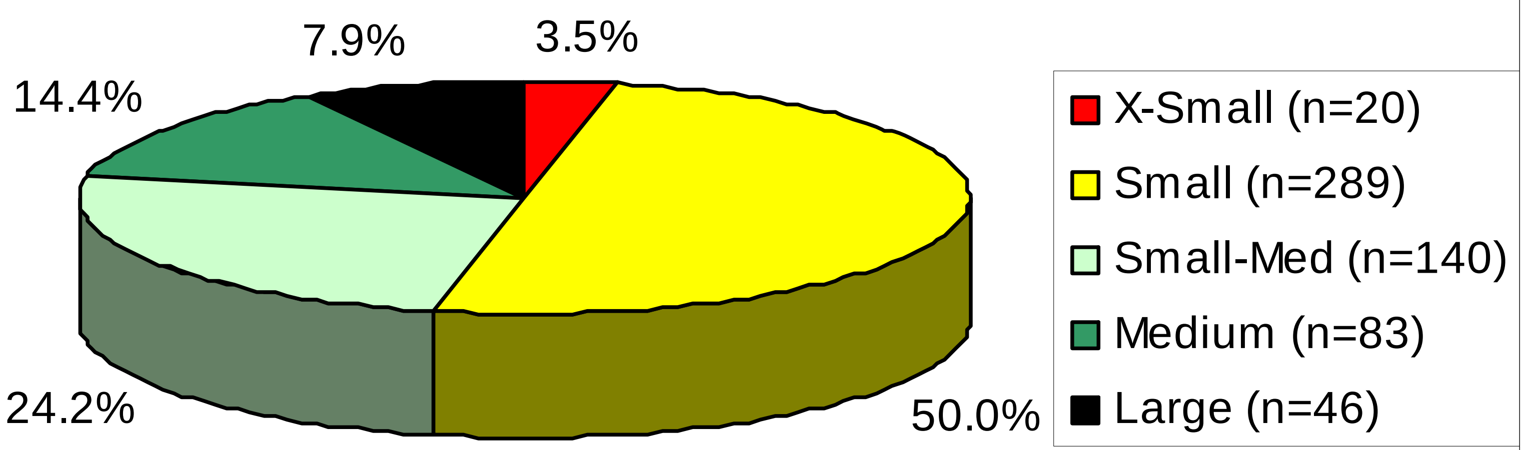


Figure 70. Size Class Categories of All Turtle Sightings (n=578).



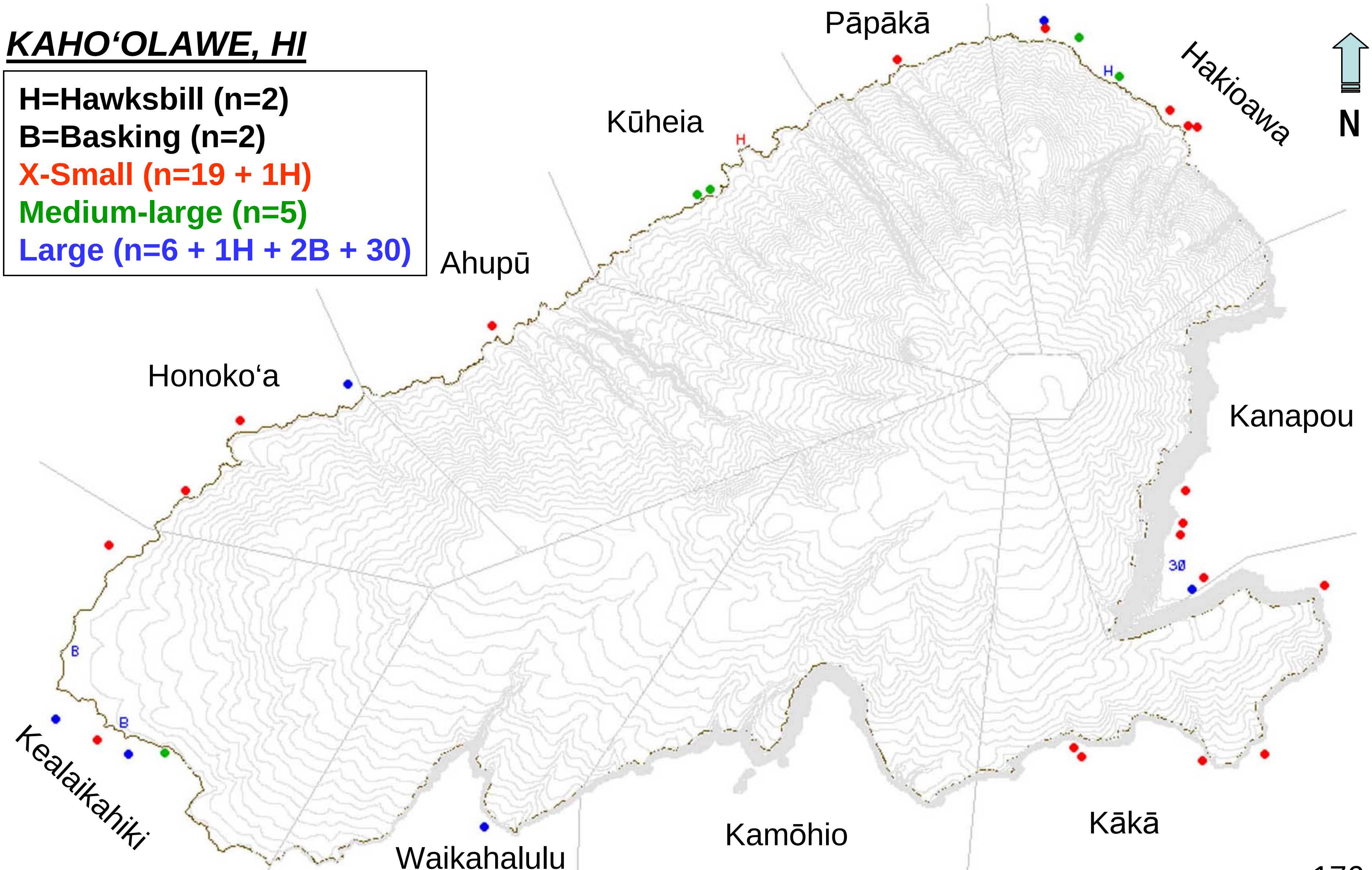


Figure 71. Extra-small, Medium-large, and Large Sized Turtle Distribution from All Data Sources.

Figure 72. Size Class Categories of All In-water Turtle Sightings (n=96).

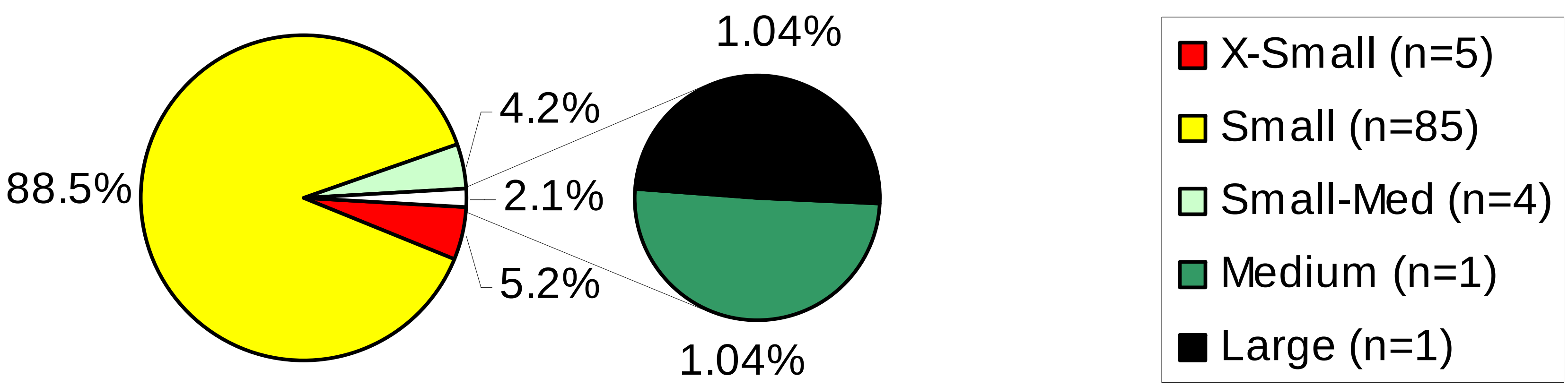


Figure 73. “Blotchy Head Syndrome” Affecting Turtles in ‘Ili 6.

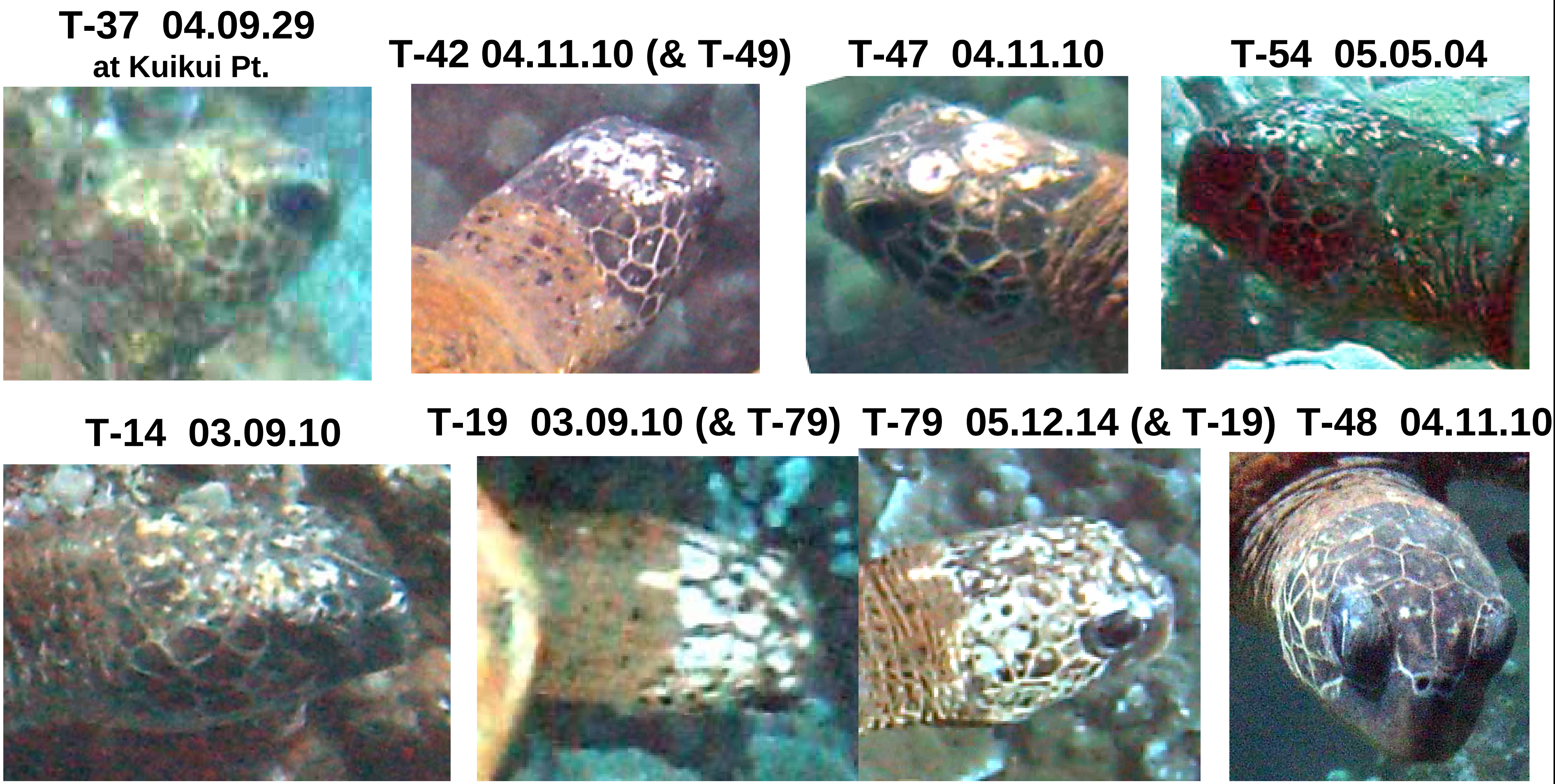
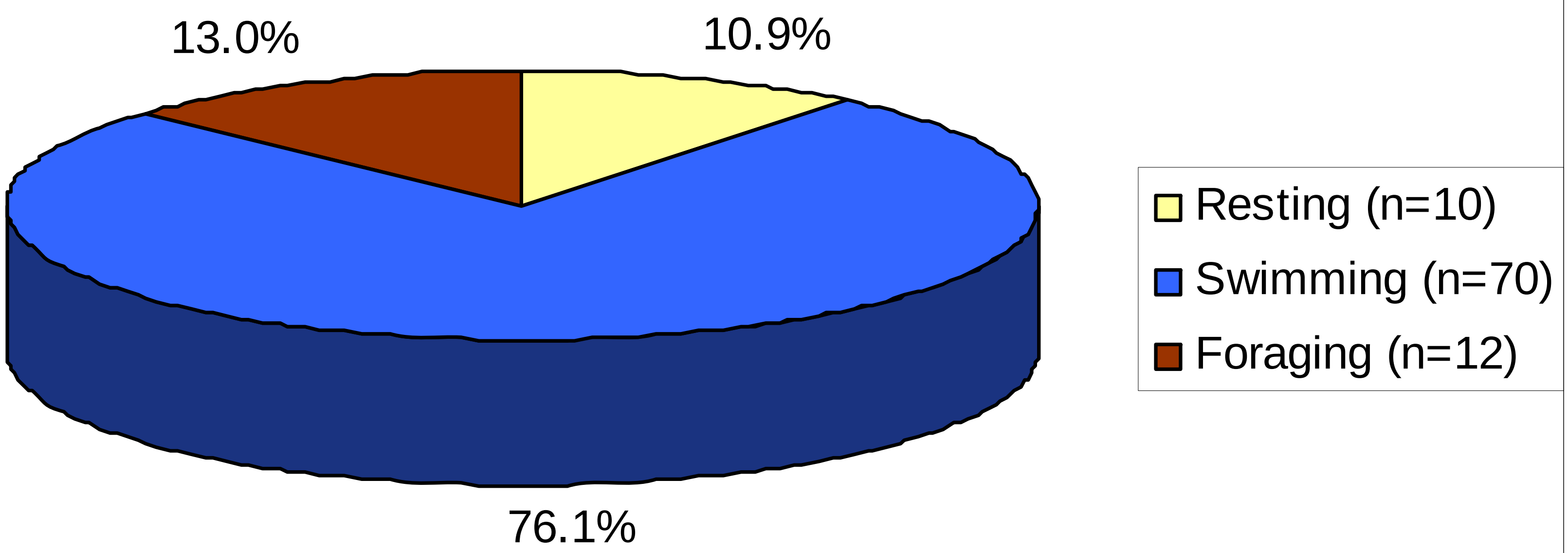


Figure 74. Initial Behaviors of Turtles Sighted Incidentally and During In-water Transects (n=92).



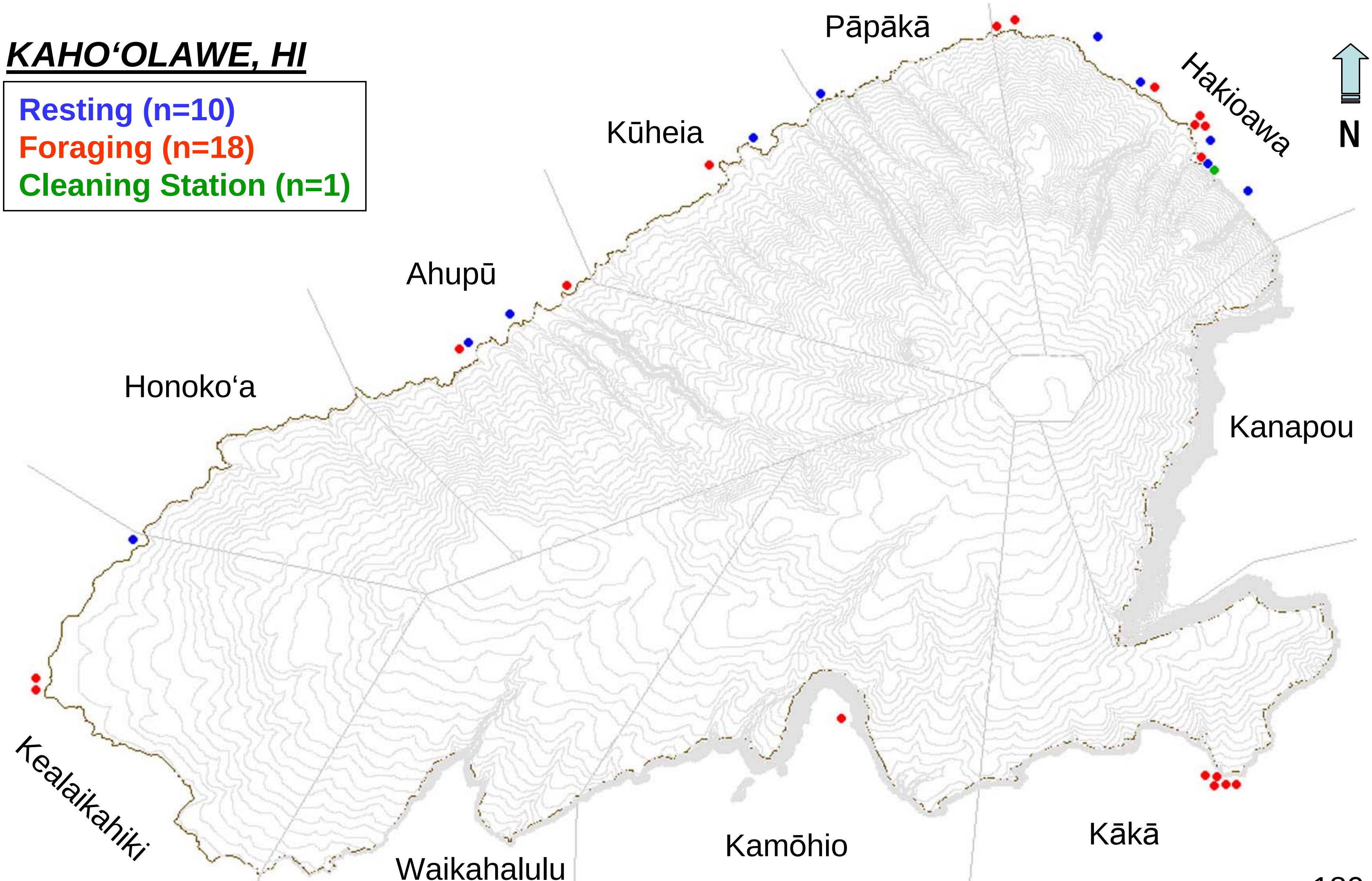


Figure 75. Distribution Map of Cleaning Station, Foraging, and Resting Turtles.

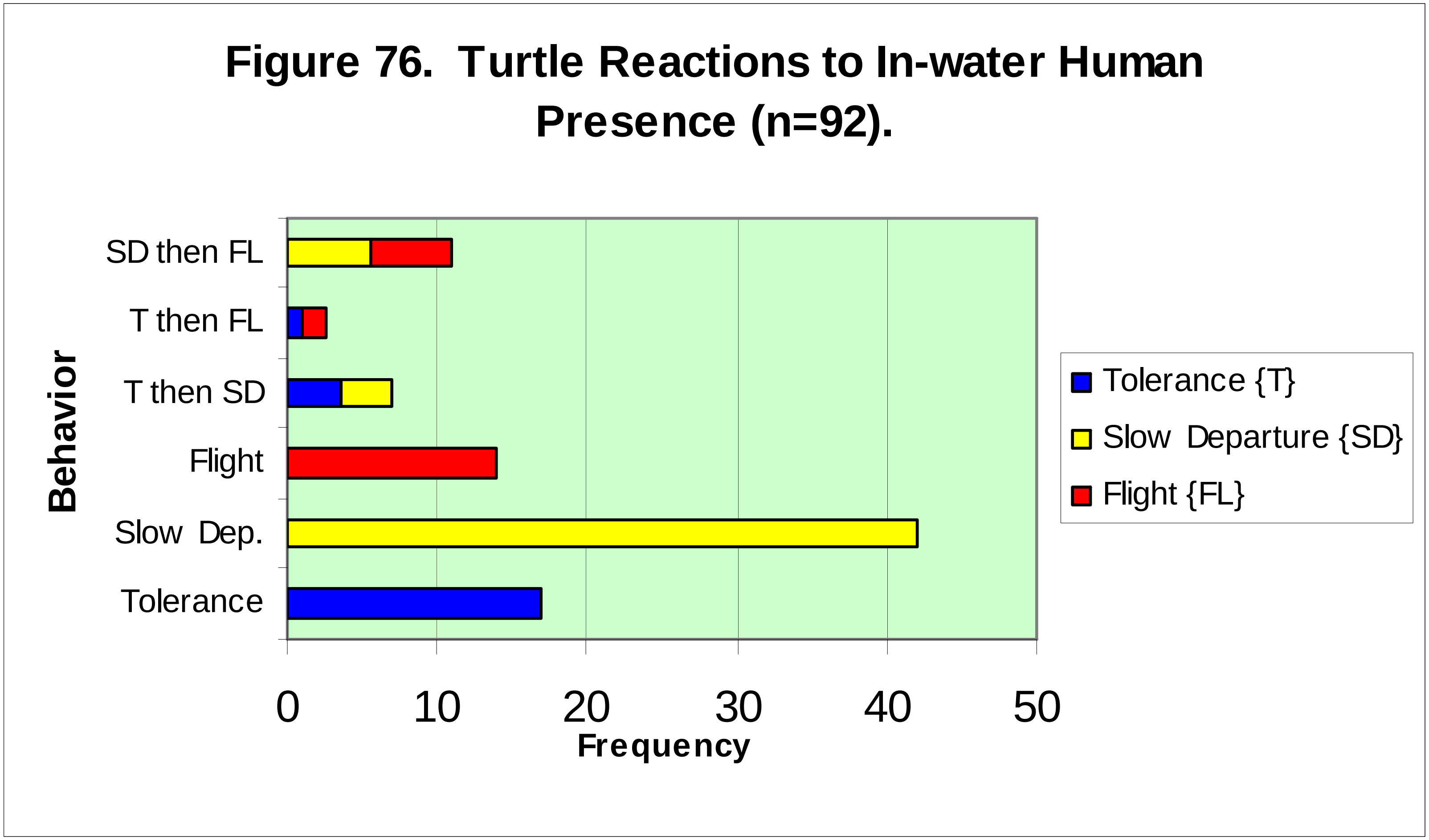


Figure 76. Turtle Reactions to In-water Human Presence (n=92).
Behavior
SD then FL
T then FL
T then SD
Flight
Slow Dep.
Tolerance
0
10
20
30
40
50
Frequency
Tolerance {T}
Slow Departure {SD}
Flight {FL}

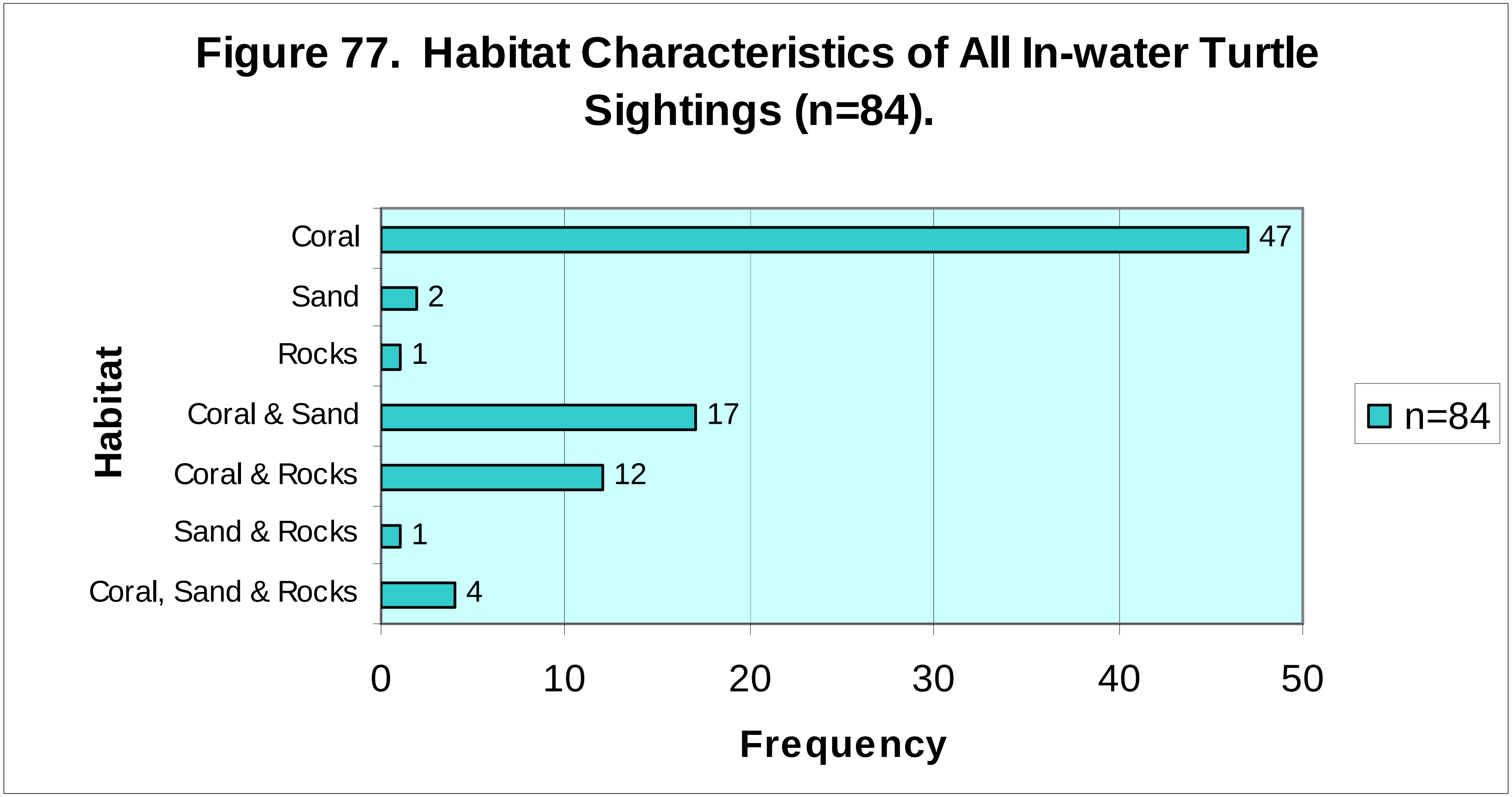


Figure 77. Habitat Characteristics of All In-water Turtle Sightings (n=84).
Habitat
Coral
Sand
Rocks
Coral & Sand
Coral & Rocks
Sand & Rocks
Coral, Sand & Rocks
47
2
1
17
12
1
4
0
10
20
30
40
50
Frequency
n=84

Figure 78. Depth Categories of All Turtle Sightings (n=136).

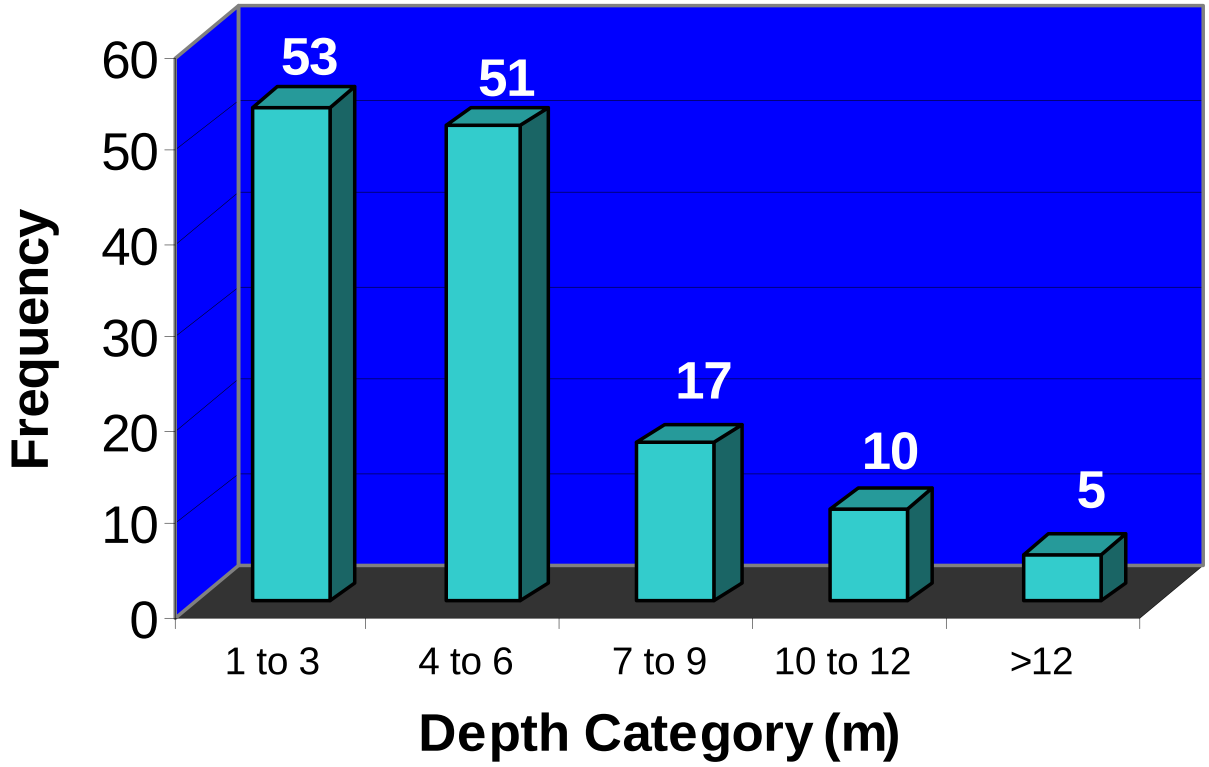


Figure 79. Relative Distances from Shore (from All Turtle Sightings, n=438).

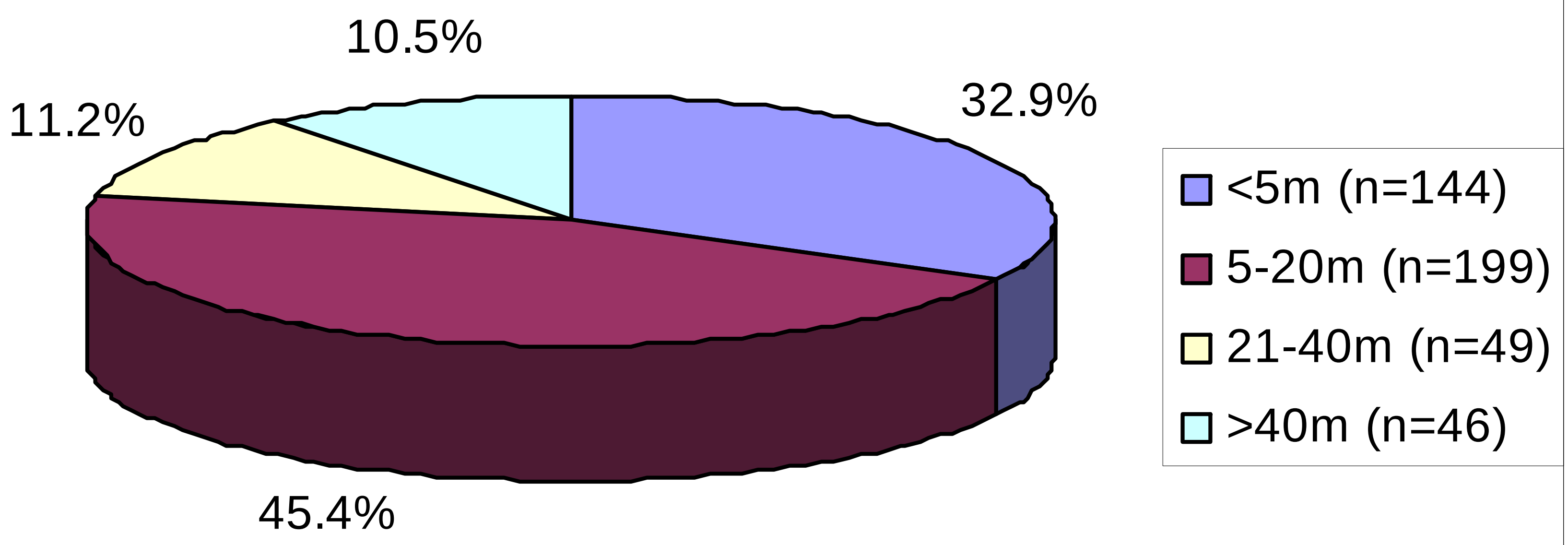


Figure 80. Relative Distances from Shore (from In-water Surveys, n=57).

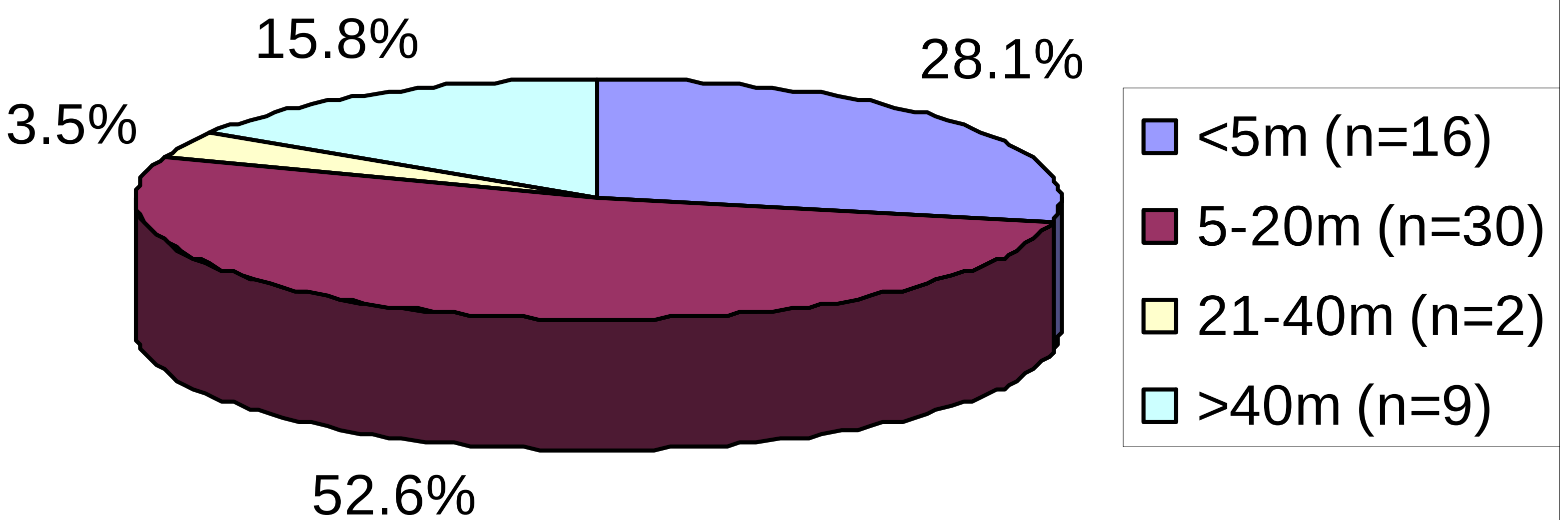
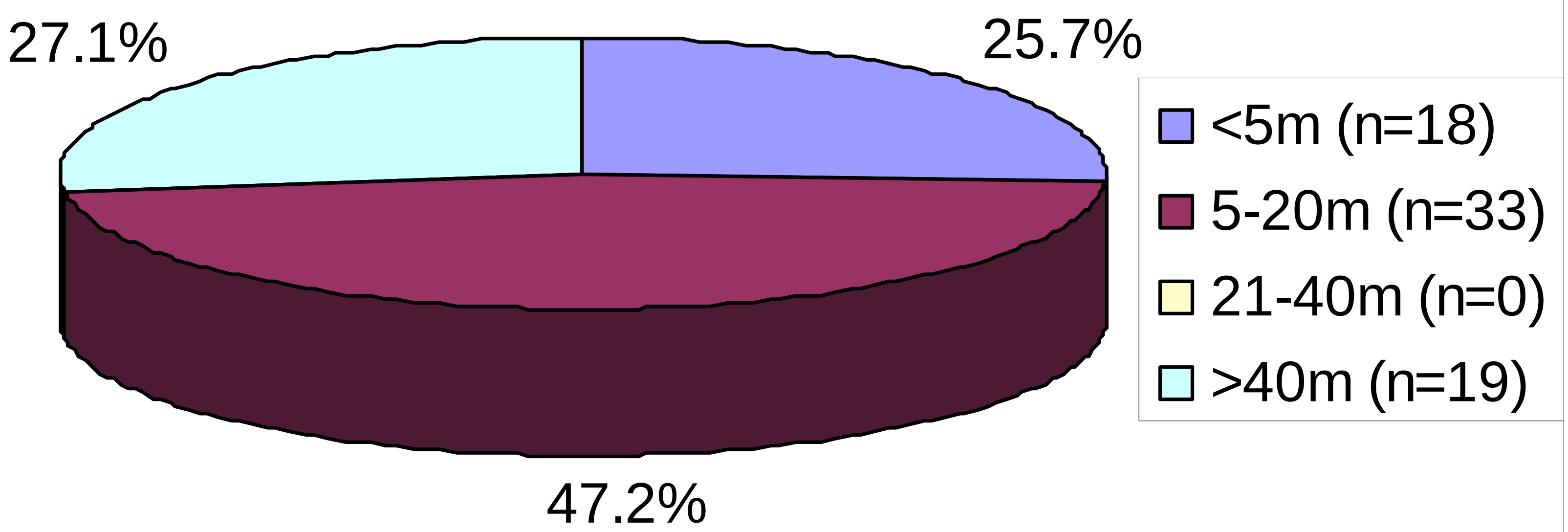


Figure 81. Relative Distances from Shore (from *Hākilo* Incidental Sightings, n=70).



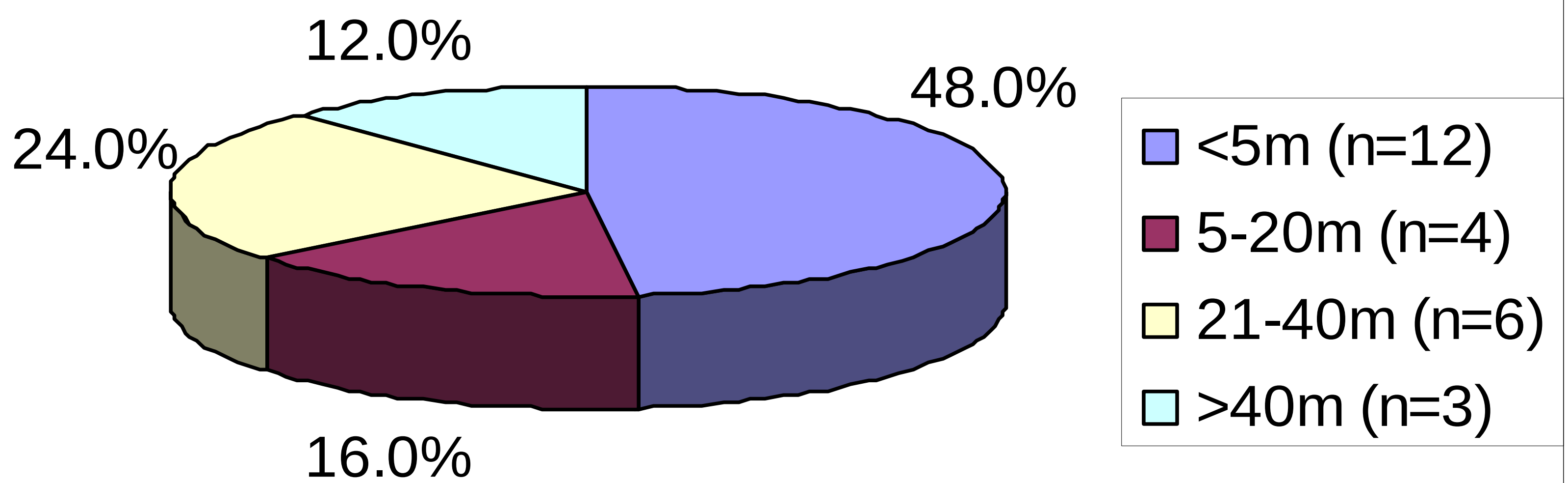
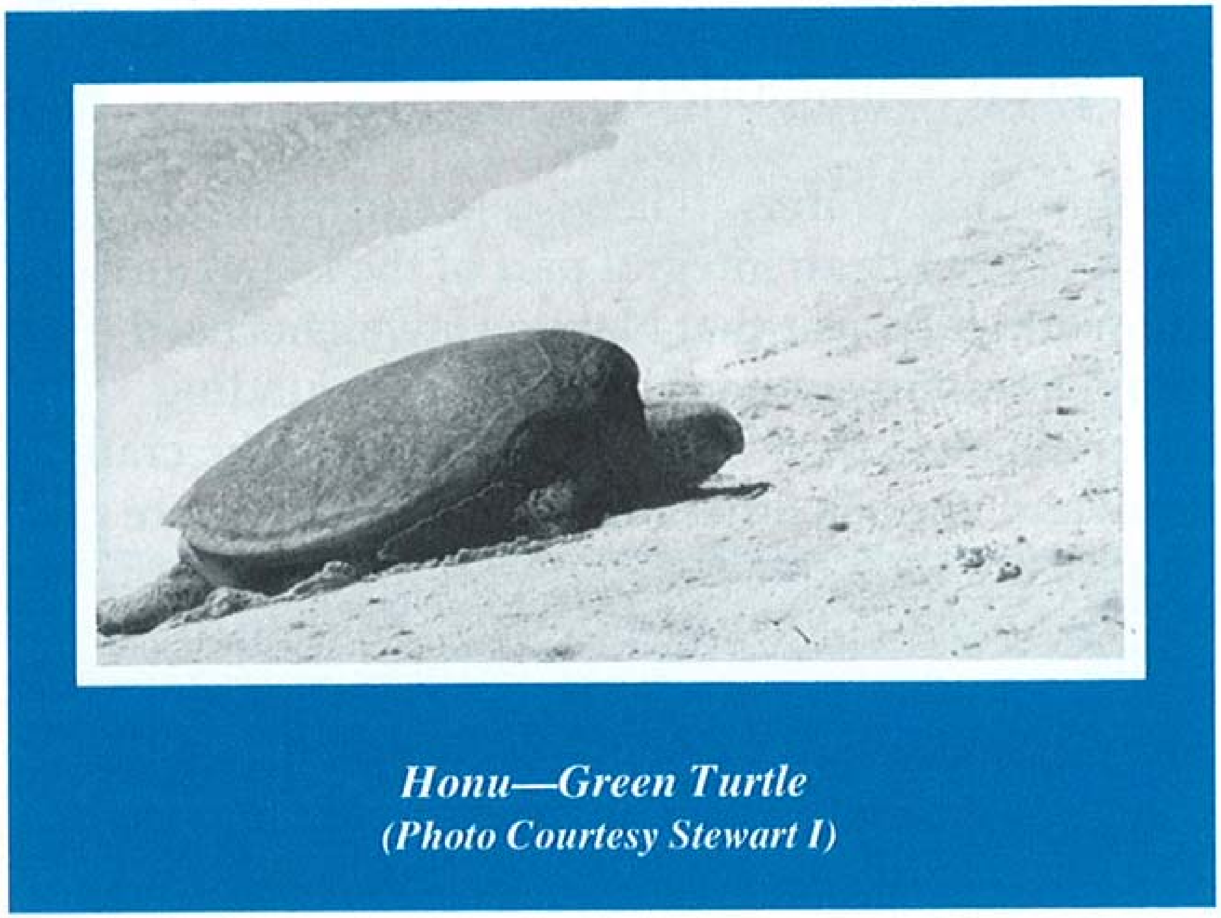


Figure 82. Relative Distances from Shore (from Past Reports, *Hākilo* Logs, and Opportunistic Sightings, n=25).

Figure 83. Turtle Bones from Stranding at Keoneuli Beach, Kanapou (9/27/99).

Figure 84. Picture from "Kaho'olawe: Restoring a Cultural Treasure" of a Basking *Chelonia mydas*.



Honu—Green Turtle
(Photo Courtesy Stewart I)

Figure 85. Photographs of Kanapou Bay Marine Debris Accumulation and Cleanup.

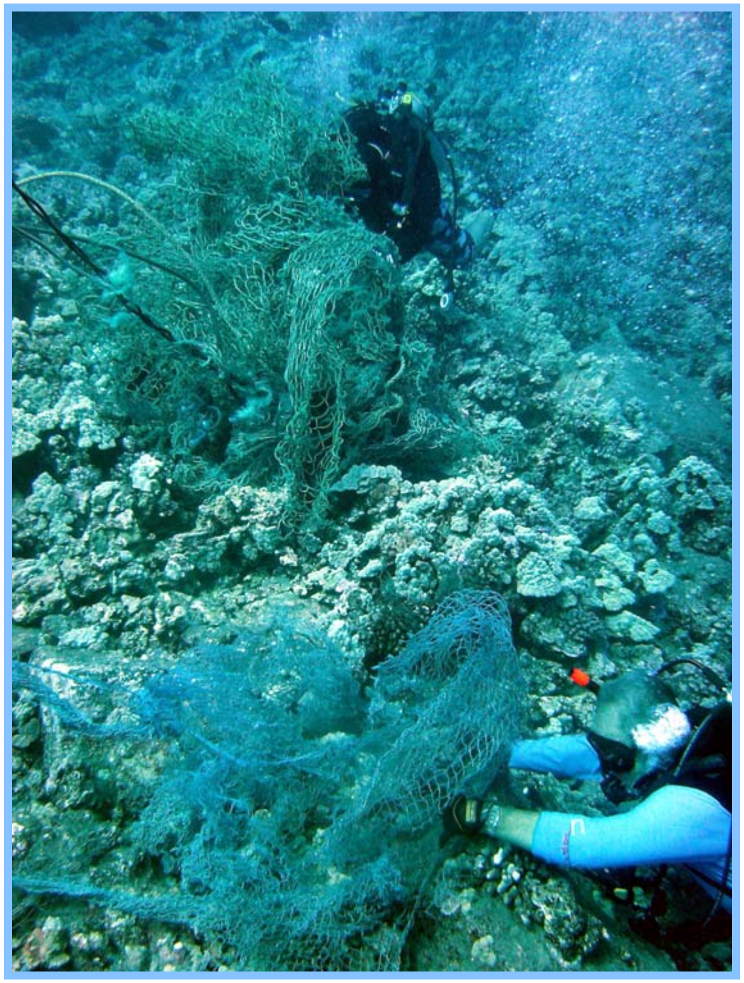


Figure 86. Map of Adult Female (Post-nesting) Hawksbill Foraging Sites.

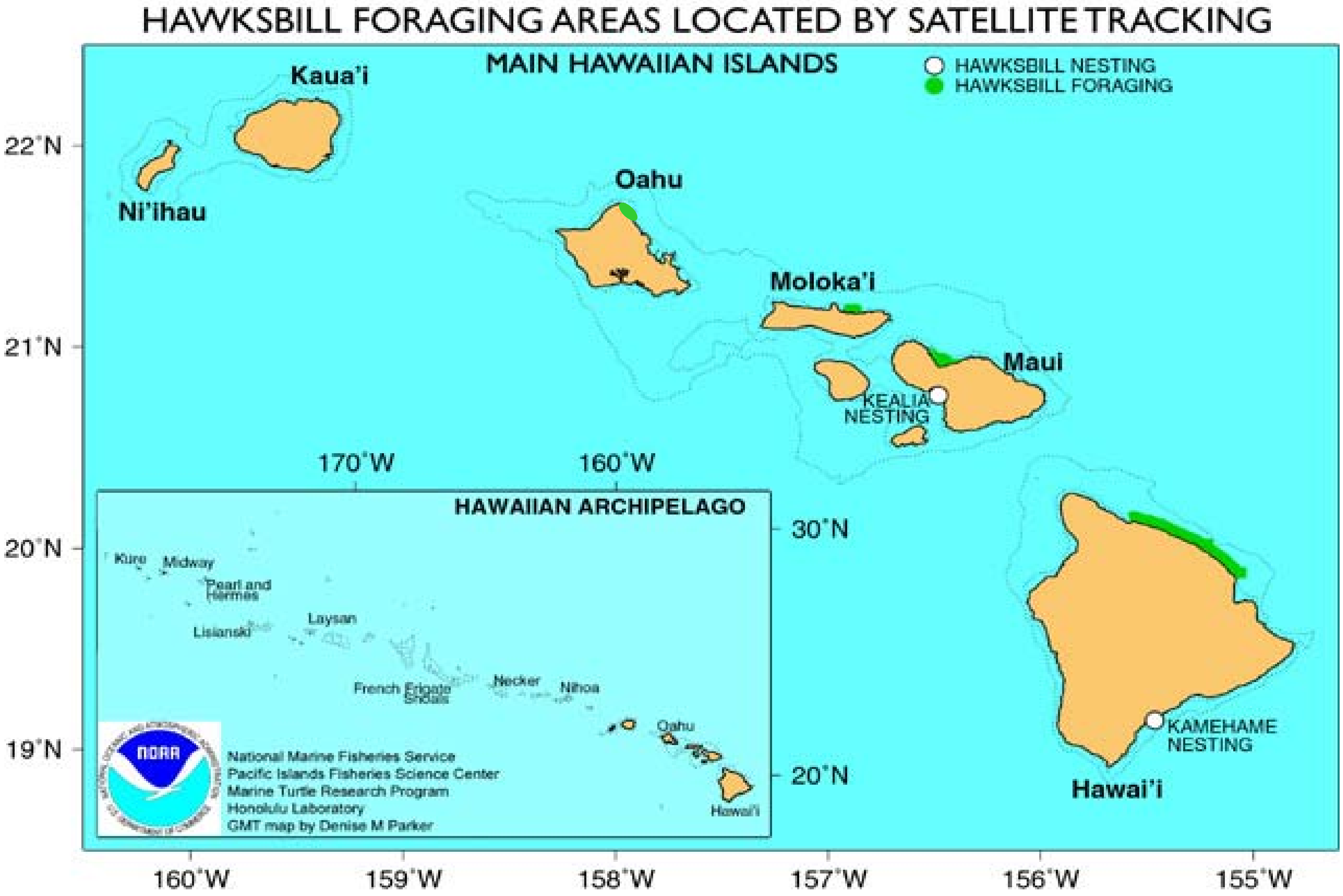
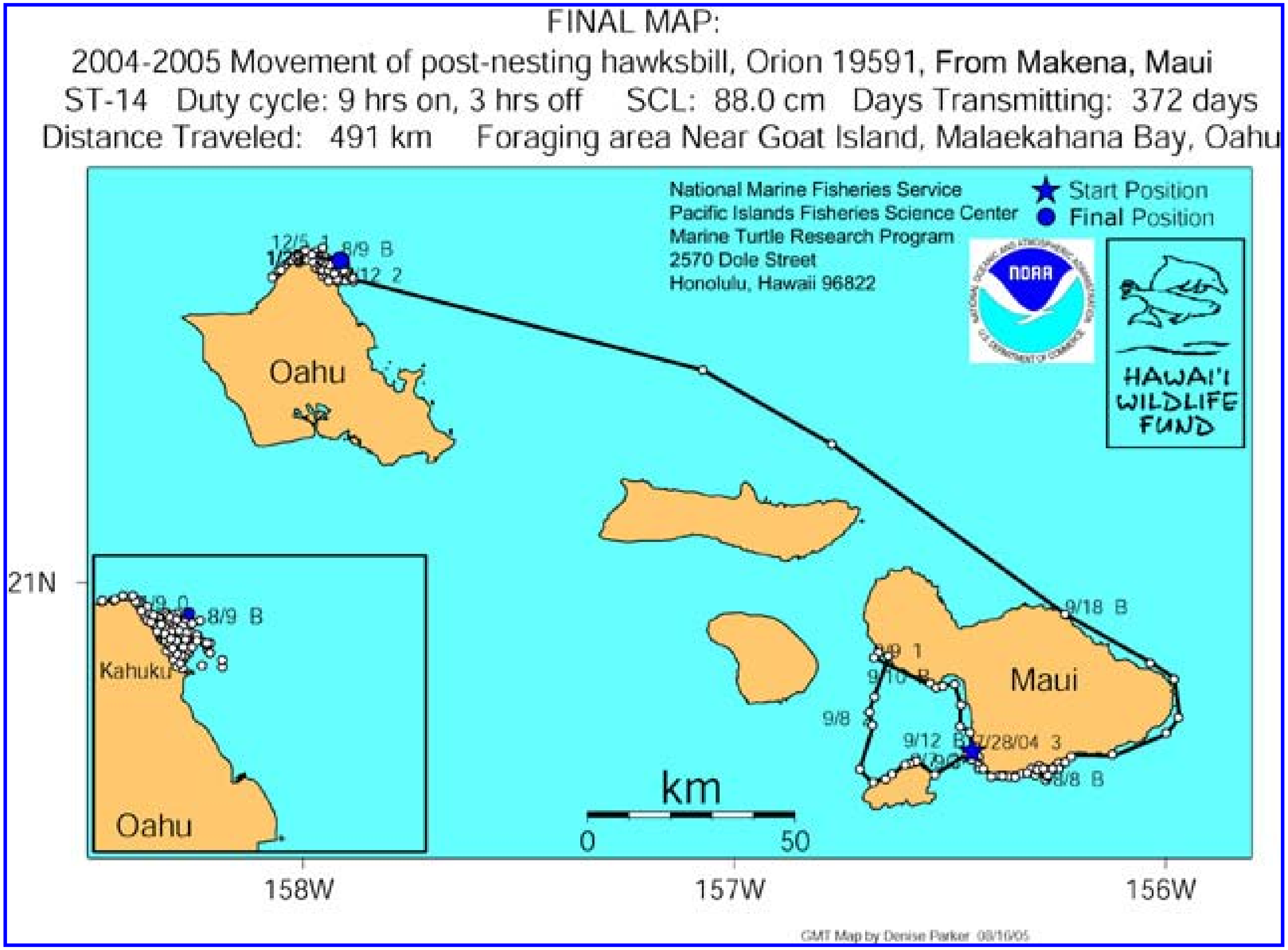


Figure 87. Satellite Map of Inter-nesting and Post-nesting Movements of Hawksbill “Orion”.



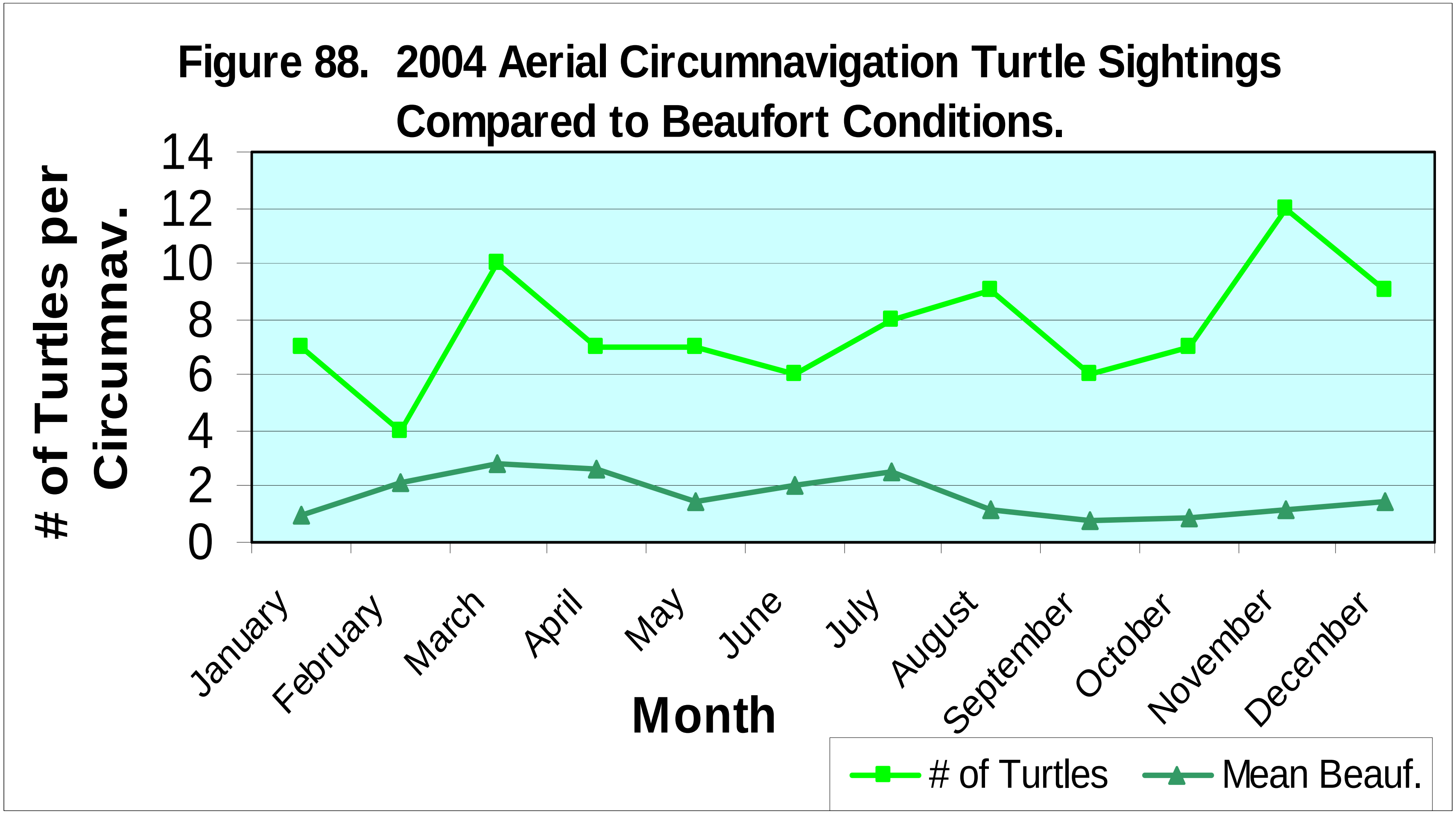


Figure 88. 2004 Aerial Circumnavigation Turtle Sightings
Compared to Beaufort Conditions.
# of Turtles per Circumnav.
14
12
10
8
6
4
2
0
January
February
March
April
May
June
July
August
September
October
November
December
Month
# of Turtles
Mean Beauf.

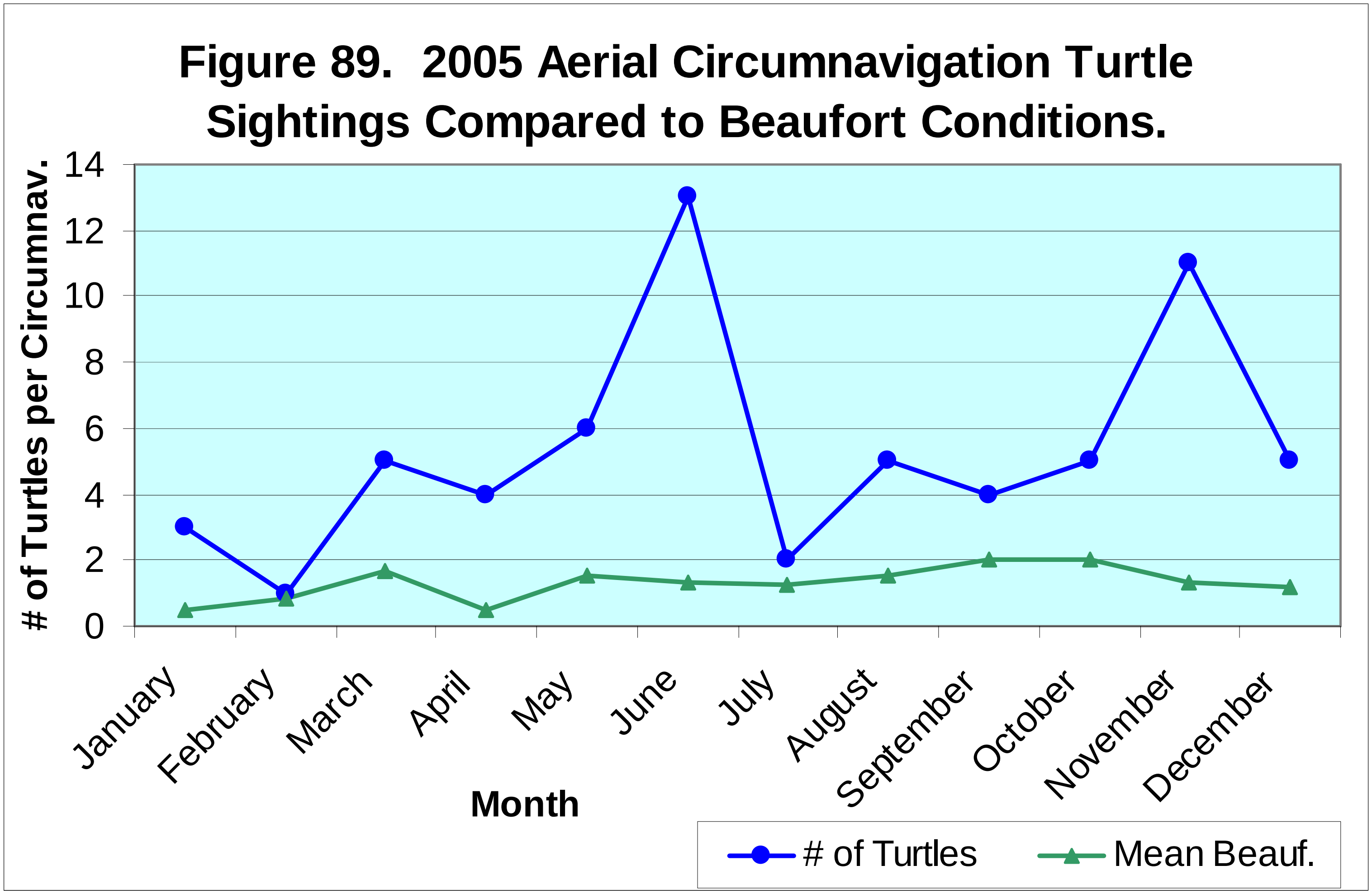


Figure 89. 2005 Aerial Circumnavigation Turtle Sightings Compared to Beaufort Conditions.
# of Turtles per Circumnav.
14
12
10
8
6
4
2
0
January
February
March
April
May
June
July
August
September
October
November
December
Month
# of Turtles
Mean Beauf.

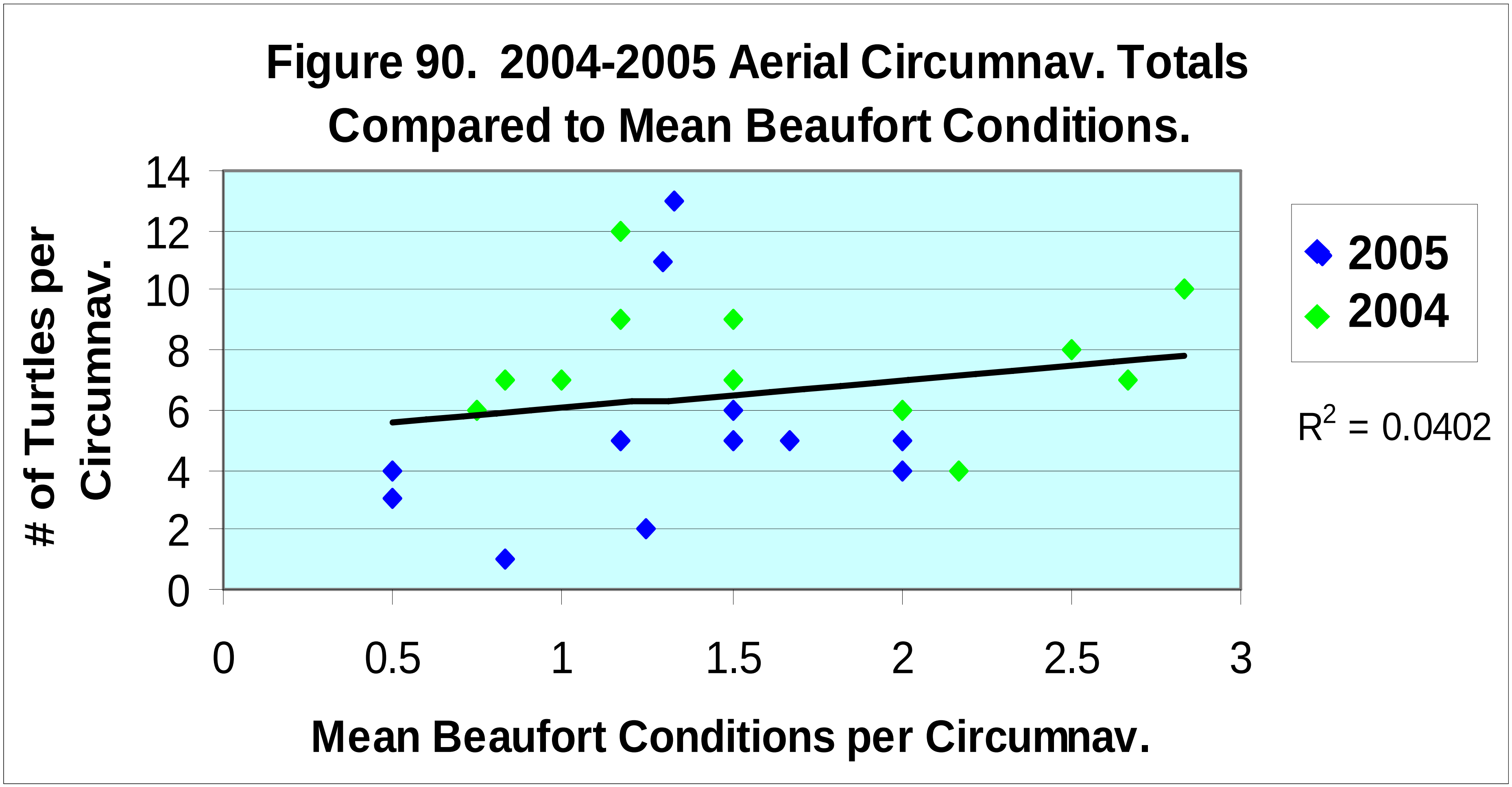


Figure 90. 2004-2005 Aerial Circumnav. Totals Compared to Mean Beaufort Conditions.
# of Turtles per Circumnav.
Mean Beaufort Conditions per Circumnav.
0
2
4
6
8
10
12
14
0
0.5
1
1.5
2
2.5
3
2005
2004
R2 = 0.0402

Table 1. Distributions by 'Ilis for All Survey Types and Sources.

'Ili Name	Kealaikahiki	Honokoa	Ahupu	Kuheia	Papaka	Hakioawa	Kanapou	Kaka	Kamohio	Waikahalulu	
'Ili #	1	2	3	4	5	6	7	8	9	10	TOTALS
PAST REPORTS	17	12	10	4	4	3	1	0	2	1	54
ANECDOTAL/TS	5	2	0	2	0	5	2	1	1	1	19
OPPORTUNISTIC	8	3	1	1	1	10	3	10	0	2	39
SHORE-BASED	4	0	0	0	0	0	0	0	0	0	4
HAKILO Logs	9	10	4	3	0	10	2	7	7	3	55
HAKILO Incid.	21	11	11	7	3	29	5	8	2	0	97
IN-WATER	5	8	8	5	6	41	0	6	3	0	82
AERIALCirc	27	9	9	13	9	35	27	49	13	18	209
AERIAL N.Coast	8	1	10	7	3	14	n/a	n/a	n/a	n/a	43
AERIAL Incid.	12	5	7	4	9	10	10	6	3	3	69
TOTALS	116	61	60	46	35	157	50	87	31	28	671

Table 2. Summary of Total Sightings for All Survey Types and Sources.

INFORMATION SOURCE	TOTAL #
Standardized Aerial Circumnavigations	209
Standardized Aerial North Coasts	43
Aerial Incidentals & Independent Obs.	69
In-water Surveys	82
Hakilo Incidentals	98
Hakilo Logbooks	63
Shore-Based	4
Opportunistic Sightings	42
Anecdotal / Talk Story	32
Past Reports / Literature	66
TOTAL	708

Table 3. Past KIR Studies' Turtle Sightings and Research Efforts.

Year	Author	Title	Turtles	Days	Sites
1972	State of HI Dept.of Fish & Game	Kaho'olawe Fish Survey	0	4	n/a
1978	U.S.Dept of Navy (by EISC)	Environmental Impact Statement Military Use of K. Training Area	13	6	n/a
1978	Envt'l Impact Study Corp.	Environmental Impact Statement Military Use of K. Training Area	0	6	~18
1978	NOAA/NMFS (George Balazs)	Sea Turtles of Kaho'olawe a Preliminary Survey	4	4	16.5%****
1991	US Dept of Commerce	Kaho'olawe Island National Marine Sanctuary Feasibility Study	0	n/a	n/a
1992	The Nature Conservancy (Gon et al.)	Biological Database & Reconnaissance Survey of Kaho'olawe…	0 (4*)	20**	~26
1993	DLNR Dept of Aquatic Resources	Kaho'olawe Island Nearshore Marine Resource Inventory	>12	14	46
1993	UH HIMB (Jokiel et al.)	An Evaluation of the Nearshore Coral Reef Resources of Kaho'olawe	20	6	19
1997	Protect Kaho'olawe Fund	Contemporary Subsistence Fishing Practices Around Kaho'olawe	13	11	~21
1997	USGS & Dept of Ag. (Lindsey et al.)	Technical Options & Recommendations for Faunal Restoration of…	0	n/a	n/a
1998	Bishop Museum (Coles et al.)	Determination of Baseline Conditions for Introduced Marine Spp…	0***	3	6
		Totals	**62 (4*)**	**74**	**~136 (&16.5%)**

0= no turtles found with an effort to do so
*= sightings were in 1990
**= surveyed inland also
***= no mention of turtles
****= % of coastline searched

Table 4. Aerial (Standardized) Circumnavigation Survey Effort (2003-2005).

YEAR	# turtles	# surveys	# / survey
2003	53	5	10.60
2004	92	12	7.67
2005	64	12	5.55
Totals & Mean	**209**	**29**	**7.21**

Table 5. Aerial (Standardized) North Coast Survey Effort (2003-2005).

YEAR	# turtles	# surveys	# / survey
2003	17	6	2.83
2004	16	9	1.78
2005	10	4	2.50
Totals & Mean	**43**	**19**	**2.30**

Table 6. In-Water Survey Effort (2002-2005).

YEAR	# turtles	# transects	# per transect
2002	8	8	1.00
2003	12	10	1.20
2004	32	21	1.52
2005	30	28	1.07
Totals & Mean	**82**	**67**	**1.22**

Table 7. *Hakilo* Incidental Sightings and Survey Effort (2002-2005).

YEAR	# turtles	# days	# per day
2002	1	4	0.25
2003	15	11	1.36
2004	29	27	1.12
2005	53	34	1.56
Totals & Mean	**98**	**76**	**1.29**

Table 8. *Hakilo* Logbook Recorded Sightings and Effort (1997-2005).

YEAR	# turtles	# days	# per day
1997	6	5	1.20
1998	5	19	0.26
1999	22	64	0.34
2000	11	33	0.33
2001	5	27	0.19
2002	2	4	0.50
2003	6	33	0.18
2004	5	25	0.20
2005	1	8	0.13
Totals & Mean	**63**	**218**	**0.29**

Table 9. Total Distribution by 'Ili (and Their Relative Abundance Ranks) of All Survey Types and Sources.

'Ili Name	Kealaikahiki	Honokoa	Ahupu	Kuheia	Papaka	Hakioawa	Kanapou	Kaka	Kamohio	Waikahalulu
'Ili #	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
TOTAL %	**17.3%**	**9.1%**	**8.9%**	**6.9%**	**5.2%**	**23.4%**	**7.5%**	**13.0%**	**4.6%**	**4.2%**
TOTAL Rank	**2**	**4**	**5**	**7**	**8**	**1**	**6**	**3**	**9**	**10**
AERIAL Circ %	12.9%	4.3%	4.3%	6.2%	4.3%	16.7%	12.9%	23.4%	6.2%	8.6%
AERIAL Circ Rank	3 & 4	8, 9 & 10	8, 9 & 10	6 & 7	8, 9 & 10	2	3 & 4	1	6 & 7	5
TOTAL AERIAL %	14.6%	4.7%	8.1%	7.5%	6.5%	18.4%	11.5%	17.1%	5.0%	6.5%
TOTAL AERIAL Rank	3	10	5	6	7 & 8	1	4	2	9	7 & 8
N. COAST AERIAL %	18.6%	2.3%	23.3%	16.3%	7.0%	32.6%	n/a	n/a	n/a	n/a
N. COAST AERIAL Rank	3	6	2	4	5	1				
INCID AERIAL %	17.4%	7.2%	10.1%	5.8%	13.0%	14.5%	14.5%	8.7%	4.4%	4.4%
INCID AERIAL Rank	1	7	5	8	4	2 & 3	2 & 3	6	9 & 10	9 & 10
IN-WATER %	6.1%	9.8%	9.8%	6.1%	7.3%	50.0%	0.0%	7.3%	3.7%	0.0%
In-Water Rank	6 & 7	2 & 3	2 & 3	6 & 7	4 & 5	1	9 & 10	4 & 5	8	9 & 10
HAKILO Logs %	16.4%	18.2%	7.3%	5.5%	0.0%	18.2%	3.6%	12.7%	12.7%	5.5%
HAKILO Logs Rank	3	1 & 2	6	7 & 8	10	1 & 2	9	4 & 5	4 & 5	7 & 8
HAKILO Incid. %	21.7%	11.3%	11.3%	7.2%	3.1%	29.9%	5.2%	8.2%	2.1%	0.0%
HAKILO Incid. Rank	2	3 & 4	3 & 4	6	8	1	7	5	9	10
Shore-Based %	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Shore-Based Rank	1	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Anec/TS & Opport. %	22.4%	8.6%	1.7%	5.2%	1.7%	25.9%	8.6%	19.0%	1.7%	5.2%
Anec/TS & Opp. Rank	2	4 & 5	8, 9 & 10	6 & 7	8, 9 & 10	1	4 & 5	3	8, 9 & 10	6 & 7
Past Reports %	31.5%	22.2%	18.5%	7.4%	7.4%	5.6%	1.9%	0.0%	3.7%	1.9%
Past Reports Rank	1	2	3	4 & 5	4 & 5	6	8 & 9	10	7	8 & 9

Table 10. Monthly Turtle Sightings and Means from All Aerial Circumnavigation Surveys (2002-2005).

	2002	2003	2004	2005 + I.O.	2002-2005		2003-2005Standard.		03-05 plus I.OBS	
					TOTALS	Mean	TOTALS	Mean	TOTALS	Mean
January	n/a	n/a	7	3	10	5	10	5	10	5
February	n/a	0	4	1	5	1.7	5	2.5	5	2.5
March	1	4	10	5	20	5	15	7.5	15	7.5
April	0	2	7	4	13	3.3	11	5.5	11	5.5
May	0	1	7	6 + 2	14	3.5	13	6.5	**15**	**7.5**
June	n/a	9	6	13	28	9.3	19	9.5	19	9.5
July	n/a	14*	8	2	24	8	24	8	24	8
August	n/a	11	9	5 + 2	25	8.3	25	8.3	**27**	**9**
September	n/a	8	6	4	18	6	18	6	18	6
October	12	14	7	5	38	9.5	26	8.7	26	8.7
November	n/a	n/a	12	11	23	7.7	23	11.5	23	11.5
December	7	6	9	5	27	6.75	20	6.67	20	6.67
Totals	**20**	**69 / 53**	**92**	**64 / 68**	**245**		**209**		**213**	
# / survey	**4**	**6.9 / 10.6**	**7.7**	**5.3 / 5.7**		**6.3**		**7.2**		**7.3**

*Standardized surveys began here.
I.O.= Independent Observer's sightings

Table 11. Monthly Turtle Sightings from Standardized Aerial Circumnavigation Surveys (2003-2005).

month	2003	2004	2005
January	n/a	7	3
February	n/a	4	1
March	n/a	10	5
April	n/a	7	4
May	n/a	7	6
June	n/a	6	13
July	14	8	2
August	11	9	5
September	8	6	4
October	14	7	5
November	n/a	12	11
December	6	9	5
TOTAL	53	92	64
MEAN	10.6	7.7	5.3

Table 12. Standardized Aerial and In-water Survey Summary with Densities.

	~km (miles)/survey	mean time/survey	# of surveys	# of turtles	range	mean # of turtles (SE)	mean density/km (mile)	mean density/min (hour) CPUE	max density/min (hour)
Circumnavs	~47 (29)	63.9 min	29	209	1 to 14	7.2 (0.64)	0.153 (0.248)	0.11 (6.78)	0.29 (17.16)
North Coasts	~18 (11)	19.7 min	19	43	0 to 6	2.3 (0.40)	0.131 (0.209)	0.12 (7.02)	0.46 (27.72)
In-water	~0.8 (0.5)	56 min	67	82	0 to 8	1.2 (0.22)	1.53 (2.44)	0.02 (1.31)	0.13 (8.00)

TABLE 13. DISTRIBUTIONS BY ʻILI FOR ALL AERIAL SURVEY SIGHTINGS (N=321).

ʻILI #	Kealaikahiki 1	Honokoa 2	Ahupu 3	Kuheia 4	Papaka 5	Hakioawa 6	Kanapou 7	Kaka 8	Kamohio 9	Waikahalulu 10	TOTAL	MEAN
AERIAL												
CIRCUM.	{# OF STANDARDIZED SURVEYS}											
2003 {5}	7	1	1	2	2	6	11	12	8	3	53	10.60
2004 {12}	16	6	2	5	4	17	12	20	3	7	92	7.67
2005 {12}	4	2	6	6	3	12	4	17	2	8	64	5.33
N.COAST												7.21
2003 {6}	3	0	4	3	2	5	n/a	n/a	n/a	n/a	17	2.83
2004 {9}	4	1	3	1	0	7	n/a	n/a	n/a	n/a	16	1.78
2005 {4}	1	0	3	3	1	2	n/a	n/a	n/a	n/a	10	2.50
INCID & I.O.												2.26
2002	4	3	2	0	7	6	0	3	1	2	28	
2003	4	1	1	2	1	1	8	3	1	1	23	
2004	0	0	0	0	0	0	1	0	0	0	1	
2005	4	1	4	2	1	3	1	0	1	0	17	
TOTAL												
2002	4	3	2	0	7	6	0	3	1	2	28	
2003	14	2	6	7	5	12	19	15	9	4	93	
2004	20	7	5	6	4	24	13	20	3	7	109	
2005	9	3	13	11	5	17	5	17	3	8	91	
												80.3/yr
TOTAL	47	15	26	24	21	59	37	55	16	21	321	

% of total	14.6%	4.7%	8.1%	7.5%	6.5%	18.4%	11.5%	17.1%	5.0%	6.5%

Table 14. Distance From Shore Categories for All Survey Types and Sources.

Survey Type	<5m	5-20m	21-40m	>40m	Total
Aerial Surveys	98	132	41	15	286
In-Water Surveys	16	30	2	9	57
Hakilo Incidentals	18	33	0	19	70
Hakilo Logbooks	6	0	2	0	8
Opportunistics	4	4	2	1	11
Past Reports	2	0	2	2	6
Total	**144**	**199**	**49**	**46**	**438**
%	**32.9%**	**45.4%**	**11.1%**	**10.5%**	

Table 15. Size Class Totals for All Survey Types and Sources.

Survey Type	X-Small	Small	Small-Med	Medium	Large	Total
Aerial Surveys	n/a	101	98	60	6	265
In-Water Surveys	3	74	4	0	1	82
Hakilo Incidentals	8	63	8	2	1	82
Hakilo Logbooks	4	25	3	12	0	44
Opportunistics	3	8	7	0	2	20
Anecdotal/TS	1	4	0	0	34	39
Past Reports/Lit.	1	14	20	9	2	46
Total	**20**	**289**	**140**	**83**	**46**	**578**
%	**3.5%**	**50.0%**	**24.2%**	**14.4%**	**8.0%**	

Table 16. Depth Information for All Survey Types and Sources (n=136).

Survey Type	total n	mean (m)	1 to 3 m	4 to 6 m	7 to 9 m	10 to 12 m	>12 m
Aerial Surveys	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Past Reports	11	6.2	6	1	1	1	2
Opportunistic	1	5.2	0	1	0	0	0
***Hakilo* Logbooks**	8	11.9	1	1	4	0	2
***Hakilo* Incidental**	37	6.5	8	16	8	4	1
In-Water	79	4.4	38	32	4	5	0
Totals	**136**	**5.6**	**53**	**51**	**17**	**10**	**5**
%			**39.0%**	**37.5%**	**12.5%**	**7.4%**	**3.7%**

Table 17. Worldwide Examples of Turtle Dive Behaviors.

Author	Location	Species	Life History Stage	n	% submerged minimum	maximum	mean
Mendonca & Pritchard (1986)**	n/a	*Lk*	inter-nesting	9	n/a	n/a	**97.6%**
Byles (1988)**	Virginia	*Lk*	subadults	2	n/a	n/a	**83.5%**
Byles (1989)*	Gulf of Mexico	*Lk*	post-nesting	14	n/a	n/a	96.0%
Balazs (1993)	Hawaii	*Cm*	post-nesting	3	95%	96%	n/a
Renaud et al. (1993)*	Texas	*Cm*	juv & subad.	9	80.8%	97.8%	n/a
Renaud & Carpenter (1994)*	Gulf of Mexico	*Cc*	juvenile	3	90.0%	95.7%	n/a
Renaud et al. (1994)*	TX & LA	*Lk*	n/a	33	**71.0%**	96.0%	n/a
Renaud (1995)*	Gulf of Mexico	*Lk*	juvenile	2	94.0%	**98.6%**	n/a
Gritschlag (1996)**	SE Atlantic	*Lk*	subadults	2	n/a	n/a	95.0%
Gritschlag (1996)**	SE Atlantic	*Lk*	adult	1	n/a	n/a	94.0%
VanDam & Diez (1996)	Caribbean	*Ei*	immature	n/a	n/a	n/a	96.4%
Renaud & Williams (1997)	Texas	*Lk*	juvenile	6	91.2%	95.4%	92.9%
Renaud & Williams (1997)	Texas	*Cm*	subadults	2	93.2%	96.1%	96.1%
Morreale & Standora (1998)**	NE Atlantic	*Lk*	subadults	16	n/a	n/a	95.1%
Schmid et al. (2002)	Florida	*Lk*	subadults	7	95.7%	97.6%	96.5%

*in Renaud & Williams (1997)

**in Schmid (2002)

Table 18. The Generation of Adjustment Factors from the Percentage of Time KIR Turtles May Spend at the Surface for Population Density/km Estimates.

possible % submerged	possible % at the surface (X)	FORMULA	resulting adjustment factor	mean=7.2 (max=14) aerial circumnav density/km	corrected mean (max) density/km	~kms of coastline	mean (max) Island-wide pop'n estimate
80%	20%	1/X	5	0.153 (0.298)	0.765 (1.490)	47 km	36.0 (70.0)
85%	15%		6.7		1.025 (1.997)		48.2 (93.8)
90%	10%		10		1.530 (2.980)		71.9 (140.1)
95%	5%		20		3.060 (5.96)		143.8 (280.1)
97%	3%		33.3		5.095 (9.923)		239.5 (466.4)
98%	2%		50		7.65 (14.9)		359.6 (700.3)
99%	1%		100		15.30 (29.8)		719.1 (1400.6)

Table 19. The Generation of Adjustment Factors from the Percentage of Time KIR Turtles May Spend at the Surface for Population Density/mile Estimates.

possible % submerged	possible % at the surface (X)	FORMULA	resulting adjustment factor	mean=7.2 (max=14) aerial circumnav density/mile	corrected mean (max) density/mile	~miles of coastline	mean (max) Island-wide pop'n estimate
80%	20%	1/X	5	0.248 (0.483)	1.24 (2.42)	29 miles	36.0 (70.0)
85%	15%		6.7		1.66 (3.24)		48.2 (93.9)
90%	10%		10		2.48 (4.83)		71.9 (140.1)
95%	5%		20		4.96 (9.66)		143.8 (280.1)
97%	3%		33.3		8.26 (16.08)		239.5 (466.4)
98%	2%		50		12.40 (24.15)		359.6 (700.4)
99%	1%		100		24.8 (48.30)		719.2 (1400.7)