No. 105

AN ECOLOGICAL ASSESSMENT OF GREEN TURTLES (*CHELONIA MYDAS*) IN COASTAL FORAGING AND RESTING HABITATS OF KAILUA BAY, LANIAKEA, AND PAPAILOA, ON OAHU, HAWAIIAN ISLANDS

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MASTER OF SCIENCE
JULY 2000

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ABSTRACT

The shallow coastal waters of Hawaii serve as foraging pastures for a genetically discrete population of green turtles (*Chelonia mydas*). The population has increased annually over the past 20 years, but threats such as shoreline fishing, coastal development, marine debris, and a tumour forming disease with a probable viral etiology, fibropapillomatosis remain. An ecological assessment aimed at elucidating behaviour and preferences in activity schedules and conditions was conducted at three study sites on Oahu: Kailua, Laniakea, and Papailoa. The two study sites at North Shore, Laniakea, and Papailoa, serve as foraging grounds for juvenile to adult-sized individuals. In the Kailua area, located on the east coast, the juveniles of the population dominate. At North Shore, high tide and/or high surf provide optimum foraging conditions, and the mid-day and afternoon hours of the day display most activity. No such tide or time related activity peak was revealed in Kailua, where the reef area is accessible at all times. However, a 50% affliction with fibropapillomas was found at the Kailua study site, apparently a situation much more severe than at the North Shore study sites. Behavioural changes, such as basking at Laniakea and Kailua, and increased tameness at Laniakea were documented.

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1 INTRODUCTION

1.1 General information on *Chelonia mydas*

Green turtles (*Chelonia mydas*) are marine reptiles known to frequent the shallow benthic habitats encompassing the Hawaiian Islands. This narrow, 2,450 km stretch of coastal water, serves as important foraging pastures for the genetically discrete population of Hawaiian green sea turtles or *honu*, as they are called in Hawaiian (Bowen et al., 1992). This species, along with the other six species of sea turtles found worldwide, has acquired a protected status. The Hawaiian population gained its protection in 1978, when it was listed as Threatened under the U.S. Endangered Species Act. Since then, the number of individual turtles has successfully increased, although not to historical levels (Balazs, 1980). The increase is due to ongoing research, protected nesting grounds at French Frigate Shoals (lat. 23°45'N, long. 166°10'W), Northwestern Hawaiian Islands, efficient law enforcement, and conservation education of the public. Today it is not uncommon to witness turtles foraging close to shore on reef flats, and along coral outcroppings and rock ledges. Green turtles are mainly herbivorous, feeding on algae, seagrasses, and occasionally invertebrates, such as sponges, crustaceans, and jellyfish.

Even though there have been documented increases in population size, for example a substantiated increase in the nesting colony, the Hawaiian green turtle still faces threats such as coastal development, marine debris, shoreline fishing (resulting in hooking or entanglement), and most severely from a neoplastic disease called fibropapillomatosis. Strandings of live and dead green turtles have increased annually over the past 17 years, the majority of cases are afflicted by fibropapillomas (Murakawa et al., In Press).

1.2 History, characteristics, and etiology of fibropapillomatosis

This disease was originally described in green turtles from the Florida Keys in 1938, and in Hawaii the first documented case was in 1954 (Smith and Coates, 1938; Balazs, G. H., 1991; Work T. M. and G. H. Balazs, 1999). Fibropapillomatosis (FP) is a debilitating disease, causing lobulated, although histologically benign, tumours to form on the soft external tissues, as well as on internal organs (Quackenbush et al., 1998). The tumours range in size from 1 mm to 30 cm in diameter, and are pigmented black to white (Aguirre et al., 1998). The later stage of the disease, of white massive tumours, has a cauliflower-like appearance. The condition is known worldwide, posing a serious threat in the Hawaiian Islands, Australia, Florida, and certain cites in the Caribbean (Balazs et al., 1998). Other sea turtle species such as loggerhead (*Caretta caretta*) and olive ridley (*Lepidochelys olivacea*) have been documented suffering from fibropapillomatosis (Aguirre et al., 1999). In Hawaii, the most commonly infected external tissues are the eyes, oral cavity, neck, flippers, and tail. FP leads in many cases eventually to death through starvation or suffocation as a result of blocked eyesight, airways, and increased drag when swimming. Research is ongoing in several areas since the cause of the disease is likely to be multifactorial. However, a viral agent appears to be the responsible pathogen, and a herpesvirus, a retrovirus, and a papillomavirus are all implicated (Quackenbush et al., 1998).

Other factors likely to make the green turtles more prone to infection include chronic stress, response to trematode ovas in tissues, and environmental pollutants impairing the immune system (Graczyk et al., 1995). Most cases of FP are found near urban or agricultural activities that are associated with eutrofication (Balazs, G.H., 1991; Aguirre et al., 1994; Casey et al., 1997).

Fibropapillomatosis has been shown to be transmissible in laboratory experiments, using an injection of cell-free tumour homogenate (Herbst et al., 1999).
Whereas attempts at isolating and characterizing the etiologic virus of green turtle fibropapillomatosis (GTFP) are urgently needed, equally important are studies aimed at clarifying the transmission of GTFP among green turtles in their natural habitat (Lu et al., 2000).

1.3 Behavioural changes

In recent years several notable changes in behaviour have been observed in the Hawaiian population, many of them unique to Hawaii and not reported to occur anywhere else in the world among other populations of green turtles or other species of sea turtles. Basking is a terrestrial emergence occurring along shorelines or exposed coral heads and rock formations. The turtles–both male and female–emerge during daylight hours. They appear healthy, and this behaviour is not to be confused with sick and dead individuals prone to stranding ashore. Instead, possible explanations could be thermoregulation and conservation of energy (Rice et al., In Press.; Harrington et al., In Press.). Apart from this resting purpose, the only time turtles are seen emerging from the water is during nesting season and then only the females of the population. A change of foraging times seems to take place among the Hawaiian green turtles. Feeding during nighttime has switched to daytime in some coastal developed areas, and could be linked to increased population numbers and/or greater tolerance to humans. Tameness is another remarkable behaviour shown, where turtles allow people to come close to them and even hand-feed natural algae to them in the water.

1.4 Description of study sites

Three study sites were selected after initial scoping. Accessibility and known presence of sea turtles in the area were of vital importance. Dissimilarities between the study sites, such as different habitats and other factors likely to influence the activity of the sea turtles (for example presence of people) were considered and desired.

Kailua, situated on the east coast of Oahu (lat. 21°26'N, long. 157°45'W), salinity 34‰, has a history of serving as foraging grounds for *C. mydas*. The Kawainui Canal, salinity 32‰, feeds into the bay, and drains the Kawainui marsh area further inland. The water quality depends on many factors: nutrient input, growth and decay of vegetation, rainfall, and surrounding agricultural and pasture land contributing fertilizer or pesticides (Ahuna, L., and R. Fujioka, 1993). Private homes border the canal and bay shoreline. Plants frequently found on shore are naupaka kahakai (*Scaevola sericea*), and coconut palm trees (*Cocos nucifera*). The bottom substrate consists of fine-grained sand alternating with coral reef where benthic algae species such as *Dictyota crenulata* and *Acanthophora spicifera* grow.

Laniakea, located on the North Shore of Oahu, (lat. 21°37'N, long. 158°05'W), with a salinity of 34‰. The beach was named after a small freshwater spring, found among the rocks at the sea's edge (Clark, 1977). Surf conditions differ from the ones found in Kailua, and rough conditions prevail during the winter months. This beach is heavily frequented by tourists, surfers, and other water users such as spearfishermen, fishermen, and snorklers. A road directly behind the beach makes access easy. Most of the shoreline is fronted by a low reef, and the offshore bottom is rocky. The bottom substrate consists of sand, alternating with algae-covered rocks and rock ledges. Common species are *Ulva* sp., *Pterocladia capillacea* and *Acanthophora spicifera*. At the back of the beach ironwood trees *(Casurina equisetifolia)* give shade.

Papailoa, (lat. 21°36'N, long. 158°05'W), salinity 34‰, a study site located adjacent to Laniakea on the North Shore of Oahu, is a desolete beach, its existence known only by locals, spearfishermen, and the few people inhabiting the private homes along the beach. The shoreline is rocky, with course-grained calcareous sand. Strong inshore currents are common, especially when the surf is high, as a result of only slight protection from the reef. Ironwood *(Casurina equisetifolia)*, naupaka kahakai (*Scaevola sericea*), and coconut palm trees (*Cocos nucifera*) are present at the back of the beach. Along the shoreline coralline rock ledges jut into the water, and large rocks emerge from the water surface. These are covered with algae, mainly *Ulva* sp., *Hypnea* sp., and *Pterocladia* sp.

The objectives of this study were to assess and gather baseline data, and to gain an increased understanding of these foraging grounds on Oahu, never previously studied, but with a history of harboring green turtles ranging from immature to adult sizes. Aspects such as health, numbers, size classes, preferences in feeding schedules and forage species, weather conditions, and activity were considered. Assessing differences/similarities between the three study sites, as well as documenting characteristics for each site was emphasized. The necessity of evaluating the population numbers and health status in nearshore foraging grounds is evident, not only because it is the habitat where the turtles spend the majority of their lives, but also in order to allow sound long-term planning and protection, an insight into factors influencing the daily life of the population is of major importance.

1.5 Hypotheses

* Feeding occurs more frequently at certain hours of the day

*Feeding occurs more frequently at high tide

*The composition of size classes differs at the three study sites

2 METHODOLOGY

2.1 Terrestrial assessment

Observations were made at:
*Different hours of the day; morning (8-11a.m.), mid-day (11a.m.-2p.m.), afternoon (2-5p.m.)
*Different tides (low, rising, high, and receding)
Field studies totaling approximately 30 days at each study site were conducted between February and June 2000. Each site was divided into several sections in order to facilitate observations. Head counts and estimations of size classes (small (35-65 cm straight carapace length (SCL)), medium (65-85cm SCL), large (85<cm SCL)) were made with the naked eye, and presence/absence of tumours and tumour status (see 2.6 Tumour scoring system) were, when necessary, clarified with a 7 x 35 binocular. Activity of the turtles (foraging, swimming, resting), as well as activity in the area (boats, presence of people, etc.), surf and weather conditions were documented. The turtle's identity was (if possible) clarified by the location of barnacles, tumours, cuts or other abnormalities, size, engraved numbers (see 2.7 Capturing/tagging assessment) or metal tags. Each observation-interval lasted 30 minutes, based on an article on submergence intervals (Brill et al., 1994).

2.2 In-water assessment

Snorkeling along imaginary transects took place at sites of particular interest based on where turtles had been seen surfacing for air during initial terrestrial observations.

Individuals were frequently observed on reef flats and along coral- and rock ledges. Activity (resting, foraging, swimming), health status, size classes, sex (which could be determined on mature males only and was specified when it was possible), activity in area were noted, and if possible forage species seen eaten. A turtle's identity was clarified by the distinctive features mentioned in 2.1 Terrestrial assessment. All information was written down on a dive slate. Visibility, surf, and weather conditions were documented.

2.3 Fecal pellets; sampling and processing

Pellets washed ashore or floating along Kailua beach, were collected in plastic zipper-bags and temporarily placed in a freezer before processing. When processed in a laboratory facility, the pellets were cut in half and based on the diameter, the individual pellets were divided into size-classes: small (0-1 cm), medium (1-2 cm), and large (2 cm<). Each pellet was broken up, hydrated, shaken, and rinsed using a U.S.A. Standard Testing Sieve (mesh opening 0.71 mm) in order to clean the integral fragments. These were picked with forceps and placed in a plastic vial, covered with 10% formalin, and sealed with parafilm, then sent to Dr. Dennis J. Russell, American University of Sharjah, United Arab Emirates, for identification of content. Presence of abnormal content, such as fishing line was noted (Balazs et al., 1993).

2.4 Algae sampling

Sampling of algae growing on rocks, coral ledges and reef flats took place at the three study sites. The algae were collected as a means to identify potential green turtle forage growing at the study site, as compared to species seen being foraged upon or present in fecal samples found in the area. Additional information on species consumed as forage in Kailua, Laniakea and Papailoa was obtained from stranding/necropsy data dating back to 1985 (Appendix 8.3, Table 18).

2.5 Statistics – data analysis

For balanced data (equal sample sizes) and for simple Analysis of Variance testing, PROC ANOVA was used (SAS Institute Inc., SAS/STAT* User's Guide, Volume 1,Version 6, Fourth Edition, 1989). In this a Duncan-Waller multiple-range test was done on all main effect means and determined groups that are significantly different from each other at the alpha = 0.05 level. In the grouping means with the same letter were not significantly different. For unbalanced data, testing interactions between effects, and multivariate analysis, MANOVA, PROC GLM, was used (SAS Institute Inc., SAS/STAT* User's Guide, Volume 2, Version 6, Fourth Edition, 1989).

2.6 Tumour scoring system

An overall tumour score was assigned to each turtle observed based on a protocol designed by Work and Balazs, 1999. The scoring system was based on tumour size and number of tumours (Table 1.).

Table 1. Number of each size class of tumours used for placement into a particular tumour score category for green turtles in Hawaii afflicted with fibropapillomatosis (from Work and Balazs, 1999.)

	Overall tumour score			
	0	1	2	3
Tumour size(max.Ø)	Number of tumours			
<1 cm	0	1-5	>5	>5
1-4 cm	0	1-5	>5	>5
>4-10 cm	0	0	1-3	>4
>10 cm	0	0	0	>1

This scoring system facilitates estimation of health status in the field and the categories 0-3 range from nonafflicted (0), lightly afflicted (1), moderately afflicted (2), to severely afflicted individuals (3).

2.7 Capturing/tagging assessment

This assessment took place in Kailua (March 17, April 14, and June 7, 2000). In order to capture individual turtles, a set net 100x5 feet was placed on the reef flat; the net was watched at all times. Scoop nets and hand/snorkeling were used to capture individual turtles in the canal and the remaining bay area. Entangled turtles were taken to shore in inner tubes with a plywood bottom, and kept under a tarp to be released after measurements and sampling.

The following data collection and techniques were employed: Biometrics recorded on each turtle with an aluminium caliper, Haglöf, Sweden, consisted of straight-line (SCL) and curved-carapace length (CCL) from the center of the precentral scute to the posterior tip of the longest postcentral scute. SCL from the center of the precentral to the notch between the postcentrals, SCL- and CCL width at the widest point (the sixth marginal scute), straight-line plastron length along the midline. Straight-line head width at the widest point, and straight-line flipper width from the claw scale to the sixth scale on the trailing edge were measured as described in (Balazs et al., 1987). Tail length from the posterior rigid edge of the plastron to the tip of the tail, and from the posterior edge of the plastron to cloaca were done with a flexible measuring tape.

Passive Integrated Transponder (PIT) tags were applied on both left and right hind flippers. This technique to identify individual turtles is fairly new in sea turtle research, and is based on small inert microprocessors sealed in glass, that can transmit a unique identification number to a handheld reader. The PIT tag is inserted between the digits of a hind flipper. This internal location prevents tag loss over time (Balazs G. H., 1998).

An oral exam was made using a speculum to detect potential injuries such as fishhooks, presence of FP, parasites, and residual food particles (Balazs G. H., 1995). If unswallowed particles of food were present, they were removed from the mouth for identification.

Blood samples were drawn from the paravertebral sinus, on either side of the midline of the dorsal neck surface, and the turtle's weight was recorded. *Liquamycin LA-200 (oxytetracycline)* was injected on both front flippers, to mark skeletal components. The purpose of this procedure is for future age estimation of stranded, previously injected individuals.

A battery-powered Dremel moto-tool was used to harmlessly engrave a 1-2-mm deep identification number on the second lateral scute on each side of the the carapace, and white paint was applied to the engraved number. This facilitates terrestrial and aquatic assessments. Presence/absence of tumours and tumour status were documented according to 2.6 Tumour scoring system. General estimation of health status such as emaciation, injuries, past and present; entangled fishing lines, missing scutes, etc. was noted.

3 RESULTS

3.1 Terrestrial and in-water assessment

A MANOVA of number of turtles by place, tide, and size for all three study sites (Appendix 8.2, Table 9) resulted in $p = 0.8835$. No significance was found between place, tide and size, however differences between place and size were found.

The Duncan-Waller grouping (Table 2) shows that no significant difference exists between the two locations at North Shore; Papailoa and Laniakea. Therefore, the data on those two sites were merged. There are significant differences in number of turtles between Kailua and the North Shore sites.

Table 2. Duncan-Waller grouping of number of turtles by place. Mean is the mean number of turtles sighted at each place, and N is the number of sightings. Means with the same letter are not significantly different.

Duncan Grouping	Mean	N	Place
A	4.0	99	Papailoa
A	3.4	121	Laniakea
B	2.6	159	Kailua

An ANOVA of number of turtles by tide for Kailua (Appendix 8.2, Table 10) resulted in $p = 0.7753$, showing that tide does not significantly influence the number of individuals present.

An ANOVA of number of turtles by tide at North Shore (Appendix 8.2, Table 11) resulted in $p = 0.0001$. There are significant differences between tide height and number of turtles. The Duncan-Waller grouping on tide height and numbers (Table 3) shows that the significance is found when comparing high and low tide. More turtles were present at high tide.

Table 3. Duncan-Waller grouping of number of turtles by tide height at North Shore. Mean is the mean number of turtles sighted at each tide, and N is the number of sightings.

Duncan Grouping	Mean	N	Tide
A	4.7	102	High
B A	3.6	30	Rising
B A	3.0	8	Falling
B	2.3	83	Low

An ANOVA on number of turtles by time at North Shore (Appendix 8.2, Table 12) resulted in $p = 0.0005$. There are significant differences in number of turtles by time. The Duncan-Waller grouping (Table 4) shows that the significance in numbers of individuals by time is found when comparing morning with mid-day and afternoon. No significant difference is found between mid-day and afternoon. There are fewer turtles seen during morning hours.

Table 4. Duncan-Waller grouping of numbers of turtles by time at North Shore. Mean is the mean number of turtles sighted at each time of day, and N is the number of sightings.

Duncan Grouping	Mean	N	Time
A	4.7	83	Afternoon
A	3.6	71	Mid-day
B	2.4	69	Morning

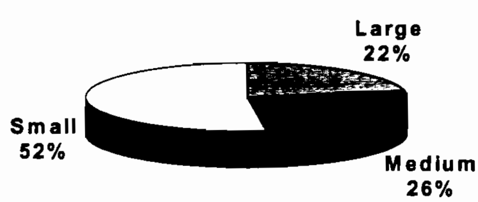
An ANOVA on differences in number of turtles by time for Kailua (Appendix 8.2, Table 13) resulted in $p = 0.511$. No significant difference is found when comparing time and numbers of individuals in Kailua.

An ANOVA on differences in number of turtles by size for North Shore (Appendix 8.2, Table 14) resulted in $p = 0.0001$. There are significant differences in numbers by size. The Duncan-Waller groping (Table 5) shows that there are significantly more small-sized turtles than medium and large-sized ones. No significant difference is found in numbers between medium- and large-sized turtles.

Table 5. Duncan-Waller grouping of number of turtles by size at North Shore. Mean is the mean number of turtles sighted of each size class, and N is the number of sightings.

Duncan Grouping	Mean	N	Size
A	5.1	82	Small
B	2.7	78	Medium
B	3.0	60	Large

Figure 1. Percent turtles in each size class at North Shore.



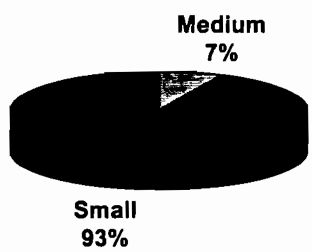
Significantly more small-sized turtles were observed at North Shore.

An ANOVA on differences by size for Kailua (Appendix 8.2, Table 15) resulted in $p = 0.0127$. There are significant differences in numbers by size. A Duncan-Waller grouping (Table 6) shows that there are significantly more small-sized turtles than medium-sized. Not a single large individual was detected during the field observations.

Table 6. Duncan-Waller grouping of number of turtles by size in Kailua. Mean is the mean number of turtles sighted of each size class, and N is the number of sightings.

Duncan Grouping	Mean	N	Size
A	2.9	134	Small
B	1.2	25	Medium

Figure 2. Percent turtles in each size class in Kailua



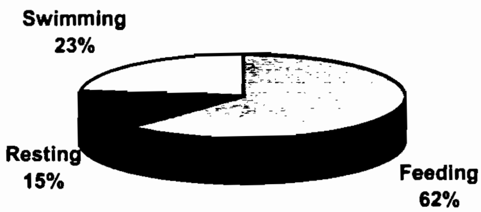
The majority of turtles documented during the terrestrial and in-water assessments in Kailua were small-sized.

An ANOVA on activity and number of turtles in Kailua (Appendix 8.2, Table 16) gave $p = 0.0001$. There are significant differences in numbers by action. The Duncan-Waller grouping (Table 7) shows that significantly more turtles were seen foraging than resting or swimming. No significant difference was found between numbers swimming and resting.

Table 7. Duncan-Waller grouping of number of turtles by action in Kailua. Mean is the mean number of turtles sighted doing each activity, and N is the number of sightings.

Duncan Grouping	Mean	N	Act
A	8.0	31	Feeding
B	2.2	40	Swimming
B	2.0	24	Resting

Figure 3. Percent turtles for activity class in Kailua



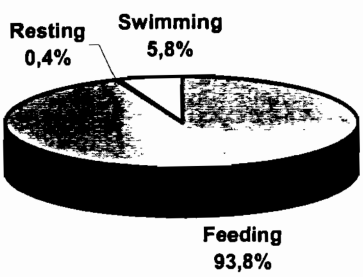
The majority of turtles are seen feeding.

A MANOVA on differences in number of turtles by size and action for North Shore (Appendix 8.2, Table 17) resulted in p = 0.0002. There are significant differences in numbers by action. The Duncan-Waller grouping (Table 8) shows that significantly more turtles were seen foraging than resting or swimming. No significant difference was found between numbers swimming and resting.

Table 8. Duncan-Waller grouping of number of turtles by action at North Shore. Mean is the mean number of turtles sighted doing each activity, and N is the number of sightings.

Duncan Grouping	Mean	N	Act
A	6.5	117	Feeding
B	1.5	31	Swimming
B	1.0	3	Resting

Figure 4. Percent turtles for activity class on the North Shore.



The majority of turtles are seen feeding.

3.2 Identification of fecal contents and sampled algaes

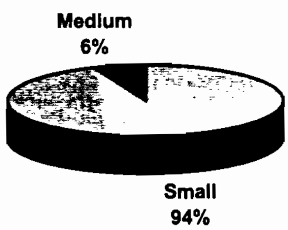
The contents of the fecal pellets were dominated by a few algae species; *Codium arabicum, C. edule, Melanamansia glomerata, Sargassum obtusifolium* (Appendix 8.5, Table 20). Several pellets contained small objects such as fishing line, monofilament line, and plastic or synthetic twine. These seemed to have passed through the gastro-intestinal tract without harm to the turtle. No difference was found in content of pellets with different diameters. The algae sampled at the three study-sites (Appendix 8.4, Table 19) were not the same. Several species found growing on the reef flat in Kailua were not found at Laniakea or Papailoa; however, the species found at those two North Shore sites overlapped to a great extent.

3.3 Capturing/tagging assessment

A total of 32 sea turtles were captured in Kailua Bay during March 17, April 14, and June 7, 2000. Several had injuries such as entangled fishing line in mouth or around the flippers, slits in carapace, cuts, missing marginal scutes. Two individuals were amputated and were missing one of the front flippers. A few suffered from mild emaciation. Mouth samples collected from three turtles contained 1) *Acanthophora spicifera* (100%), 2) Soft coral (octacoral, 100%), and 3) *Dictyota crenulata* (60%), *Laurencia sp.* (40%).

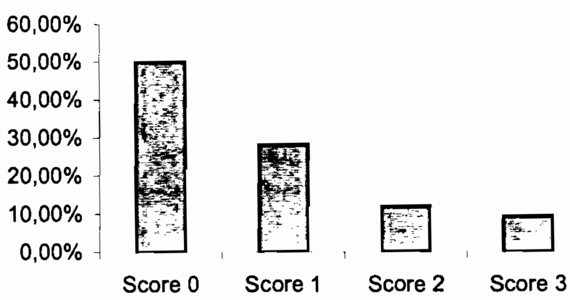
Tumours were found on front flippers, eyes, neck, mouth, and tail, but most frequently on front flippers and eyes. The number of turtles afflicted with fibropapillomas was 50%.

Figure 5. Percent turtles in each size class in Kailua. Based on a total of 32 captured turtles.



The dominating size-class of the captured turtles was size small.

Figure 6. Tumour score (0-3) in percent on turtles captured in Kawainui Canal and Kailua Bay. Where 0 = nonafflicted; 1 = mildly afflicted; 2 = moderately afflicted, and 3 = heavily afflicted. Based on a total of 32 turtles.



In Kailua the dominating tumour score is 0. These are apparently healthy individuals. Mildly afflicted individuals have a tumour score 1. Total number of turtles with tumour score 2 and 3 were less common.

4 DISCUSSION

4.1 Terrestrial and in-water assessment

In this study no differences were documented between the two study sites at North Shore, Laniakea and Papailoa, when comparing several factors; however, Kailua, situated on the east coast of Oahu, differed significantly. The two North Shore study sites are situated adjacent to each other, and the habitat along the shoreline is similar. Kailua Bay foraging habitat is constituted by coral ledges and is completely different from Laniakea and Papailoa. Different algae species dominate on the reef as opposed to the rock ledges found at North Shore. The number of species identified growing on the reef outnumbered the amount of species sampled in the rocky, more exposed North Shore area.

In Kailua, the number of individuals present at the different tide heights was the same, while at North Shore a significant difference was found when comparing number of turtles by tide. More turtles were found foraging during high tide than at low tide. An explanation could be that in Kailua the reef flat is accessible at all times, no matter the tide height. Whereas at North Shore, the rock ledges and rocks along the shoreline are exposed during low tide, preventing access. During high tide turtles of all size classes take advantage of the higher water level and ride the incoming waves up onto the algae-covered rock ledge, where they beach themselves for a few seconds. With the following receding wave, they are swept back to sea. The majority of individuals, though, stay in the water and nibble on the algae growing along the shoreline. Not only tide height, but also surf seems to affect the behaviour of the turtles. High surf allows turtles to forage even during low tide.

Fewer turtles were observed at Laniakea and Papailoa during morning (8-11 a.m.), than during mid-day (11 a.m.–2p.m.), and afternoon (2-5 p.m.). In Kailua Bay no such increase in activity was found; turtles were observed foraging at all times. A possible explanation is that morning and low tide often coincide during the months of this study. Low tide resulted in fewer foraging individuals at North Shore, whereas in Kailua Bay no such trend in decreased numbers of individuals was evident.

The juvenile size class was most commonly observed at all study sites (Figures 1,2, and 5). In Kailua only juveniles (small sized) and juveniles/adults (medium sized) were found. At North Shore all three size classes, small, medium, and large, were observed. No significant difference was found between numbers of medium-sized and large-sized turtles.

More turtles were observed foraging than resting or swimming. Resting is likely to take place further out from the shoreline, in deeper areas with plenty of protecting coral outcroppings and crevices. This applies especially to the two North Shore beaches, Laniakea and Papailoa. In Kailua, turtles are found resting during the day along coral ledges in the bay area and along the Kawainui Canal. During the night, turtles are often seen emerging onto the bank along the canal to rest. This behaviour is likely to conserve energy, but might also serve as protection from shark predation.

The hypotheses of this study were that feeding occurs more frequently during certain hours of the day, that feeding occurs more frequently at high tide, and that the composition of size classes differs at the three study sites. The first two hypotheses turned out to be correct for Laniakea and Papailoa. Time and tide influenced the number of turtles present. The composition of size classes differed from Kailua, but not between Laniakea and Papailoa. For Kailua, the first two hypotheses had to be rejected. Neither tide nor time influence the number of turtles present. The assumption that the composition of size classes differs from Laniakea and Papailoa was proven correct. No large-sized individuals were observed in Kailua, as opposed to the North Shore study sites. While Laniakea and Papailoa seem to serve mostly as a foraging area, Kailua Bay with the Kawainui Canal serves two purposes: as foraging and as resting grounds.

Too few aquatic surveys at North Shore, and difficulty in detecting tumour presence in the terrestrial assessment, resulted in a limited amount of data on tumour score. Although not proven statistically, the majority of turtles at Laniakea and Papailoa appeared healthy. While the tagging/capturing assessment in Kailua gave insight into the tumour status of the area, no such assessment was feasible at North Shore due to hazardous working conditions coupled with the large size of the turtles present.

The assessment methods used complemented each other. An initial terrestrial assessment was used to estimate numbers present and sites preferred within the study area. A negative flaw to this method was a possible lack of certainty whether the same individual was observed surfacing for air at frequent intervals, or possibly two similar sized ones at less frequent intervals. The advantage of the method was being able to conduct observations independent of weather conditions. Poor visibility was not an obstacle, but choppy waves could at times prevent the spotting of heads. The estimation of size classes with the naked eye proved to work quite well, and the estimations were verified during snorkeling in the in-water assessment.

The in-water assessment was highly affected by visibility in order to observe individuals in the water. Murky conditions prevented individual turtles very likely nearby from being observed. Incoming tide in Kailua stirred up considerable amounts of sediment, with resulting cloudy conditions. Rain lasting for a consecutive period of days brought terrestrial material into the canal, resulting in brownish water with no visibility, leading to poor snorkeling conditions.

At North Shore the winter and spring months are dominated by high surf and strong nearshore currents. In-water surveys were not feasible during the majority of the field-study period, as the conditions were judged unsafe. A field study, including an in-water assessment, would therefore be recommended during the summer-and early autumn months, when the surf conditions are more flat. When snorkeling was possible, it provided excellent opportunities for close encounters with individual turtles. Ability to document characteristics such as cuts, barnacles, tumours, and tags was valuable and provided the possibility to estimate health status among the population at the study site. Numbers engraved during tagging/capturing assessment facilitated gathering of baseline data in Kailua. However, with time these numbers were hidden by algae growth, likely enhanced by nutrient input from the Kawainui Canal.

Changes in behaviour that have been noted in Hawaii overall included basking at Laniakea and Kailua and tameness towards people in Laniakea, where people handfed large- and medium-sized turtles with *Ulva* sp. growing on rocks by the water. The reason why the latter behaviour occurs could be the increases in population size and decrease in illegal poaching. People entering the water even seemed to attract approaching turtles. Foraging times occurred during daytime at all study sites. That foraging also takes place at nighttime cannot be eliminated.

4.2 Identification of fecal contents and sampled algaes

The algae species in the collected fecal pellets and algae species sampled from the Kailua study site did not coincide. The algae species found in the majority of pellets, and also dominating in quantity, were *Codium* spp. None of the *Codium* species were found among the algae growing on the reef near shore. An explanation could be that these species grow further out in the bay in deeper waters and not on the shallow reef flats.
However, during the capturing and tagging assessment, mouth samples that were taken from three individuals contained *Acanthophora spicifera* and *Dictyota crenulata*, both algae species documented in the sampling of the reef. So another possible explanation for the difference in algae composition between algae growing and algae extracted from the fecal pellets could be that the fecal pellets collected came from turtles foraging further down Kailua Beach, or that the individuals observed foraging in Kailua Bay also forage further out in deeper waters. Fecal pellets of different diameter still contained the same algae species, meaning that larger turtles forage upon the same species of algae as smaller turtles. Fecal pellets found on Kailua Beach frequently contained fishing line and twine. If any fecal pellets had been found at the North Shore beaches, they would most likely have contained the same nonfood items since the same kind of fishing takes place, possibly to an even greater extent.

4.3 Capturing/tagging assessment

Half of the turtles in Kailua were afflicted with fibropapillomas, and this observation concurs with stranding data dating back to 1986. Kailua Bay and adjacent Kaneohe Bay comprise the nearshore habitats on Oahu most severely afflicted by the disease, yielding far more stranding incidents than other parts of the island. Both areas are populated by a substantial number of people, and an effect on the environment is bound to take place. At Kapoho point, where the Kawainui Canal enters Kailua Bay, fishing with rod-and-reel is common and is likely to be affecting the number of turtles found with fishing lines entangled around flippers and in the mouth. Given that 32 individuals were captured, tagged, and engraved with a number on the carapace, the population size in Kailua has proved to exceed that number since nonengraved individuals were regularly seen when snorkeling during this study.

4.4 For the future

Continued annual monitoring will be needed to confirm these findings and to assess seasonal changes and long-term trends. Additional monitoring should take place at Laniakea and Papailoa during summer and early autumn months, allowing close-up viewing of individual turtles and the possibility to estimate health status. A capturing/tagging assessment could provide substantial information if surf conditions allow.

Although evident increases in numbers of turtles, numerous at the three study sites, the population is still well below historical numbers, and fibropapillomatosis remains a serious threat.

5 CONCLUSIONS

- More turtles forage during mid-day and afternoon at Laniakea and Papailoa.
- More turtles forage during high tide as opposed to low tide at Laniakea and Papailoa. During high tide, the algae-covered rocks are accessible to the turtles.
- No such trends in time or tide were found in Kailua. Turtles forage at all times on the reef flats.
- Juvenile, small-sized turtles dominated at all three study sites. In Kailua, adult, large-sized turtles were absent.
- In Kailua 50 % of the individuals were afflicted with fibropapillomas. The most common stage of affliction was tumour score 1, mildly afflicted individuals.
- Behavioural changes, such as basking in Kailua and basking and tameness among individuals in Laniakea, were observed on several occasions.
- Foraging occurs regularly during day light hours at all three study sites as opposed to previously assumed exclusive night time feeding.

6 ACKNOWLEDGMENTS

My deepest gratitude to George Balazs for making a dream come true by sharing his considerable knowledge and providing help all the way, to Shawn K. K. Murakawa and Thierry Work for guidance and field assistance, to Denise M. Parker for field assistance and much appreciated help with the statistics, to Dennis Russell for help with analyses of fecal contents, to April Burd and Liz Arnone for keeping me and the computer on friendly terms, to Joanne Pettigrew and the Scherman family for their great hospitality. Logistical support and sponsorship by the National Marine Fisheries Service, Honolulu Laboratory, were greatly appreciated. Danielle and Filiesha kept my spirits high during these unforgettable months and last, but not least, I thank my family for love and encouragement.

7 REFERENCES

Aguirre, A. A., G. H. Balazs, T. R. Spraker, and T. S. Gross. 1995. Adrenal and Hematological Responses to Stress in Juvenile Green Turtles (*Chelonia mydas*) with and without Fibropapillomas. Physiological Zoology **68**(5): 831-854.

Aguirre, A. A., T. R. Spraker, G. H. Balazs, and B. Zimmerman. 1998. Spirorchidiasis and fibropapillomatosis in green turtles from the Hawaiian Islands. Journal of Wildlife Diseases, **34**(1).

Aguirre, A. A., T. R. Spraker, A. Chaves, L. Du Toit, W. Eure, and G. H. Balazs. 1999. Pathology of Fibropapillomatosis in Olive Ridley Turtles *Lepidochelys olivacea* Nesting in Costa Rica. Journal of Aquatic Health **11**:283-289.

Ahuna, L., and R. Fujioka. 1993. Impact of Kawainuicanal on the recreational water quality of Kailua Bay (KB-4). Project Report PR-94-07.

Balazs, G. H. 1980. Synopsis of biological data on the green turtle in the Hawaiian Islands. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-SWFSC-7 and University of Hawaii Sea Grant Cooperative Report CR-81-02, 141 p.

Balazs, G. H., R. G. Forsyth, and A. K. Kam. 1987. Preliminary assessment of habitat utilization by Hawaiian green turtles in their resident foraging pastures. U.S. Department of Commerce NOAA Technical Memorandum NMFS-SWFC-71, Honolulu, Hawaii, 107 pp.

Balazs, G. H., R. Fujioka, and C. Fujioka. 1993. Marine Turtle feaces on Hawaiian Beaches. Marine Pollution Bulletin. **26**(7): 392-394.

Balazs, G. H. 1995. Innovative techniques to facilitate field studies of the green turtle *Chelonia mydas*. Proceedings of the twelfth annual workshop on sea turtle biology and conservation. NOAA Technical Memorandum NMFS-SEFSC-361.

Balazs, G. H. 1999. Factors to consider in the tagging of sea turtles. *In:* K. L. Eckert, K. A. Bjorndal, F. A. Abreu-Grobois, and M. Donnelly (eds.), Research and Management Techniques for the Conservation of Sea Turtles. IUCN/SSC Marine Turtle Specialist Group. Publication No. **4** (101-109).

Balazs, G. H., S. K. K. Murakawa, D. M. Ellis, and A. A. Aguirre. In Press. Manifestation of fibropapillomatosis and rates of growth of green turtles at Kaneohe Bay in the Hawaiian islands. In Press. Proceedings of the Eighteenth Annual Symposium On Sea Turtle Biology and Conservation, Mazatlan, Mexico, 1998.

Brill, R. W., G. H. Balazs, K. N. Holland, R. K. C. Chang, S. Sullivan, and J. C. George. 1995. Daily movements, habitat use, and submergence intervals of normal and tumor-bearing juvenile green turtles (*Chelonia mydas*) within a foraging area in the Hawaiian islands. Journal of Experimental Marine Biology and Ecology **185**: 203-218.

Casey, R. N. , S. L. Quackenbush, T. M. Work, G. H. Balazs, P. R. Bowser, and J. W. Casey. 1997. Evidence for retrovirus infections in green turtles *Chelonia mydas* from the Hawaiian Islands. Dis Aquat Org **31**: 1-7.

Clark, J. R. K. 1977. The beaches of Oahu. University Press of Hawaii.

Graczyk, T. K., A. A. Aguirre, and G. H. Balazs. 1995. Detection by ELISA of circulating anti-blood fluke (*Carettacola, Hapalotrema,* and *Learedius*) immunoglobulins in Hawaiian green turtles (*Chelonia mydas*). J. Parasitol. **81**(3): 416-421.

Harrington, K. A., M. R. Rice, and G. H. Balazs. In Press. Habitat use of mixohaline fish ponds by green turtles at Kiholo Bay, Hawaii. Proceedings of the Twentieth Annual Symposium on Sea Turtle Biology and Conservation., February 29-March 4, 2000, Orlando, Florida.

Harvell, C. D., K. Kim, J. M. Burkholder, R. R. Colwell, P. R. Epstein, D. J. Grimes, E. E. Hofmann, E. K. Lipp, A. D. M. E. Osterhaus, R. M. Overstreet, J. W. Porter, G. W. Smith, G. R. Vasta. 1999. Emerging Marine Diseases-Climate Links and Anthropogenic Factors. Science **285**

Herbst, L. H., E. R. Jacobson R. Moretti, T. Brown, J. P. Sundberg, and P. A. Klein. 1995. Experimental transmission of green turtle fibropapillomatosis using cell-free tumor extracts. *In*: Landsberg J. H., G. H. Balazs, K. A. Steidinger, D. G. Baden, T. M. Work, and D. J. Russell. 1999. The potential Role of Natural Tumor Promoters in Marine Turtle Fibropapillomatosis. Journal of Aquatic Animal Health **11**.

Herbst L. H., E. R. Jacobson, P. A. Klein, G. H. Balazs, R. Moretti, T. Brown, and J. P. Sundberg. 1999. Comparative Pathology and Pathogenesis of Spontaneous and Experimentally Induced Fibropapillomas of Green Turtles (*Chelonia mydas*). Vet Pathol **36**: 551-564.

Lu, Y., Q. Yu, J. P. Zamzow, Y. Wang, G. S. Losey, G. H. Balazs, V. R. Nerurkar, and R. Yanagihara. 2000. Detection of Green Turtle Herpesviral Sequence in Saddleback Wrasse *Thalassoma duperrey*: A Possible Mode of Transmission of Green Turtle Fibropapilloma. Journal of Aquatic Animal Health **12**:58-63.

Murakawa, S. K. K., G. H. Balazs, D. M. Ellis, S. Hau, and S. M. Eames. In Press. Trends in Fibropapillomatosis among green turtles stranded in the Hawaiian Islands, 1982-98. Proceedings of the Nineteenth Annual Symposium on Sea Turtle Biology and Conservation. March 2-5, 1999, South Padre Island, Texas.

Quackenbush, S. L., T. M. Work, G. H. Balazs, R. N. Casey, J. Rovnak, A. Chaves, L. Du Toit, J. D. Baines, C. R. Parrish, P. R. Bowser, and J. W. Casey. 1998. Three Closely Related Herpesviruses Are Associated with Fibropapillomatosis in Marine Turtles. Virology **246**:392-399.

Rainey, W. E. 1994. Guide to sea turtle visceral anatomy. U. S. Department of Commerce. NOAA Technical Memorandum. NMFS-SEFSC-82, pp 82.

Rice, M. R., G. H. Balazs, D. Kopra, and G. C. Whittow. In Press. Ecology and behavior of green turtles basking at Kiholo Bay, Hawaii. Proceedings of the Twentieth Annual Symposium on Sea Turtle Biology and Conservation, February 29-March 4, 2000, Orlando, Florida.

SAS Institute Inc. 1989. Procedure for General Linear Models. SAS/STAT* Users Guide, Volume 1&2, Version 6, Fourth edition.

Smith, G. M., and C. W. Coates. 1938. Fibro-epithelial growths of the skin in large marine turtles, *Chelonia mydas* (Linnaeus). *In*: Work, T. M., and G. H. Balazs. 1999. Relating Tumor Score to Hematology in Green Turtles with Fibropapillomatosis in Hawaii. Journal of Wildlife Diseases, **35**(4): 804-807.

Work, T. M., R. E. Raskin, G. H. Balazs, S. D. Whittaker. 1998. Morphologic and cytochemical characteristics of blood cells from Hawaiian green turtles. AJVR **59**(10).

Work, T. M., and G. H. Balazs. 1999. Relating Tumor Score to Hematology in Green Turtles with Fibropapillomatosis in Hawaii. Journal of Wildlife Diseases, **35**(4): 804-807.

8 APPENDICES

8.1 Maps of study sites

Figure 7. Study site located in Kailua Bay and Kawainui Canal, Oahu, Hawaiian Islands

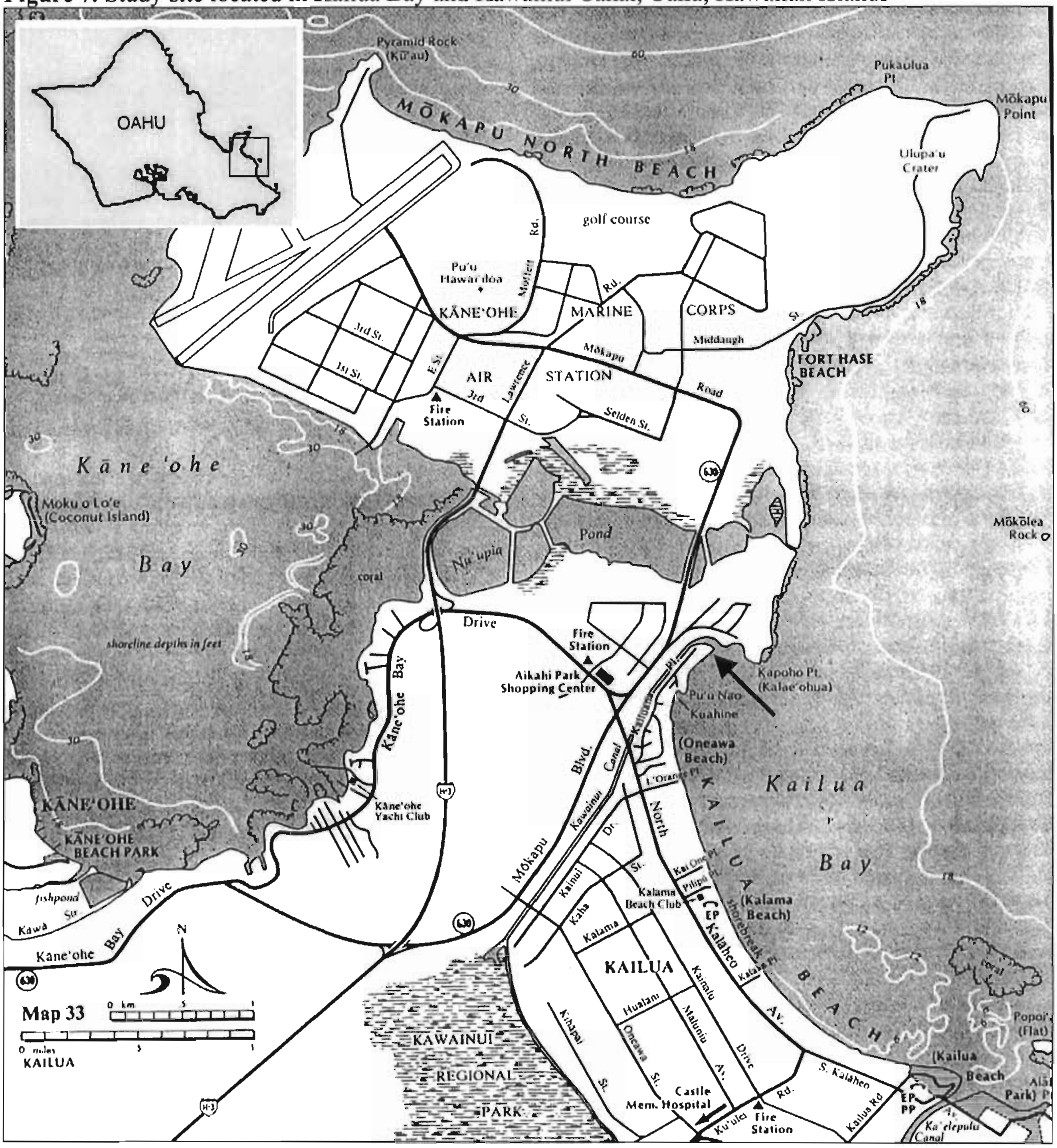
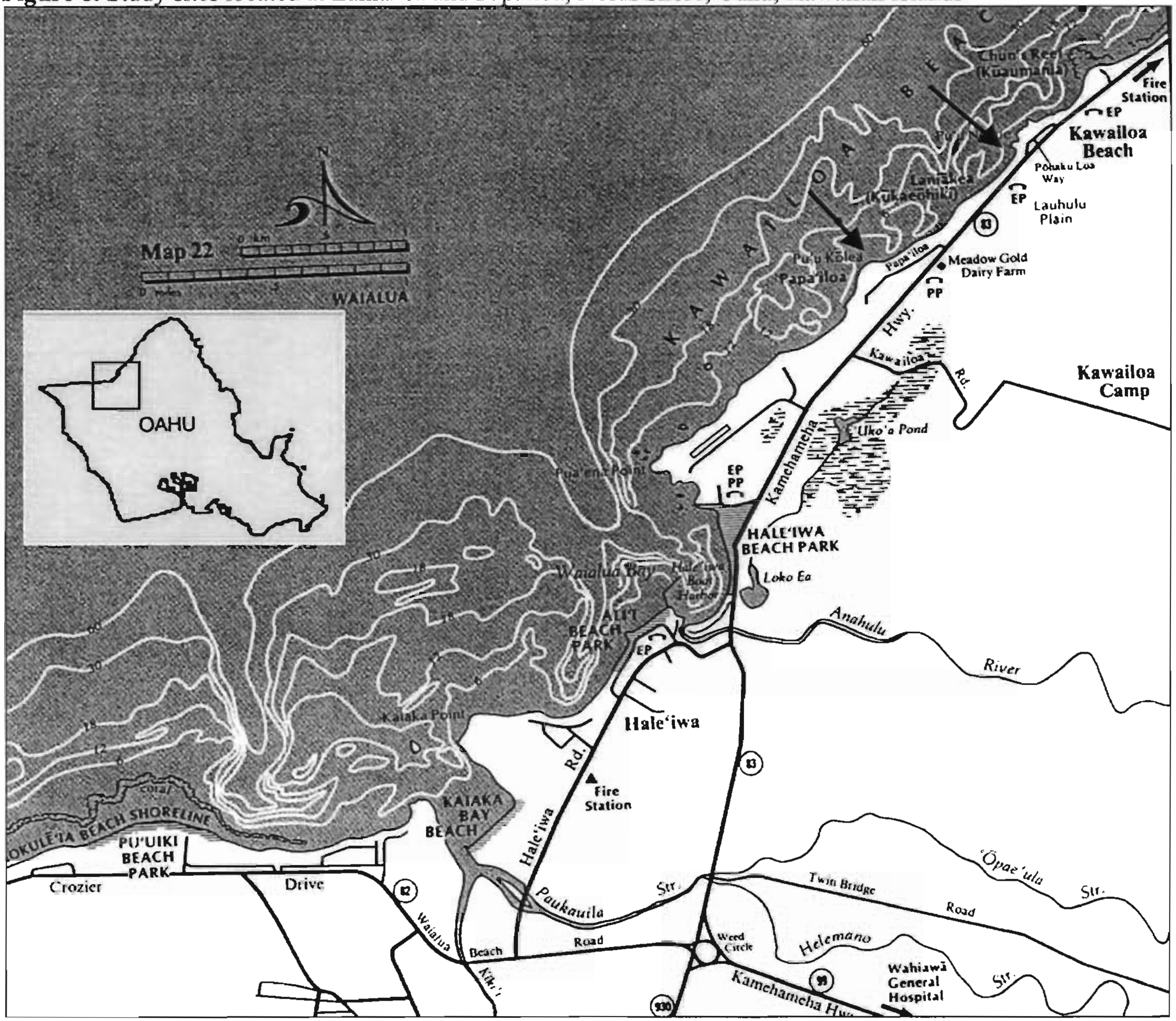


Figure 8. Study sites located at Laniakea and Papailoa, North Shore, Oahu, Hawaiian Islands



8.2 ANOVA tables of terrestrial and in-water assessments

Table 9. 3-factor Analysis of variance (MANOVA) for number of turtles by place, tide and size

General Linear Models Procedure

Class Level Information

Class	Levels	Values
PLACE	3	Kailua, Laniakea, Papailoa
TIDE	4	Falling, High, Low, Rising
SIZE	3	Large, Medium, Small

Number of observations in data set = 388

Dependent Variable: NR

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	28	838.58957282	29.94962760	2.98	0.0001
Error	350	3513.89591530	10.03970262		
Corrected Total	378	4352.48548813			

R-Square	C.V.	Root MSE	NR Mean
0.192669	98.19134	3.1685490	3.2269129

Source	DF	Type I SS	Mean Square	F Value	Pr > F
PLACE	2	129.56378395	64.78189197	6.45	0.0018
TIDE	3	192.03203924	64.01067975	6.38	0.0003
PLACE*TIDE	5	91.79083416	18.35816683	1.83	0.1065
SIZE	2	343.88981675	171.94490837	17.13	0.0001
PLACE*SIZE	3	18.68605643	6.22868548	0.62	0.6022
TIDE*SIZE	6	32.42815194	5.40469199	0.54	0.7790
PLACE*TIDE*SIZE	7	30.19889037	4.31412720	0.43	0.8835

Source	DF	Type III SS	Mean Square	F Value	Pr > F
PLACE	2	175.53937211	87.76968606	8.74	0.0002
TIDE	3	183.55541192	61.18513731	6.09	0.0005
PLACE*TIDE	5	71.18948521	14.23789704	1.42	0.2170
SIZE	2	169.95188505	84.97594252	8.46	0.0003
PLACE*SIZE	3	14.22560835	4.74186945	0.47	0.7018
TIDE*SIZE	6	30.16826155	5.02804359	0.50	0.8077
PLACE*TIDE*SIZE	7	30.19889037	4.31412720	0.43	0.8835

Table 10. ANOVA for number of turtles by tide for Kailua

Analysis of Variance Procedure

Class Level Information

Class	Levels	Values
TIDE	4	Falling, High, Low, Rising

Number of observations in data set = 165

Dependent Variable: NR

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	10.92713409	3.64237803	0.37	0.7753
Error	161	1588.32135076	9.86535000		
Corrected Total	164	1599.24848485			

R-Square	C.V.	Root MSE	NR Mean
0.006833	125.7891	3.1409155	2.4969697

Source	DF	ANOVA SS	Mean Square	F Value	Pr > F
TIDE	3	10.92713409	3.64237803	0.37	**0.7753**

Table 11. ANOVA for number of turtles by tide for North Shore

Analysis of Variance Procedure

Class Level Information

Class	Level	Values
TIDE	4	Falling, High, Low, Rising

Number of observations in data set = 223

Dependent Variable: NR

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	266.13845644	88.71281881	7.91	0.0001
Error	219	2455.44001890	11.21205488		
Corrected Total	222	2721.57847534			

R-Square	C.V.	Root MSE	NR Mean
0.097788	92.07180	3.3484407	3.6367713

Source	DF	Anova SS	Mean Square	F Value	Pr > F
TIDE	3	266.13845644	88.71281881	7.91	**0.0001**

Table 12. ANOVA for number of turtles by time for North Shore

Analysis of Variance Procedure

Class Level Information

Class	Levels	Values
TIME	3	Morning, Noon, Afternoon

Number of observations in data set = 223

Dependent Variable: NR

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	182.68079521	91.34039760	7.91	0.0005
Error	220	2538.89768013	11.54044400		
Corrected Total	222	2721.57847534			

R-Square	C.V.	Root MSE	NR Mean
0.067123	93.41041	3.3971229	3.6367713

Source	DF	ANOVA SS	Mean Square	F Value	Pr > F
TIME	2	182.68079521	91.34039760	7.91	**0.0005**

Table 13. ANOVA for number of turtles by time for Kailua

Analysis of Variance Procedure

Class Level Information

Class	Levels	Values
TIME	3	Morning, Noon, Afternoon

Number of observations in data set = 165

Dependent Variable: NR

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	13.20026029	6.60013015	0.67	0.5110
Error	162	1586.04822456	9.79042114		
Corrected Total	164	1599.24848485			

R-Square	C.V.	Root MSE	NR Mean
0.008254	125.3105	3.1289649	2.4969697

Source	DF	ANOVA SS	Mean Square	F Value	Pr > F
TIME	2	13.20026029	6.60013015	0.67	**0.5110**

Table 14. ANOVA for number of turtles by size for North Shore

Analysis of Variance Procedure

Class Level Information

Class	Levels	Values
SIZE	3	Large, Medium, Small

Number of observations in data set = 223

Dependent Variable: NR

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	262.28445051	131.14222525	11.76	0.0001
Error	217	2419.07464040	11.14780940		
Corrected Total	219	2681.35909091			

R-Square	C.V.	Root MSE	NR Mean
0.097818	90.57255	3.3388335	3.6863636

Source	DF	ANOVA SS	Mean Square	F Value	Pr > F
SIZE	2	262.28445051	131.14222525	11.76	**0.0001**

Table 15. ANOVA for number of turtles by size for Kailua

Analysis of Variance Procedure

Class Level Information

Class	Levels	Values
SIZE	2	Medium, Small

Number of observations in data set = 165

Dependent Variable: NR

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	60.76170281	60.76170281	6.36	0.0127
Error	157	1499.66597015	9.55201255		
Corrected Total	158	1560.42767296			

R-Square	C.V.	Root MSE	NR Mean
0.038939	119.2744	3.0906330	2.5911950

Source	DF	Anova SS	Mean Square	F Value	Pr > F
SIZE	1	60.76170281	60.76170281	6.36	**0.0127**

Table 16. ANOVA for number of turtles by action for Kailua

Analysis of Variance Procedure

Class Level Information

Class	Levels	Values
ACT	3	Feeding, Resting, Swimming

Number of observations in data set = 95

Dependent Variable: NR

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	725.13026316	362.56513158	32.84	0.0001
Error	92	1015.77500000	11.04103261		
Corrected Total	94	1740.90526316			

R-Square	C.V.	Root MSE	NR Mean
0.416525	82.41944	3.3228049	4.0315789

Source	DF	ANOVA SS	Mean Square	F Value	Pr > F
ACT	2	725.13026316	362.56513158	32.84	**0.0001**

Table 17. MANOVA for number of turtles by size and action for North Shore

General Linear Models Procedure

Class Level Information

Class	Levels	Values
SIZE	3	Large, Medium, Small
ACT	3	Feeding, Resting, Swimming

Number of observations in data set = 223

Dependent Variable: NR

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	6	474.33299492	79.05549915	7.63	0.0001
Error	213	2207.02609599	10.36162486		
Corrected Total	219	2681.35909091			

R-Square	C.V.	Root MSE	NR Mean
0.176900	87.32041	3.2189478	3.6863636

Source	DF	Type I SS	Mean Square	F Value	Pr > F
SIZE	2	262.28445051	131.14222525	12.66	0.0001
ACT	2	189.47900503	94.73950252	9.14	0.0002
SIZE*ACT	2	22.56953938	11.28476969	1.09	0.3384

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SIZE	2	55.40324979	27.70162490	2.67	0.0713
ACT	2	186.02446348	93.01223174	8.98	**0.0002**
SIZE*ACT	2	22.56953938	11.28476969	1.09	0.3384

8.3 List of forage species from stranding data

Table 18. List of forage species identified in stomach/intestine samples from necropsied stranded green turtles 1985-2000. Based on records and analyses completed by the National Marine Fisheries Service, Honolulu Laboratory.

Kailua Bay/Kawainui Canal	Laniakea	Papailoa
Acanthophora spicifera	Amansia glomerata	Amansia glomerata
Amansia glomerata	Codium sp.	Pterocladia capillacea
Caulerpa sp.	Diatoms	Sargassum echinocarpum
Chondrococcus sp.	Hypnea sp.	Ulva rigida
Cladophoropsis sp.	Pterocladia capillacea	
Codium arabicum	Ulva sp.	
Codium edule		
Corallina sp.		
Dictyosphaeria sp.		
Dictyota crenulata		
Gelidium sp.		
Geramium sp.		
Gracilaria sp.		
Halimeda discoidea		
Hypnea musciformis		
Laurencia sp.		
Lyngbya sp.		
Polysiphonia sp.		
Pterocladia capillacea		
Sargassum sp.		
Sphacelaria sp.		
Sponges		
Tolypiocladia sp.		
Turbinaria sp.		

8.4 List of algae species growing at study sites

Table 19. Species of algae identified growing at the three study sites.

Kailua Bay	Kawainui Canal	Laniakea	Papailoa
Acanthophora spicifera	Ceramium sp.	Acanthophora spicifera	Colpomenia sinuosa
Caulerpa sp.	Hypnea pannosa	Hypnea sp.	Hypnea sp.
Dictyopteris australis	Pterocladiella capillacea	Pterocladia capillacea	Pterocladia capillacea
Dictyosphaeria cavernosa		Sargassum sp.	Sargassum sp.
Dictyota crenulata		Ulva sp.	Ulva sp.
Halimeda discoidea			
Padina japonica			
Sphacelaria furcigera			

8.5 Fecal sample content

Table 20. Fecal sample content

Date	Content in size S pellet	%
3/15/00	Codium edule	70
	Melanamansia glomerata	20
	Pterocladiella capillacea	10
3/15/00	Codium edule	70
	Melanamansia glomerata	24
	Sargassum sp.	6
3/15/00	Codium edule	63
	Melanamansia glomerata	25
	Sargassum sp.	12
3/15/00	Melanamansia glomerata	60
	Codium edule	40
3/15/00	Sargassum obtusifolium	85
	Codium edule	10
	Melanamansia glomerata	5
	Synthetic twine	
3/15/00	Sargassum obtusifolium	95
	Codium edule	5
3/15/00	Sargassum obtusifolium	99
	Codium edule	1
	monofilament line	
4/26/00	Sargassum obtussifolium	50
	Codium edule	30
	Codium arabicum	15
	Melanamansia glomerata	5
4/26/00	Sargassum obtussifolium	50
	Codium arabicum	25
	Codium edule	15
	Melanamansia glomerata	10
4/26/00	Sargassum obtussifolium	50
	Codium arabicum	25
	Codium edule	15
	Melanamansia glomerata	10
4/26/00	Codium arabicum	80
	Codium edule	15
	Sargassum obtussifolium	5
	Fishingline	
4/26/00	Sargassum obtussifolium	99
	Codium edule	1
	Plastic twine	
4/26/00	Codium arabicum	99
	Sargassum obtussifolium	1
	Plastic twine, fishingline	

Date	Content in size M pellet	%
3/15/00	Melanamansia glomerata	60
	Codium edule	40
3/15/00	Sargassum obtusifolium	85
	Codium edule	10
	Melanamansia glomerata	5
	Synthetic twine	
3/15/00	Sargassum obtusifolium	95
	Codium edule	5
3/15/00	Sargassum obtusifolium	99
	Codium edule	1
4/26/00	Sargassum obtusifolium	99
	Codium edule	1
	Plastic twine	
4/26/00	Codium sp.	100
	Plastic twine	
4/26/00	Codium edule	80
	Codium arabicum	20

Date	Content in size L pellet	%
4/26/00	Sargassum obtusifolium	50
	Codium edule	30
	Codium arabicum	15
4/26/00	Sargassum obtusifolium	95
	Siphonocladus tropicus	5
	Plastic twine	
4/26/00	Codium edule	60
	Codium arabicum	40
4/26/00	Codium arabicum	60
	Codium edule	40