ECOLOGY OF THE GREEN TURTLE IN THE FEEDING PASTURES OF KA'U, HAWAII

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ABSTRACT

In order to develop baseline data on the ecology of the Hawaiian green turtle (Chelonia) population in a feeding pasture situation, intensive tagging studies were conducted on the island of Hawaii (19°N; 155°W) during the months of July through September, 1976. The population was sampled using techniques devised by the authors and involved hand captures with subsequent examination and tagging. These investigations were designed to compliment tag and recapture studies of Chelonia at French Frigate Shoals (24°N; 160°W) and Midway (29°N; 179°W) being conducted by George Balaz of the Hawaii Institute of Marine Biology and the U. S. Fish and Wildlife Service.

INTRODUCTION

There are selected areas within the major islands of the Hawaiian Archipelago (19° to 29°N; 155° to 179°W) which maintain a feeding population of green turtles. These turtles graze primarily on benthic algaes found along the coastal regions and often venture within several meters of the shoreline. Uneven distribution and accessability restrict the indepth investigation of most feeding sites and remain complicating factors in those choice sites where investigations are possible. The criteria for the investigation of green turtles in the feeding pasture situations ultimately centers on the problem of capturing adequate numbers of animals directly from the sea.

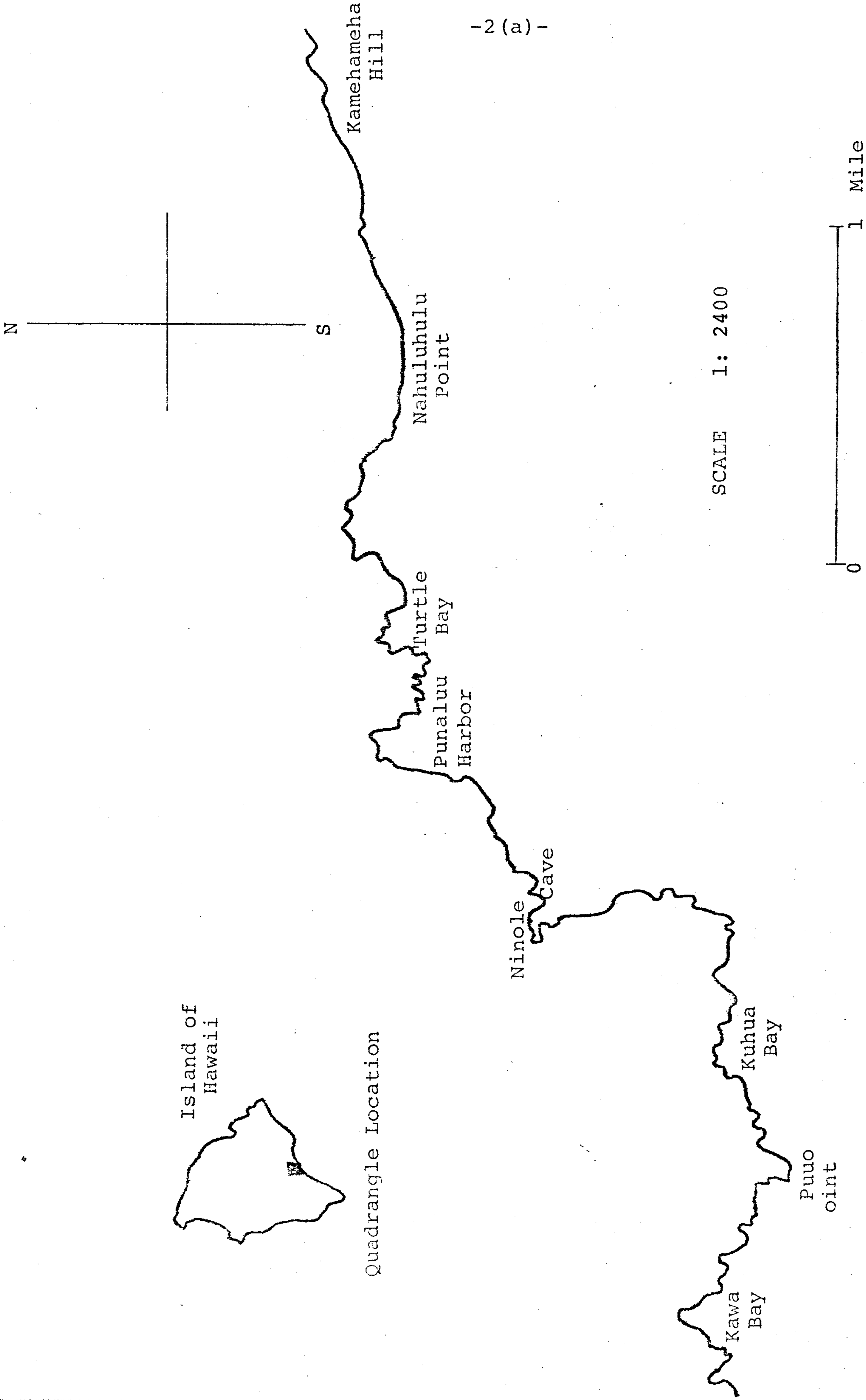
In order to obtain information on turtles present in the feeding pastures, a study area was chosen in the district of Ka'u on the island of Hawaii. Extending from the small bay at Kawa to the black sand beach at Kamehame (Fig. 1), this study area may best be described as a windblown stretch of basaltic, cliff bearing coastline located on the southeast shore of the island of Hawaii.

The principal objectives of this baseline study were to tag as many turtles as possible within the time frame allowed and to make behavioral observations of green turtles in the wild.

RESEARCH TECHNIQUES

The development of a simple technique for the capture of green turtles that would satisfy both the conditions of the scientific collecting permit (#76-51) (a copy of the permit in Appendix I) and the need to maximize the unit

(Fig. 1)


N
S
Kamehameha Hill
Nahuluhulu Point
Turtle Bay
Punaluu Harbor
Ninole
Cave
Kuhua Bay
Puuo oint
Kawa Bay
SCALE 1: 2400
0
1
1 Mile
Island of Hawaii
Quadrangle Location

effort finally centered on the use of "SCUBA" and the "one turtle, one diver" approach. One member of the dive team would capture the animal and allow the turtle to swim until tires. At this point, the other diver would aid in swimming the marine reptile to the boat. The size of the turtle was inconsequential, for although the larger had greater acceleration and strength, the subsequent cessation of activity allowed the second member of the team to aid in handling the animal.

The agility and speed of a marine turtle when approached by divers is substantial and captures were successful only when the animal was caught unaware. The most practical and useful approach involved a particular phase of sea turtle behavior termed the "sleep phase."

With the development of a successful capture technique, a problem arose dealing with finding the turtle in the "sleep phase." The recognition of suitable resting areas became almost intuitive and involved substrate identification in terms of likely areas for sleeping turtles.

Each capture required that the animal be brought aboard the inflatable for measurements and careful examination. A tape measure was used to record the naturally arched carapace length and width termed "curved line" and calipers determined the "straight line" measurements. Both were made along the vertebral scutes beginning with the precentrals and terminating at the postcentrals. The length of the tail beyond the plastron and carapace was noted. A visual examination was made for abnormal plate counts (carapace) and other unusual morphological characteristics. A numbered metal tag bearing the inscription "notify University Hawaii, HIMB, Kaneohe, 96744" was attached to the proximal, caudal portion of one of the pectoral flippers. Weights were taken on turtles under 50 lbs. The animal was then released with the entire above water procedure averaging less than ten minutes.

HABITAT AND BEHAVIOR

SLEEPING

The bottom topography was of major importance in determining areas searched for turtles. The best chances to affect a capture were times when the turtles were in a "sleeping phase", and this directed our attention to a particular type of substrate. We identified three major kinds of suitable habitat for sleeping, with the common factor to each being the presence of some type of recession. Along the Ka'u coastline these areas included the following underwater substrates: (1) large boulders; (2) the base of cliff faces; and (3) a series of grooves alternating with spurs which extend seaward.

Our observations on the behavior of turtles while in the "sleeping phase" indicates that both the orientation of the turtle and the state of awareness exhibited are variable. Subsequently, sleeping behavior can be divided into seven stages:

(1) Selection of a recess;

(2) Movement into the recess;

(3) Positioning for sleep;

(4) Sleep;

(5) Awakening;

(6) Movement out from the recess; and

(7) Swimming away or surfacing for air.

Weather conditions and allowable scuba time limited our observations to just a small portion of this sequence. We can only speculate on the time involved for this sleeping behavior, but we do feel that at most times a turtle's presence in a recess or compartment indicates that it is in a "sleeping phase."

Factors in the selection of suitable recess are likely dependent upon:

(1) Size of the turtle relative to the recess;

(2) Protection from surge;

(3) Safety from predation.

We found turtles sleeping in recessions, compartments and other niches ranging from narrow ledges to large open boulder areas. There seems to be a marked preference for sleeping in areas with some sand--which forms a "bed;" although compartments were observed in which a turtle would sleep on rock rubble. We always found sleeping turtles to be laying with the plastron in contact with the bottom of the recess.

One question which we felt was important concerned whether turtles return to the same compartment or general area for sleeping. Twice turtles were found sleeping in the same recess where the initial capture was made; both occurring after a period of several weeks. Most of our re-captures on individual turtles were made in the general area of initial capture. We transported one turtle captured off Kamehame hill to Punaluu beach for a series of photographs due to the unique nature of the turtle's carapace and its lack of algae growth. The following week we captured this same turtle, once again at Kamehame, a distance of approximately two miles. Our speculation is that while off the feeding pastures, turtles are somewhat stationary, and therefore, will occasionally sleep in the same recess or general vicinity.

We earlier mentioned the three types of suitable habitat for sleeping. During the course of the study we found these to be depth independent. The majority of our sleeping captures were made between 30 and 45 feet in depth, yet we also made a capture as shallow as 8 feet.

Many times we noticed that turtles would be sleeping in close proximity. Perhaps there is some community association here, or it may be a factor of the availability of compartments. Twice we found two turtles sleeping in the same recess.

Usually a compartment selected for sleeping contained a very limited population of fish; although on occasions we noticed these types which frequent recessions similar to those used by sleeping turtles: Menapachi (<u>Myripristis Berndti</u>), Aweoweo (Priacanthus Cruentafas), Palani (Acanthurus Dussumier), Kala (Naso Unicornis) and various cardinal fishes (family Apogonidae).

Generally, our dives were made at sunrise or during the early morning hours. This precluded our establishing a standardized daily pattern for the sleeping phase, if indeed one exists. Upon advisement from a local turtle expert, Mr. Arnold Howard, a series of five night dives were made at Punaluu in areas where turtles have been known to sleep at night. Under varying conditions of tide, moon phase and weather, one juvenile was sighted and another captured. Both areas were sand ledges well inside the reef break and close to shore.

RESTING

The differentiation between sleeping and resting is based on the turtle's behavior, although there may be some overlap between the two. Sleeping turtles were always found in some type of recession, yet many times turtles were observed out in the open in a resting or perched attitude on the bottom. A turtle exhibiting this behavior is alert and will flee when approached. Similarly, turtles were found in recessions equally alert but simply may have been entering or leaving the sleeping phase. This constitutes the potential overlap.

Suitable habitats for the resting behavior are: an open sand area or any flat patch of sand amongst a coral or lava substrate. When in this resting phase, turtles can be approached but are hard to capture due to their propensity to rise and move away as divers close in. While leaving the bottom, turtles exhibit a very mobile use of the front flippers. They will rise up on the two pectoral limbs, shove off and begin swimming. At times, turtles also use the flippers as walking limbs while moving into and away from their sleeping compartments.

Depth was an interesting factor in the locations where resting turtles were observed. The majority of our sightings were between 30 and 80 feet, with the deepest at 110 feet.

SWIMMING

The bulk of our turtle sightings come under this heading. Inclusive here are transit to and from the feeding pastures and sleeping areas. Turtles swim with a graceful, gliding pace; only the front flippers are used for locomotion, and these stroke in unison. The only time we observed a rapid swimming movement was when a turtle was attempting to evade capture. Older turtles (adults and sub-adults) were more alarmed by the presence of divers than the juvenile members of the population. This is evidenced by the size range of turtles which were captured via the swimming methods (no turtle larger than 19 inches).

A turtle's location in the water column while swimming is dependent upon its activities. In the relatively shallow waters where our observations were made, turtles seem to prefer swimming near the bottom. Breathing required a brief trip to the surface, where a turtle may take one or several breaths before making its descent. If approached while surfacing for air, turtles will flee, usually without renewing their air supply. Almost all evasive movements were made toward deep water.

On one occasion we observed a grooming activity take place with a swimming turtle. A school of rudder fishes (Kyphosus Cinerascens) surrounded a large turtle and were eating algae from the carapace. It seemed that the turtle was consciously allowing the fish to execute this behavior, as it remained motionless in the water column for a period of about two minutes before moving away.

FEEDING

The feeding pastures along the Ka'u coastline consist of a series of bays and inlets where algae growth is abundant in the shallows. Our observations of feeding behavior were strictly limited to shoreline sightings. All of our attempts to view this aspect while diving were thwarted by the turtles fleeing toward deep water.

An ideal location for shoreline observations of feeding turtles is found at a site locally known as Turtle Bay, some 200 yards northeast of Punaluu. A small inlet in the bay is surrounded by 20-foot high cliffs which afford an excellent view of the turtle's feeding behavior. The frequency of feeding and concentrations of turtles at this site made our observations worthwhile. It was in this area where we tried to establish a daily pattern for feeding based upon tides in conjunction with the time of day. We were unsuccessful in that we found turtles feeding at varying hours and all stages of tide.

Feeding is an active process which appears to require a fair amount of energy output. Turtles are usually in a vertical position with the head cropping algae while the limbs maintain this posture. Breath-holding while feeding is very limited. Average down times are between 2-4 minutes, with a range of 1-8 minutes. Turtles will rise to the surface, thrust their head up, and take one or several deep inhalations before descending to resume feeding. At times during this brief surface interval, we were able to identify individual turtles by the location and extent of coralline algae markings on the carapace. These markings enabled us to determine that many turtles feed in the same area day after day. On numerous occasions, tagged turtles were noticed amongst the feeding population at Turtle Bay. We suspect that these turtles use the sleeping areas directly outside the bay, where a large percentage of our captures were made.

With what appeared to be their principal food supply being in shallow water near shore, turtles along this coastline must cope with the strong swell conditions generally present. In severe surge and swell conditions, several feeding turtles were observed completely overturned by a breaking wave. These surf conditions are probably one of the main causes of the many types of damage we observed on the carapace and plastron of turtles which we captured.

The bottom topography at Turtle Bay is a combination of lava substrate and boulders; all of which is covered by a dense algae mat. Seven algae types present were identified; all in the Rhodophyta (red algae) family:

Halymenia Formosa
Amansia Glomerata
Pterocladia Capillocia
Gelidium Pusillum (variety pacificum)
Martensia (_hemitrema_)
Desmia (_chondrococcus_)
Cladymenia Pacifica

Although no turtle was actually observed ingesting food, the activity was recorded at depths ranging between 2 and 10 feet. High tide enables the turtles to graze the algaes closer inshore, but no zonation of algae types with depth seemed to be present in the areas where collections were made. Apparently, the turtles feeding in Turtle Bay are not selective in taking specific algaes, as they seem too interspersed on the bottom.

SIZE COMPOSITION

With a large segment of the coastline being explored on a daily basis, we were able to view a representative sample of the turtle population along the Ka'u coast. Our data on daily sightings and the measurements of captured turtles yield a population that consists mostly of sub-adults and juveniles (Fig. 2). The three terms used in this paper to differentiate size categories we define as:

Juvenile - Straight line carapace length up to 18 inches;

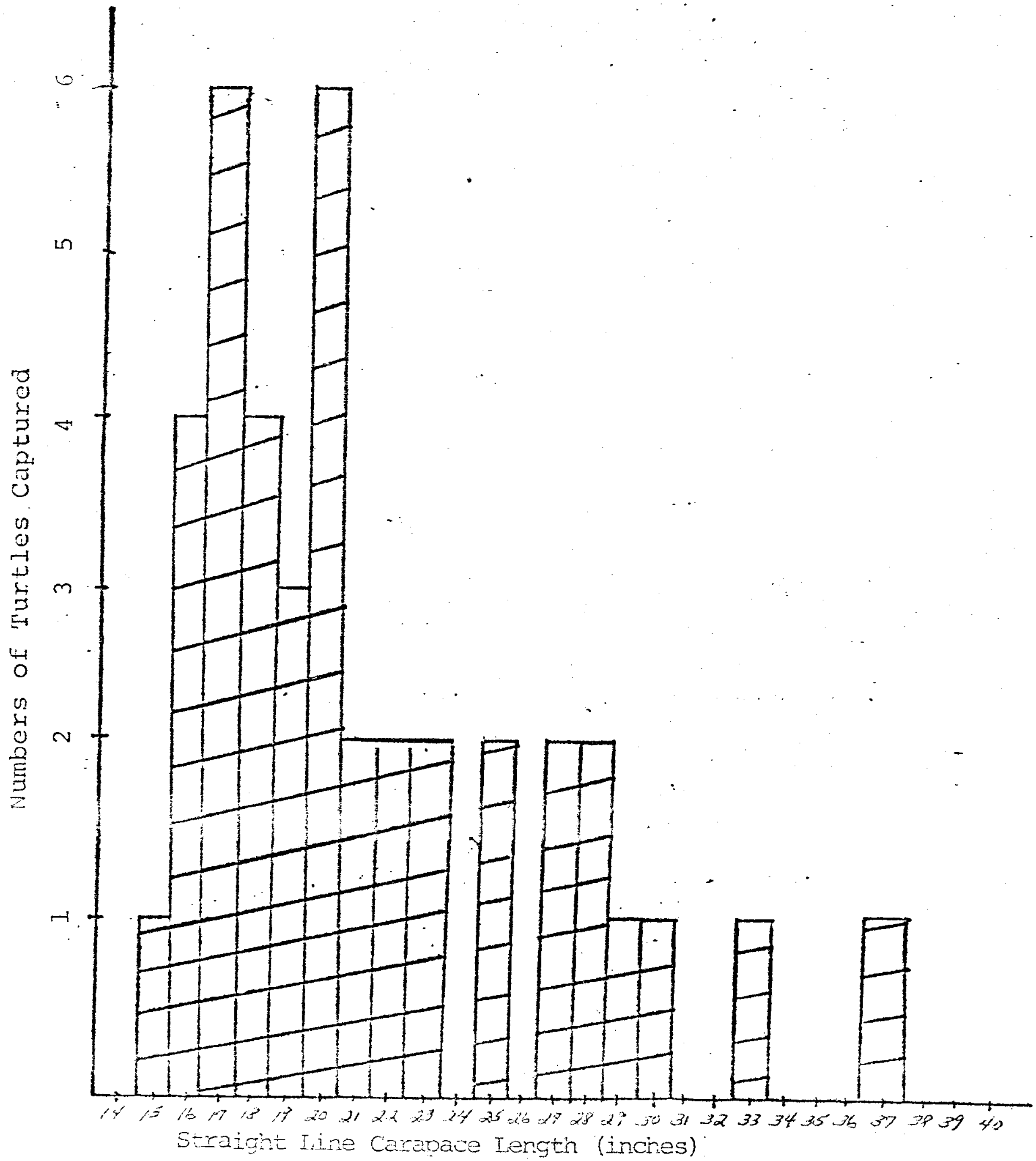
Sub-Adult - Straight line carapace length between 18 and 28 inches;

Adult - Straight line carapace length 29 inches and greater.

TABLE I.

Sizes (in inches) of green turtles captured on the feeding pastures near Punaluu. Straight line measurements. N = 39 (total captures)

	MEAN	RANGE
Carapace length	21.4	14.8 - 37
Carapace width	17.5	12.5 - 28



SIZE CATEGORIES OF CAPTURED TURTLES

TABLE II.

Sizes (in inches) of green turtles captured; Curved line carapace measurements.

	MEAN	RANGE
Carapace length	23.0	16 - 40
Carapace width	20.7	15 - 36

TABLE III.

Percentages of the population based on 39 captures:

18 Sub-Adults	48.7%
14 Juveniles	36.1%
6 Adults	15.4%

This data on the size composition of captured turtles is closely supported by our daily recordings of turtle sightings. The sightings consist mainly of our observations of resting and swimming turtles. After numerous sightings and our measurements of captured turtles, we became fairly adept at judging size distinctions between juveniles, sub-adults and adults.

TABLE IV.

Percentages of the population based upon 161 total sightings:

Sub-Adults	49%
49 Juveniles	39%
32 Adults	12%

We recognize that there is some inherent error in these sighting data; however, its effect is probably negligable in these results. The close correlation for both captures and sightings illustrates the non-selectiveness of our capture methods: they proved to show a representative population sample.

It is important here to note that our assessment of the size composition of turtles at Punaluu represents the summer months only; these figures could possibly shift toward a more substantial adult population with an influx of turtles from nesting beaches sometime later in the year.

SEX RATIOS

Virtually nothing is known about sex ratios in juvenile and sub-adult green turtle populations. The principal distinguishing feature between the sexes (an elongated tail in males) does not show development until the onset of reproductive maturity, when the turtle is approximately 28 inches in straight line carapace length. Since the turtle population off the Ka'u coastline consists mainly of these indeterminate sub-adults and juveniles, our assessment of the sex ratio is limited to the adult population.

None of the captured adults or sizeable sub-adults we examined evidenced any unusual elongation in the tail. The 32 sightings of adult turtles yielded only 2 definite males, which illustrates a preponderance of females in the adult turtle population off Ka'u.

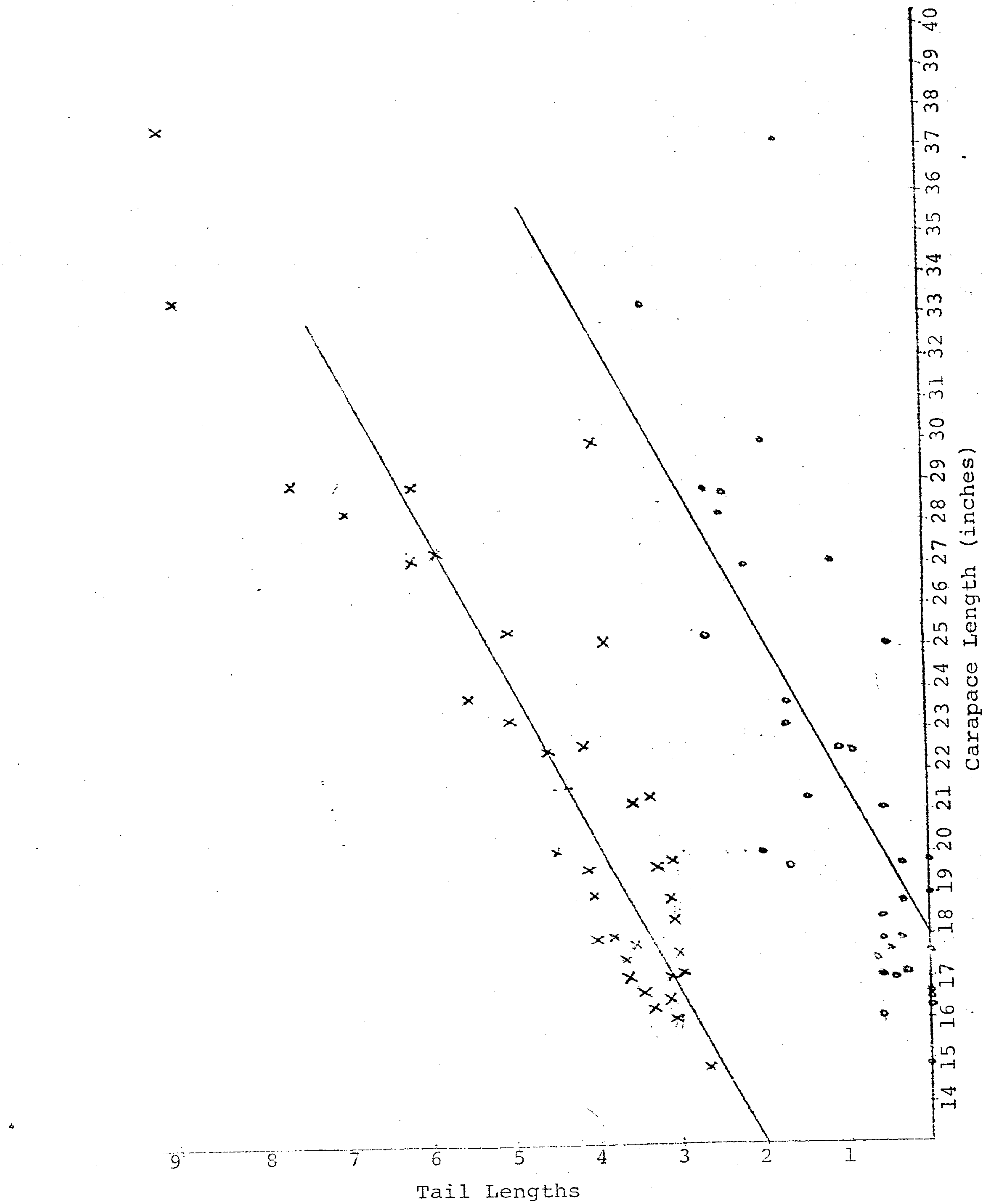
In an effort to obtain information on sex ratios in the sub-adult and juvenile members of the population, measurements were taken of the tail lengths past both the carapace and plastron on all captured turtles. Using this data, a regression analysis was performed. The resultant set of points closely fit the regression line, substantiating the linear relationship between carapace length and growth of the tail. (Fig. 3)

TABLE V.

Tail lengths (in inches) of captured turtles.

N = 39.

	MEAN	RANGE
Tail past carapace	.99	0 - 2.5
Tail past plastron	4.29	2.5 - 9



REGRESSION ANALYSIS OF TAIL LENGTHS

· = distance (in inches) of tail beyond carapace
x = distance (in inches) of tail beyong plastron

UNIT EFFORT AND ABUNDANCE

During the course of the study 160 scuba bottles (72 cubic inches) were used in 44 days of diving. We sighted 161 turtles, captured and tagged 39, and recaptured 13; which gives a total of 213 observations. This yields an average of 4.8 turtles observed per day. From this data alone, it's difficult to make an estimation of the population abundance of turtles off the Ka'u coastline. Many of our turtle sightings were undoubtedly repeat observations, and our limited diving time precluded our viewing the entire population. A more extensive tagging operation with some type of visible identification to differentiate individual turtles would be required in order to make this assessment.

In addition to our green turtle sightings, we made six identifications of hawksbill turtles (Eretmochelys). Visible differentiations which we noticed between the green and hawksbill turtles include: the hawksbill's more narrow, pointed head; different counts for pre-frontal and post-orbital scales of the head; overlapping scutes of the carapace; two claws on each of the front flippers; and a slightly different coloration of the flippers, carapace and head.

Among the six hawksbill sightings were three adults and three sub-adults. It's interesting that these three adults were among the largest turtles sighted all summer, and all were females. Due to identification difficulties, we inadvertently twice captured hawksbills; these we released after making our usual observations and measurements. To our knowledge, no hawksbills have nested at Punaluu beach within the past year.

TURTLE MOVEMENTS

Three factors seem to indicate that the green turtle population in the Punaluu area was stationary during the course of the study: (1) Of the 39 turtles captured, 13 were subsequently recaptured; with 8 being sub-adults, 4 juveniles and 1 adult; (2) Our shoreline observations of feeding turtles which were tagged or otherwise noticeably marked showed daily usage of the same feeding area; (3) While diving, many turtle sightings were of the same individuals, and on occasions, turtles were found using established sleeping areas.

Abundant feeding areas, the availability of good sleeping sites, and a low level of predation probably all contribute in making this an ideal feeding pasture for green turtles.

Migration routes for the recruitment of new individuals, and remigrations for reproductive and nesting purposes are not thoroughly known for green turtles on the Big Island. Our study could potentially shed some light on the subject; with recaptures of turtles tagged at Ka'u on other islands or nesting beaches.

The smallest juveniles sighted were approximately 14 inches in straight line carapace length; this is probably close to the size where recruitment into the Ka'u feeding population occurs.

One interesting capture was a juvenile turtle (16-7/8 inches straight line carapace length) which had been tagged and released by G. H. Balaz at Coconut Island in Kaneohe Bay, (Tag #474), Oahu, 11 months previous. This is a minimum travel distance to Ka'u of 344 kilometers. Although this young turtle had been raised in captivity, it appeared to have successfully adapted to natural conditions. Growth during the time period from release to capture was only 1/4 inch in carapace width, with no increase in length.

INJURIES AND ABNORMALITIES

Perhaps the most noticeable injuries centered on the turtle's carapace. Appearing primarily on the coastal scutes of all size groups, these injuries were both fresh and healed, indicating a common or ongoing occurance. Considering the fact that feeding turtles frequent shallow areas with high surge and wave activity, this carapace damage is not unreasonable. Observations of turtles upon entrance or exit from recesses indicated a deliberate process incapable of violent gouges and cuts. All indications, therefore, point to the feeding activity as a source of injury and evidence the usefulness of both the plastron and carapace in protecting a shallow feeding marine turtle.

The pelvic limbs used primarily for steerage sustained a 15% incidence of partial or total amputation. These missing portions were accompanied by scar tissue along the healed edge suggesting violent attack rather than a feeding activity injury. In certain instances, the damage extended to the post centrals of the carapace, resulting in some degree of deformation.

Injuries to the pectoral limbs were not as common (5%) or severe as those to the pelvic region. There are several possible reasons for this, but the most practical is the fact that the pectoral limbs are the swimming appendages of the turtle. A severe injury to this region would cause a loss of locomotion at least for a time and result in a greater vulnerability to predation and severely handicap the main means of obtaining food. In addition, the primary defensive behavior is rapid and sustained flight. As previously mentioned, the pelvic limbs are used for steerage and as such remain trailing behind the bulk of the animal offering a good target for an attacking predator. The pectoral limbs do not offer such a perfect target.

In the case of one turtle, the right pectoral limbs had been broken as evidenced by an improperly healed bone. The accompanying scar tissue suggested a violent rather than feeding activity accident with man or shark being the most probable predator.

The abnormalities most commonly observed again centered in the region of the carapace (15%) in the form of abnormal plate counts. These irregular plate counts were consistently in the vertebral region and appeared as subdivided vertebral plates remaining essentially within the region normally occupied by a single plate.

Abnormalities cannot be adequately discussed without mention of Chelonia No. 1862. In general terms, this turtle was absolutely free of algal growth and markedly lighter in color than all of the turtles sampled during the study period. The carapace evidenced the common sunburst dark and light brown coloration and the plastron was light enough to appear white as compared to the yellow plastron most commonly observed. No feeding activity injuries were observed and both the pectoral and pelvic limbs, along with the caudal portion of the carapace, evidenced a transparent, very thin, breakable border which initially appeared as a new growth region. Any of the feeding activity commonly observed would have resulted in the complete destruction of these areas. In all external morphological respects, this turtle was normal. The main abberations were coloration, lack of injuries, absence of algal growth and the thin, transparent borders described. This member of the feeding population was not representative of the turtles sampled in any respect and poses many questions well beyond the scope of this study.

PREDATION

We noticed damages which were probably incurred by attack from sharks on nearly 20% of the captued turtles. These included missing flippers, scars and previously broken bones and damages to the carapace. It's likely that these attacks occurred before the turtles made their arrival at Punaluu, because there seems to be no real incidence of large sharks in inshore areas. White tip reef sharks are common, but don't constitute a threat to turtles. Only once during the project duration did we see a large shark (a grey reef) and this occurred when tuna long line fishermen were directly outside Punaluu Bay.

The major threat to sea turtles residing along this coastline comes from man. There's a long history of turtle catching in the region: during the six-month period, from June to November, 1976, we were able to verify five separate cases of turtle poaching.

With the given size composition of turtles at Ka'u being mostly sub-adults and juveniles, and with the particular scarcity of larger individuals (36" straight line carapace length or greater to be legally taken) nearly all captures are made with complete disregard to the State's restrictions.

CONCLUSION

The Ka'u area warrants further investigation by virtue of its turtle population in view of the numerical results of this study. Suitable sites also exist within this area for alternative capture methods such as nets across the shallow feeding areas.

The capture methods developed were both effective in obtaining specimens and non-injurious to the turtle. They could be adapted to any area of concentrated turtle population, including nesting and breeding sites.

Consideration must also be given to this Ka'u area in lieu of future coastal development, especially at Punaluu. The occasional nesting hawksbill turtles, along with the feeding population of green turtles, must be considered in terms of possible wildlife conservation.

ACKNOWLEDGMENTS

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