Report to the University of Hawaiʻi at Hilo Marine Option Program

Observing Patterns in UH Hilo MOP Turtle Tagging Data through Statistical Analyses

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Abstract

Over the past 40 years, George Balazs and UH-Hilo MOP have conducted Hawaiian green sea turtle (*Chelonia mydas*) surveys at Punaluʻu Beach Park on Hawaiʻi Island. Turtles were originally tagged and observed in the 1980's as an effort to study and conserve declining sea turtle populations. The tagging events continued and turned into a long term study to understand Hawaiian green sea turtle population growth and sizes. At tagging events, teams of UH-Hilo MOP students hand capture turtles and bring them to shore to be weighed, measured, observed, and then released into the water. A comprehensive statistical analysis of the entire UH Hilo MOP turtle tagging dataset has never been undertaken. For my MOP project, I organized and analyzed the extensive turtle tagging dataset that had been compiled between 1978 and 2018, to elucidate trends and identify potential relationships among variables for ongoing analysis. Over the 40 years, 1,220 records were collected and data included species, tag ID, sex, tumor presence, straight carapace length (SCL), curved carapace length (CCL), and weight as well as periodic notes about injuries, stomach samples, and other health conditions. Initial analyses compare weight and carapace length between males and females, and between turtles with and without tumors. While no statistically significant differences were found, strong, positive correlations were found among SCL, CCL, and weight. Future analyses could shed light on trends in health related to age, growth rates, and sex ratios.This report offers insight into how past data were collected and identifies directions for future data collection and analysis. Continued analysis of this long term data set will provide a basis for better understanding of the Punalu'u Hawaiian green sea turtle population.

1. INTRODUCTION

The Punaluʻu Turtle Project, led by George Balazs, began as an effort to study Hawaiian green sea turtles (*Chelonia mydas*) and monitor population health and recovery. Green sea turtle populations in the Pacific were noticeably declining during the 1960's due to commercial overfishing and the use of gill nets (Martin 2016). The decrease in global populations was so severe that green sea turtles were listed as an endangered species under the Federal Endangered Species Act of 1973 (NOAA Fisheries 2015). To assist Hawaiian sea turtles' return to a healthy population size, in 1985 the National Marine Fisheries Service (NMFS), the U.S. Fish and Wildlife Service (USFWS), and the Hawaii State Division of Land and Resources (DLNR) formed a turtle recovery team that drafted a formal recovery plan (Martin 2016, Penisten & Dudley 1991). This plan gave Hawaiian sea turtles state and federal protection, making it illegal to harm, disturb, or kill these animals (Martin 2016, Penisten & Dudley 1991).

George Balazs, now retired, was a sea turtle biologist for the NOAA Pacific Islands Fisheries Science Center (NOAA PIFSC) and studied the depleted sea turtle populations in Hawaiʻi. In 1983, he received funding from the UH Sea Grant College Program to continue research and find ways to conserve the remaining stocks of green sea turtles (Klemm 1984). Marc Rice, the director of the Sea Turtle Research Program at Hawaiʻi Preparatory Academy (HPA), began assisting Balazs to capture, measure, and tag green turtles at Punaluʻu Beach Park to track turtle growth and monitor the population size (Martin 2016). Turtle tagging events were carried out a few times a year under permits from the National Marine Fisheries Service (Martin 2016). University of Hawaiʻi at Hilo Marine Option Program students and faculty joined what is now known as the Punaluʻu Turtle Project to help this effort as research assistants. For 40 years, teams of UH Hilo MOP students, under the supervision of Balazs, have entered the waters at Punaluʻu Beach Park to harmlessly capture turtles and bring them to shore to be tagged or checked for a Passive Integrated Transponder (PIT) tag ID to take note of to correlate with the turtle's past records, thoroughly examined, and record their measurements.

Portions of the data collected by Balazs and UH Hilo MOP have been used for larger studies aimed to understand Hawaiian green sea turtle growth rates, foraging behaviors, and recapture rates among Punaluʻu and other study sites across the Hawaiian islands (Rice et al 2000, Balazs et al 2004, Wibbels et al 1993). Recaptures at these turtle tagging events help Balazs and other researchers collect census information to estimate population size (Parks 1992). This study has recorded data since 1978, so there is a lot of information from over the years on the turtle population's health and growth at Punaluʻu that signal recovery is occurring. A comprehensive statistical analysis of the entire UH Hilo MOP turtle tagging dataset has never been undertaken and would contribute to a greater understanding of Hawaiian green sea turtles at this study site. For my MOP project, I analyzed the extensive turtle tagging dataset compiled between 1978 and 2018 using statistical tests to find trends in health and distribution from that data collected so far and identified directions for data collection and analysis for the Hawaiian green sea turtle population at Punaluʻu, Hawaiʻi.

2. MATERIALS AND METHODS

2.1 Study Site

Punaluʻu Beach Park is the study site MOP used for turtle tagging and data collection. The site (Figure 1) is a black sand beach created by past lava flows on the southeast coast of Hawaiʻi Island in the district of Ka'u. This location is a popular foraging site for green sea turtles in Hawaiʻi and recreational beach and fishing area for people in Kaʻu (Figure 2). Green sea turtles are found basking in the sand or feeding, mostly on *Pterocladia capillacea,* an intertidal red algae (Rice et al 2000).

Figure 1: Punaluʻu Beach Park is located on the southeast side of Hawaiʻi Island, also shown as the red pin in this image (Google Earth, 2021). Latitude: 19.1353928, Longitude: -155.5048865

Figure 2: Turtle tagging events take place at this section of Punaluʻu Beach Park. Tents are set up on the sand and teams enter the water here to find turtles (Dustin, 2019).

2.2 Data Collected

About twice a year, George Balazs, NOAA researchers, and teams of UH Hilo Marine Option Program students set up at Punaluʻu Beach Park to measure, weigh, and record observations of Hawaiian green sea turtles captured by hand in the water. The data collected includes the following: event type (basking, in water, sighting, stranding), turtle ID, tag number, date of observation, island, area, site, species (*Chelonia mydas* (Cm) and *Eretmochelys imbricata* (Ei)), sex (male (M), female (F), unidentified (U)), straight carapace length (SCL), curved carapace length (CCL), mass, tumor presence (yes (Y), no (N), unknown (U)), whether blood or stomach samples were taken, capture platform, capture method, tag information, and other comments about what's in their mouth and any abnormalities like carapace damage, injuries, and tumors are noted.

2.3 Cleaning the Dataset

All of the data collected are on an Excel spreadsheet that were imported into RStudio, an open source software that is an integrated development environment for the programming language R. RStudio has packages or code written by programmers to be reused for common tasks. The "dplyr" and "tidyr" packages have functions designed for data frame manipulation. These functions allowed me to fix typos, add or remove columns of data to use for analysis, change the date column format, and filter out cells with 'N/A's, unidentified labels, or missing values.

For this analysis, all of the numerical measurement variables, SCL, CCL, and mass, were filtered to show records with measurements greater than zero. Some of the measurements recorded as zero were likely entered in the data sheet this way to show a measurement was not taken of that turtle. After filtering, 821 of the 1,220 turtle observations were available for analysis. This data frame manipulation created a consistent, organized format of the data that is readable in R and ready for conducting statistical analyses.

2.4 Statistical Analysis

R is a programming language designed to calculate statistics. Through this interface, summary statistics such as the mean, median, and range were calculated for the numerical variables: straight carapace length (SCL), curved carapace length (CCL), and mass. Summary statistics provide an idea of the types of data collected and how measurements are distributed among the sampled turtles. To understand how turtle size measurements were distributed among groups of turtles, I focused on comparing carapace length and mass between males and females and between turtles with tumors and without tumors. Testing for normal distributions with the

Shapiro-Wilk test and equal variances with Levene's test were conducted first to determine whether to make comparisons with parametric or non-parametric tests. Comparisons of the average mass and carapace lengths of the groups of turtles will be made with a two sample t-test if parametric or the Wilcoxon signed-rank test if non-parametric. For comparing central tendencies among sex and tumor presence, unidentified individuals recorded were filtered out. Pearson's correlation test was used to find the strength and direction of the relationships between the measured characteristics: SCL, CCL, and mass.

3. RESULTS

From January 20, 1978 to July 9, 2018, 1,220 turtle observations were recorded during MOP turtle tagging events on Hawaiʻi Island. A total of 1,219 of the turtles were identified as green sea turtles (*Chelonia mydas*) and one turtle was identified as a hawksbill sea turtle (*Eretmochelys imbricata*). Over this 40 year period, about 434 different turtles were tagging or had a different ID number than previous records. Turtle observations were recorded at Punaluʻu Beach Park on approximately 99 dates, with observations ranging from one turtle to 23 turtles recorded on a given day. Seventeen of the observations were recorded as sightings, four as strandings, 59 as basking, and 1,140 of the turtles were found in the water.

Of the 821 turtle observations with measurements, five were identified as females, 26 were male, and the remaining 790 turtles' sex were unidentified. Most of the labels are unidentified due to capturing mostly sexually immature sea turtles that observers were unable to discern the sex visually. Twenty-three of the turtles were found with tumors, 790 did not show any tumors, and eight of the turtles' were listed as unknown for showing tumors. Straight carapace length ranged from 19.8 to 89.5 cm, with a mean of 60.6 cm and median of 61.5 cm (Figure 3). Curved carapace length ranged from 21.0 to 94.6 cm, with a mean of 65.1 cm, and median of 66.0 cm (Figure 4). Mass ranged from 2.3 to 114.8 kg, with a mean of 33.0 kg, and median of 31.8 kg (Figure 5).

The Shapiro-Wilk test for normal distributions for all three size characteristics calculated p-values less than 0.5, indicating that these data are not normally distributed. The Levene's test for equal variance calculated p-values greater then 0.5 and both tumor presence (yes and no) and sex (male and female) categories have equal variances. Based on the non-normal distributions and equal variances, non parametric tests were used to compare SCL, CCL, and mass between turtles with and without tumors, and between males and females. The Wilcoxon test determined that SCL, CCL, and mass between turtles with and without tumors (Figure 6) and between males and females (Figure 7) are not statistically significantly different from one another. Pearson's correlation test demonstrated that the relationship between SCL, CCL, and mass are strong, positive associations all having Pearson correlation coefficients greater than 0.9 (Figure 8).

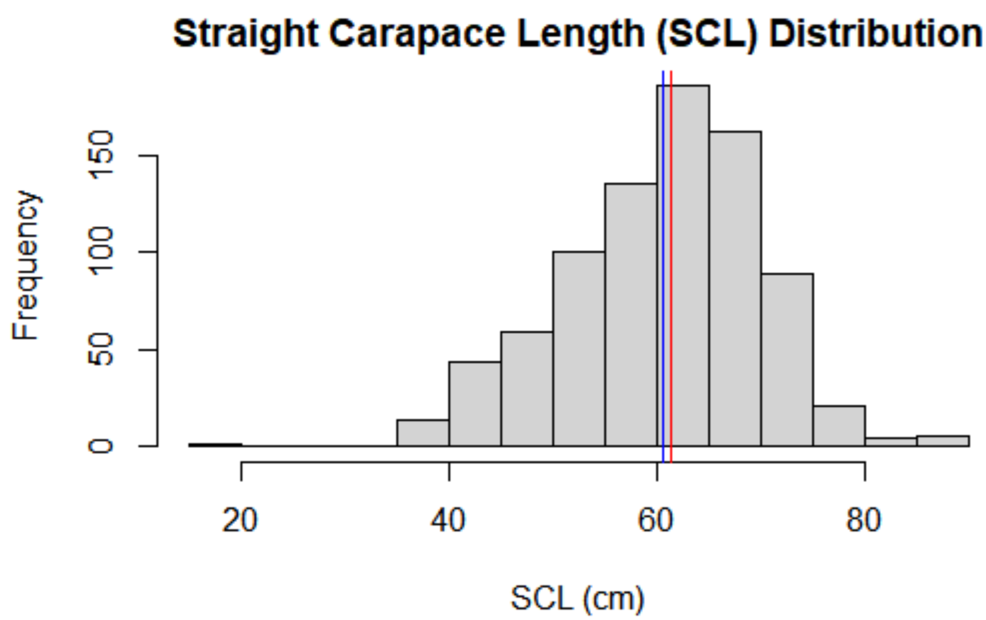

Figure 3: Histogram of straight carapace length. Blue line shows the mean (60.6 cm) and the red line shows the median (61.5 cm).

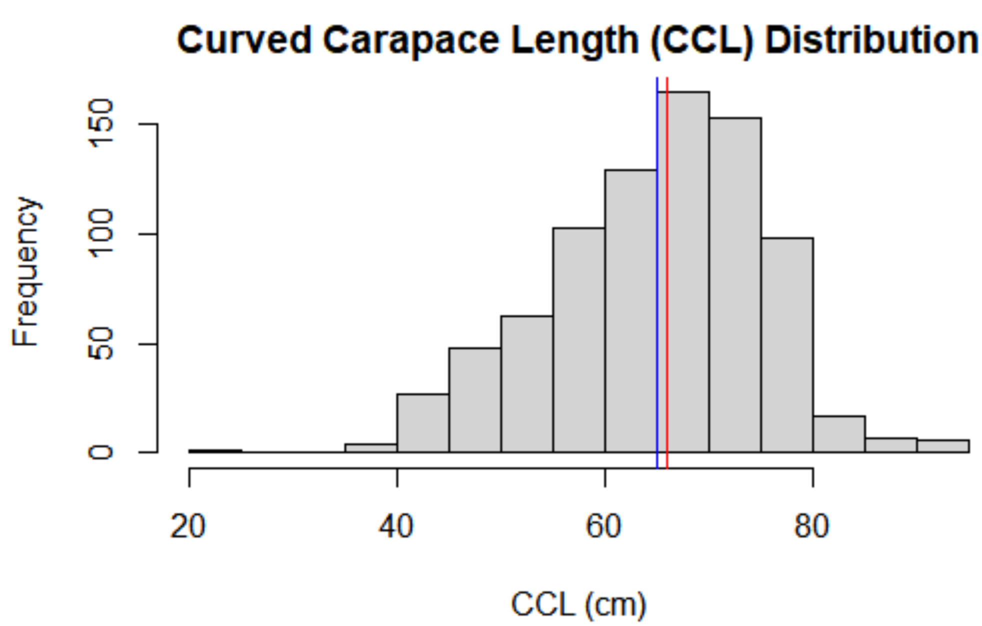

Figure 4: Histogram of curved carapace length. Blue line shows the mean (65.1 cm) and the red line shows the median (66.0 cm).

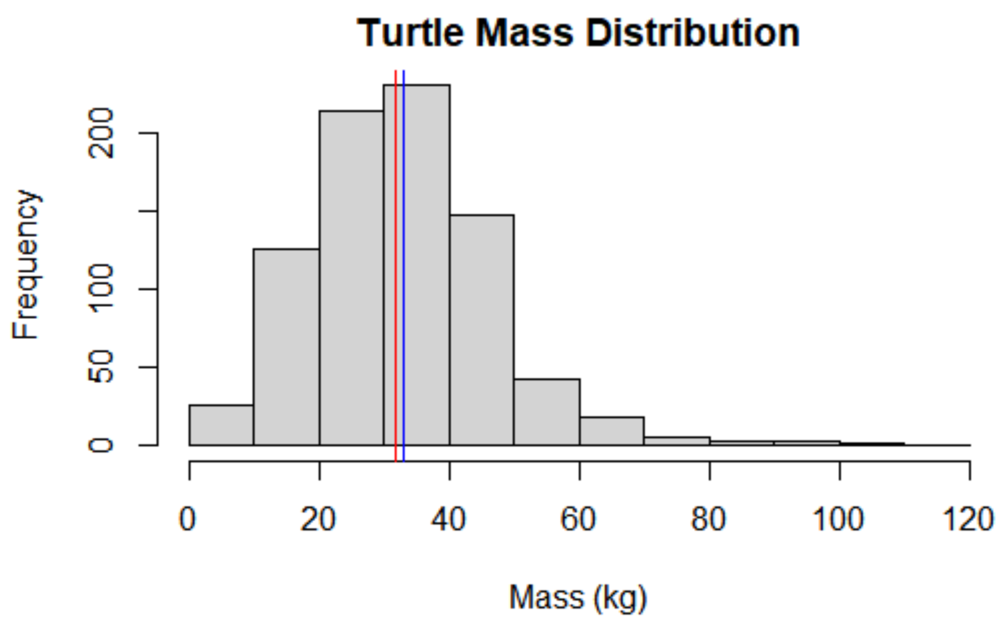

Figure 5: Histogram of turtle mass. Blue line shows the mean (33.0 kg) and the red line shows the median (31.8 kg).

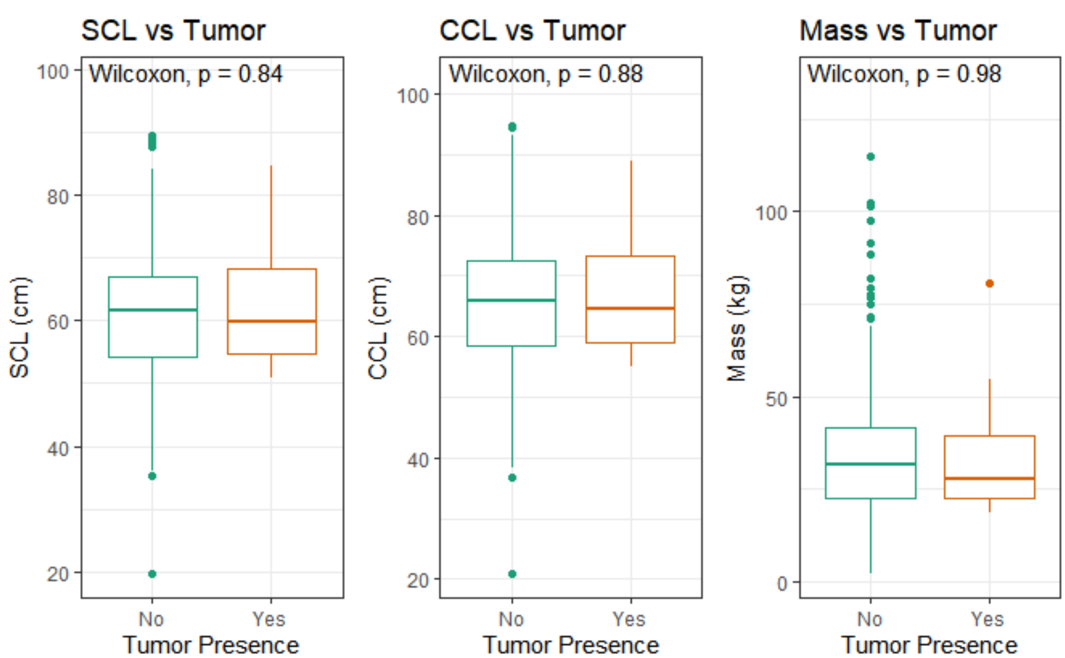

Figure 6: Box plots showing the distribution and central tendencies of turtle SCL, CCL, and mass within groups of turtles with tumors (Yes) and without tumors (No).

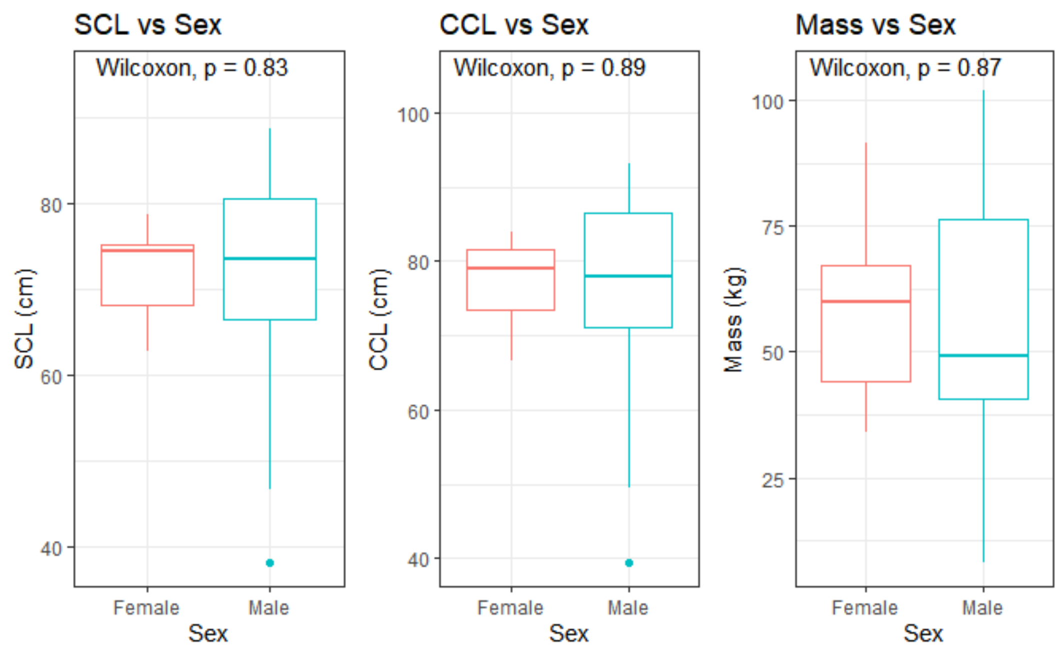

Figure 7: Box plots showing the distribution and central tendencies of turtle SCL, CCL, and mass within groups of turtles males and females.

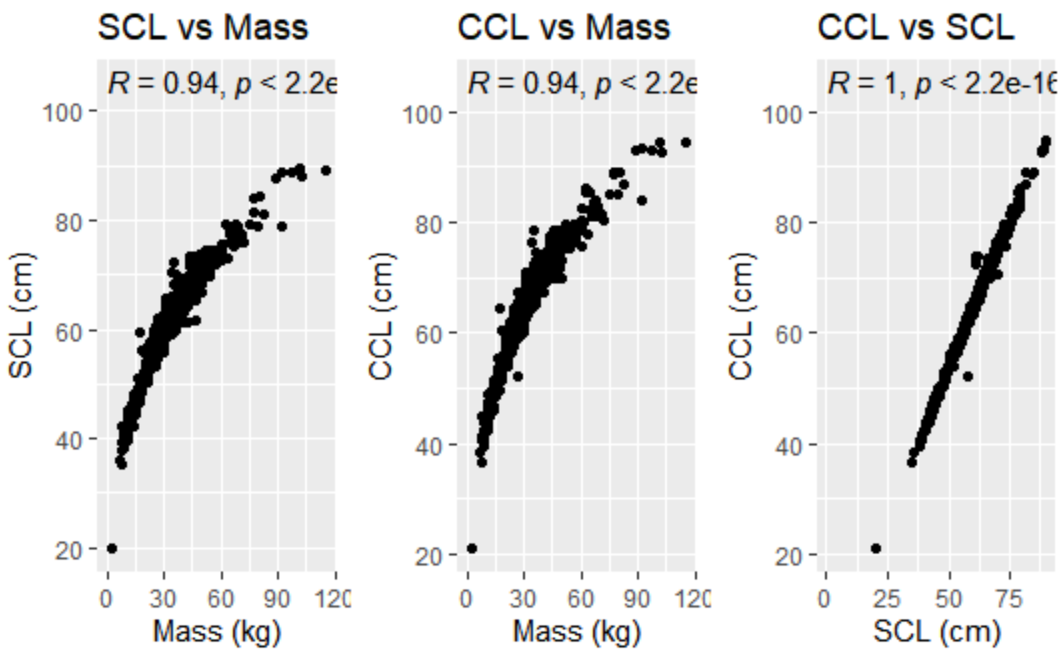

Figure 8: Scatter plots that show the strong, positive association between two of the size characteristics and their Pearson correlation coefficient (R).

4. DISCUSSION

The results of this analysis provide insight into this long term study of Hawaiian green sea turtles at Punaluʻu Beach Park. For the statistical analysis, I focused on summarizing trends in the dataset and pulling out information that tells more about the turtle tagging events over the past 40 years, including the number of survey events, turtles observed per tagging event, and the average sizes of turtles found at Punaluʻu Beach Park. Comparisons between male and female turtles, and between turtles with and without tumors to find any significant differences, similarities, and trends among the groups were made. This project was not an exhaustive analysis of the dataset, but the start to finding what we can learn about the data collected so far.

One of the most important things to note in this report is the sample size. Although there are 821 observations of turtle carapace length and weight, majority of the records were unable to visually identify the sex of the turtles due to still undergoing sexual development, which left five females and 26 males as samples to represent the entire population of Hawaiian green sea turtles at Punalu'u. Confident comparisons between average male and female measurements cannot be made from these data. However, in the original field notes, tail measurements of the posterior edge of plastron to tip of tail and the posterior edge of plastron to vent (cloaca) were taken on majority of the captures and a few blood samples were taken at some early tagging events. Going through past notes or blood sample results and updating this dataset could be a task worth doing in order to make more confident comparisons between male and female sizes. If turtles have been caught a number of times over the years and recorded as juveniles at first, we may be able to go back and record male or female now that they've been seen several years and may have sexually matured.

For future turtle tagging events, recording whether a turtle appears to be a juvenile versus an adult would be worth noting to make size comparisons based on age. For future data analysis, including the measurements for the plastron and the tail length could be interesting size characteristics to add and make comparisons and correlations with. The more information that can be recorded and tracked, the more variables that can be used to make statistical inferences with. This will allow us to gain a better understanding of other aspects of Hawaiian green sea turtle populations in Punalu'u including the information already recorded.

Another interesting component to add to this analysis, would be making use of the date and turtle tag ID records. Compiling the records associated with a turtle tag ID, in which turtles are captured at more than one event, allows us to compare their measurements over the years. Isolating an individual's measurements to be compared amongst themselves can identify years of significant growth or consistency. Grouping turtles captured in the past and present can also be a way to find whether carapace length and mass have changed over time. The dates can be organized from oldest to newest to make plots for each turtle ID to show SCL, CCL, or mass by date. Patterns within individual turtles' growth can then be used to find patterns of growth that may be similar or different to other turtles.

5. CONCLUSION

UH Hilo MOP and George Balazs have compiled over 40 years of data from Hawaiian green sea turtles they have tagged and measured. This project provides an overview of significant elements they have collected, answers questions about trends in weight and size for the recovering green sea turtle population, insight into how past data were collected, and identifies directions for future data collection and analysis. While population health and size have improved at Punalu‘u Beach Park, it is important to continue turtle tagging. Finding and tagging new turtles can be a sign of population growth. Green sea turtle nesting sites in the Northwestern Hawaiian Islands are disappearing due to increasingly severe tropical storms and sea level rise caused by climate change. This leaves the future of Hawaiian green sea turtle populations a mystery, so having tag records or a photo database that identifies turtles can help wildlife managers and researchers keep track of nesting females and get an idea of the Hawaiian green sea turtle demography. Identifying growth in these sea turtles shows there are adequate food resources available for turtles at Punaluʻu, while slow growth and poor body shape can indicate a limit in food supply. These data are valuable for understanding turtle growth in Punaluʻu and continuing to advocate for the conservation and wise management of green sea turtle populations in Hawaiʻi. It is important to continue expanding this dataset to better understand turtle growth rates and gain insight into the environmental conditions green sea turtles are faced with. Tagging and observation events can branch out to other sites on the islands to understand Hawaiian green sea turtle populations as a whole. We have learned a little bit more about what has been collected so far and we can continue learning how individuals and populations of Hawaiian green sea turtles are growing in the changing world.

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