AN ABSTRACT OF THE THESIS OF

Scott Thomas Eanes for the degree of Master of Science in Marine and Environmental Sciences presented on March 29, 2016

Title: Assessing habitat utilization by the juvenile and sub-adult hawksbill sea turtles (*Eretmochelys imbricata*) along the artificial marine habitat of the Cyril E. King runway

Abstract approved:

Dr. Paul Jobsis

The marine habitat created by the extension of the Cyril E. King (CEK) runway on the island of St. Thomas, USVI is an artificial reef habitat that has become an important developmental area for critically endangered, juvenile and sub-adult hawksbill sea turtles. The marine runway habitat was divided into five sections (Section 1-NER-1, Section 2-NWR-2, Section 3-SWR-3, Section 4-SSR-4, and Section 5-SER-5). Benthic surveys examined two factors along the runway, composition of sessile benthic communities, and crevice size in an effort to link hawksbill turtle hourly usage of the habitat to either, or both factors. Five Vemco acoustic receivers were placed around the marine runway habitat to maximize acoustic coverage. Six hawksbill turtles were then captured and tagged acoustically with either a V13 or V16 acoustic (Vemco) tag, with two turtles being fitted with depth tags. Turtles were tracked for a maximum of 200 days to a minimum of 100 days. The calculated hourly habitat usage in examination with benthic composition and/or crevice size

data shows a link between marine runway sections with the largest crevice size and the smallest turtles tagged in the study, with depth and benthic community composition results being inconclusive.

Assessing habitat utilization by the juvenile and sub-adult hawksbill sea turtles (*Eretmochelys imbricata*) along the artificial marine habitat of the Cyril E. King runway

by

Scott Thomas Eanes

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I understand that my thesis will become part of the permanent collection of the University of the Virgin Islands Library. My signature below authorizes release of my thesis to any reader upon request.

Scott Thomas Eanes

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This thesis was an extremely tough task. The NMFS permit alone took almost 3 years to acquire and even then funding was limited. First and foremost the committee members, Dr. Robert Van Dam and Rafe Boulon, need to be thanked for their patience and assistance. Second, and most important is Dr. Paul Jobsis. His endless support in all aspects allowed for the completion of this study. Dr. Marilyn Brandt was instrumental in the statistical aspect of this study and is an amazing teacher. Jon Jossart and Rosmin Sinead were crucial for their knowledge and wisdom in acoustic data collection, analysis, and CPCe benthic composition collection and analysis. This study took close to 48 months from beginning to end and along the way there were many volunteers that without their assistance would have made this study more difficult, those individuals are: Dr. Tyler Smith, Dr. Rick Nemeth, Ian Lundgren, Clayton Pollock, Alex Gulick, Alex Webb, Victoria Beasley, Samuel Mitchell, Daniel Qualls, and Haley Goodson (if I forgot anyone I apologize). This was a total team effort, and with that being said, ONE TEAM, ONE DREAM.

CONTRIBUTION OF AUTHORS

Dr. Paul Jobsis assisted with data collection. Dr. Marilyn Brandt and Dr. Tyler Smith assisted with the experimental design. Dr. Marilyn Brandt, and Jon Jossart assisted with the interpretation of data and data analysis.

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Introduction

Sea turtles have been described as mega-vertebrates and their presence in the ecosystem cannot be replaced; if absent it is felt through the "dramatic reduction and qualitative change of grazing and excavation of sea grasses, predation on sponges, loss of production to adjacent ecosystems, and the structure of the food chain" (Jackson 1997). Sea turtles have also been described as an "ecosystem engineer" and having a great importance in "structuring the physical and biological components of their environment to create habitat" (Coleman and Williams 2002). Sea turtles are extremely important to marine ecosystems but their ability to play these important roles has been affected by the systematic overharvest.

Beginning in 1968, hawksbill turtles (*Eretmochelys imbricata*) were classified as endangered by the IUCN (IUCN 1968). In 1996, with a continued population decline at 80% globally over the previous three generations (Meylan and Donnelly-1999), their status on the IUCN Red List was upgraded to, critically endangered (IUCN 1996). Their status as of 2008, the last year assessed, remained at the level of critically endangered (IUCN 2008). Critically endangered means they face a very serious threat of going extinct in the wild (IUCN 2011). The exploitation of hawksbill turtles occurs because they are harvested for their meat and eggs, but most of all, their carapace scutes (Meylan 1999). Hawksbill turtle carapace scutes have been used to make jewelry and other decorative items for decades in some countries, and centuries in Japan, where it is called "Bekko."(Canin 1991).

Before hawksbill turtles can be turned into "Bekko", they begin their lives like that of other sea turtle species emerging from a nest after roughly 60 days of incubation. The hatchling turtles in a, "frenzy", sprint for the ocean. The "frenzy" stage of the hatchling can last two days with the goal of getting to ocean currents offshore. Hatchling hawksbill turtles then begin an oceanic stage lasting 1-3 years before their recruitment to a reef habitat community as a juvenile (Carr et al 1966, Musick and Limpus 1997). This recruitment of young juvenile hawksbill turtles to reef habitats has major implications on their conservation. Nesting habitats have been identified but the identification of juvenile and adult feeding habitats, also known as foraging habitats; have been largely unrecorded (Bowen and Karl 2007). Furthermore, the attributes/qualities of a strong foraging habitat need to be identified to ensure adequate food resources are protected. The identification and protection of foraging habitats is the next step in sea turtle conservation and would lead to increased survivability in juvenile and sub-adult hawksbills.

There are signs of recovery for some Caribbean populations. Hawksbill populations in Antigua and Barbados, which have been monitored for decades, are recording an upswing in number of nests and nesting female hawksbills due mostly to protection of nesting beaches (Richardson et al 2006, Beggs et al 2007). The increase in nesting females due to the protection and conservation of nesting beaches has allowed other questions concerning hawksbill ecology to emerge. Interest in juvenile in-water ecology has become an important research topic because of the gaps in our knowledge in this stage of their development.

The 1993 NMFS and USFW recovery plan for the critically endangered hawksbill turtle listed several important goals that needed to be met in order to delist the species in 25 years, the year 2018. Specifically, in part two of the recovery plan it states “the protection of marine habitat, including foraging habitats” (NMFS 1993) is desirable. The recovery plan stresses the importance of locating and identifying foraging habitats with a special emphasis on the habitat requirements for smaller hawksbills (NMFS 1993). The recovery plan recommends the identification of important foraging habitats, and that once these areas are identified they should be designated as protected areas (NMFS 1993). And finally, an important step in the protection and management of juvenile and sub-adult hawksbill turtle populations is acquiring more data on their distribution and abundance in the Caribbean region (NMFS 1993).

Hawksbill Turtle "Home Range"

Juvenile hawksbill turtle research on "home ranges" has been examined in several locations in the Caribbean including Mona Island, Puerto Rico, the Dominican Republic, and Rio Lagartos, Mexico. The studies have concluded hawksbill "home range is less than $1km^2$ (Van Dam and Diez, 1998) in Puerto Rico, $0.36km^2$ in the Dominican Republic (Leon and Diez, 1999), and a radius of $1.1km^2$ in the Rio Lagartos Sea Turtle Sanctuary in Mexico (Cuevas, 2007). This earlier studies show that, juvenile hawksbill turtles stay within relatively small natural foraging areas during this stage of their lives. It is unclear how the artificial marine habitat created by the CEK airport affects the home range of these animals.

The Cyril E. King runway artificial marine habitat description

The CEK runway is an 1800 meters long artificial shoreline consisting of 600 meters on the north side, 275 meters on the west side or tip, and 900 meters on the south side (figure 1 below). The runway is not a homogenous marine habitat. The north side consists of rock rubble nearest to the natural shoreline with some intermittent boulders at the bottom on the ocean floor and has a depth of 8-9 meters. The marine runway habitat then increases in depth as it projects westward into the adjacent bay reaching a maximum depth of 27 meters. The west side or "tip" is between 26-27 meters deep. The south side runs back into the natural shoreline and becomes shallow again to 8-9 meters. Rock rubble exists for roughly 85% of the entire runway at a depth greater than 13-14 meters with the south side shallow habitat consisting of concrete dolos. Above 13-14 meters starting 500 meters along the north side, large multi ton concrete dolos line the runway. The concrete dolos exist the remaining 1300 meters of the runway, running across the west facing "tip" of the runway and the entire south side. The concrete dolos exist to a depth of 12-13 meters and then large granite boulders exist between the concrete dolos and rock rubble creating a small 10-meter lip before the rock rubble slants off to the bottom of the ocean floor. The entire underwater artificial reef has an area of roughly six hectares. A depth profile can be seen below in figure 2.

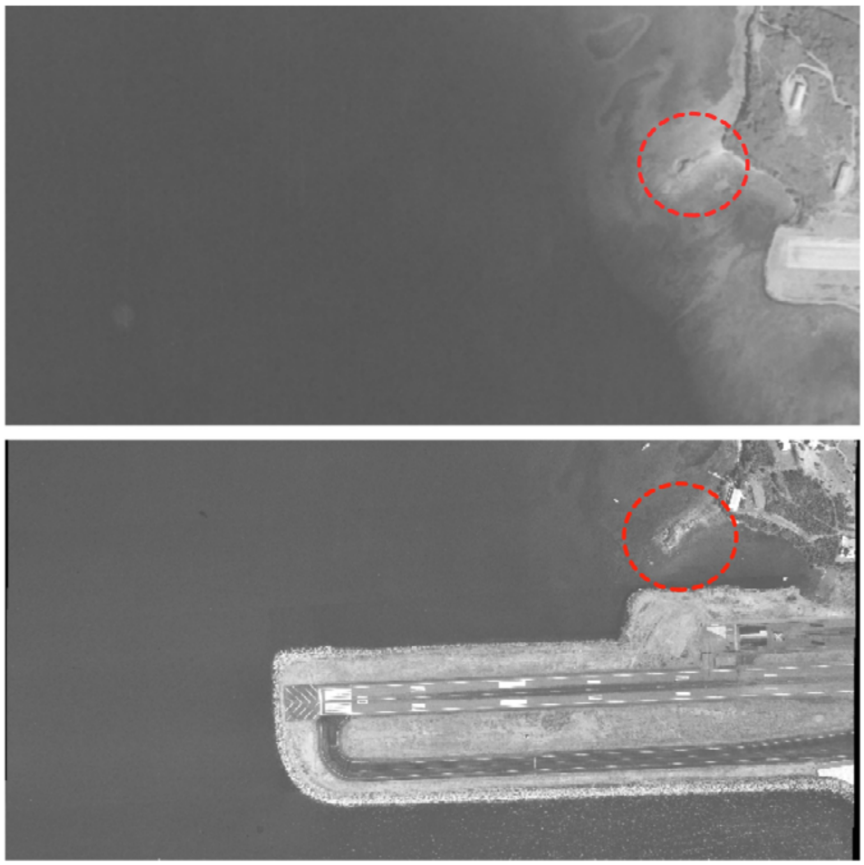


Figure 1. The image on the top is of the CEK runway in 1954. The image on the bottom is the CEK runway in 1994 with the extension.

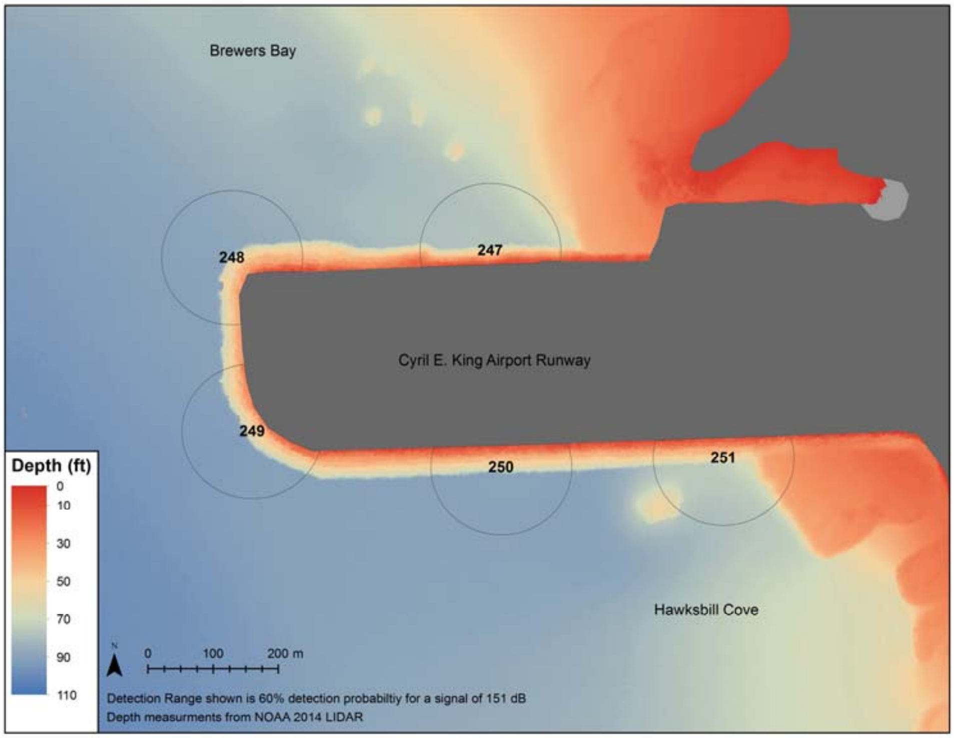


Figure 2. The marine habitat of the CEK runway depth image including receiver stations 247 through 251 and their approximate detection radius.

The following hypotheses came to fruition due to unique nature of the CEK marine runway habitat and the seemingly connection to juvenile hawksbill turtles in an effort to explore and understand their “residency” in the area.

Hypothesis

- H_0: Juvenile and sub-adult hawksbill turtle calculated hourly habitat usage will be equal across all receivers.

- H_1: Juvenile and sub-adult hawksbill turtle calculated hourly habitat usage will not be equal across all receivers.

- H_0: Juvenile and sub-adult hawksbill turtle total detections will be equally split across all receivers

- H_1: Juvenile and sub-adult hawksbill turtle total detections will not be equally split across all receivers

- H_0: Juvenile and sub-adult hawksbill turtles will have equal detections at all depths

- H_1:Juvenile and sub-adult hawksbill turtles will not have equal detections at all depths

- H_0: Benthic community composition will be equal across the entire habitat and at all depths

- H_1: Benthic community composition will not be equal across the entire habitat and at all depths

- H_0: Crevice sizes will be equal across all sections and at all depths.

- H_1: Crevice sizes will vary across all sections and all depths with the shallow sections having the greates crevice sizes

Methods

Crevice size transects

Fifty meter transects for crevice size were conducted at three depths, Shallow (4m-5m), Intermediate (13m-14m) and Deep (21m-22m) within each section of the runway (Section 1-NER-1, Section 2-NWR-2, Section 3-SWR-3, Section 4-SSR-4, Section 5-SER-5) except, Section1-NER-1 and Section 5-SER-5, where there wasn't depth for a deep transect. In each section and at each depth, crevice size was measured at twenty random points along a 50 meter transect. A PVC pipe, 1.5m long, was used to measure the width and the depth of the crevice. If a random transect point occurred on a concrete dolo, granite boulder or flush to the artificial reef surface, crevice size was listed as zero. For points that landed on an actual crevice, a de facto area was calculated for the crevice by multiplying the length x depth, with the understanding this was an estimate given the complex 3D properties of a crevice. The crevices along the runway, specifically in the concrete dolos areas make for complex crevices and caverns, making an precise crevice size measurement very difficult.

Figure 3. Concrete dolos (concrete structure at the top of the image) are used to stop erosion and displace wave energy. Daniel Qualls releases a tagged hawksbill.

Benthic Video Transects

Benthic video transects were taken in the spring of 2014 to deduce benthic community species composition. Video transects occurred at three depths; Shallow (3m-4m), Intermediate (13m-14m), and Deep (21m-22m) in each of the five sections (Section 1-NER-1, Section 2-NWR-2, Section 3-SWR-3, Section 4-SSR-4, Section 5-SER-5) of the runway except Section 1-NER-1 and Section 5-SER-5 which were not deep enough to conduct surveys (Figure 4 below).

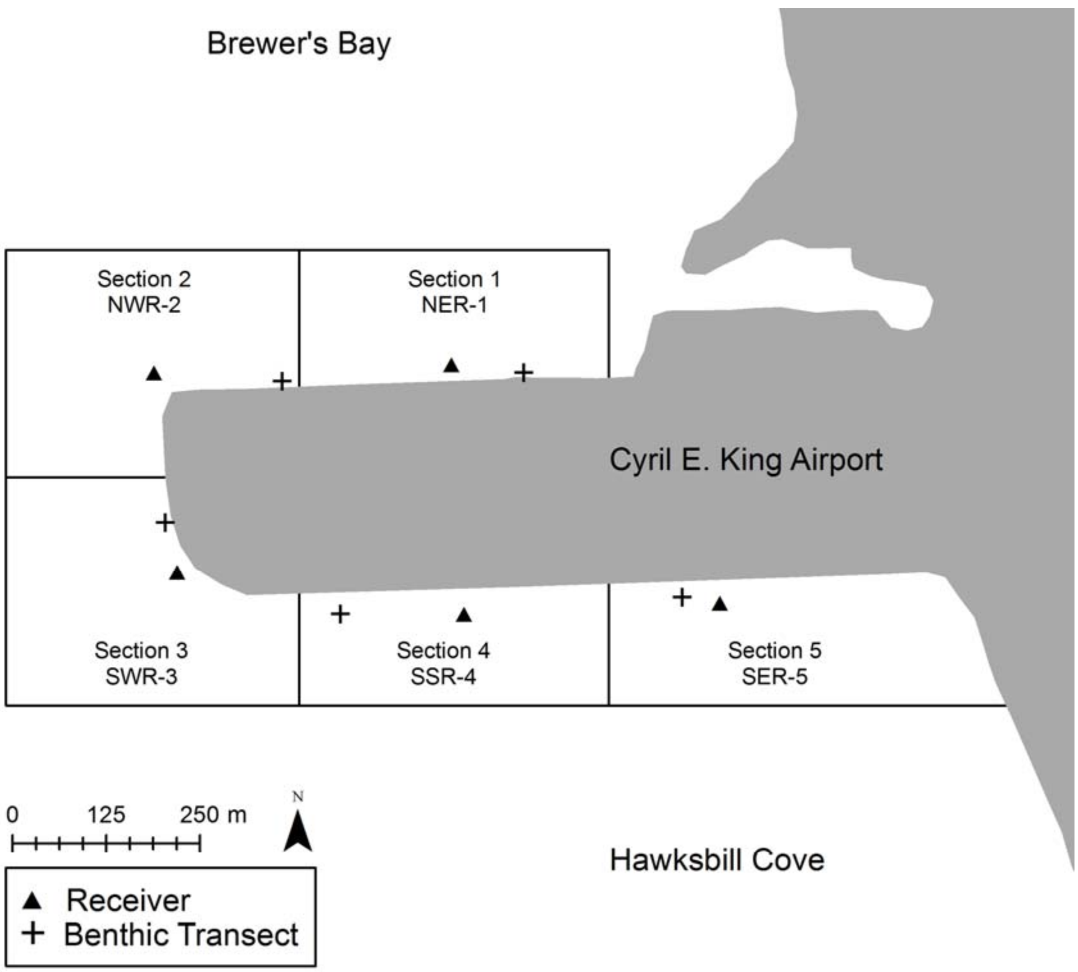


Figure 4. The marine habitat of the CEK runway divided into sections with the placement of acoustic receivers and location of benthic transect.

Each video transect was 100 meters in length. A GoPro was attached to a PVC pipe wand making the distance between the GoPro and the bottom of the benthic habitat a uniform distance in each sectional recording. A total of 13 video transects were recorded and analyzed. All 13 video transects were then cut into 9 smaller videos. Each section was analyzed by randomly selecting of 5 out of the 9 smaller videos and the program CPCe (Coral Point Count with excel extensions) (Kohler and Gill, 2006).

Acoustic Habitat and Range Testing

Five Vemco acoustic receivers were used for this study (Vemco Canada VR2W-69kHz). Each receiver was attached to a rebar spike by plastic zip ties, and then anchored by a cinder block. Concrete was added to the holes in the cinder block to secure the rebar spike and to add additional weight and stability. All receivers were placed on the existing lip of the marine habitat of the CEK runway that exists at approximately 15-16m. Vemco receivers are advertised as having a 300-meter detection radius. Six Vemco acoustic tags (two V13/four V16) were used for this study with two tags, one V13 and one V16, being able to transmit their depth. V13 and V16 have different transmitting signal strengths. For the marine runway habitat, one receiver was placed on the north side, one off each the corner on of the runway, and two on the south side of the runway in an effort to create maximum acoustic coverage of the artificial marine runway habitat (figure 5 below).

Figure 5. The exact placement of the 5 acoustic receivers in Brewer's Bay and Hawsbill Cove on the island of St. Thomas, US Virgin Islands.

The acoustic receivers were placed on the lip, approximately 15m-16m deep, between sections of large concrete dolos and granite boulders, and the rock rubble that reaches the bottom of the habitat. The rationale being, this allows for the greatest spherical acoustic coverage taking into account the structural complexity of the habitat.

The range of detection for each receiver was determined using sentinel acoustic tags. Six tags, distributed between three buoy floats, were placed along the marine runway structure at different distances from each receiver (see figure 6 below). The three floats were constructed solely for the sentinel tag range testing. The floats were created using polypropylene rope; a white float buoy labeled 1, 2 or 3, and was anchored by a cinder block. Each float was 15-16 meters in length from the tip of the float to the bottom of the cinder block. This length allowed for an acoustic tag to be tested above and below the depth of the acoustic receiver. Float 1 had a V13D (depth gauge) at 20m and a regular V16 at 9 meters. Float 2 had two regular V16 tags at 20m and 10.5m. Float 3 had a V16D (depth gauge) at 20m and a regular V13 at 11m. Range testing was conducted over a two-week period in February 2015. Each float was placed and left for 48 hours. Upon the completion of the 48 hours the floats were retrieved and moved to the next location in the testing process.

Figure 6. Aerial image the CEK runway, with acoustic receivers and the location of each sentinel range testing deployment.

Kayak Range Testing

To complement the sentinel acoustic tag range testing data collection, a kayak acoustic range testing session on February 22nd, 2015 at 3:02pm was performed. The path and detections from each receiver can be seen below in figure 7:

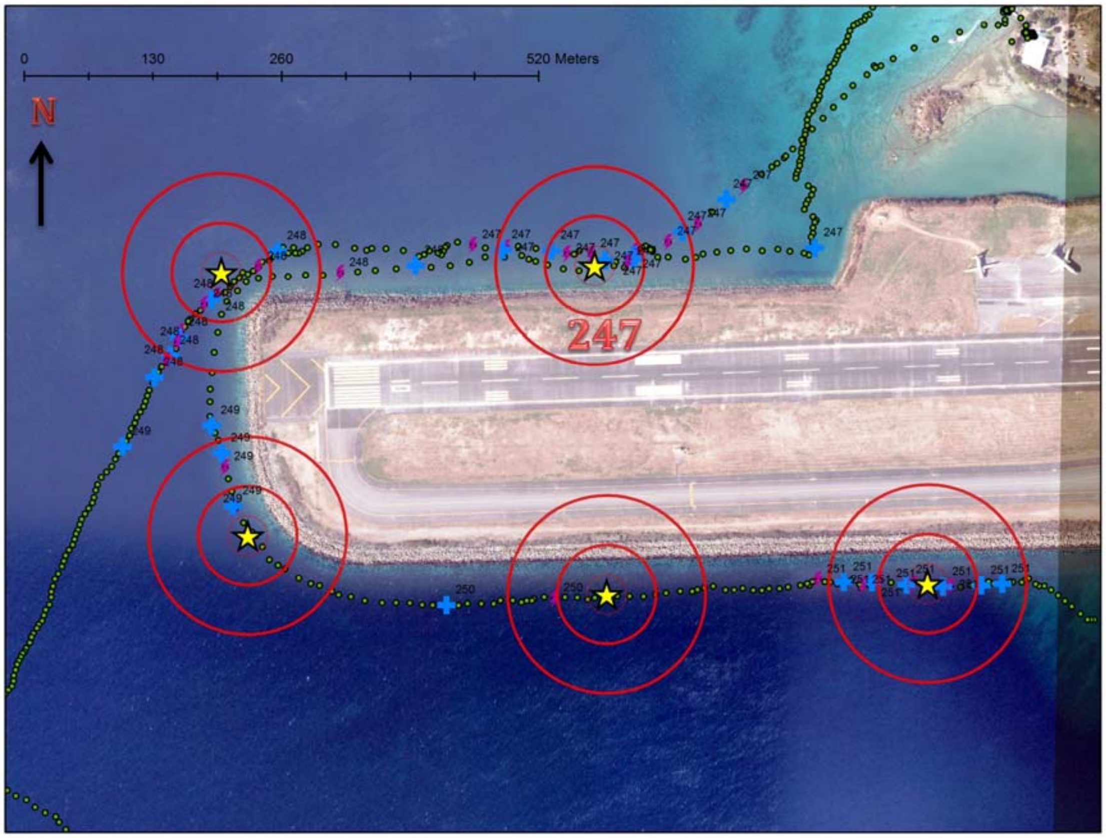


Figure 7. The kayak acoustic range-testing path is displayed with small green circles. Registered detections are by V13 tags are displayed with purple lightning bolts while V16 registered acoustic detections are blue crosses.

Each small green circle is the path of the kayak with each circle being a GPS point recorded. GPS points were recorded every 15 seconds for a total of 714 GPS points. The V13 and V16 acoustic tags with the depth transmitters were attached to a polypropylene rope and anchored by a small weight. The rope was then attached to kayak and pulled through the path visible in figure 7. The V16 detections are shown as blue crosses while the V13 detections are purple lightning bolts. Each blue cross or purple lightning bolt is marked with the number of the receiver their signal was recorded on. Each receiver is marked with a yellow star, the receiver 247 is the receiver to the northeast of the runway and then in order going west then south then east are receivers 248, 249, 250 and 251.

Turtle Acoustic Data Examination

Six hawksbill turtles received acoustic transmitters for this study and each turtle was examined for the following information; total number of detections, total detections by receiver, percent detections by receiver, total days detected, number of possible days detected (turtles in this study began transmitting at different days due to capture dates), percentage of days detected, consecutive days detected, consecutive days detected at a specific receiver, average hours spent per day detectable, average hours spent per day at a specific receiver, day detections, night detections, and percentage detections day versus night.

Two turtles, Turtle-MM and Turtle-TD transmitted depth data with each detection. Those detections were also broken down into maximum day depth and maximum night depth, number of detections at 0m (breathing), detections at 0m (breathing) by receiver, nighttime detections at 0m (breathing) by receiver, and most common night detected depth.

Sample Size, Six Turtles

All six turtles were captured by hand. Acoustic transmitters were attached to their marginal carapace scutes by marine putty and fastened with plastic covered wire utilizing two small holes drilled into the marginal scutes. All turtles acoustically tagged are listed in the chart below. Turtle-MM and Turtle-TD have the letter "D" in their Tag Type and Signal Strength column to indicate their tags recorded their depth.

Table 1. Summary of the six turtles with acoustic tags. Asterisks denote a tag with a depth transmitter.

Turtle #	Date Acoustically Tagged	Length (cm(tip))	Weight (kg)	Tag Type and Signal Strength	Size Class
CR	02/22/2015	47.5	10.9	V16 (150dB)	Juvenile
MM	04/08/2015	48.3	10	V16D*(150dB)	Juvenile
SP	05/16/2015	65	27.8	V16 (150dB)	Sub-adult
SC	02/21/2015	45	9.1	V16 (150dB)	Juvenile
TT	02/21/2015	28.1	1.4	V13 (147dB)	Juvenile
TD	02/21/2015	22.4	1.4	V13D*(147dB)	Juvenile

Total Detections/Total Detections by Receiver/Total Detections by Receiver as a Percentage-total detections, total detections by receiver, and total detections by receiver as a percentage is the first step in examining the data to determine habitat usage. Total detections are the total number of registered detections by all the receivers used in this study during the eligible dates from each tagged animal. Total detections by receiver are the number of detections each receiver recorded throughout the study. Total detections by receiver as a percentage is the percentage of detections based on each receiver.

Total Days Detected-total days detected was examined to determine if at a minimum, a single detection per day was recorded by a receiver in the habitat because it would mean spending time in the habitat was a daily occurrence. This was also calculated as a percentage to determine how important the habitat area is to the turtle. The lower the percentage the more likely the turtle doesn't utilize this habitat.

Consecutive Days Detected & Consecutive Days Detected at a Specific Receiver-these calculations were used to determine if a turtle used the entire habitat or a specific part of the habitat every single day during the study. The number of consecutive days and number of days at a specific receiver demonstrates a repetitive behavior for the turtles.

Average Hours Spent per Day in Habitat and at a Specific Receiver- total detections is one way to determine habitat usage, but issues can arise when it is the only method for calculating habitat usage. Another is using total detections to calculate an estimate of hourly usage. A single detection was adjusted to the value of 15 minutes, two detections adjusted to 30 minutes; three detections adjusted to 45 minutes and four detections or greater were adjusted to one hour of residency at the specific receiver.

This helped calculate time spent in the habitat and time spent at a specific receiver in an effort to know the average time spent in the habitat per day, and average time spent at a particular receiver.

Day Detections and Night Detections and at a Specific Receiver-day and night detections were calculated using the US Naval Observatory sunrise/sunset times for this GPS location (Charlotte Amalie, US Virgin Islands). The detections were then separated into day and night depending on the date and time of day the detection was recorded. This was done to determine day and night behavior as it relates to their usage of the habitat.

Depth Detections-depth detections were examined to look at habitat usage in a third dimension. The data was examined for maximum and minimum depth recorded as well as the most recorded depths, with a special emphasis on 0 meters because it meant the animal was breathing at the surface.

Dot Density Maps

The dot density maps from July 23rd to November 30th will be used to support individual turtle conclusions. This dot density maps use an additional two months of data collected after the last receiver data download for this study. Each green dot is 30 detections and their placement within the detection circle receiver radius is random, it is not the animal's exact location. (For example, using figure 35. (pg. 61), which is the dot density map for Turtle-MM, there are a few green dots in some of the most northern receivers with some green dots in their circles. Those green dot are not the exact location of Turtle-MM, each dot is placed at random and represents 30 total detections within the detection range of the individual receiver)

Results

Crevice Size

Due to the abundance of zeros in the data set (crevices that did not have a measurement) any attempt to transform the data to correct for normality and equal variances failed. The data was then transformed to averaged rank data and a non-parametric nested ANOVA was run with sections, nested in depth to test for a difference amongst depths and sections. The results of the non-parametric nested ANOVA of the three depths and 13 sections measured along the CEK runway yielded a significant difference between the Shallow section of the runway and the remaining two depths, Intermediate and Deep (DF 2, F Ratio 17.2831, (Depth) P <.0001). There was also a significant difference between the 13 sections across all depths (DF 10, F Ratio 4.7348, Section(Depth) P<.0001).

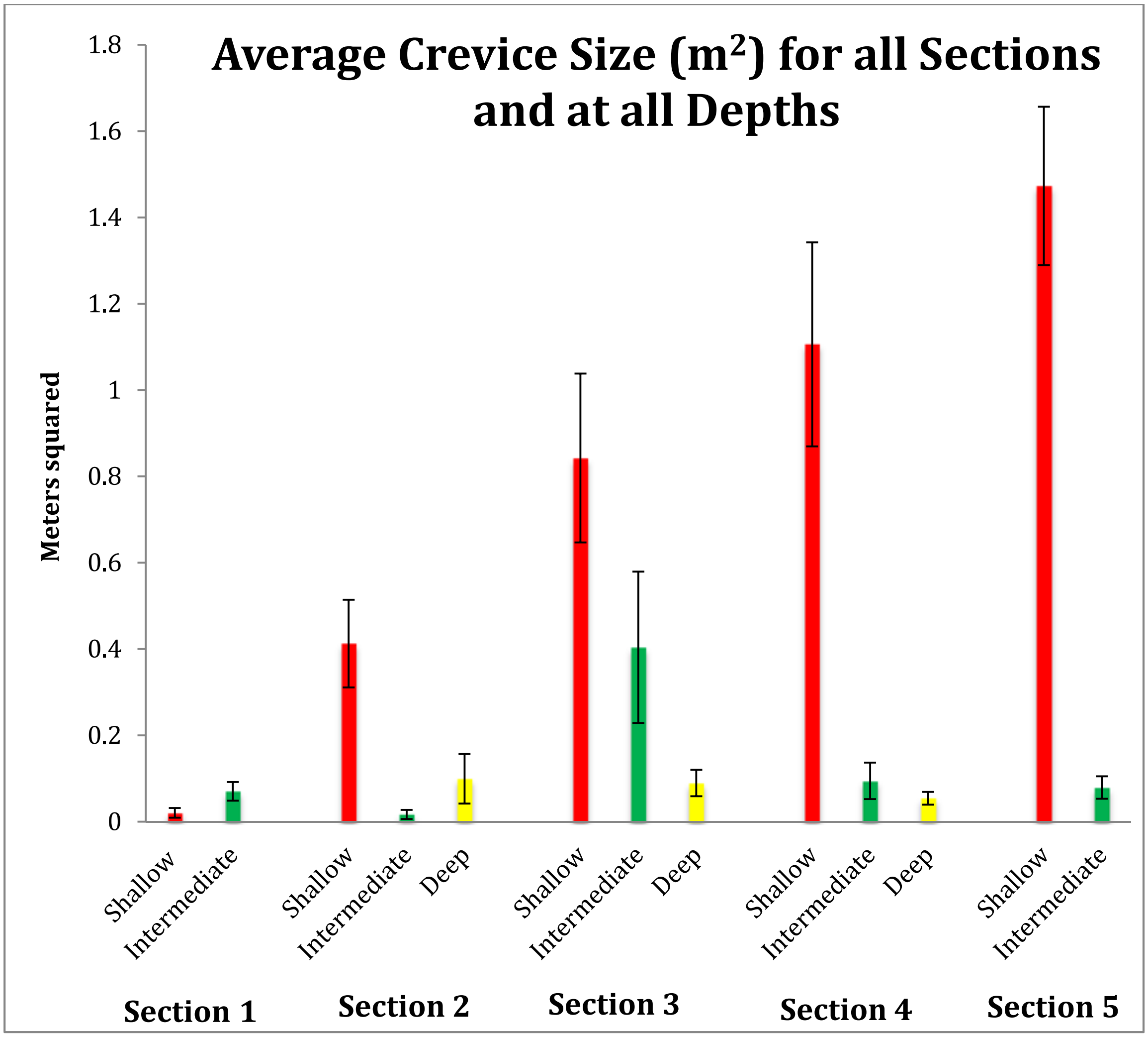


Figure 8. Average crevice size for all sections and at all depths in meters squared

The average crevice size measurement in the Shallow section is 0.77 meters squared while the Intermediate (.13m^2) and Deep (.08m^2) were statistically significantly less (DF 2, F Ratio 17.2831, (Depth) P <.0001).

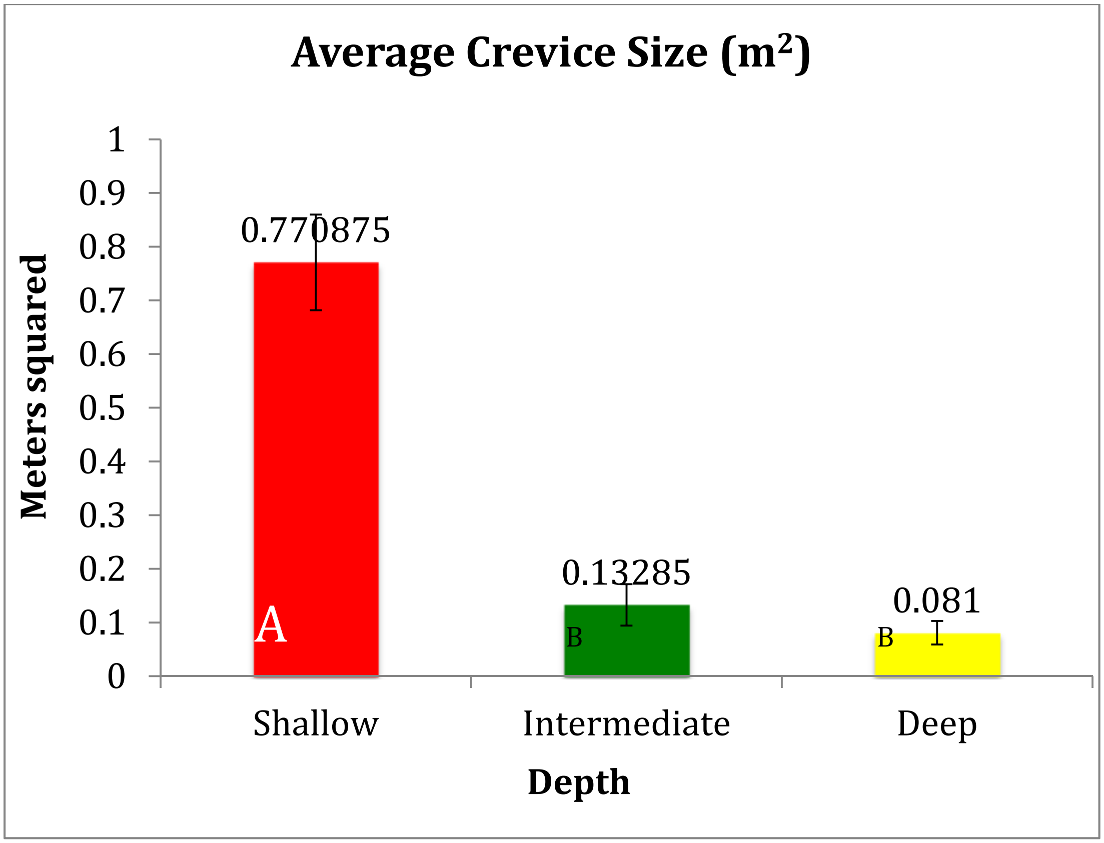


Figure 9. Average crevice size at each depth.

Due to the complexity of measuring three-dimensional crevices and quantifying them in a two dimensional manner, any crevice, measuring 1.5 meters by 1.5 meters crevice or greater was given a “maximum crevice” designation. This was calculated because some crevices were actually much larger than could ever be quantified using this technique but should be accounted for to show the difference in abundance of “maximum crevices” size per depth and sections. The Shallow sections had 19 “maximum crevices” while the Intermediate had two and Deep, had zero.

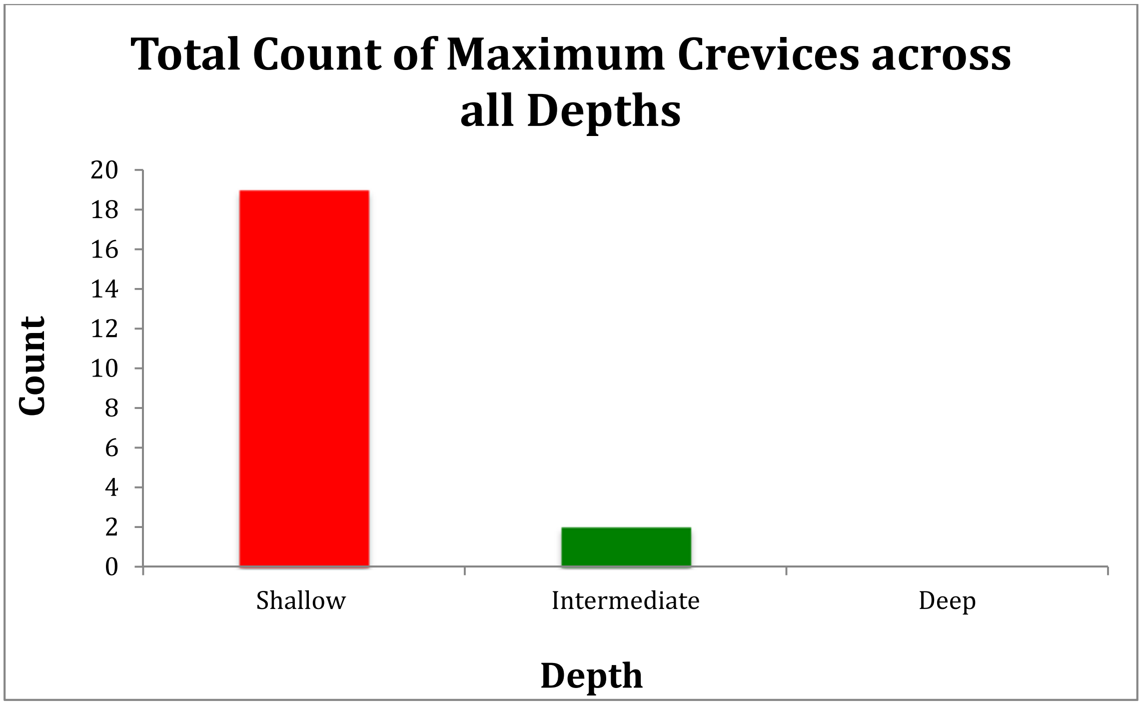


Figure 10. Total count of maximum crevices across all depths.

The non-parametric nested ANOVA on the ranked crevice size data did show a statistically significant difference between sections. The Shallow sections of the CEK runway are of consequence because of their construction. The Shallow depth was significantly different from the Intermediate and Deep depths and had 19 maximum crevices and in the nested ANOVA (Section(depth)), Shallow sections 2,3,4 and 5 (NWR-2, SWR-3, SSR-4, and SER-5) all shared a letter in the matching letter report (Appendix 1 and 1a).

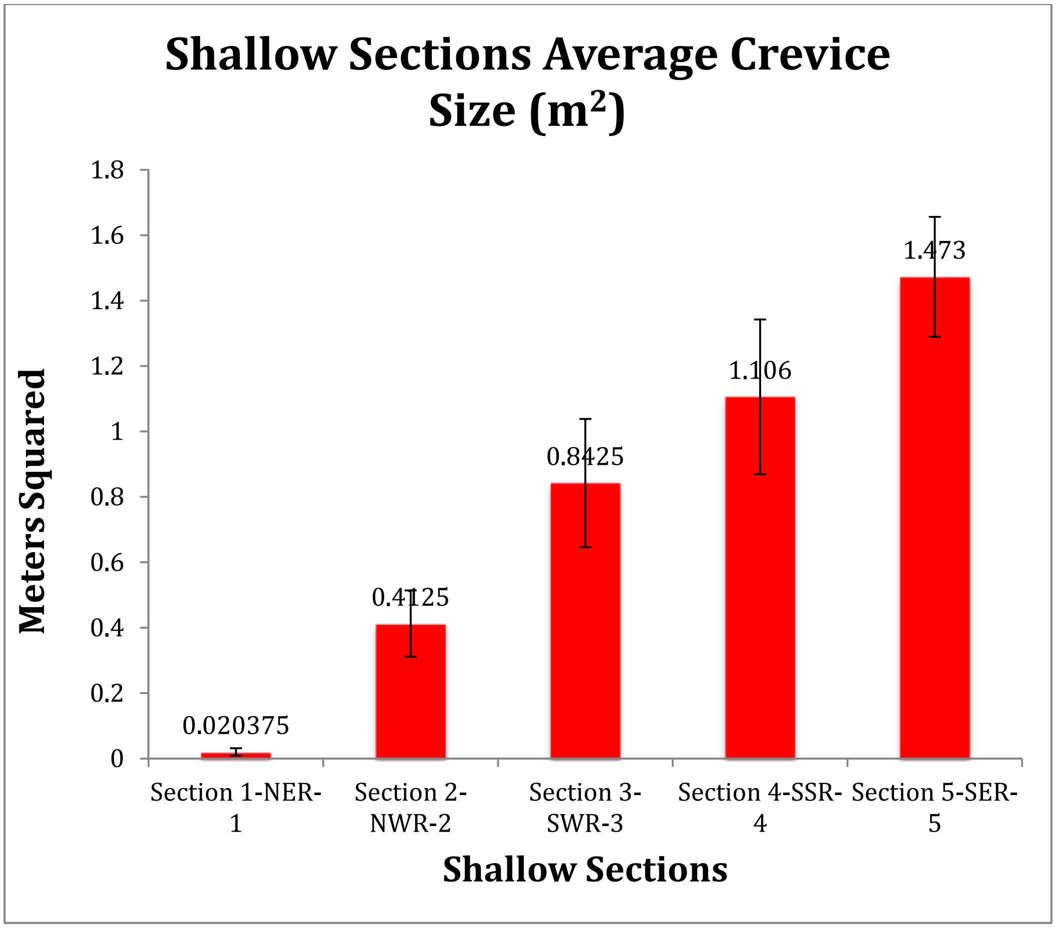


Figure 11. Shallow sections average crevice size in meters squared.

Crevice size increased from Shallow Section 1-NER-1 to Shallow Section 5-SER-5. Average crevice size area calculated in Shallow Section 1-NER-1 is 0.02m^2 while the largest average crevice size area was found in Shallow Section 5-SER-5 of the runway with 1.47m^2. The number of "maximum crevices" was calculated again between each shallow section. Shallow Section 4-SSR-4 and Section 5-SER-5 were tied with 8 maximum crevices, the tip (Shallow Section 3-SWR-3) had 3 maximum crevices and Shallow Section 1-NER-1 and Shallow 2-NWR-2 had zero maximum crevices.

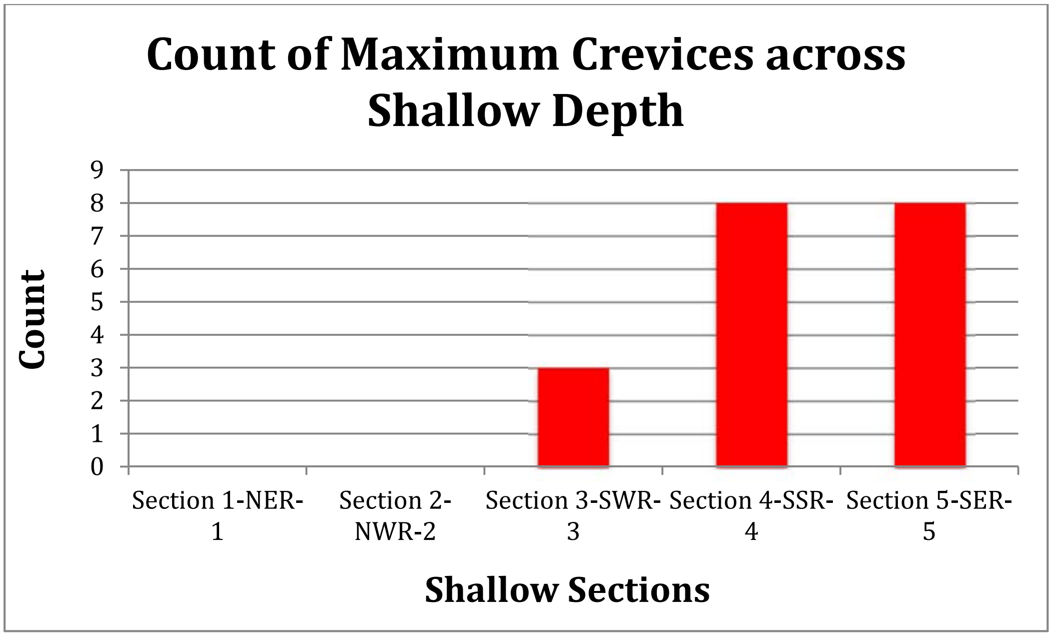


Figure 12. Total count of maximum crevices across the Shallow depth.

Benthic Composition

Coral Results

The coral data did not meet the assumptions needed to run an ANOVA(normality and equal variances) and needed a Log transformation in order to be suitable for statistical analysis. After the Log transformation it was concluded there wasn't a significance of depth on the coral cover but there was significant result detected between sections across depth (DF 2, F ratio 14.2561, $P<.0001$). The sections with the highest average coral cover were Shallow-Sections 3-SWR-3 and Shallow 4-SSR-4, with an average coral cover near 20%. In general, the observation made during swimming surveys is there is higher coral cover in the Shallow-Section 3-SWR-3, Shallow Section 4-SSR-4, and Shallow Section 5-SER-5 with coral cover declining with depth; however, there are some subtle nuances worth noting as this habitat is not homogenous. Section 1-NER-1 and Section 2-NWR-2, both Shallow and Intermediate consist primarily of barren rock rubble, with little coral cover, which explains why Deep Section-2-NWR-2 has more coral cover than the other 4 aforementioned sections. Section 2 NWR-2 is the "transitional area" of the marine runway habitat as it changes from rock rubble to concrete dolos, which explains the subtle increase in coral cover from Section 1 to Section 2. Two of the Intermediate Section 3-SWR-3 and Section 5-SER-5, registered coral cover greater than 10%. Intermediate Section-5 actually begins on the runway habitat but partially on the adjacent reef, which explains the more abundant coral cover. As a whole, visual observations confirm higher coral cover in the areas of the runway that contain concrete dolos, with *Siderastrea siderea* the most observed coral, and when the depth changes, flatter *Agaricia lamarcki* corals are observed most commonly.

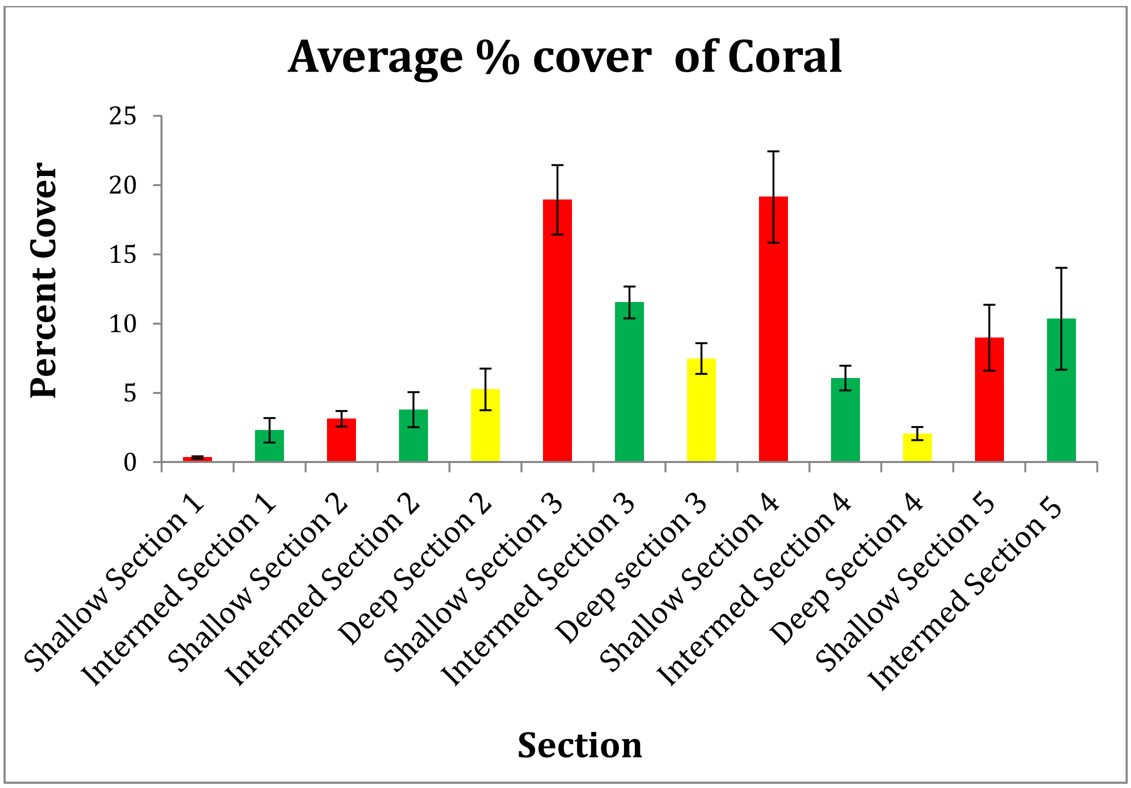


Figure 13. Average percent cover of coral across all sections and at all depths.

Sponge results

The sponge data also did not meet the assumptions needed to run a one way nested ANOVA and had to be transformed. A Log transformation allowed for the data to meet the assumptions and a one way nested ANOVA was performed. The results from the ANOVA found a statistical significance of sponges based on depth (DF 2, F ratio 78.57, P<.0001), and sections across depths (DF 10, F ratio 11.131, P<.0001). The three sections with the most average sponge cover are Deep Sections 1-3 (Section 2-NWR-2, Section 3-SWR-3, and Section 4-SSR-4). The presence of sponge cover increases as depth increases. In addition to the Deep sections containing the most sponge cover the matching letter report identifies Shallow Section 1-NER-1 and two Intermediate Sections (Section 2-NWR-2 and Section 5-SER-5) as a single letter group (appendix 3 and 3a). The sections grouped together by the matching letter report that had the lowest sponge cover were Shallow Sections (Section 2-NWR-2, Section 3-SWR-3, Section 4-SSR-4, and Section 5-SER-5). The results from this analysis are similar to what is observed in swimming diving turtle surveys, with very little sponge presence found in the Shallow Sections-2-5 (NWR-2, SWR-3, SSR-4, and SER-5) and an increase in sponge observations as the depth increases.

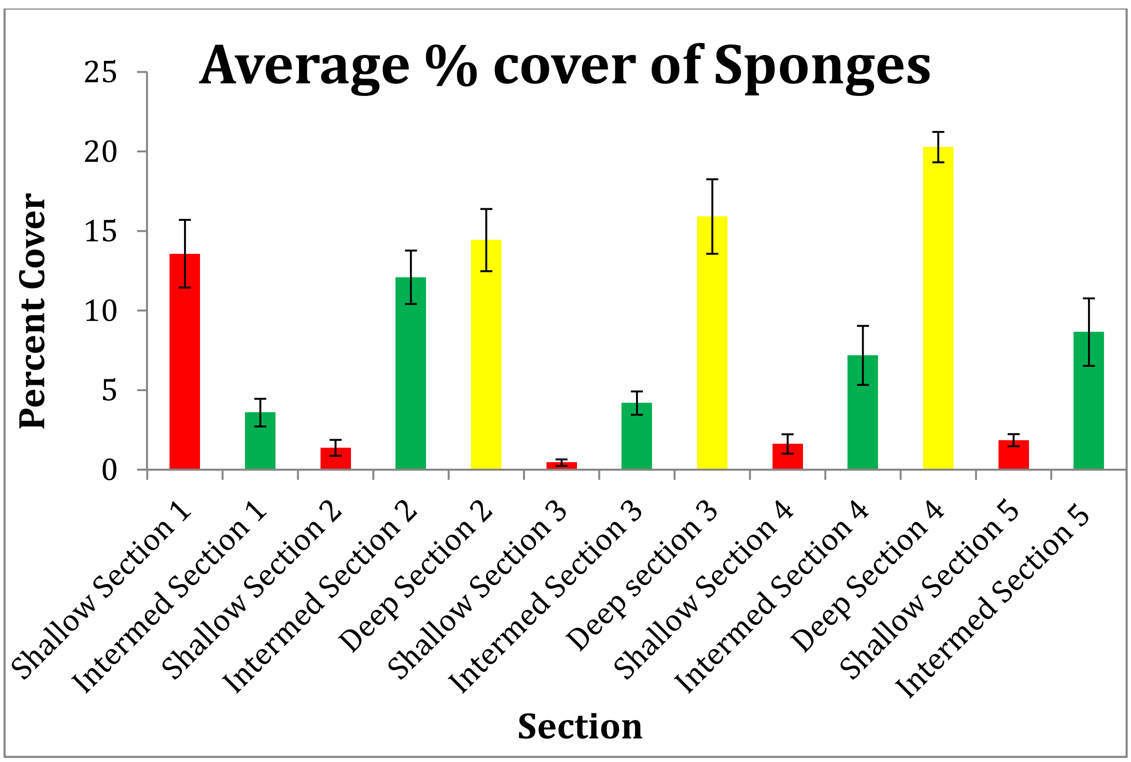


Figure 14. Average percent cover of sponges across all sections and at all depths

Coralline Algae Results

Coralline algae data did not meet the assumptions of an ANOVA and would only do so once the data was transformed to averaged ranked data. This occurred because the presence of coralline algae was detected in a percent cover above or near 20% in Shallow Sections 3-5 (SWR-3, SSR-4, SER-5) but in small percentages, if at all, in the remaining 10 sections. Once the data was transformed an ANOVA was performed and there was a significance of depth (DF 2, F ratio 28.0485, P<.0001) , and sections across depths (DF 10, F ratio 9.0638, P<.0001). Each depth was significantly different from each other (appendix 4 and 4a). The graphed average coralline algae cover shows the Shallow Sections-3-5 (Section 3-SWR-3, Section 4-SSR-4, Section 5-SER-5) with the highest average coralline algae cover. Coralline algae which may not be obvious during swimming surveys was detected in large percentages during the video transects.

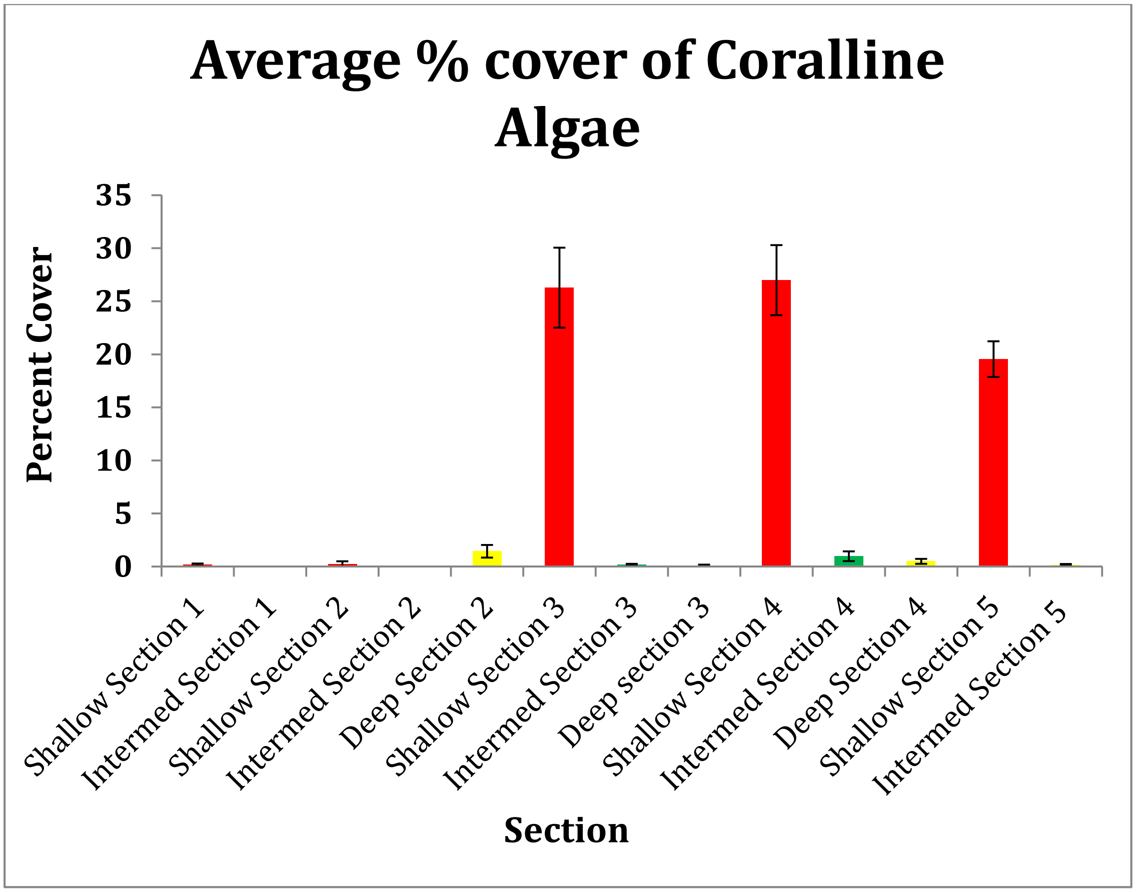


Figure 15. Average percent cover of coralline algae across all sections and at all depths.

Macro algae results

Macro algae data did not meet the assumptions of ANOVA and had to be transformed. An ANOVA was performed on the average ranked data. The results found a significance of depth (DF 2, F ratio 113.3175. P<.0001), and sections across depth (DF 10, F ratio 6.7736, P<.0001). The depth results determined a significant difference between Shallow, and the Intermediate and Deep depths with an increase in percent cover of macro algae as the depth increases. The matching letter report for the analysis of individual sections show the Shallow sections are their own group with the Intermediate and Deep sections being more similar in percentage cover of macro algae (appendix 5 and 5a). The statistical analysis supports what is observed visually; macro algae cover clearly increases as the depth increases and is considerably noticeable as you reach maximum depths along the runway habitat.

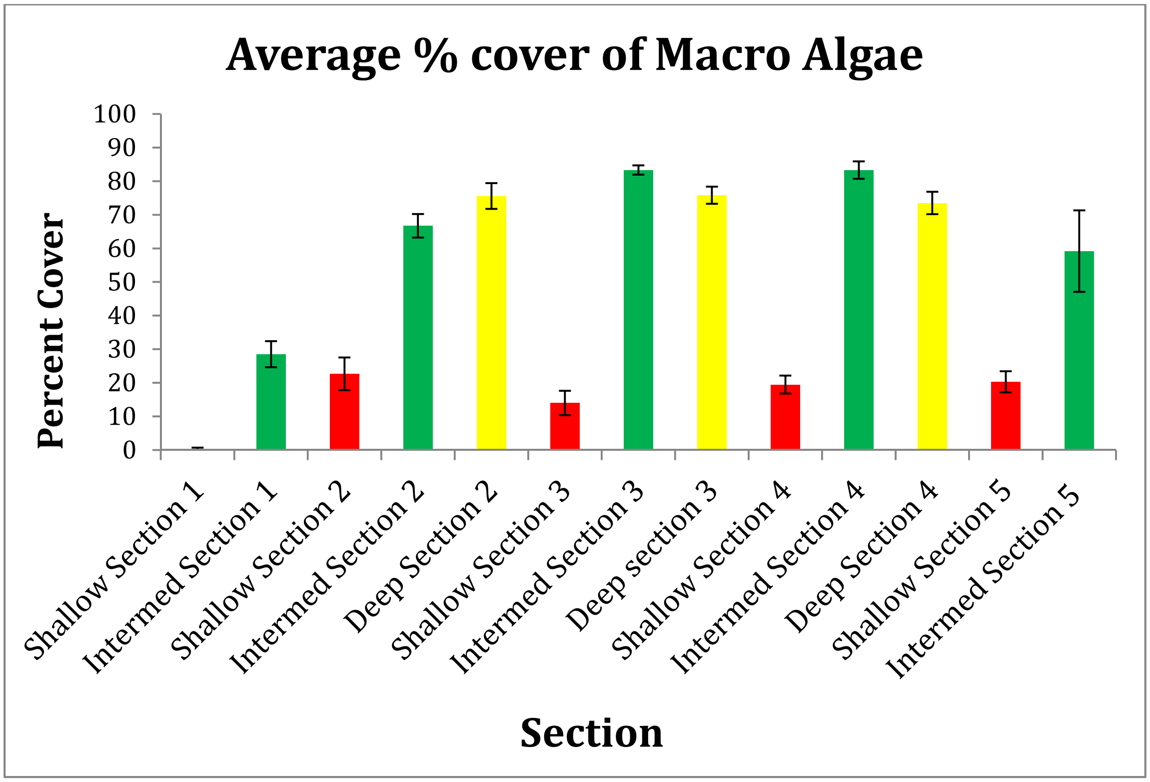


Figure 16. Average percent cover of macro algae across all sections and at all depths.

Dead Coral w/Turf Algae

The DCA (dead coral with turf algae) data did not meet the assumptions on ANOVA and had to be transformed. An ANOVA was performed on the average ranked data. The results show a statistical significance between depths (DF 2, F ratio 197.1394, P<.0001), with each depth being statistically different from each other. There was also a statistical significance of sections across depths (DF 10, F ratio 18.8191, P<.0001). The graphed data, per sections and depth, shows Deep Sections 2-4 and Intermediate Sections 3-4 are statistically different than any other depth or sections, in that they had very little DCA (appendix 6 and 6a). The remainder of the matching letter report puts the remaining 5 Shallow sections and 3 Intermediate sections into

4 different groups, with some sharing matching letters. The matching letter report matches what is observable within the habitat. The Shallow sections are more likely to have DCA than Intermediate or Deep, but Intermediate has the next highest DCA cover, with Deep possessing the least.

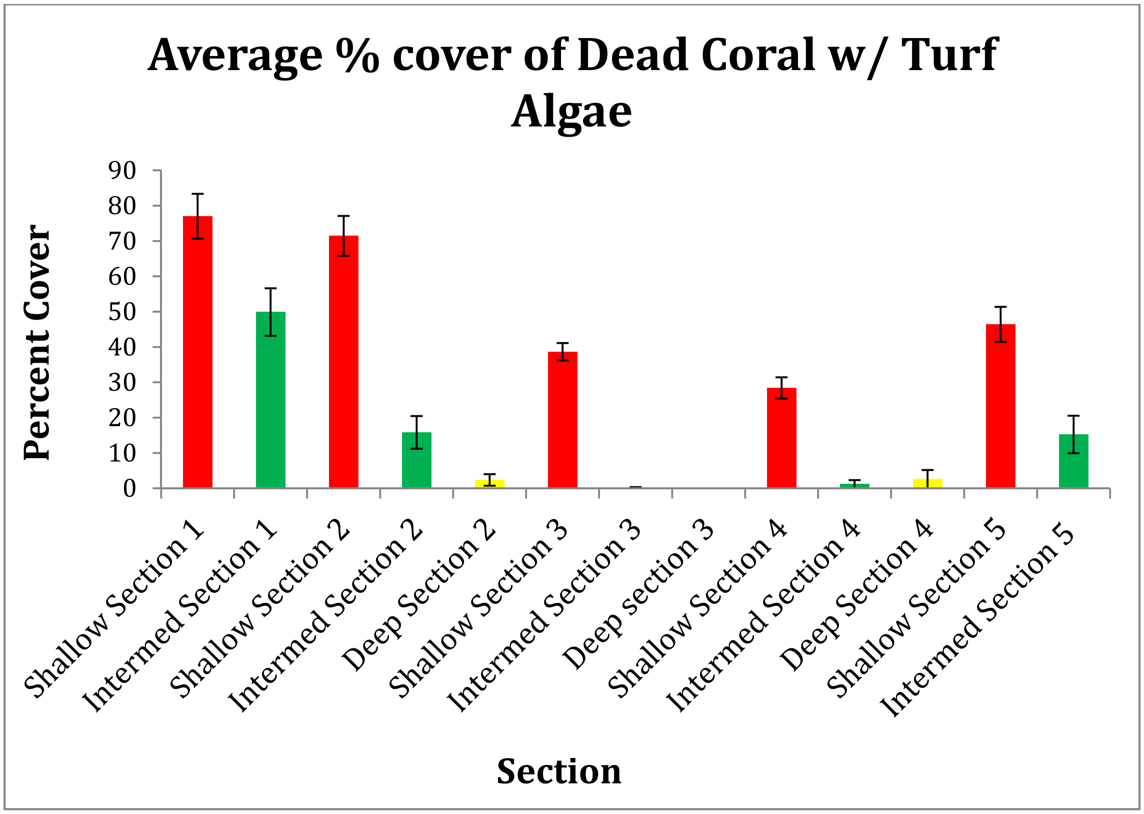


Figure 17. Average percent cover of DCA across all sections and at all depths.

Gorgonians

Gorgonians, while visually observed along the runway habitat, were only recorded in 5 of 13 sections and at a presence of 1% cover in only one of those 5 sections detected. This led to no statistically significant results for gorgonians based on depth or section.

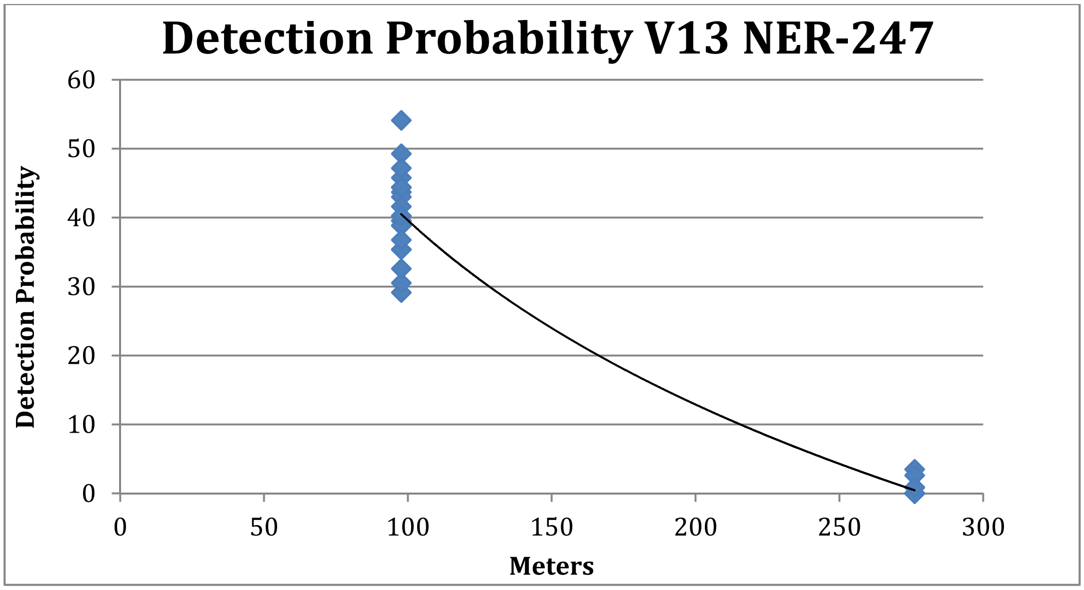
Zooanthids

Zooanthids, while difficult to visually observe along the runway habitat, were recorded in 5 of 13 sections but never at a presence of greater than 1% cover in any of those 5 sections detected. This led to no statistically significant results for zooanthids based on depth or section.

Range Testing

The five acoustic receivers were range tested and each receiver had its own detection range analyzed. Figure 6 is below as a reminder of the receiver stations and the sentinel range testing positions.

Section 1-NER-1 (Receiver 247)-is located inside the southern part of Brewer's Bay but is the most northwestern receiver in this study. It is also the receiver located closest to the mangrove lagoon inside Brewer's Bay. Using an 80% detection probability for this receiver would put the range of detection at 35m for the V13 tags and 42m for the V16 tags. Using a 50% detection probability increases the range of the V13 and V16 tag detection to 75m and 81m, respectively.



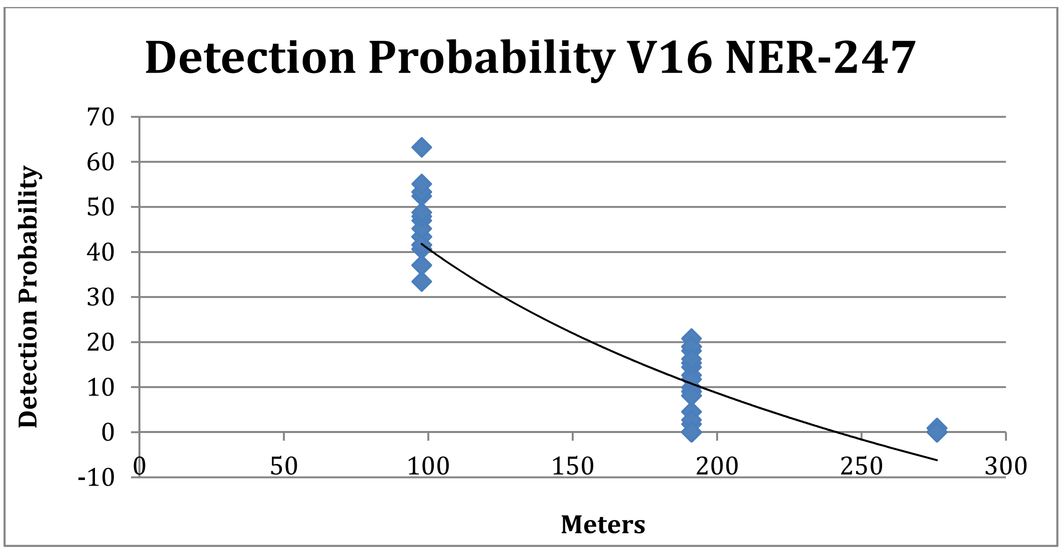
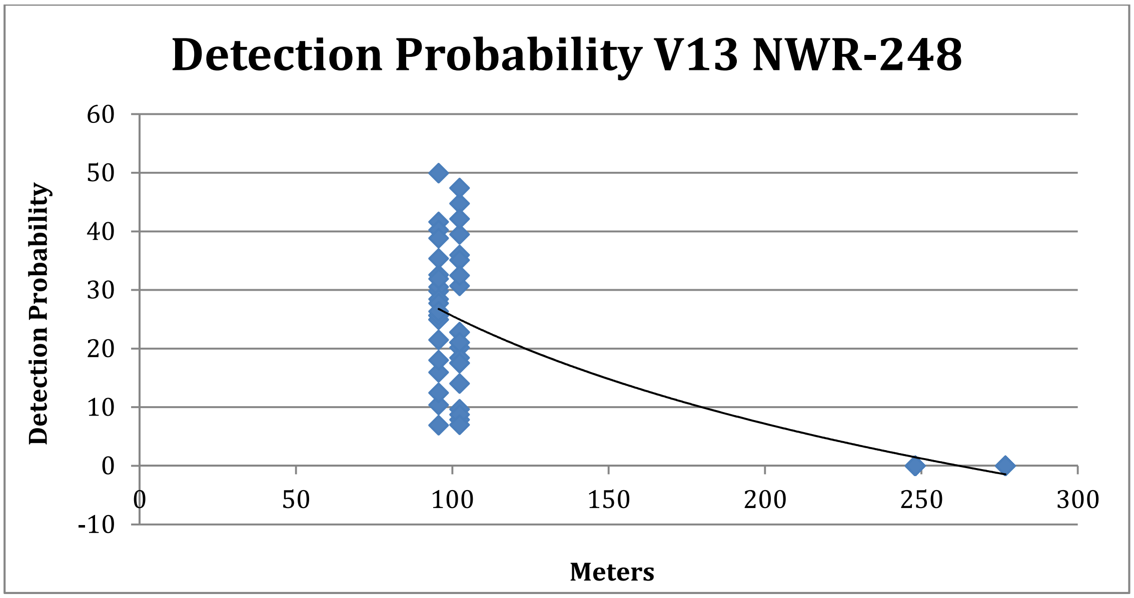


Figure 18. Graphs of both detection curves for Section 1-NSR-1 (Receiver 247) (V13 and V16)

The kayak range testing of Section 1-NER-1 (receiver 247) recorded detections of the V13 and V16 tags. Detections by the receiver 247 from the V13 tag increased as the distance between the tag and receiver decreased. Detections of the V13 tag were recorded as far away as 115m, 125m, and 171m. The receiver 247 also increased in detections from the V16 tag as the distance between tag and receiver diminished. Detections of the V16 tag were recorded as far away as 152m and 224m.

Section 2-NWR-2 (Receiver 248)-is located on the northwestern tip of the CEK runway. This receiver sits on the edge of the Brewer's Bay marine habitat. Using an 80% probability detection would put the range of this receiver at 13m for the V13 tag and 48m for the V16 tag. Using a 50% detection probability increases the range of the V13 and V16 tag detection to 39m and 86m, respectively.



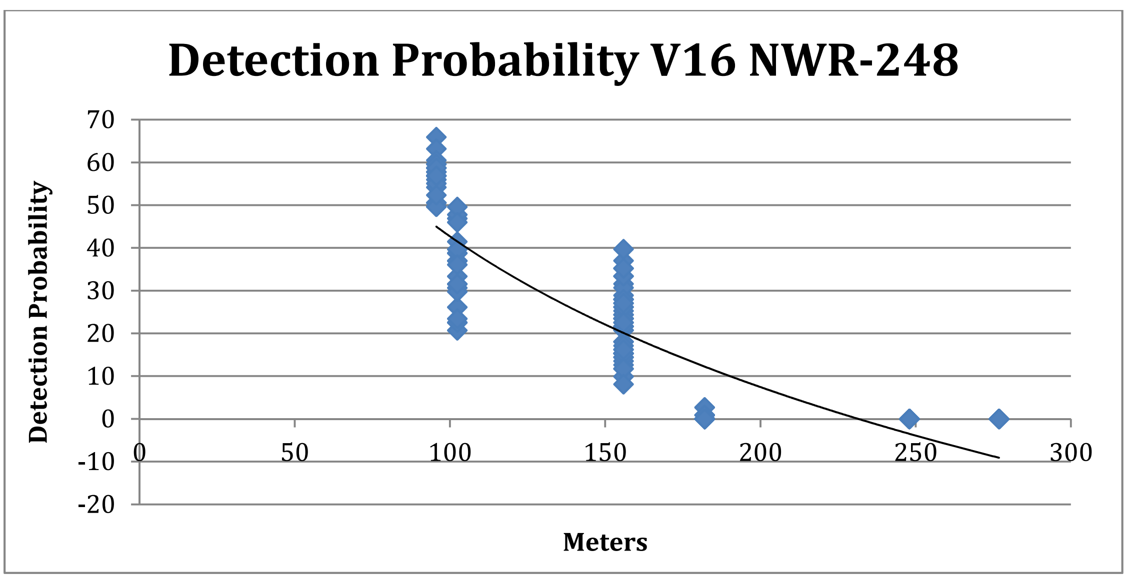
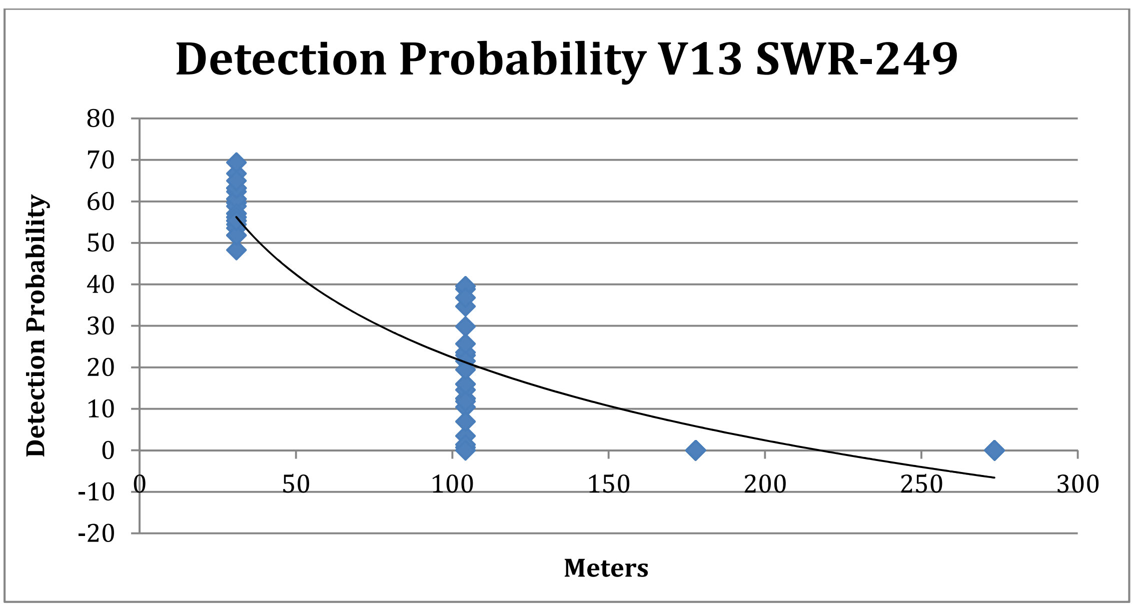


Figure 19. Graphs of both detection curves Section 2-SWR-2 (Receiver 248) (V13 and V16)

The kayak range testing of Section 2-NWR-2 (receiver 248) recorded detections of the V13 and V16 tags. Detections by the receiver 248 increased as both the V13 and V16 tag came closer in proximity and were out of Brewer's Bay and along the west side of the runway facing the open Caribbean Sea. Detections by receiver of the V13 tag were recorded as far away as 120m. Detections by the receiver for the V16 tag were recorded at a maximum distance of 128m and 197m.

Section 3-SWR-3 (Receiver 249)-is located on the southwestern tip of the CEK runway. This receiver sits on the edge of the Hawksbill Cove habitat. Using 80% probability detection would put the range of this receiver at 13m for the V13 tag and 17m for the V16 tag. Using a 50% detection probability increases the range of the V13 and V16 tag detection to the 38m and 49m, respectively.



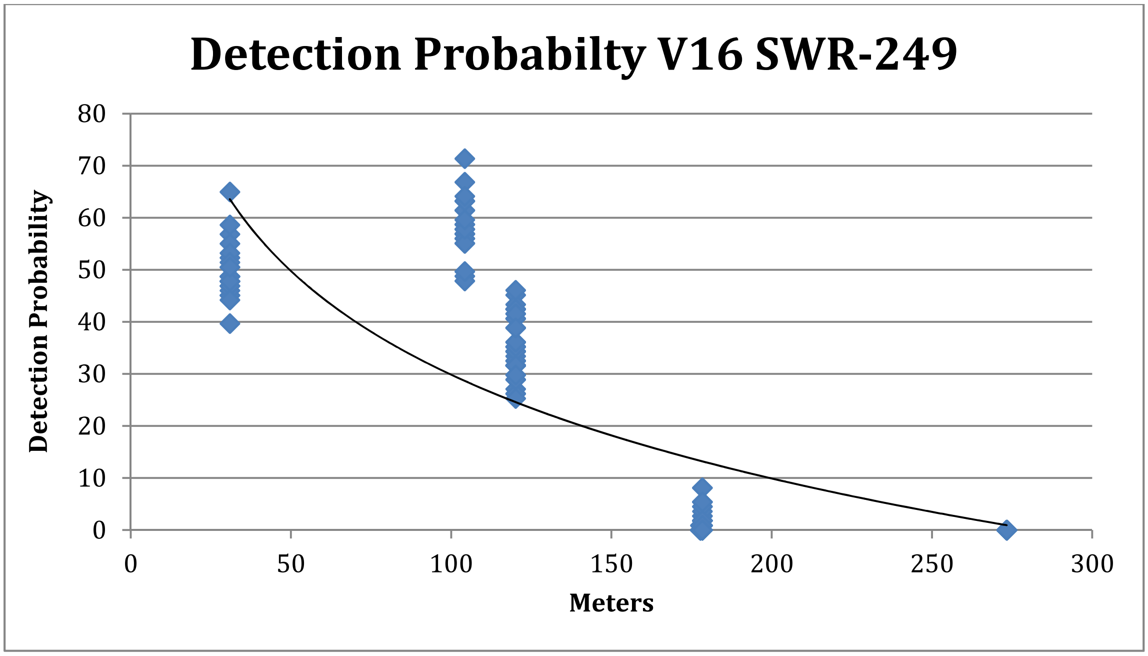
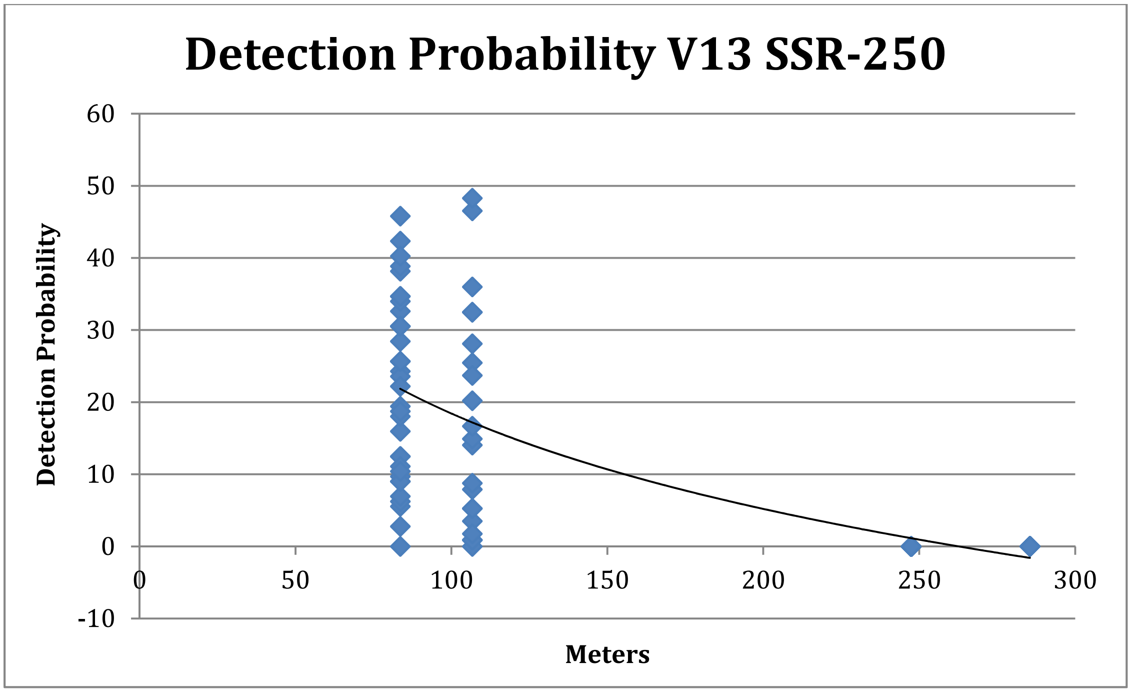


Figure 20. Graphs of both detection curves Section 3-SWR-3 (Receiver 249) (V13 and V16)

The kayak range testing of receiver 249 recorded detections of the V13 and V16 tags. Detections by the receiver 249 were non-existent from either tag V13 or V16 west of the receiver. Detections were only made north of the receiver on the west side of the runway. Detections by receiver of the V13 tag were recorded as far away as 70m. Detections by the receiver for the V16 tag were recorded at a maximum distance of 87m, 117m and 156m.

Section 4-SSR-4 (Receiver 250) -is located on the south side of the CEK runway in Hawksbill Cove. Using an 80% probability detection would put the range of this receiver at 4m for the V13 tag and 49m for the V16 tag. Using a 50% detection probability increases the range of the V13 and V16 tag detection to the 19m and 90m, respectively.



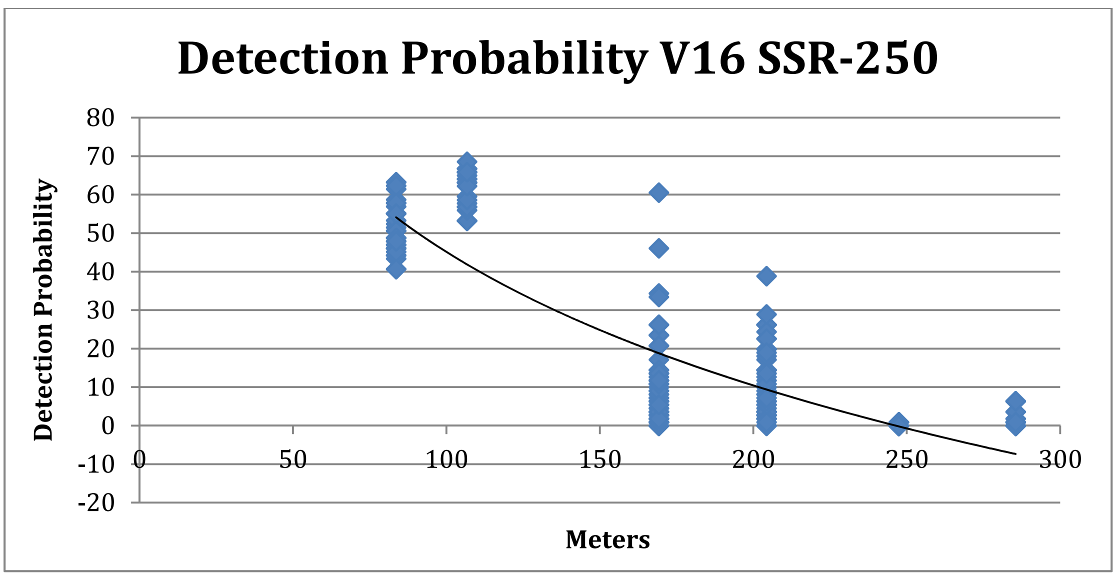
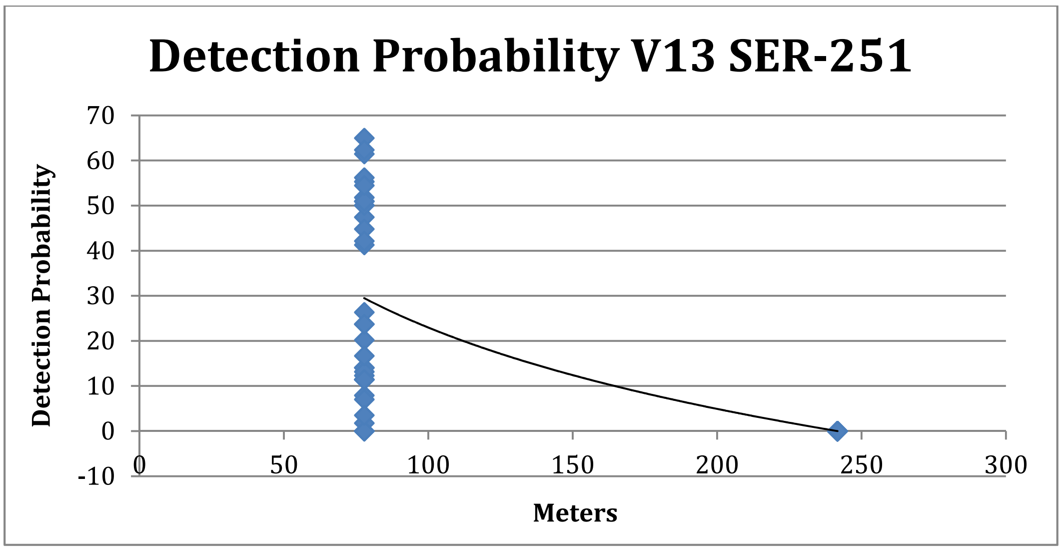


Figure 21. Graphs of both detection curves Section 4-SSR-4 (Receiver 250) (V13 and V16)

The kayak range testing of receiver 250 recorded detections of the V13 and V16 tags. Total detections by the receiver during the kayak range testing session totaled two, a single V13 detection, and a single V16 detection. The single detection by receiver 250 of the V13 tag was 51m in distance. The single detection by receiver 250 from the V16 tag was at a distance of 158m.

Section 5-SER-5 (Receiver 251)-is located on the south side of the CEK runway. This receiver is located the furthest southwest in Hawksbill Cove. Using an 80% probability detection would put the range of this receiver at 11m for the V13 tag and 34m for the V16 tag. Using a 50% detection probability increases the range of the V13 and V16 tag detection to the 35m and 75m, respectively.



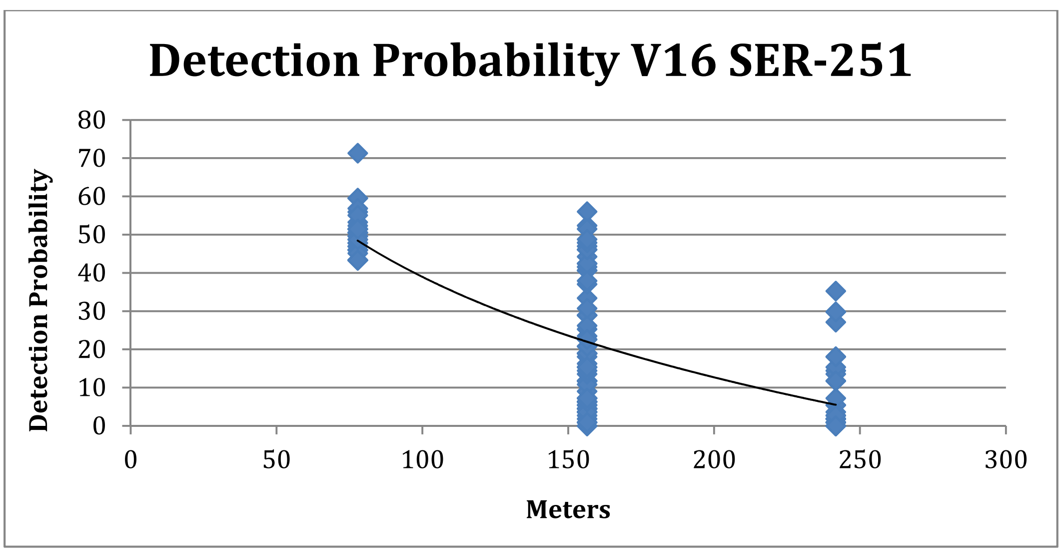


Figure 22. Graphs of both detection curves Section 5-SER-5 (Receiver 251) (V13 and V16)

The kayak range testing of receiver 251 recorded detections of the V13 and V16 tags. Detections by the receiver 251 were recorded both east and west of the receiver and from either tag V13, or V16. Detections by receiver of the V13 tag were recorded at a maximum of 111m. Detections by the receiver for the V16 tag were recorded at a maximum distance of 79m.

Night and Day comparison

Sentinel range testing yielded no noticeable difference between the detection range at night or day for all five receivers except Section 5-SER-5 receiver 251. During the 48-hour sentinel range testing in the middle of the night, each night, (3am) for a period of three hours each, the detection range dropped to zero for all transmitting acoustic tags. Furthermore, without an in depth investigation it would be difficult to determine what caused this loss of detection. Possible causes include: airport construction, poor weather, or treated sewage release, there is a treated sewage outflow in the same bay but how it only affected receiver 251 and not 250 is unknown.

Turtle Acoustic Data Results

<u>Turtle-CR</u>

1. Date tagged 2/22/2015
2. Weight 10.9kgs
3. Length 47.5cm CCL Tip
4. Possible detection start and end date 2/24/15-9/30/2015
5. Total number of detections-**1,635**
6. Total Detections by receiver from most to least (SER-5-1,043, SSR-4-240, NER-1-204, SWR-3-125, NWR-2-23)
7. Total Detections by receiver as % of total detections from highest to lowest (SER-5-**<u>63.8</u>**, SSR-4-14.7, NER-1-12.5, SWR-3-7.65, NWR-2-1.4)
8. Days Detected-34
9. Possible days detected-214

10. Percentage of Days Detected-**16%**
11. *Consecutive Days Detected-6*
12. Consecutive Days Detected at Specific Receiver-6 days-SER-5
13. Average Hours Spent per Day in habitat-**0.52hr/day**
14. Average Hours Spent per Day at a Specific Receiver-**SER-5-0.36hr/day**
15. Filler info for #9 and #10-(Possible Hours-5136/Possible Days-214/Total Hours spent in Habitat-111.25/Total Days Spent in Habitat-4.64)
16. Day Detections-1540:**94%**
17. Night Detections-95:**6%**

Turtle-CR

Turtle-CR is a juvenile hawksbill caught on February 22, 2015. It weighed 10.9kgs at the time of its capture. Turtle-CR had a total of 1, 635 detections, it was the least recorded turtle in this study. Turtle-CR was detected most on Section 5-SER-5, 1,043 out of 1,635 detections. Turtle-CR was detected 34 days out of a possible 214 days and was last recorded May 14th, 2015. It was detected 16 percent of eligible days, no more than 6 days consecutively, and had an adjusted time spent in habitat to 0.52 hours per day. Turtle-CR had 1,540 daytime detections and 95 nighttime detections.

Turtle-MM

1. Date tagged 4/08/2015
2. Weight 10kgs
3. Length 48.3cm CCL Tip
4. Possible detection start and end date 4/10/2015-9/30/2015
5. Total Number of detections-**17,428**
6. Total Detections by receiver from most to least (NER-1-12,695, NWR-2-3,580, SWR-3-1,138, SSR-15)
7. Total Detections by receiver as % of total detections from highest to lowest (NER-1-**72.85**, NWR-2-**20.5**, SWR-3-6.5, SSR-4-0.10)
8. Days Detected-169
9. Possible days detected-169
10. Percentage of Days Detected-**100%**
11. *Consecutive Days Detected-83 and 86*
12. Consecutive Days Detected at Specific Receiver-**NER-1-83 and 86**

13. Average Hours Spent per Day in habitat-**4.94hrs/day**
14. Average Hours Spent per Day at a Specific Receiver-**NER-1-3.15hrs/day-----NWR-2-1.4hrs/day**
15. Filler info for #9 and #10-(Possible Hours-4056/Possible Days-169/Total Hours spent in Habitat-837.5/Total Days Spent in Habitat-34.9)
16. Day Detections-17349:**99.5%**
17. Night Detections-79:**0.5%**
18. Max Depth Recorded-24m@day/14m@night
19. Detections at 0m, suggestive of breathing-1507/17428**-(8.6)-3m was the most detected depth with 2169 detections (2nd being 4m with 1676 detections, 3rd being 0m with 1507)**
20. Breathing Detections by Receiver-**NER-1-898/1507:59.5%** /NWR-2-**476/1507:31.5%** /SWR-3-**129/1507**:**8.5%**
21. Night time detections at 0m (Total 46)—NER-1-45/1507:**2.9%** /NWR-2-1/1507:**0.66%**
22. Most Common Depth of Night time detections from-NER-1-0m-(45 detections)
23. Depth data by receiver-Section-1-NER-1-3m the most detected depths, most detections between 3m-6m-MAX-21m.
24. Section-2-NWR-2-0m most detections, next most 3m-MAX-23m.
25. ***ODD TO NOTE, IN SECTION-2-NWR-2 MARIOTA DEPTH DATA TAILS OFF TO LESS AND LESS DETECTIONS UNTIL 13m, WHEN IT JUMPS BACK UP TO 320 DETECTIONS.
26. Section-3-SWR-3-3m-4m---***MAX -24m.***
27. **Interesting to note the most recorded depth at all three stations was either 0m or 3m.**

Turtle-MM

Turtle-MM is a juvenile hawksbill caught in Section 1-NER-1 originally on January 10th, 2015. Turtle-MM was recaptured (in the same section) and fitted with an acoustic tag on April 8th, 2015. Both captures occurred while the animal was foraging along the marine habitat of the CEK runway. Turtle-MM had a weight of 22kgs and a CCL(t) of 48.3cms. Turtle-MM was detected 17,428 times over the course of this study, making Turtle-MM the second most detected turtle. Of Turtle-MM's 17,428 detections, 12,695 or 72.85% were detected in Section 1-NER-1 of the study area with 3,580 detections or 20.5%, being recorded in Section 2-NWR-2. Turtle-MM was detected 169 days out of a possible 169 days and is the only turtle recorded every single day the turtle was eligible. Along with being detected every single day in the habitat, Turtle-MM was recorded every single day in Section 1-NER-1 on receiver 247. Adjusted detections to reflect hourly usage on the habitat calculated 4.94 hours per day within the habitat, with 3.15 hours per day within Section 1-NER-1.

Day and Night

Turtle-MM recorded 17,349 daytime detections and 79 nighttime detections. This means that 99.5% of all Turtle-MM's detections came during the day. It is important to note that 3 out of 5 turtles acoustically tagged had their day detections account for over 90% of all detections, with the remaining two turtles having their daytime detections account for 71.4% and 82.5% of their detections.

Depth

Turtle-MM had a depth transmitting V16 acoustic tag. The most detected depth was 3m, (2169 of 17,428 detections) or 12.4% of all detections, with the majority of detections between 2m and 10m. Detections at 0m, most likely due to breathing, accounted for 8.6% of all detections. Sea turtles may spend minutes on the surface and 0m could produce the best angle to transmit to the receivers. Detections at 0m, or breathing detections, were most often recorded in Section-1-NER-1 (898/1507 or 59.5%). Finally, and this point will be discussed further when analyzing the depth data with Turtle-TD, both turtles had similar looking depth data when graphed (see below). The difference being Turtle-TD's most recorded detection depth was 0m while Turtle-MM 's most recorded depth is 3m, then 4m, and then 6m. Broken down between receivers Section-1-NER-1, Section-2-NWR-2, and Section-3-SWR-3 the depth data is consistent in that 2m-10m is the most record depth. This is suggestive that this is the depth at which this turtle spends the majority of its time. Section-2-NWR-2 did have an interesting spike in detections at 13m, which is not fully understood. Maximum depth data recorded is noteworthy in that Turtle-MM was recorded deepest in the section it was detected the least amount in, Section-3-SWR-3 (24m-SWR-3/23m-NWR-2), and shallowest in the section it spent the most time, Section-1-NER-1. This is most likely due to the logistics of the runway depth increasing as it progresses from Section-1-NER-1 to Section-3-SWR-3.

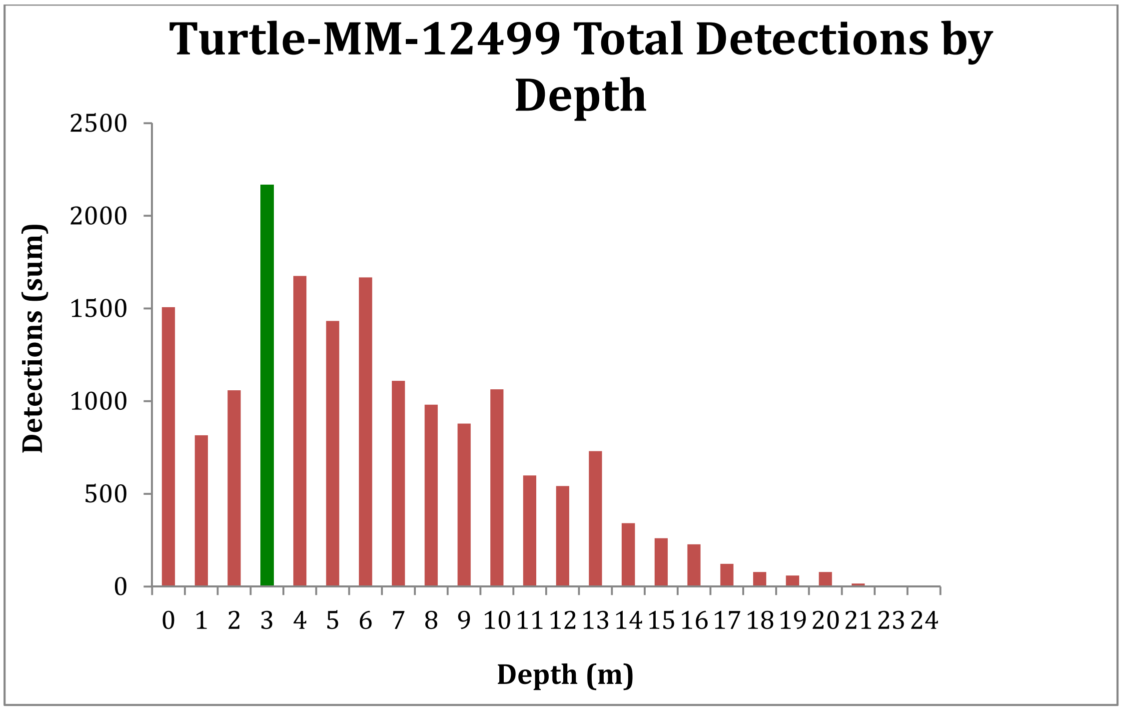


Figure 23. Total depth detections for Turtle-MM.

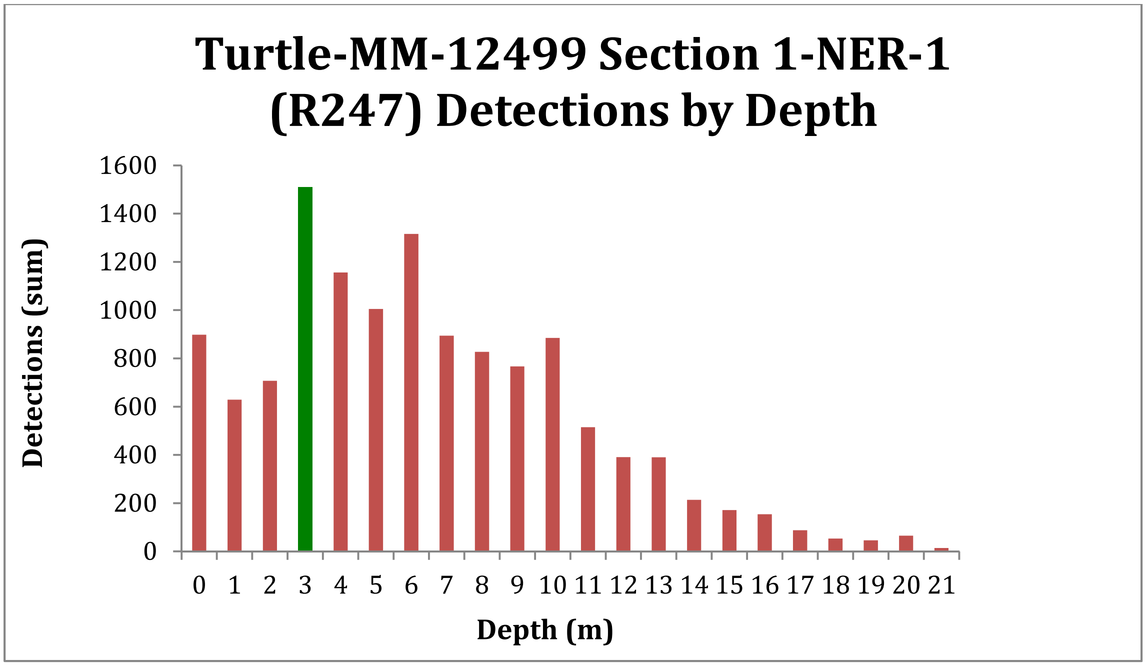


Figure 24. Depth detections for Turtle-MM in Section 1-NER-1.

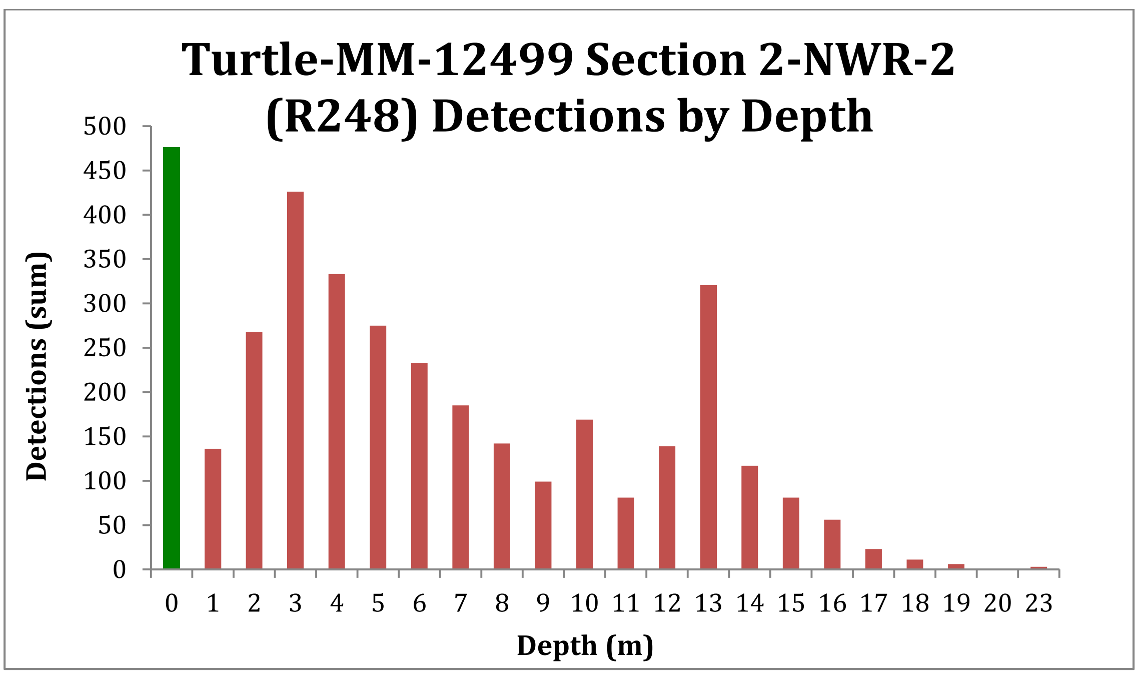


Figure 25. Depth detections for Turtle-MM in Section 2-NWR-2.

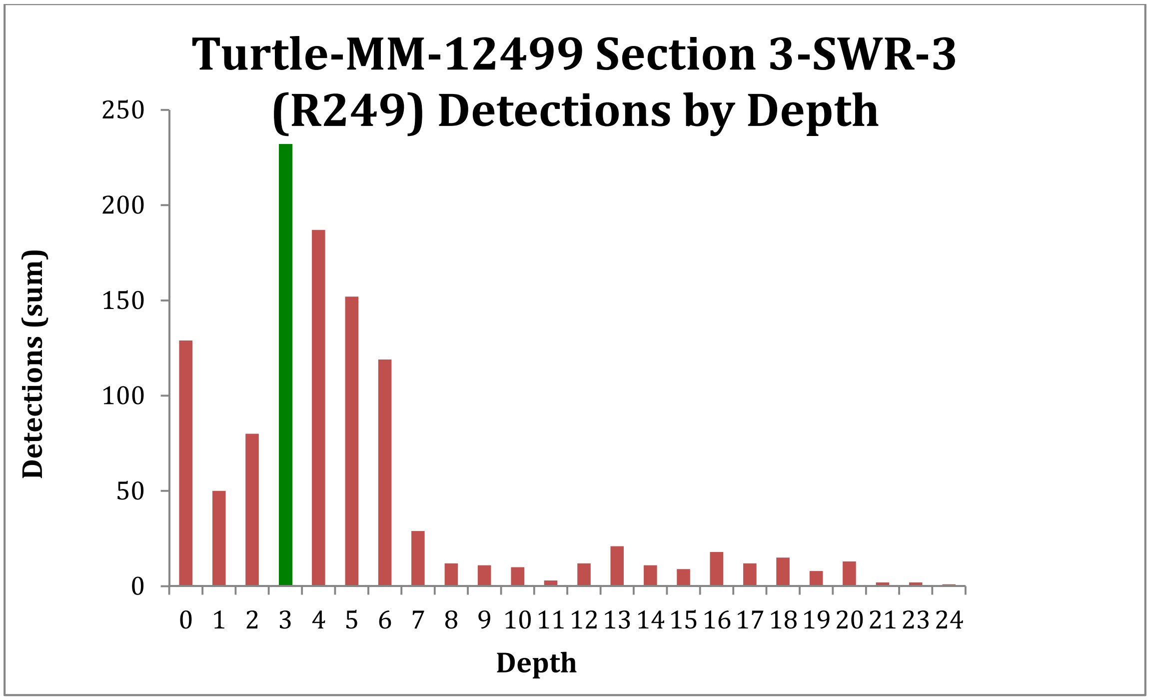


Figure 26. Depth detections for Turtle-MM in Section 3-SWR-3.

Turtle-SP

1. Date tagged 5/16/2015
2. Weight 27.8kgs
3. Length 65cm CCL Tip
4. Possible detection start and end date 5/18/2015-9/30/2015
5. Total Number of detections-**15,140**
6. Total Detections by receiver from most to least (NER-1-13,954, NWR-2-1,123, SWR-3-56, SSR-4-7)
7. Total Detections by receiver as % of total detections from highest to lowest (NER-1-**92.2**, NWR-2-7.40, SWR-3-0.40, SSR-4-0.05)
8. Days Detected-121
9. Possible days detected-131
10. Percentage of Days Detected-**92%**
11. *Consecutive Days Detected-70*
12. Consecutive Days Detected at Specific Receiver-**NER-1-42-70-DAYS(-7-3-adds up to 121 which means every day this turtle was recorded it was recorded on NER-1-247)**
13. Average Hours Spent per Day in Habitat-**5.04hrs/day**
14. Average Hours Spent per Day at a Specific Receiver-**NER-1-4.73hrs/day**

15. Filler info for #9 and #10-(Possible Hours-3144/Possible Days-131/Total Hours spent in Habitat-661.25/Total Days Spent in Habitat-27.55)
16. Day Detections and %-15053:**99.4%**
17. Night Detections and %-87:**0.6%**

Turtle-SP

Turtle-SP is a sub-adult caught in Section-1-NER-1 on May 16th, 2015. Turtle-SP was fitted with an acoustic tag and released in the same location it was captured. Turtle-SP is the lone sub-adult for this acoustic movement study. Turtle-SP was also a bit of a surprise, as we normally do not observe turtles this large in the study area. Turtle-SP weighed 27.8kgs and a length of 65cm CCL(t). Turtle-SP is the largest, both weight and length, fitted with an acoustic tag. During the course of this study Turtle-SP recorded 15,140 detections, making Turtle-SP the third most recorded turtle in the study, which is interesting because Turtle-SP was the last turtle acoustically tagged, almost three months after the initial four turtles (2/21/2015). Of Turtle-SP 15, 140 detections, 13,954 were detected in Section-1-NER-1 or 92.2% of all detections. The only other section with even more than a single percent of detections is Section-2-NWR-2 with 1,123 detections or 7.4%, resulting in Section-1-NER-1 and Section-2-NWR-2 combined for 99.6% of all detections. Turtle-SP was detected 121/131 days or 92% of all days eligible. Turtle-SP had consecutive day detections of 42 and 70 days at the Section-1-NER-1 receiver, meaning every day this turtle was detected; it was detected in this particular section. Adjusted detections to reflect hourly usage of the habitat calculated 5.04hrs per day in the habitat, with 4.73hrs per day being spent in Section-1-NER-1.

Night and Day

Turtle-SP recorded 15,053 daytime detections and 87 nighttime detections. This means 99.4% of all detections from Turtle-SP came during the day.

Turtle-SC

1. Date tagged 2/21/2015
2. Weight 9.1kgs
3. Length 45cm CCL Tip
4. Possible detection start and end date 2/23/2015-9/30/2015
5. Total Number of detections-**34,973**
6. Total Detections by receiver from most to least (SER-5-17,275, SWR-3-8,509, SSR-4-8,270, NWR-2-830, NER-1-89)
7. Total Detections by receiver as % of total detections from highest to lowest (SER-5-**49.4**, SWR-3-**24.35**, SSR-4-**23.65**, NWR-2-2.4, NER-1-0.25)
8. Days Detected-209
9. Possible days detected-215
10. Percentage of Days Detected-**97%**
11. *Consecutive Days Detected-77*
12. Consecutive Days Detected at Specific Receiver-**SER-5-77 Days**
13. Average Hours Spent per Day in habitat-**9.3hrs/day**
14. Average Hours Spent per Day at a Specific Receiver-**SER-5-5.1hrs/day—SSR-4-2.2hrs/day---SWR-3-1.7hrs/day**
15. Filler info for #9 and #10-(Possible Hours-5160/Possible Days-215/Total Hours spent in Habitat-2002/Total Days Spent in Habitat-83.42)
16. Day Detections and %-28883:**82.5%**
17. Night Detections and %-6090:**17.5% (SER-5-4,479, SSR-4-293)**
18. Night Detections %**-SER-5-94%, SSR-4-6%**

Turtle-SC

Turtle-SC is a juvenile hawksbill turtle caught in Section-5-SER-5 on February 21st, 2015. Turtle-SC was fitted with an acoustic tag and released in the same location as its capture. Turtle-SC weighed 9.1kgs and had a length of 45cm CCL(t). This turtle registered 34,973 detections over the course of this study, twice as many detections as the next closest turtle (Turtle-MM with 17,428). Turtle-SC's detections were spread somewhat evenly amongst three receivers all located on the south side of the CEK runway. Section-5-SER-5 recorded 17,275 detections, Section-3-SWR-3 recorded 8,509 detections, and Section 4-SSR-4 recorded 8,270 detections. The percentage breakdown went Section-5-SER-5-49.4%, Section-3-SWR-3-24.35%, and Section-4-SSR-4-23.65%. Together those three receiver locations accounted for 97% of all detections. Turtle-SC was detected 209/215 days eligible or 97% of eligible days. During the study Turtle-SC was detected for a span of 77 straight days at the Section-5-SER-5 receiver 251. Adjusting for detections to reflect hourly habitat usage it is calculated Turtle-SC spends 5.1 hours per day in Section-5-SER-5, the most of any section adjusted. Adjusting detections for hourly usage Section-4-SSR-4 and Section-3-SWR-3 the rate becomes 2.2 hours per day, and 1.7 hours per day. It is of note that the total number of detections is greater in Section-3-SWR-3 than Section-4-SSR-4 but when adjusted to reflect hourly usage it was calculated more time was spent in Section-4-SSR-4. The adjustment would also appear to be accurate as Section-4-SSR-4 is adjacent to Section-5-SER-5 (the most utilized section) but also, the turtle would be expected to swim through Section-4-SSR-4 to get to Section-3-SWR-3. Turtle-SC's hourly usage of the habitat, 9.3 hours per day, is near double the next closest turtle (Turtle-SP, 5hrs per day).

Night and Day

Turtle-SC had 34,973 detections over the course of this study, 28,883 or 82.5% came during daylight hours, 6,090 detections or 17.5% came from the night time detections. This was the first turtle to have their nighttime detections examined because the previous 2 turtles (Turtle-MM and Turtle-SP) had a greater than 99% daytime detection rate. Turtle-SC's nighttime detections were split between Section-5-SER-5 and Section-4-SSR-4, with Section-5-SER-5 accounting for 94% of nighttime detections, while Section-4-SSR-4 accounted for the remaining 6% of nighttime detections.

Turtle-TT

1. Date tagged 2/21/2015
2. Weight 1.4kgs
3. Length 28.1cm CCL Tip
4. Possible detection start and end date 2/23/2015-9/30/2015

5. Total Number of detections-**6,682**
6. Total Detections by receiver from most to least (SER-5-6,389, SSR-4-293)
7. Total Detections by receiver as % of total detections from highest to lowest (SER-5-**95.60**, SSR-4-4.40)
8. Days Detected-176
9. Possible days detected-215
10. Percentage of Days Detected-**82%**
11. *Consecutive Days Detected-51*
12. Consecutive Days Detected at Specific Receiver-**SER-5-51 DAYS**
13. Average Hours Spent per Day in habitat-**4.47hrs/day**
14. Average Hours Spent per Day at a Specific Receiver-**SER-5-4.26hrs/day**
15. Filler info for #9 and #10-(Possible Hours-5160/Possible Days-215/Total Hours spent in Habitat-916.75/Total Days Spent in Habitat-40.1)
16. Day Detections and %-4772:**71.4%**
17. Night Detections and %-1910:**28.6%**
18. **Night Detections-100%---ALL 1,910 NIGHT TIME DETECTIONS CAME FROM SECTION 5-SER-5 (RECEIVER 251)**

Turtle-TT

Turtle-TT is a juvenile turtle caught in Section 5-SER-5 originally on November 16th, 2014. Turtle-TT was recaptured on February 21st, 2015 and fitted with an acoustic tag. Turtle-TT was released in the same location in Section-5-SER-5 as it was captured. Turtle-TT weighed 1.4kgs and had a length of 28.1cm CCL(t). Turtle-TT and Turtle-TD are the smallest juvenile turtles, each weighing less than 2kgs, and less than 30cm in length. During the course of the study Turtle-TT recorded 6,682 detections. Those 6,682 detections were split between Section-5-SER-5-6,389, and Section-4-SSR-4-293. This means that 95.6% of all its detections came from the Section-5-SER-5. Turtle-TT was detected 176 out of 215 days or 82% of all days eligible. Turtle-TT was recorded 51 straight days with at least a single detection in Section-5-SER-5.The adjusted detections to reflect hourly habitat usage reveal 4.47hrs per day in the habitat with 4.26hrs per day in Section-5-SER-5.

Day and Night

Turtle-TT recorded 1,910 nighttime detections (1910 out of 6682 or 28.6% of all detections). One hundred percent of its nighttime detections were in Section-5-SER-5.

<u>Turtle-TD</u>

1. Date tagged 2/21/2015
2. Weight 1.4kgs
3. Length 22.4cm CCL Tip
4. Possible detection start and end date 2/23/2015-9/30/2015
5. Total Number of detections-**6,085**
6. Total Detections by receiver from most to least (NWR-2-2,894,NER-1-2,365, SWR-3-779, SSR-4-35, SER-5-12)
7. Total Detections by receiver as % of total detections from highest to lowest (NWR-2-**<u>47.5</u>**, NER-1-**<u>38.9</u>**, SWR-3-12.8, SSR-4-0.60, SER-5-0.20)
8. Days Detected-197
9. Possible days detected-215
10. Percentage of Days Detected-**92%**
11. *Consecutive Days Detected-106*
12. Consecutive Days Detected at Specific Receiver-**NWR-2-70 DAYS**
13. Average Hours Spent per Day in habitat-**2.95hrs/day**
14. Average Hours Spent per Day at a Specific Receiver-**NWR-2-<u>1.96hrs/day</u>---NER-1-.<u>62hrs/day</u>**
15. Filler info for #9 and #10-(Possible Hours-5160/Possible Days-215/Total Hours spent in Habitat-634.75/Total Days Spent in Habitat-26.45)
16. Day Detections and %-5494:**90.3%**
17. Night Detections and %-591:**9.7%**
18. Night Detections-588/591:**99.4%-NWR-2**
19. <u>Max Depth recorded-15m@day/4m@night</u>
20. Detections at 0m, suggestive of breathing-1934/6085 **(31.7%)-0m was the most detected depth at 1934 detections (2nd being 1m with 956 detections and then 3m with 741 detections)**
21. Breathing Detections by Receiver-**<u>NWR-2-63%</u>** /NER-1-**<u>25.9%</u>** /SWR-3-**9.8%**
22. **All** Night time detections at 0m came from **NWR-**2 158/1934:**(8%)**
23. Most Common Depth of Night time detections from 1m (345/591):**58%**, but the next was 3m (45/591)-7.6%
24. Depth data by receiver-Section-1-NER-1-after 0m the most detected depths between 5m (356)-6m (379)----***<u>MAX-15m.</u>***

25. Section-2-NWR-2-After 0m, next most detected depth 1m (692) and then again at 3m (370) MAX-12m.
26. Section-3-SWR-3-After 0m most detected depth is 3m (182)-MAX 11m.

Turtle-TD

Turtle-TD is a juvenile turtle originally caught in Section-2-NWR-2 on January 25th, 2015. Turtle-TD was recaptured on February 21st, 2015 and fitted with an acoustic tag. It was released in the same location as its capture. Turtle-TD weighs 1.4kgs and has a length of 22.4cm CCL(t), making it tied for the smallest turtle in this study. Turtle-TD recorded 6.085 detections over the course of this study, 2,894 came from Section-2-NWR-2, 2,365 detections came from Section-1-NER-1, and 779 detections came from Section-3-SWR-3. The percentage breakdown from each section means Section-2-SWR-2 recorded 47.5% of all detections, while Section-1-NER-1 was 38.9% of all detections, and finally Section-3-SWR-3 was 12.8% of all detections. Turtle-TD was detected at least once 197 out of 215 days or 92% of all eligible days. Turtle-TD was detected 106 days straight with 70 of those days being detected at Section-2-NWR-2. When its detections are adjusted to reflect hourly usage of the habitat, it is calculated Turtle-TD spends 2.95 hours per day in the habitat, with 1.96 hours per day being in Section-2-NWR-2.

Day and Night

Turtle-TD recorded 5,494 or 90.3% of its detections during the daylight hours, with 591 detections or 9.7% coming the night. Of all its nighttime detections, 588 out of 591 or 99.4% came from Section-2-NWR-2. . Turtle-TD's most detected nighttime depth was 1m, with 58% of all detections.

Depth Data

Turtle-TD was fitted with an acoustic transmitter that recorded its depth over the course of this study. The maximum depth recorded for the daytime and overall depth was 15m. The maximum depth recorded during the nighttime was 4m. Detections at 0m, suggestive of breathing behavior were recorded 1934 out of 6085 detections or 31.7% of all detections, and was the most detected depth. The second and third most detected depth registered was 1m, and 3m. Nighttime breathing detections, 158 of 1934 detections all came from Section-2-NWR-2. Depth data by sections after 0m (the most detected depth), in Section 1-NER-1 was between 5m-6m. In Section-2-NWR-2, the section with the most detections and hours per day calculated, the most detected depth (after 0m) is 2m-3m. Finally, in Section-3-SWR-3, the most detected depth (after 0m) is 3m-4m.

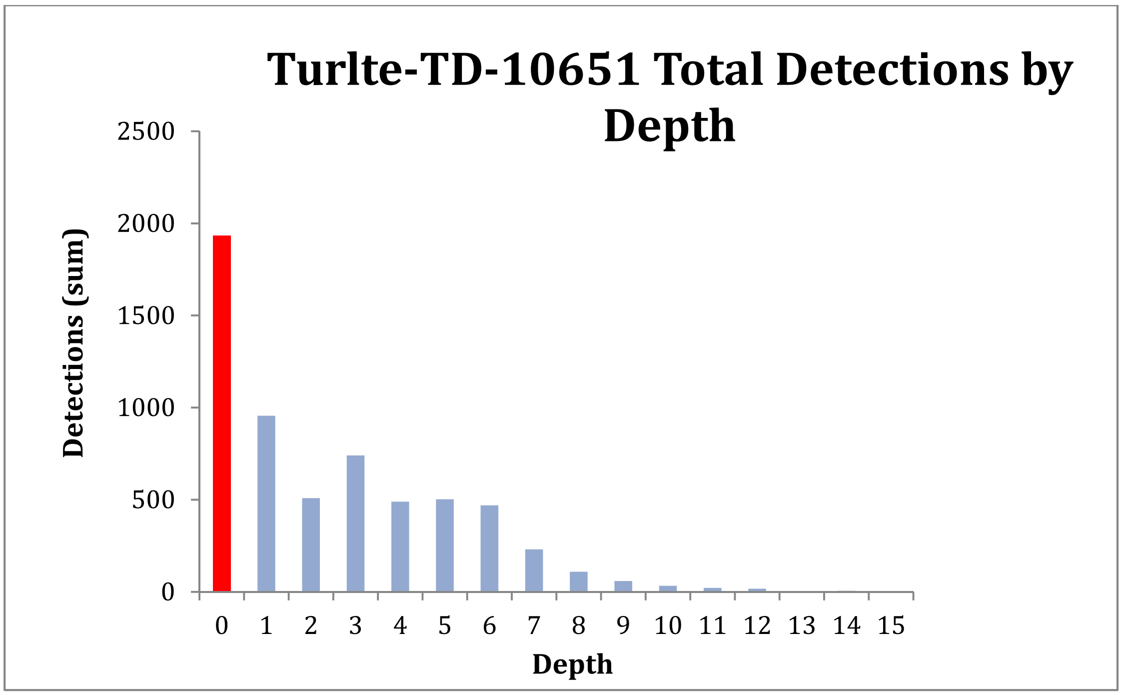


Figure 27. Total depth detections for Turtle-TD.

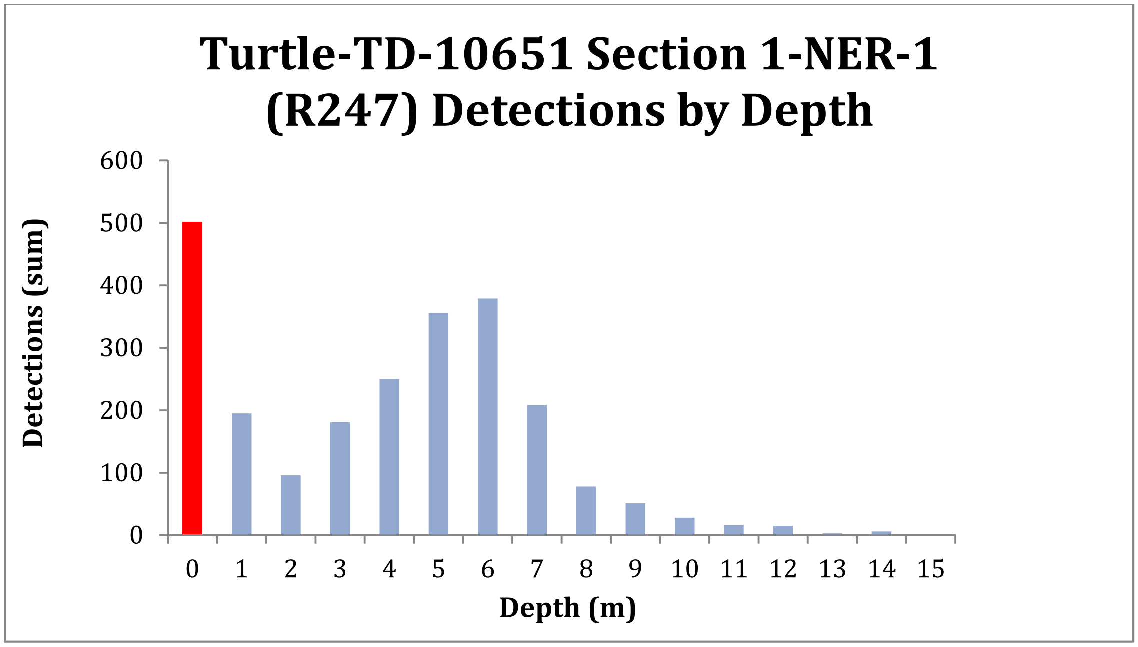


Figure 28. Depth detections for Turtle-TD in Section 1-NER-1.

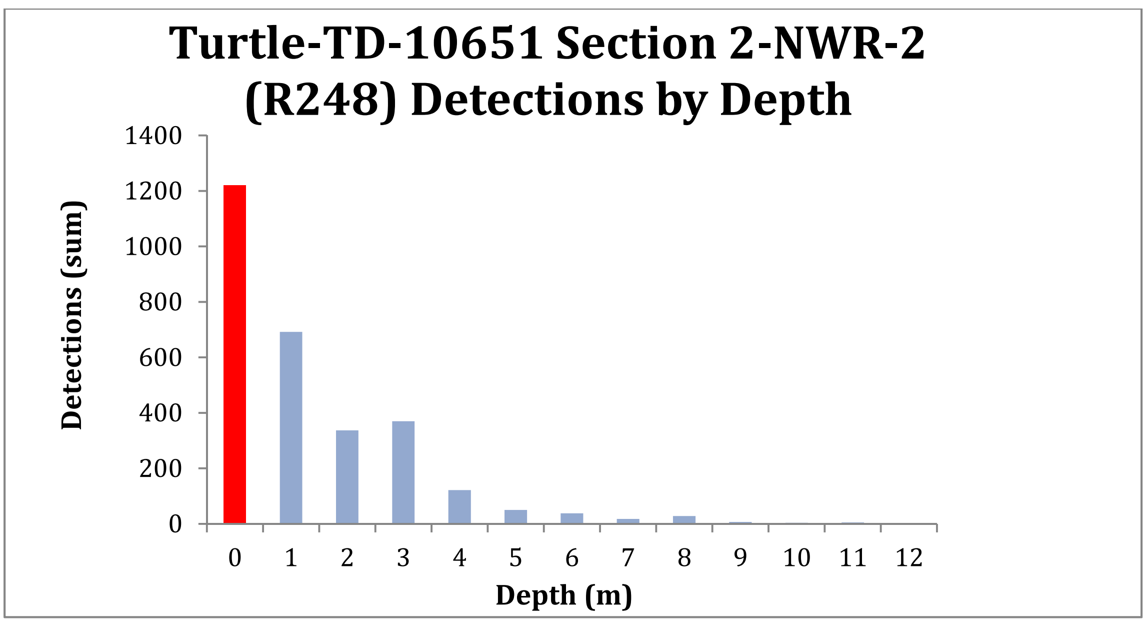


Figure 29. Depth detections for Turtle-TD in Section 2-NWR-2.

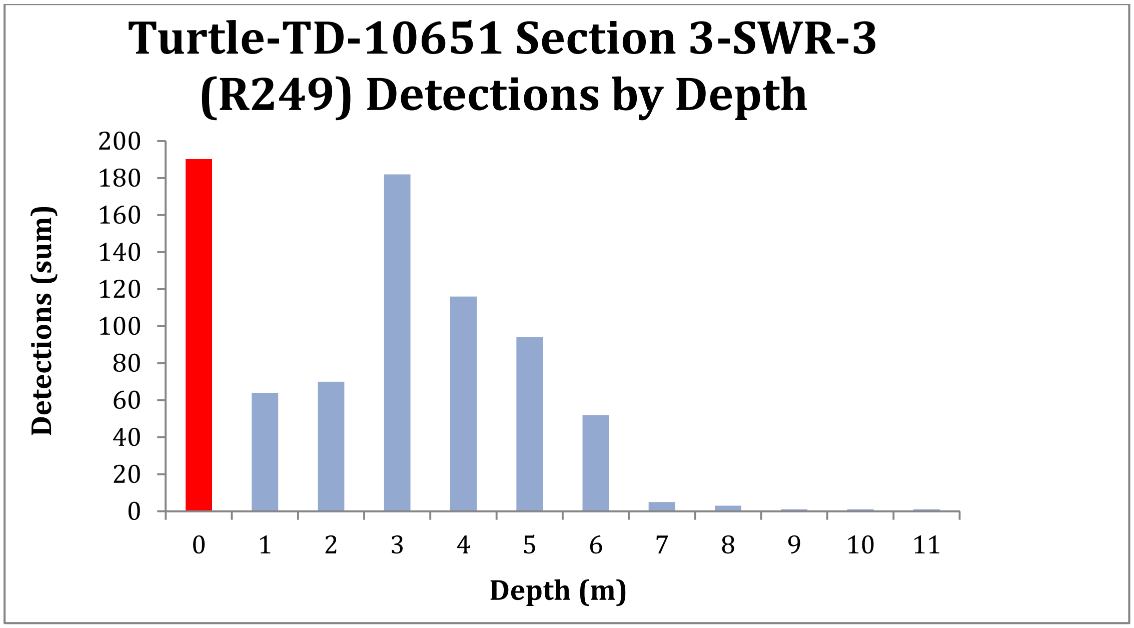


Figure 30. Depth detections for Turtle-TD in Section 3-SWR-3.

Discussion

Crevice Size

The results of the crevice size data and analysis accepts the alternative hypothesis. The construction of CEK runway was deliberately engineered and planned. The planning consisted of small rock rubble as a base progressing into larger granite boulders and finally concrete dolos. The results show that the shallower areas consisting of the concrete dolos are statistically different than the other depths. The Intermediate and Deep sections of the runway are either rock rubble or a small number of granite boulders mixed in with rock rubble which produces statistically smaller crevice sizes. The statistical difference between sections was more difficult to determine. The matching letter report shows the Shallow sections, specifically sections 2-5 (NWR-2, SWR-3, SSR-4, SER-5), are grouped (A) together but Shallow sections 2-4 (NWR-2, SWR-3, SSR-4) still share a letter (B) with sections with very little crevice size of any significance. For example, Shallow section 4-SSR-4, the second largest average of all sections measured for crevice size shares a common letter (B) with deep section 2-NWR-2, one of the smallest sections measured for crevice sizes.

The expected result of the sections test would have shown a difference between Shallow sections 3-5 (SWR-3, SSR-4, and SER-5), Shallow Section 2-NWR-2, and every other section measured. This didn't occur but statistically the difference in Least Sq. Means between sections and the graphed raw data show Shallow Sections 3-5 (SWR-3, SSR-4, and SER-5) with a much larger average crevice size, and more maximum crevices than the other remaining sections. Shallow Section 2-NWR-2 would then be the "transitional section" between Shallow Section 1-NER-1 and Shallow Sections 3-5 (SWR-3, SSR-4, and SER-5).

Benthic Community Composition

The result of the benthic community composition data and analysis accepts the alternative hypothesis. The benthic composition of the runway habitat varies with depth and section amongst the major benthic groups recorded (corals, sponges, coralline algae, macro-algae, and DCA). The recorded and analyzed video transects provide data to support what is observable when snorkeling or scuba diving. The Shallow sections especially in the concrete dolos, Shallow Sections of 3-5 (SWR-3, SSR-4, and SER-5) have a greater coral cover than the Intermediate or Deep sections with the trend being that of coral cover declining as depth increases. The same can be said for DCA and coralline algae; DCA and coralline algae prevalence decreases as depth increases and coralline algae, is only detected in any percentage greater than 2%, in Shallow sections 3-5 (SWR-3, SSR-4, and SER-5).

The inverse occurs for both sponge and macro-algae. As depth increases so does sponge cover and macro-algae cover. Sponge cover and macro-algae cover are both statistically different between all three depths with the Deep depth having the highest percentage of both sponge and macro-algae cover.

This may be explained by the concrete dolos and overall composition of the runway habitat and also by known distribution patterns of sponges. The concrete dolos in shallow water, perhaps because of the current and abundant sunlight, appear to be favorable to the growth of hard corals, and coralline algae but not sponges or macro-algae. There is the very real possibility the lack of sponge cover in the Shallow Sections 2-5 (NWR-2, SWR-3, SSR-4, and SER-5) is also due to new sponge growth being predated upon by the juvenile hawksbill turtles, although grazing scars on new sponge growth was not examined or observed. Sponge cover increases as depth increases possibly due to the dive/foraging limitations of the juvenile turtles or natural sponge distribution patterns. Depth data recorded from two juvenile hawksbill turtles shows most frequent depth recordings between 0m-9m. This may explain in part why sponge cover increases as depth increases. Another possible explanation is that the Intermediate and Deep depths are high in macro-algae cover and thus not as good a foraging habitat for the juvenile hawksbills, but a study by Goately et all (2012) on the Great Barrier Reef concluded that while minimal, and perhaps not well understood, hawksbills will target leathery macro algae for a portion of their diet. What is most likely is a study by Wilkenson and Evans (1988) and Wilkenson and Cheshire (1989) on the Great Barrier Reef concluded the optimal depth for sponge growth is between 10-30 meters with less than 10 meters being less than optimal due to physical factors. This may ultimately be the cause of the lack of sponges in the Shallow Sections along the marine habitat of the CEK runway.

Range Testing

The individual receiver ranges concluded from the sentinel and kayak testing sessions were less than expected but not completely surprising. The first question on the Vemco website under FAQ is “what is the range that can be expected from the acoustic receivers?” Their response is as follows:

“Detection range depends on so many factors that it is difficult to estimate without knowledge of the environment and prior experience with telemetry. Range depends on transmission power, signal absorption, line of sight, reflection/refraction, multipath and environmental noise (man-made & natural), and the receiving quality of the receiver/hydrophone. Typically areas that have clear water, sand or silt flat bottoms and low current exhibit the greatest ranges. Conversely, areas with turbid water, complex rocky bottom topography and high current exhibit low ranges. In all cases, extreme weather events and periods of high wind (waves) may significantly reduce range.”

In most cases greater transmission power output (dB) results in greater range. For example, in good conditions a V7-VR2W range test could yield a range of 300-400 m and a V16-VR2W test could yield ranges of 800-1200 m. There are some exceptions where high power and a reflective and low noise environment may cause detection breakdowns.”

The CEK runway at each receiver had one if not more of the conditions needed to meet poor detection. Receiver 247 and 248 are often in turbid waters due to a local ghut drainage point and their proximity to a small mangrove lagoon, which drains along the north side of the runway. The marine runway habitat itself creates what could be considered complex rocky topography and can occasionally have a current. Likewise, receivers 249, 250, and 251 can experience turbidity after major rain events, due to local drainage points, and often have a current and or strong wave action. The location of receivers 249, 250, and 251 also exist along the artificial habitat that has complex rocky topography.

Six tags were used during range testing, four V16 tags and two V13 tags. Four V16 tags were purchased due to the anticipated size (greater than 35-40cms) of the juvenile hawksbill turtles using the study area and the economic budget for this study only allowed a maximum of six tags.

At each receiver the V16 tags performed better than the V13 tags, which were expected. V16 tags transmit a more powerful signal and so detection is expected to be higher than the V13. During sentinel range testing, four out of six tags used were V16, and V16 tags were used on every float. Thus, there was more data to create a V16 range test detection probability curve with each receiver. During the sentinel testing, two of the tags used were V13, and thus a V13 tag was tested on the closest float to the receiver and the float furthest away. Creating a detection probability curve with only two V13 tags means the 80% detection probability for the V13 tag and receiver 249 was calculated to be 17m and the 50% probability to be 38m while the V16 (three range testing tags) went 38m and 49m for the same probabilities. It is within reason to conclude that the actual 80% and 50% probability is better than what was reported because of the kayak distance detections for both V13 and V16 tags were much better, but uncertainty exists as to how much better.

The kayak range testing data gave support data to the sentinel data collected in it showed some possible maximum detection ranges. Detections were made at distances of 111m, 120m, 125m, and a maximum detection for the V13 during the kayak testing session was made at 171m with receiver 247. Meanwhile the V16 tag during the kayak testing session-registered detections at 152m, 156m, 158m, 197m, and a maximum detection was made at 224m with receiver 247. Maximum detections during the kayak session illustrate that it is possible to have single detections at a distance close to the Vemco advertised distance.

While it is likely the detection ranges for each receiver is different and fluctuates daily due to physical conditions, for this study, a 50% detection probability for the V16 acoustic transmitters is 105 meters and the 50% detection probability for the V13 acoustic transmitter is 80 meters. This was done in an effort to simplify analysis and set a standard detection range for each receiver.

Figure 31. Brewer's Bay map showing the 50% detections range of the receivers using the V16 and V13 acoustic transmitters. The green circles are the detection range for the V16 tags (105m) and the red circles are the detection ranges for the V13 tags (80m).

Individual Hawksbill Turtle Discussion and Overall Conclusion

The marine habitat of the CEK runway presents a host of issues that in and of itself could be a thesis subject. The habitat is artificial, and within the parameters of it being artificial it is extremely complex and not homogenous. The structural complexity of the concrete dolos, the granite boulders, the lip at 13-14 meters, the drop off to 26-27 meters in the Deep sections, and the poor visibility made this a very challenging habitat to work within. The artificial structure exists at roughly a 45 degree angle to the ocean floor, and above 12m-13m it is a jumble of dolos changing the depth of the habitat rapidly, making for enormous crevices, caverns, and tunnels. Anecdotally, on one swimming survey we witnessed a small juvenile turtle swim into a concrete dolo crevice at 10 meters and emerge 3 meters deeper and 15-16 meters away.

An overall assessment has led to the conclusion that; the alternative hypothesis of unequal hourly usage by receivers, unequal detections by receivers, and unequal detections by depth must all be accepted because different turtles use this artificial habitat for different reasons and in different ways. The small sample size of acoustically tagged turtles (n=6) means that any conclusions drawn from the data should account for the small sample size. For some of the turtles this is their entire world, for others, just a part of their home range that they visit daily. The smaller the turtle, the more likely they are to stick to the runway habitat and specifically the concrete dolos and large granite boulders. The larger turtles may use the habitat strictly for foraging, as has been observed in person, and inhabit a larger "home range". Much like the well-known and documented juvenile fish habitat found in mangrove prop-root communities, this habitat, its structural complexity, crevice size, benthic composition, food resources and depth, allows all turtles, and especially juveniles to have a safe shallow water habitat with a multitude of hiding and resting locations. This may serve as a transitional habitat for very young hawksbills between the pelagic and entirely benthic phases of their life history.

In addition, sea turtle behavior when threatened is to turn their shell directly to their "attacker". This habitat allows for that but also provides the security of the artificial habitat to exist at any depth (0m-27m). Furthermore, hawksbill turtles have been observed foraging along the runway habitat, Turtle-MM was captured both times while it was foraging, proving the artificial marine runway habitat is a foraging ground. Hawksbill turtles have also been observed hiding and resting along the runway, adding to the reasons why turtles may frequent the area.

Figure 32. Hawksbill turtle foraging along the marine habitat of the CEK runway. Photo credit to Dr. Paul Jobsis.

Figure 33. Hawksbill turtle using the granite boulders of the marine habitat of the CEK runway for assisted resting. Photo credit to Dr. Paul Jobsis.

The overall conclusion is different sized turtles use the habitat differently and for different reasons but with a small sample size of six turtles, a conclusion for each turtle is important. Individual conclusions are important to examine because a sweeping conclusion for how an entire species of turtle use this habitat might exclude the subtle nuances of this marine habitat. It is also important to note that parts of the conclusion will use evidence from the additional receivers placed in the bay only directly north of the CEK runway (see image 34 below).

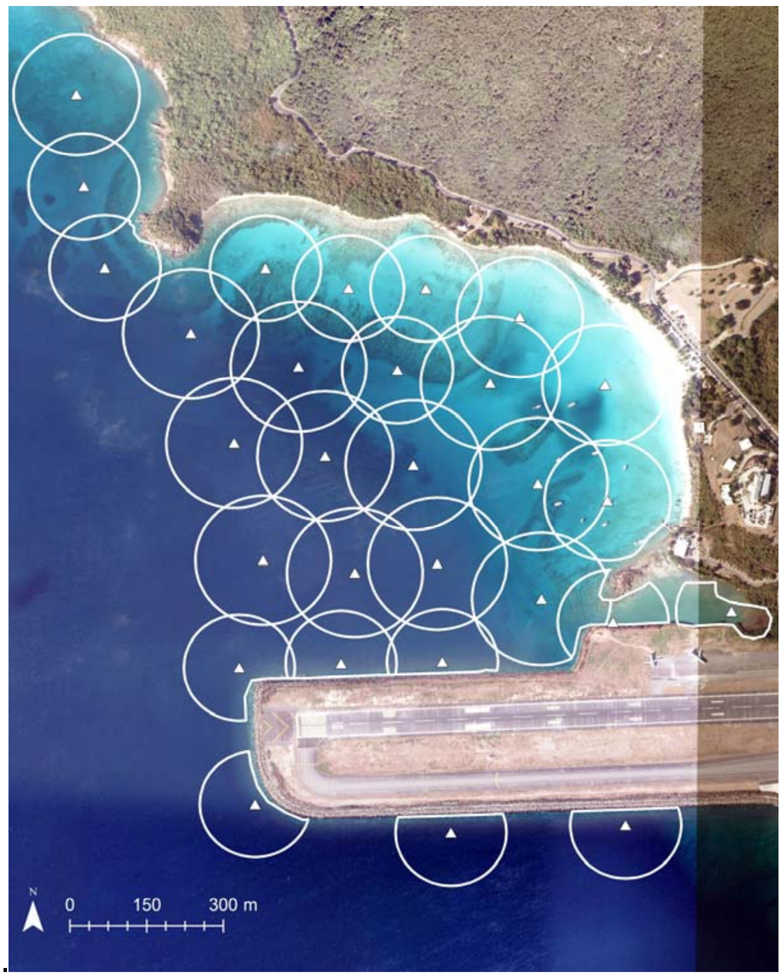


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Figure 34. Brewer's Bay, USVI with the entire acoustic array, completed July 2015.

The initial five receivers were placed along the runway in January and early February 2015, in August of 2015; an additional 19 receivers were placed in

Brewer's Bay, St. Thomas. The southern part of Brewer's Bay is the northern part of the runway. Therefore, Section-1-NER-1 and Section-2-NWR-2 are part of the Brewer's Bay array and acoustic animal movement can be tracked throughout the entire bay. This is not the case for Section-3-SWR-3, Section-4-SSR-4, or Section-5-SER-5; they remained single acoustic receivers in their respective sections. The additional receivers in Brewer's Bay means that turtles in this study that were acoustically tagged and preferred the northern section of the runway (NER-1, NWR-2) had their movement detected on the Brewer's Bay array, and while the detection data was not used in this study it will be presented as supporting evidence as to how the particular animal uses the CEK runway habitat.

Turtle-CR

Turtle-CR had the least amount of detections in this study, was recorded at least once per day the least, and had the least calculated hours per day in habitat of off the acoustic tagged turtles. Turtle-CR's most detected section was Section 5-SER-5 but was last detected in Section 1-NER-1. This turtle was tagged on February 22, 2016 and was last recorded May 14th, 2015. It is possible this turtle lost its tag and is still in the habitat, lost its tag and is not in the habitat, still has its tag and is not in the habitat, still has its tag and is no longer being detected due to tag malfunction, or it is also possible the turtle was predated and is no longer alive. All that is certain is the turtle is no longer being detected acoustically. It is important to note this turtle's movement behavior is unlike the other 5 turtles in this study that as of February 2016, are still being detected, and are still present in the habitat.

As a result there is no dot density map for this turtle, nor any anecdotal evidence.

Turtle-MM

Turtle-MM was detected every single eligible day in the study and had the second most detections of any turtle. Along with being the second most detected turtle,

Turtle-MM was detected every day by the same receiver (Section 1-NER-1). This means that Section-1-NER-1 is part of the home range of this turtle albeit only during the day, according to detections broken down to day and night. This doesn't necessarily mean the turtle isn't using the habitat for resting or sleeping, but the 99.5% of its overall detections came during the day. If this turtle were using the habitat for nighttime sleeping/resting more nighttime detections would be expected over the course of 6 months. Observed behavior of this turtle, the two times it was captured, was while the turtle was foraging. This tells us at very least the marine habitat of the CEK runway is part of its foraging habitat. The addition of the receivers in Brewer's Bay revealed the movement of this turtle, when not detected along the marine runway habitat. The additional adjacent receivers registered detections immediately north of the runway. The conclusion reached on this turtle is the 12 receivers registering detections is the home range for the turtle and it uses Section-1-NER-1, daily, and possibly Section-2-NWR-2 most days because the animal is foraging along the marine runway habitat.

Dot Density Map for Turtle-MM

The dot density map does support the conclusion reached on Turtle-MM. This turtle uses the marine habitat of the CEK runway as a part of its "home range' but it is only part of a larger area this animal utilizes as evidenced by the detections on receivers in Brewer's bay adjacent to the marine runway habitat.

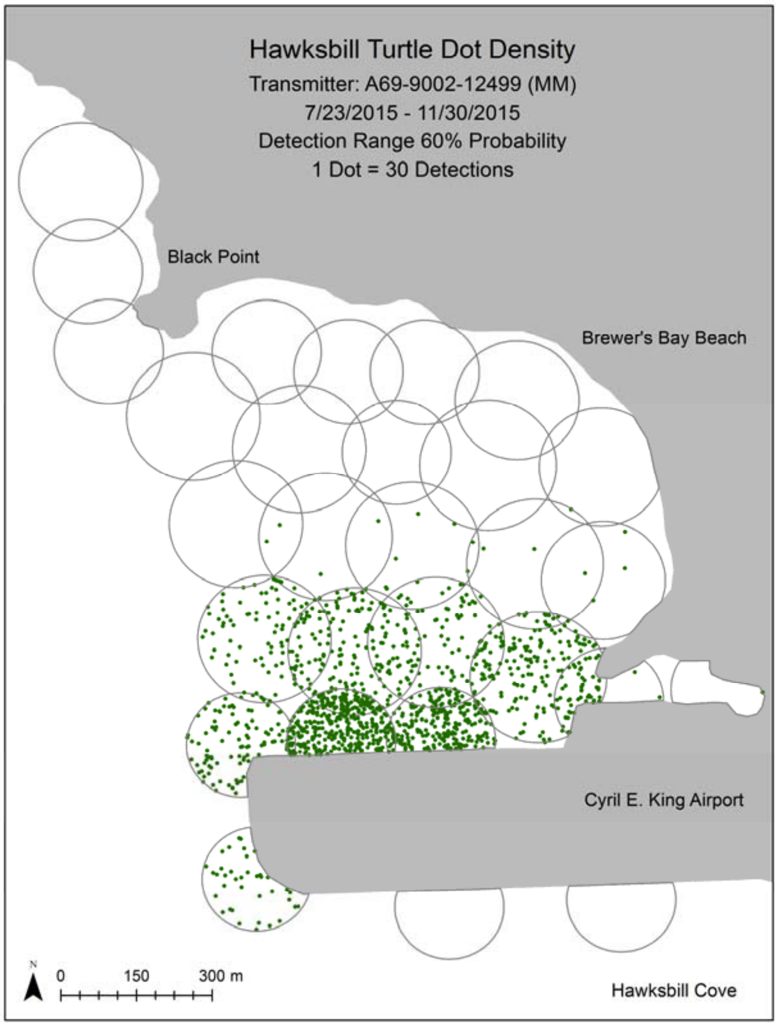

Figure 35. Turtle-MM Dot Density Map.

Anecdotal Evidence

Turtle-MM was captured both times while foraging and is most often observed along the marine habitat of the CEK runway between Section 1-NER-1 and Section 2-NWR-2. Turtle-MM is easily observable because its relatively large size compared to the majority of turtles captured along the marine runway habitat and its acoustic tag.

Turtle-SP

This turtle had the third most detections despite being the last turtle acoustically tagged (May 2015) and is the largest turtle in this study. Turtle-SP is the lone sub-adult turtle in this study and when it was tagged there was a concern that a turtle this large (65cm, 27.8kgs) would simply move out of the detection area because it was cruising through the bay and not a resident. Turtle-SP's acoustic data dispelled that concern and revealed that it, like Turtle-MM, uses the exact same section (Section-1-NER-1). Turtle-SP was detected in Section-1-NER-1 almost exclusively in the daytime and almost never at night. Turtle-SP has never been observed foraging along the runway although it is thought it probably does use the habitat for that reason because it isn't for nighttime resting and sleeping. The addition of the Brewer's Bay array has revealed Turtle-SP has been picked up on a large number of receivers and uses the entire bay as part of its home range. Turtle-SP has even been detected in the mangrove lagoon, an area previously thought never used by sea turtles, let alone a turtle of this size. The lagoon is shallow (<4m) with a murky bottom. Anecdotally, this turtle has been seen by snorkelers and is easily spotted because of its size and acoustic tag. Turtle-SP has been spotted resting at night in an adjacent section to Section-1-NER-1, meaning it is in the area at night, although not detected on the Section-1-NER-1 receiver. Based on registered detections from the additional receivers in Brewer's Bay this turtle uses the entire bay as part of its home range and the marine runway habitat is part of it, daily. Turtle-SP is not using the runway habitat for protection and because of the large crevices, leading to the conclusion that it is part of her home range, possibly for foraging.

Dot Density Map Turtle-SP

This dot density map supports the conclusion drawn on Turtle-SP. This turtle is the largest turtle acoustically tagged (both weight and length) and supports the conclusion, the larger the turtle, the larger the "home range". Turtle-SP uses the marine habitat of the CEK runway as a small part of its "home range" but utilizes other areas in Brewer's Bay as well, including the mangrove lagoon, an area previously thought to be void of turtles.

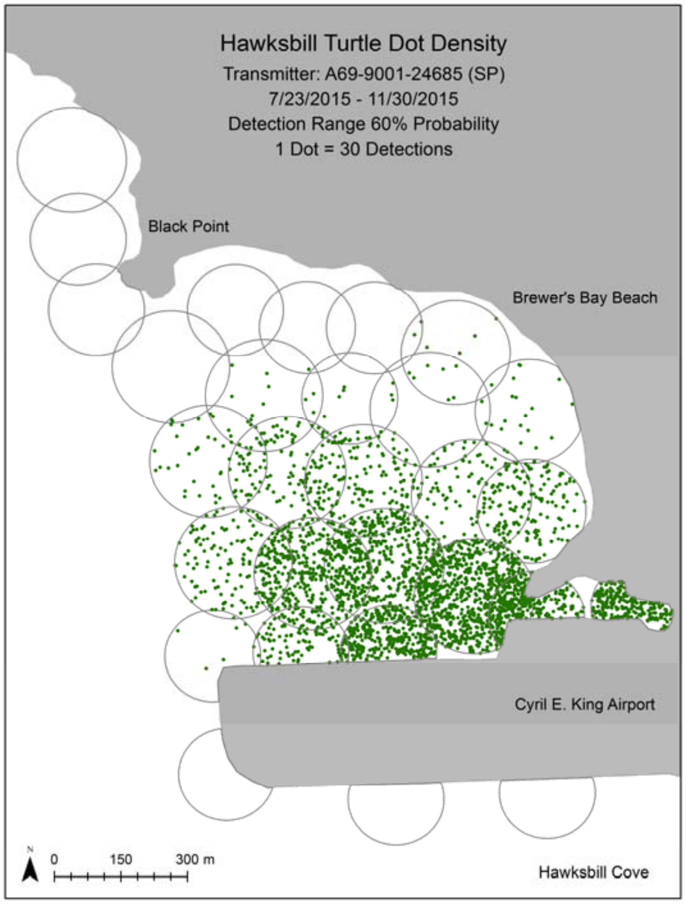

Figure 36. Turtle-SP Dot Density Map.

Anecdotal Evidence

Turtle-SP has been seen multiple times by multiple people. Turtle-SP is easily recognizable as it is the largest tagged hawksbill at this site and it has an acoustic tag attached to back of its carapace making it extremely recognizable. Turtle-SP's preference to the area Section-1-NER-1, is the main reason why it has been seen by snorkelers and divers using the area.

Turtle-SC

Turtle-SC led all turtles with detections over the course of this study by a 2-1 margin (34,000 to 17,000). This turtle, when detections are adjusted to calculate hours per day in the habitat, was calculated to be over 9hrs per day. This turtle spent the majority of its time along the south side of the runway in Hawksbill Cove, and thus was outside the detection limits of the Brewer's Bay array which could reveal any movements outside the initial five receivers. Detected most in Section-5-SER-5, then Section-4-SSR-4, and then finally Section-3-SWR-3; the conclusion reached on this turtle is the south side of the CEK runway in Hawksbill Cove is part of his home range and if the depth data from Turtle-MM is applied to Turtle-SC (similar size and weight) then it would appear it sticks to the sections with the largest crevice size of any sections along the marine habitat of the CEK runway, leading to the strongest conclusion that this turtle uses the runway habitat as part of its home range because of the security of the concrete dolos.

Finally, it should be noted this turtle was never visually observed again after it was initially captured and tagged with an acoustic transmitter. This is important to note because every other turtle tagged with an acoustic tag was seen at least once more and sometimes with regularity. Turtles not seen while swimming could be assumed to be not present, for this turtle, that assumption couldn't be more incorrect. This turtle was the most detected turtle out of all turtles acoustically tagged in this study. The conclusion reached about this turtle using the marine habitat runway sections because of the crevice sizes, possibly explains why the turtle has never been spotted again, as it may spend a lot of its time in the safety of the concrete dolos.

<u>Dot Density Maps Turtle-SC</u>

This dot density map supports the conclusion drawn on Turtle-SC. The south side of the runway, specifically Section 3-SWR-3, Section 4-SSR-4, and Section 5-SER-5 are the most utilized sections by this turtle.

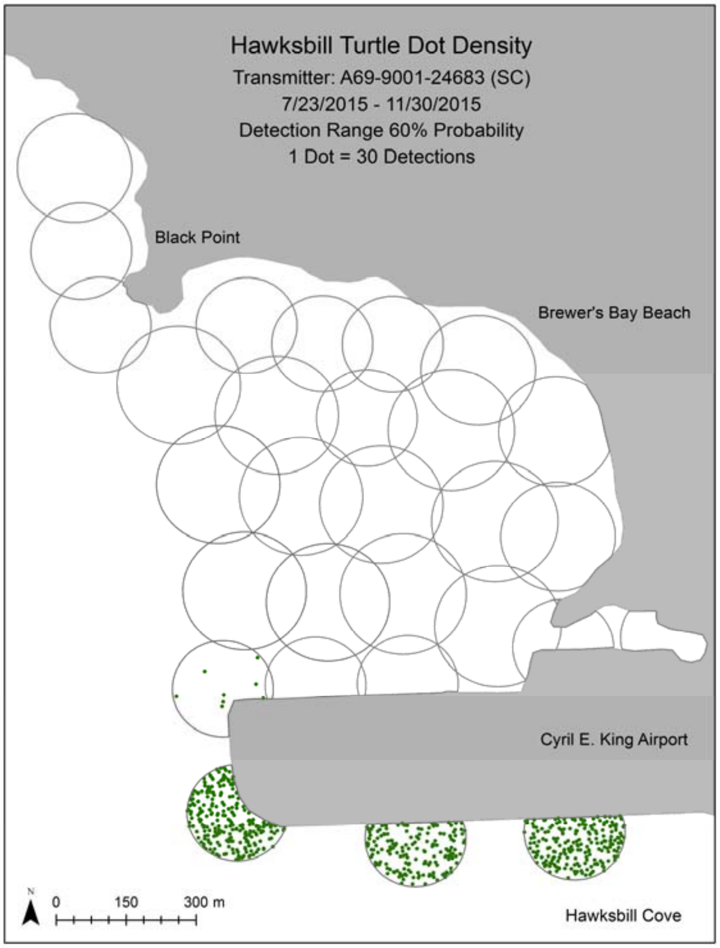

Figure 37. Turtle-SC Dot Density Map.

Anecdotal Evidence

Turtle-SC has never been seen, spotted, or recaptured since the initial capture. Every other turtle in this study that we believed to have remained in the area has been spotted again, in some cases (Turtle-TD, Turtle-TT, Turtle-SP, and Turtle-MM) they have been seen routinely. This is addressed because this habitat, with its large crevices and structural complexity, depth (0m-27m-28m in some areas) and poor visibility past 12-15 meters could lead someone not performing an acoustic study to think this turtle was no longer in the area when in fact this turtle was recorded more than any other turtle by a 2-1 margin.

Turtle-TT

Turtle-TT is one of the very small juvenile turtles acoustically tagged in the study and its results were fascinating when trying to draw a conclusion based on the data. Turtle-TT was only detected on two of the Southside runway receivers (Section-5-SER-5 and Section-4-SSR-4). These also are the sections Turtle-TT is observed during swimming surveys. The last swimming survey conducted on November 15, 2015 spotted Turtle-TT at 13 meters in Section-4-SSR-4 tucked away beneath a granite boulder. This is both a blessing and a curse. It is believed this turtle spends most if not all of its time on the marine runway habitat, but because it is small (1.4kgs) it sticks to the concrete dolos and granite boulders and therefor makes detections in those sections difficult. Another small turtle, not acoustically tagged, Turtle-JZ was witnessed foraging along the marine runway habitat, and it is therefor plausible/realistic to think these animals are foraging along the marine runway habitat. Turtle-TT is believed to be spending more time in the marine runway habitat than detected acoustically. Turtle-TT also had the most detections at night of any turtle with every single nighttime detection being detected in Section-5-SER-5. This turtle is using the marine runway sections with the largest crevice size because it is safe. Turtle-TT can spend much, if not all of its time, in the two sections with ample hiding and resting spots. If the depth data for Turtle-TD is applied to Turtle-TT because they are similar size (1.4kgs), it would spend most of its time at depth that coincided with the two largest sections for crevice size. This turtle is using both Section-4-SSR-4 and Section-5-SER-5 with Section-5-SER-5 being the section where it rests or sleeps most often. At this point in Turtle-TT's life history, the CEK marine runway habitat is this turtle's whole world.

Dot Density Map Turtle-TT

This dot density map supports the conclusion drawn on Turtle-TT. This turtle utilizes Section 5-SER-5 and to a limited detectable, Section 4-SSR-4 when along the marine habitat of the CEK runway. Due to the lack or additional receivers in

Hawksbill Cove, it is difficult to know the location of this turtle when not detected by the two aforementioned receivers.

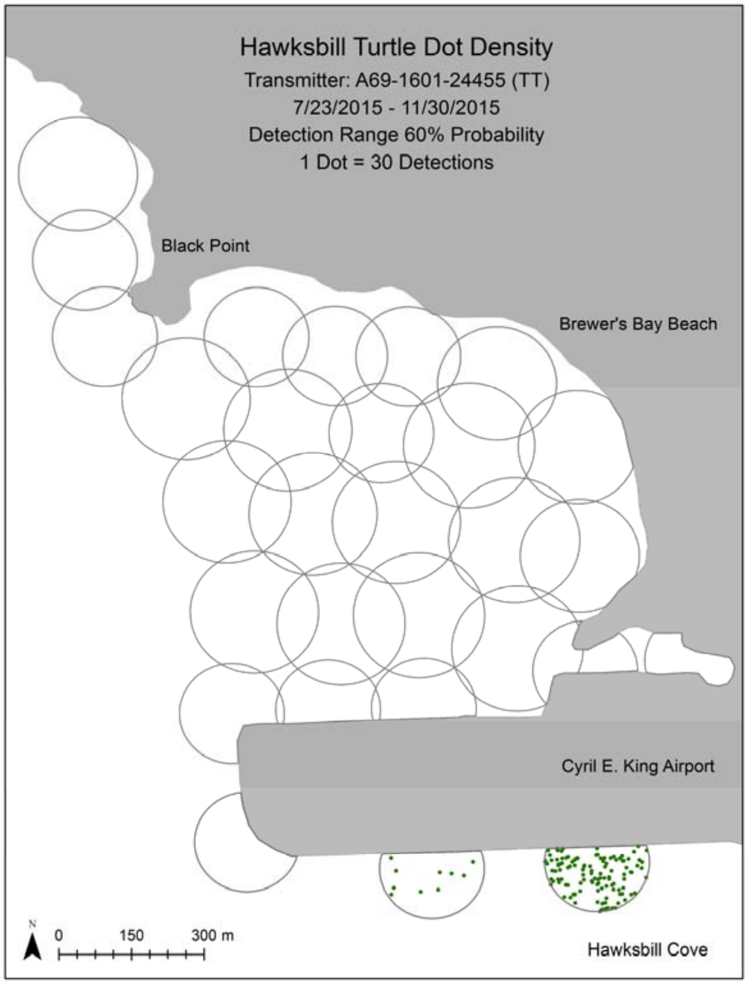

Figure 38. Turtle-TT Dot Density Map.

<u>Anecdotal Evidence</u>

This turtle has been hand captured twice and each time it was caught in shallow water (<6m) in the concrete dolos that make up the Section-5-SER-5 and Section-4-SSR-4. Turtle-TT's initial capture was in Section-4-SSR-4. Its capture that led to its acoustic tag occurred in Section-5-SER-5. Turtle-TT has also been observed, simply drifting into the concrete dolos, until no longer observable.

Turtle-TD

Another small juvenile when it was acoustically tagged (1.4kgs), Turtle-TD presents the same difficulty as Turtle-TT, with one added bonus, it had a depth transmitter. Turtle-TD was captured, tagged, and released in Section-2-NWR-2, and this is believed to be the main focus of its home range. Turtle-TD did have nearly the same amount of detections in Section-1-NER-1, but when the detections were adjusted to calculate hours per day spent in section it was calculated it spent twice as much time in Section-2-NWR-2 than Section-1-NER-1. It is believed, because of calculated hourly usage and this turtle's dot density map that this turtle spends more time in Section-2-NWR-2 than can be revealed by this acoustic study. This exists because when the remainder of the bay was filled with acoustic receivers it showed it moved off the runway, to the north, once in the two-month period. Turtle-TD is always witnessed in Secion-2-NWR-2 or between Section-2-NWR-2 and Section-1-NER-1, and has never been observed anywhere else. The conclusion reached on this turtle is very similar to Turtle-TT in that it is spending much if not all of its time on the runway habitat but that it spends it in the concreted dolos and granite boulders of Section-2-NWR-2 and transmissions are not detected to accurately reflect the actually time spent in the habitat. Turtle-TD depth data suggests it is most detected depth is between 1m-3m, which at that depth in the concrete dolos in Section-2-NWR-2, could make receiver detections more difficult because of the structural complexity of the dolos.

Dot Density Map Turtle-TD

This dot density map supports the conclusion drawn on Turtle-TD. Turtle-TD uses the north side of the marine habitat of the CEK runway and is rarely detected on adjacent receivers to Section 2-NWR-2 and Section 1-NER-1. This supports the evidence of a small "home range" for this turtle almost exclusively existing on the marine habitat of the CEK runway.

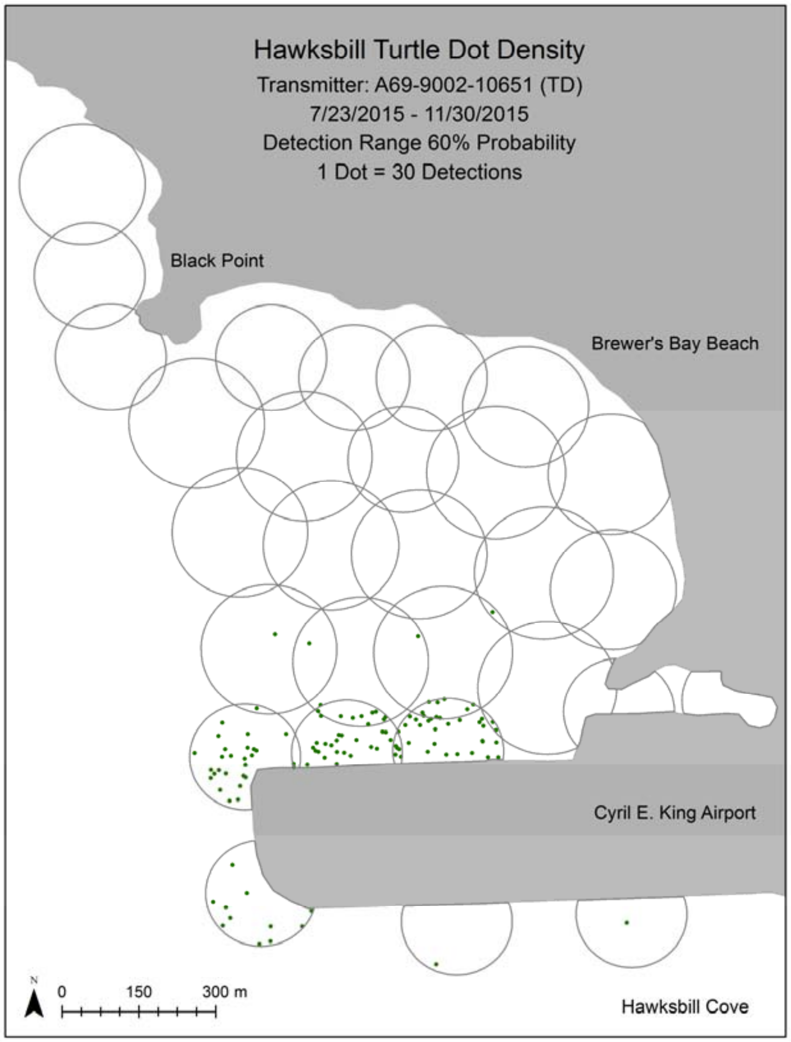

Figure 39. Turtle-TD Dot Density Map.

Anecdotal Evidence

This turtle is observed fairly regularly, it is most commonly spotted in Section-2-NWR-2 or between Section-2-NWR-2 and Section-1-NER-1. Turtle-TD is easily spotted because it is usually in shallow water and has an acoustic tag attached to its carapace. Turtle-TD has been spotted swimming and resting in Section-2-NWR-2 and can easily become hidden due to the large concrete dolos present in the segment of Section-2-NWR-2.

Turtle-MM Max Depth, Day and Night versus Turtle-TD, Max Depth, Day and Night

Turtle-MM and the Turtle-TD are had their maximum daytime and night time depths recorded. Turtle-MM recorded a maximum depth during the day of 24m (SWR-3), 23m (NWR-2), 21m (NER-1) and nighttime maximum of 14m. Turtle-TD recorded a maximum depth during the day of 15m and nighttime maximum of 4m. Given their differences in size (48.3cm CCL(t) versus 22.4cm CCL(t)) and weight (10kgs versus 1.4kgs) it is not surprising the greater recorded depths of the larger turtle, Turtle-MM. If this data is representative of larger turtle versus smaller turtle then this depth data suggests the larger juvenile turtles along the marine habitat of the CEK runway are using the entire water column, surface to sea floor, and the smaller juvenile turtles, possibly due to lack of lung capacity or physical insecurity prefer to use less of the water column. It is important to note again, the habitat of the CEK runway changes at 13m-15m from large concrete dolos and granite boulders, to rock rubble, with the rock rubble going all the way to the sea floor. It is interesting that the habitat transition from concrete dolos and granite boulders to rock rubble coincides with the deepest depth recorded by the smallest turtle in the study.

Conclusion

As mentioned before, different size turtles use this habitat for apparently different reasons. The largest turtle in this study, Turtle-SP, uses this habitat daily, as part of its home range. Smaller juveniles (Turtle-MM and Turtle-SC) use this habitat as part of their much smaller "home range" and will spend several hours a day along this habitat for the concrete dolos and the safety they provide, and/or to forage for food. The most interesting conclusion that this study provides is this is very critical or important habitat for small juvenile turtles (<4.5kgs). This habitat is their entire world. They have everything they need in a small area. The safety of the habitat, provided by the concrete dolos and granite boulders allows for complete security for the turtle. They can essentially become invisible in the habitat while still being able to meet their dietary needs.

Anecdotally, the very first turtle captured and tagged (not acoustically) as part of the mark and recapture study was a small juvenile (36cm CCL(carapace length to the tip), 2.8kgs) on September 27, 2014. It was never recaptured until November 15, 2015 (14 months later). In the time span absent it gained 3kgs, doubling in weight, and growing 8cms to a CCL(carapace length to tip) of 44cm. . Now, it is possible the turtle was gone for the time and absent from this habitat. It is more reasonable to conclude that due to the marine runway structural complexity we never saw this turtle, or we saw this turtle but were unable to recapture it. To put it plainly, this is perfect juvenile hawksbill turtle habitat by serving as a transitional area between oceanic and benthic life history phases.

Recommendations for the Future

Working in this habitat is the only way to truly grasp its importance and uniqueness. This habitat has an abundance of juvenile critically endangered hawksbill turtles, as well as large parrotfish, and other species. If the species is to make a recovery and be removed from the Endangered Species Act, juvenile foraging habitats need to be discovered, protected, and managed. This habitat should be designated and managed as a marine reserve with any stakeholder's activities being regulated and permitted.

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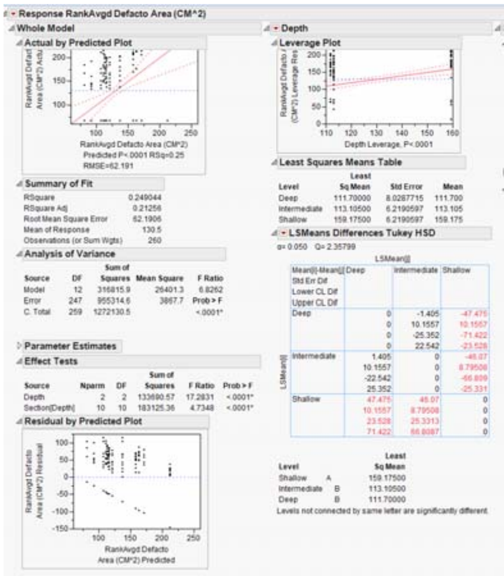
Appendix

1. Statistical ANOVA for crevice size data examination. The results showed a significant statistical difference between crevice sizes at different depths and across all sections and depths.



1a. Matching letter report for crevice size ANOVA. The MLR shows the different groups based on crevice size, statistically.

Section[Depth]

LSMeans Differences Tukey HSD

LSMean[i]	Mean[i]-Mean[j]	[Deep]Outside 1	[Deep]Secti
	Std Err Dif		
	Lower CL Dif		
	Upper CL Dif		
[Intermediate]Section 5		0.525	
		19.6664	
		-65.271	
		66.3212	
[Intermediate]The Tip		21.725	
		19.6664	
		-44.071	
		87.5212	
[Shallow]Section 1		-22.975	
		19.6664	
		-88.771	
		42.8212	
[Shallow]Section 2		42.6	
		19.6664	
		-23.196	
		108.396	
[Shallow]Section 4		55.625	
		19.6664	
		-10.171	
		121.421	
[Shallow]Section 5		97.025	
		19.6664	
		31.2288	
		162.821	
[Shallow]The Tip		48.1	
		19.6664	
		-17.696	
		113.896	

Level					Least Sq Mean
[Shallow]Section 5	A				212.12500
[Shallow]Section 4	A	B			170.72500
[Shallow]The Tip	A	B			163.20000
[Shallow]Section 2	A	B	C		157.70000
[Intermediate]The Tip		B	C	D	136.82500
[Intermediate]Section 1		B	C	D	121.35000
[Intermediate]Section 5		B	C	D	115.62500
[Deep]Outside 1		B	C	D	115.10000
[Deep]The Tip		B	C	D	113.30000
[Intermediate]Section 4		B	C	D	110.60000
[Deep]Section 2		B	C	D	106.70000
[Shallow]Section 1			C	D	92.12500
[Intermediate]Section 2				D	81.12500

Levels not connected by same letter are significantly different.

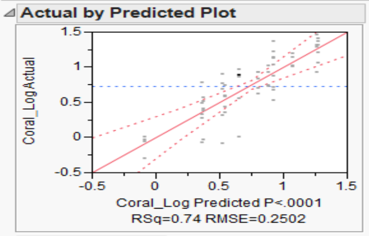
2. Statistical ANOVA for coral benthic community composition. There was not significant statistical difference off coral composition but was a significant statistical difference between sections across all depths.

Least Squares Fit

Response Coral_Log

Whole Model

Actual by Predicted Plot



Summary of Fit

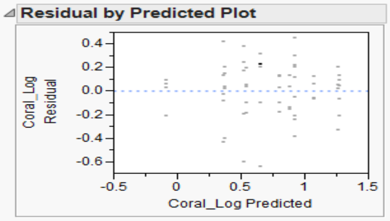
Analysis of Variance

Parameter Estimates

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Depth	2	2	0.2007565	1.6040	0.2109
Section[Depth]	10	10	8.9216669	14.2561	<.0001*

Residual by Predicted Plot



2a. Matching letter report coral benthic community composition. The MLR shows the different letter groups based on their statistical coral cover.

Level						Least Sq Mean
[Shallow]Section 3	A					1.272155
[Shallow]Section 4	A					1.261762
[Intermed]Section 3	A	B				1.072700
[Shallow]Section 5	A	B	C			0.921681
[Intermed]Section 5	A	B	C			0.916442
[Deep]Section 3	A	B	C	D		0.884033
[Intermed]Section 4	A	B	C	D		0.800289
[Deep]Section 2		B	C	D		0.654542
[Shallow]Section 2		B	C	D		0.538843
[Intermed]Section 2			C	D		0.515796
[Deep]Section 4				D	E	0.365909
[Intermed]Section 1				D	E	0.359576
[Shallow]Section 1					E	-0.089936

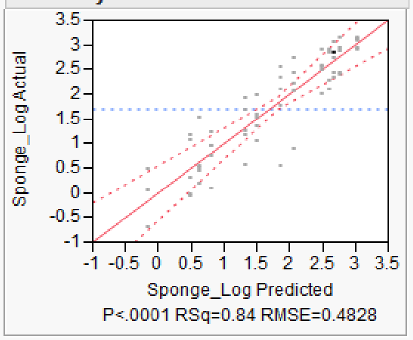
Levels not connected by same letter are significantly different.

3. Statistical ANOVA for sponge benthic community composition. The ANOVA for sponge benthic composition showed a significant statistical difference in sponge cover across different depths and then sections across depth.

Response Sponge_Log

Whole Model

Actual by Predicted Plot



Summary of Fit

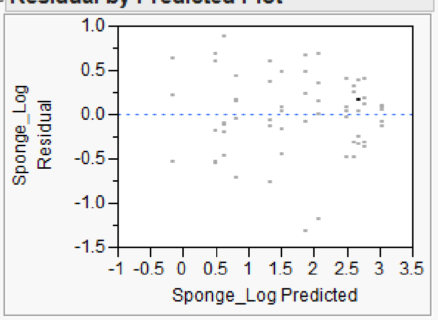
Analysis of Variance

Parameter Estimates

Effect Tests

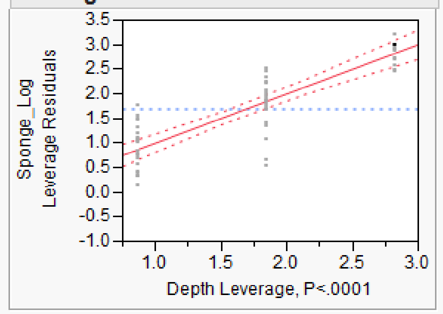
Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Depth	2	2	36.623564	78.5700	<.0001*
Section[Depth]	10	10	25.942200	11.1310	<.0001*

Residual by Predicted Plot



Depth

Leverage Plot



Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
Deep	2.8180244	0.12464969	2.81802
Intermed	1.8407790	0.09655324	1.84078
Shallow	0.8661370	0.09655324	0.86614

LSMeans Differences Tukey HSD

α= 0.050 Q= 2.4126

LSMean[j]

LSMean[i]	Mean[i]-Mean[j] / Std Err Dif / Lower CL Dif / Upper CL Dif	Deep	Intermed	Shallow
Deep		0	0.97725	1.95189
		0	0.15767	0.15767
		0	0.59685	1.57149
		0	1.35764	2.33228
Intermed		-0.9772	0	0.97464
		0.15767	0	0.13655
		-1.3576	0	0.64521
		-0.5968	0	1.30407
Shallow		-1.9519	-0.9746	0
		0.15767	0.13655	0
		-2.3323	-1.3041	0
		-1.5715	-0.6452	0

Level		Least Sq Mean
Deep	A	2.8180244
Intermed	B	1.8407790
Shallow	C	0.8661370

Levels not connected by same letter are significantly different.

3a. Matching letter report sponge benthic community composition. The MLR placed individual sections into different letter groups based on sponge cover.

Level							Least Sq Mean
[Deep]Section 4	A						3.029276
[Deep]Section 3	A	B					2.755880
[Deep]Section 2	A	B					2.668917
[Shallow]Section 1	A	B					2.591721
[Intermed]Section 2	A	B	C				2.494614
[Intermed]Section 5	A	B	C	D			2.055727
[Intermed]Section 4		B	C	D			1.850848
[Intermed]Section 3			C	D	E		1.495678
[Intermed]Section 1				D	E		1.307029
[Shallow]Section 5					E	F	0.788976
[Shallow]Section 4					E	F	0.625076
[Shallow]Section 2					E	F	0.484863
[Shallow]Section 3						F	-0.159951

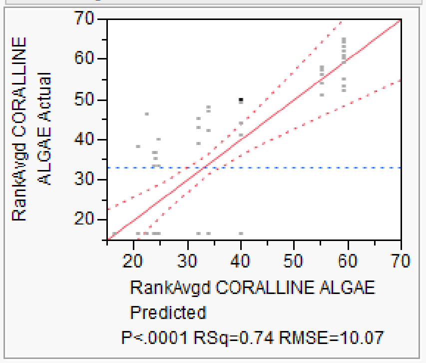
Levels not connected by same letter are significantly different.

4. Statistical ANOVA for coralline algae benthic community composition. The ANOVA for coralline algae composition had a significant statistical difference across different depths, and sections across depths.

Response RankAvgd CORALLINE ALGAE

Whole Model

Actual by Predicted Plot



Summary of Fit

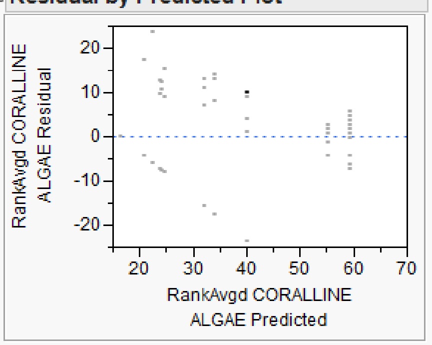
Analysis of Variance

Parameter Estimates

Effect Tests

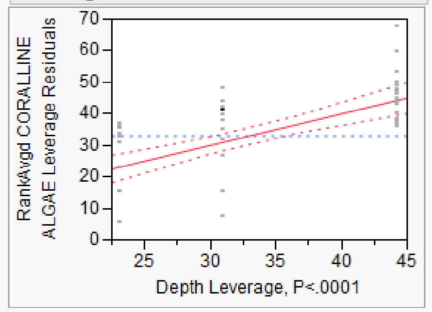
Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Depth	2	2	5688.0267	28.0485	<.0001*
Section[Depth]	10	10	9190.3733	9.0638	<.0001*

Residual by Predicted Plot



Depth

Leverage Plot



Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
Deep	30.966667	2.5999507	30.9667
Intermed	23.020000	2.0139131	23.0200
Shallow	44.200000	2.0139131	44.2000

LSMeans Differences Tukey HSD

α= 0.050 Q= 2.4126

LSMean[j]

LSMean[i]	Mean[i]-Mean[j] / Std Err Dif / Lower CL Dif / Upper CL Dif	Deep	Intermed	Shallow
Deep	Mean[i]-Mean[j]	0	7.94667	-13.233
	Std Err Dif	0	3.28871	3.28871
	Lower CL Dif	0	0.01234	-21.168
	Upper CL Dif	0	15.881	-5.299
Intermed	Mean[i]-Mean[j]	-7.9467	0	-21.18
	Std Err Dif	3.28871	0	2.8481
	Lower CL Dif	-15.881	0	-28.051
	Upper CL Dif	-0.0123	0	-14.309
Shallow	Mean[i]-Mean[j]	13.2333	21.18	0
	Std Err Dif	3.28871	2.8481	0
	Lower CL Dif	5.299	14.3087	0
	Upper CL Dif	21.1677	28.0513	0

Level				Least Sq Mean
Shallow	A			44.200000
Deep		B		30.966667
Intermed			C	23.020000

Levels not connected by same letter are significantly different.

4a. Matching letter report coralline algae benthic community composition. The MLR shows the statistical difference across sections and depth as it relates to coralline algae cover.

Level					Least Sq Mean
[Shallow]Section 4	A				59.400000
[Shallow]Section 3	A				59.400000
[Shallow]Section 5	A	B			55.200000
[Deep]Section 2	A	B	C		40.100000
[Intermed]Section 4		B	C	D	34.000000
[Deep]Section 4			C	D	32.000000
[Shallow]Section 1			C	D	24.600000
[Intermed]Section 3			C	D	24.200000
[Intermed]Section 5			C	D	23.900000
[Shallow]Section 2			C	D	22.400000
[Deep]Section 3			C	D	20.800000
[Intermed]Section 1				D	16.500000
[Intermed]Section 2				D	16.500000

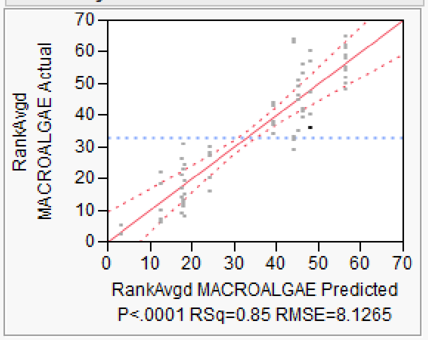
Levels not connected by same letter are significantly different.

5. Statistical ANOVA for macro algae benthic community composition. The ANOVA for the benthic composition of macro algae determined there is a significant statistical difference between depth, and sections across different depths.

Response RankAvgd MACROALGAE

Whole Model

Actual by Predicted Plot



Summary of Fit

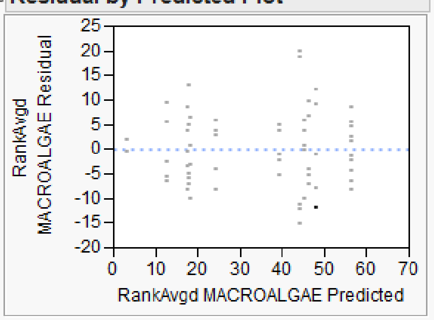
Analysis of Variance

Parameter Estimates

Effect Tests

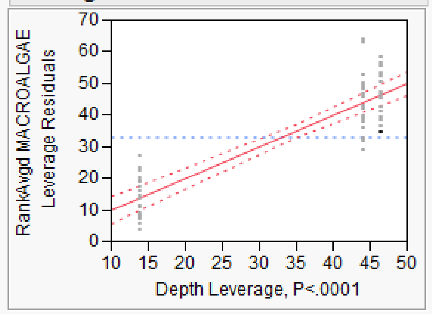
Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Depth	2	2	14967.067	113.3175	<.0001*
Section[Depth]	10	10	4473.333	6.7736	<.0001*

Residual by Predicted Plot



Depth

Leverage Plot



Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
Deep	46.466667	2.0982594	46.4667
Intermed	44.080000	1.6253047	44.0800
Shallow	13.840000	1.6253047	13.8400

LSMeans Differences Tukey HSD

α= 0.050 Q= 2.4126

LSMean[j]

LSMean[i]	Mean[i]-Mean[j] / Std Err Dif / Lower CL Dif / Upper CL Dif	Deep	Intermed	Shallow
Deep	Mean[i]-Mean[j]	0	2.38667	32.6267
	Std Err Dif	0	2.65411	2.65411
	Lower CL Dif	0	-4.0166	26.2234
	Upper CL Dif	0	8.78997	39.03
Intermed	Mean[i]-Mean[j]	-2.3867	0	30.24
	Std Err Dif	2.65411	0	2.29853
	Lower CL Dif	-8.79	0	24.6946
	Upper CL Dif	4.01664	0	35.7854
Shallow	Mean[i]-Mean[j]	-32.627	-30.24	0
	Std Err Dif	2.65411	2.29853	0
	Lower CL Dif	-39.03	-35.785	0
	Upper CL Dif	-26.223	-24.695	0

Level			Least Sq Mean
Deep	A		46.466667
Intermed	A		44.080000
Shallow		B	13.840000

Levels not connected by same letter are significantly different.

5a. Matching letter report macro algae benthic community composition. The MLR for the macro algae cover shows the breakdown of macro algae cover across all sections and depths.

Level					Least Sq Mean
[Intermed]Section 3	A				56.400000
[Intermed]Section 4	A				56.400000
[Deep]Section 2	A				48.000000
[Deep]Section 3	A				46.200000
[Deep]Section 4	A				45.200000
[Intermed]Section 5	A				44.200000
[Intermed]Section 2	A	B			39.200000
[Intermed]Section 1		B	C		24.200000
[Shallow]Section 5			C	D	18.200000
[Shallow]Section 2			C	D	18.000000
[Shallow]Section 4			C	D	17.400000
[Shallow]Section 3			C	D	12.600000
[Shallow]Section 1				D	3.000000

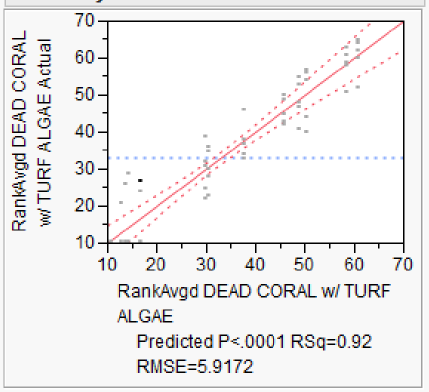
Levels not connected by same letter are significantly different.

6. Statistical ANOVA for DCA benthic community composition. There was a significant statistical difference between depth, and sections across depths for the DCA cover.

Response RankAvgd DEAD CORAL w/ TURF ALGAE

Whole Model

Actual by Predicted Plot



Summary of Fit

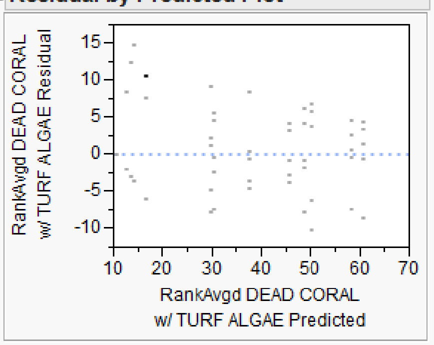
Analysis of Variance

Parameter Estimates

Effect Tests

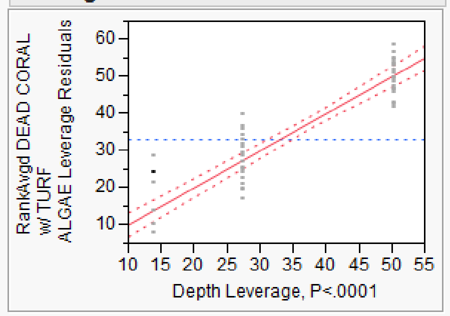
Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Depth	2	2	13805.067	197.1394	<.0001*
Section[Depth]	10	10	6589.233	18.8191	<.0001*

Residual by Predicted Plot



Depth

Leverage Plot



Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
Deep	13.733333	1.5278190	13.7333
Intermed	27.320000	1.1834435	27.3200
Shallow	50.240000	1.1834435	50.2400

LSMeans Differences Tukey HSD

α= 0.050 Q= 2.4126

LSMean[j]

LSMean[i]	Mean[i]-Mean[j] / Std Err Dif / Lower CL Dif / Upper CL Dif	Deep	Intermed	Shallow
Deep	Mean[i]-Mean[j]	0	-13.587	-36.507
	Std Err Dif	0	1.93256	1.93256
	Lower CL Dif	0	-18.249	-41.169
	Upper CL Dif	0	-8.9242	-31.844
Intermed	Mean[i]-Mean[j]	13.5867	0	-22.92
	Std Err Dif	1.93256	0	1.67364
	Lower CL Dif	8.92419	0	-26.958
	Upper CL Dif	18.2491	0	-18.882
Shallow	Mean[i]-Mean[j]	36.5067	22.92	0
	Std Err Dif	1.93256	1.67364	0
	Lower CL Dif	31.8442	18.8822	0
	Upper CL Dif	41.1691	26.9578	0

Level				Least Sq Mean
Shallow	A			50.240000
Intermed		B		27.320000
Deep			C	13.733333

Levels not connected by same letter are significantly different.

6a. Matching letter report DCA benthic community composition. The MLR shows the different groups based on the statistical difference in the cover of DCA.

Level						Least Sq Mean
[Shallow]Section 1	A					60.600000
[Shallow]Section 2	A	B				58.400000
[Intermed]Section 1	A	B	C			50.200000
[Shallow]Section 5	A	B	C			48.800000
[Shallow]Section 3		B	C			45.800000
[Shallow]Section 4			C	D		37.600000
[Intermed]Section 2				D		30.400000
[Intermed]Section 5				D		29.800000
[Deep]Section 2					E	16.500000
[Deep]Section 4					E	14.200000
[Intermed]Section 4					E	13.600000
[Intermed]Section 3					E	12.600000
[Deep]Section 3					E	10.500000

Levels not connected by same letter are significantly different.