A Preliminary Analysis of Habitat Use, Movement, and Migration Patterns of Queen Conch, *Strombus gigas*, in St. John, USVI, Using Acoustic Tagging Techniques

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ABSTRACT

Acoustic tagging has become a popular technology for detecting the presence of individuals and tracking movement patterns of a variety of marine species. Autonomous hydrophone receivers and coded acoustic tags are currently being used to track long-term movements of queen conch, *Strombus gigas*, in two bays in St. John, USVI, Fish Bay and No Name Bay. Hydrophone arrays were placed in each bay to match detection zone boundaries with changes in benthic habitat types to allow discrimination of habitat use. Receiver placements near the mouths of the bays allow us to detect conch moving from shallow to deeper waters, an expected seasonal movement associated with spawning. During each of three field visits per year, uniquely coded acoustic tags are cemented onto the shells of number-tagged queen conch of varying size and maturity. To date, a total of 33 acoustic tags have been set in Fish Bay and 24 in No Name Bay. Our preliminary findings suggest that this technology can elucidate movement patterns and size-specific habitat use, although there are some expected difficulties with sonic tracking in shallow-water environments.

KEY WORDS: Queen conch, U.S. Virgin Islands, acoustic tag

Determinando Uso del Habitat, Movimiento, y Patrones Migratorios del Caracol Reina, *Strombus gigas,* en St. John, USVI, Usando Técnicas Que Marcan con Etiqueta Acústicas

El marcar con etiquetas acústicas se ha convertido en una tecnología popular para detectar la presencia de individuos y seguir patrones de movimiento de una variedad de especies marinos. Receptores hidrofonos autonomos y las etiquetas acústicas cifradas se están utilizando actualmente para seguir los movimientos a largo plazo del caracol reina, *Strombus gigas,* en dos bahías en St. John, USVI, Fish Bay and No Name Bay. Un arreglo de hidrófonos fueron colocados en cada bahía para emparejar margenes de la zona de deteccion con los cambios en tipos bénticos del habitat para permitir la discriminación del uso del habitat. Los receptores colocados cerca de las bocas de las bahías permiten que detectemos el movimiento del caracol de aguas bajas a aguas profundas, un movimiento estacional previsto asociado con el lanzamiento de huevos. Durante cada tres visitas por año al campo, etiquetas acústicas cifradas unicas se cementan sobre las conchas de caracoles marcados con etiquetas numeradas de tamaño y de madurez que varían. Hasta la fecha, un total de 33 etiquetas acústicas se han fijado en Fish Bay y 24 en No Name Bay. Resultados preliminares sugieren que esta tecnología puede aclarar patrones de movimiento y uso del habitat por tamaños especi'ficos aunque hay algunas dificultades previstas con pistas sonicas en ambientes de agua baja.

PALABRAS CLAVES: Caracol Reina, US Virgin Islands, etiquetas acusticas

INTRODUCTION

Discerning movements and behavioral patterns of animals in their natural environment is a difficult task, particularly when only limited time can be devoted to active tracking on a regular basis. Advances in acoustic telemetry equipment and techniques now permit the collection of continuous data on long-term movement patterns and distributions of a wide variety of marine organisms. Such information is important in developing spatial management policies for fisheries and can prove invaluable in identifying essential fish habitats.

The queen conch, *Strombus gigas*, is a large marine gastropod in need of increased protection; populations continue to decline in spite of basin-wide management efforts under Appendix II of the Convention on International Trade in Endangered Species (CITES). An important commercial species throughout its distribution in the Caribbean basin and the Gulf of Mexico, many studies have been devoted to its biology, ecology, and management (*e.g.* Appeldoorn 1984, Brownell and Stevely 1981, Davis and Stoner 1994, Hesse 1979, Randall 1964, Stoner *et al*. 1988, Stoner and Sandt 1991, Wood and Olsen 1983).

Historical data for St. John, U.S. Virgin Islands, from visual surveys conducted in 1981 (Wood and Olsen 1983), 1985 (Boulon 1987), 1990 (Friedlander *et al*. 1994), 1996 (Friedlander 1997), and 2001 (Gordon 2002) show a significant decline in adult conch abundance in spite of a fishing moratorium, seasonal closures, and harvest restrictions (Friedlander 1997). Current regulations consist of a closed season from July 1 – September 30, catch limits of 150 conch commercially and six recreationally per day, and minimum shell lengths of 229 mm (9 inches) or lip thickness of at least 9.5 mm (3/8 inches).

Habitat utilization and movement patterns of queen conch differ by size and life-history stage, making it important to identify all areas and habitat types that may play a role in the recovery of this species. Small juveniles (approximately 75 - 150 mm in shell length) are consistently found in historic nursery grounds characterized by seagrass cover of intermediate density with macroalgal cover and frequent tidal flushing (Stoner and Waite 1990, Stoner 1997). However, habitat utilization patterns for older juveniles seem to vary regionally. Randall (1964) and Torres-Rosado (1987) reported juveniles in the U.S.

Virgin Islands and Puerto Rico to be most abundant in coral rubble. Glazer and Berg (1994) found juveniles in Florida utilizing a variety of available habitats including primarily reef rubble and algae-covered hard bottom. Studies in the Bahamas (Stoner *et al*. 1996, Stoner 2003) and the Turks and Caicos Islands (Hesse 1979) found juveniles preferred seagrass beds composed of turtle grass, *Thalassia testudinum*.

Movement rates reported by Hesse (1979) showed that juveniles 10 - 13 cm long had home ranges of 1,000 m^2, while those from 13 - 16 cm ranged over 2,500 - 5,000 m^2. As conch grow, habitat requirements shift, movement rates increase, and individuals utilize a wider variety of bottom types (Randall 1964, Stoner and Sandt 1992). Hesse (1979) found movement rates of adult conch throughout available habitats of 50 - 100 m per day, but was unable to determine significant home ranges. Glazer *et al*. (2003) and Delgado and Glazer (2007) used acoustic telemetry to determine that adult queen conch at various locations in Florida exhibited mean home ranges of 5,980 m^2 and 27,705 m^2.

Beginning in 2005, we utilized mark-and-recapture techniques to examine population structure and abundance of queen conch in St. John. As part of these efforts, acoustic tracking was used to determine fine-scale movements and large-scale migrations of conch and their use of various habitat types in two shallow-water embayments around the island.

METHODS

Mark-and-recapture and tracking studies were conducted in two bays in St. John, U.S. Virgin Islands, Fish Bay and No Name Bay, both historically known to contain populations of queen conch (Figure 1). Fish Bay, situated in an inhabited region along the southern coastline, is a large bay (320,000 m^2) with unrestricted access to open water and large areas of suitable conch habitat. No Name Bay is on the eastern tip of the island, is smaller and undeveloped, and has a restricted opening due to natural geologic barriers.

Three field expeditions per year were completed during a three-year period beginning in May 2005, each lasting from 10 - 14 days. During each sampling period, areas were haphazardly surveyed for the presence of conch by SCUBA and snorkel. At each animal's location we measured dissolved oxygen, salinity, depth, water temperature, air temperature, and wind speed. Spatial coordinates were collected using a portable wide area augmentation system (WAAS) global positioning system (GPS) unit. Siphonal (shell) length and lip thickness were measured with vernier calipers, and each conch categorized as juvenile or adult using size limits established under the current fishing regulations (229 mm minimum shell length or 9.5 mm lip thickness). Upon initial capture each conch was tagged with a uniquely numbered disk or T-bar spaghetti tag (Floy Tag) by drilling a small hole through the lip of the shell, pulling the tag through, and temporarily securing it with a small drop of super glue. Holes filled very quickly (2 - 3 months) with new shell material, resulting in high rates of tag retention. Benthic composition, expressed as percent cover, was quantified by centering a 1 m^2 quadrat over the conch and visually identifying and counting the total number of squares out of 100 containing each organism or substrate type.

VR2 omnidirectional hydrophone receivers (Vemco Ltd.) were deployed throughout each study site such that an array of overlapping detection zones was created corresponding with changes in general benthic habitat structure (Figure 1). Range tests were performed on several occasions by suspending coded pinger tags 10 - 20 cm above the substrate at major compass ordinates various distances from the hydrophone. Tags were incrementally moved further from the receiver until no longer detected. This distance was considered to be the maximum range of tag detection in that specific direction. Each initial hydrophone location was tested and adjusted accordingly to ensure adequate overlap in zones between neighboring receivers. Hydrophones were mounted on steel tie-down anchors, sunk approximately 1 m into the sediment such that the receiver base rested just above the sediment surface. Receivers were secured to the anchor with a combination of cable ties, hose clamps, leader wire, and a padlock to minimize the possibility of equipment loss from vandalism or natural events. HOBO® temperature loggers (Onset Computer Corp.) were deployed at each hydrophone location, as well as several surface locations throughout each bay. During the first year of the study 4 receivers were placed in No Name Bay and 6 in Fish Bay; the number was increased to a total of 10 in Fish Bay the following year.

The sizes and maturity categories of queen conch used for acoustic tracking were selected to effectively represent the composition of the population at large (see Table 1). When an individual matching a chosen size class was captured, it was tagged with a V7-4L-R64K acoustic transmitter (20.5 mm length, 7 mm diameter) with a time interval of 60 - 180 seconds and an average life expectancy of 220 days (Vemco Ltd.). Tags were cemented using Liquid Roc 700® Acrylic Twin Tube epoxy (MKT Fastening, LLC) onto the highest portion of the spire where signal transmission to the receivers was least likely to be obstructed by shell spires or bottom structure. After the epoxy had cured (10 - 15 minutes), conch were returned to their exact location of capture, marked previously by a fluorescent flag.

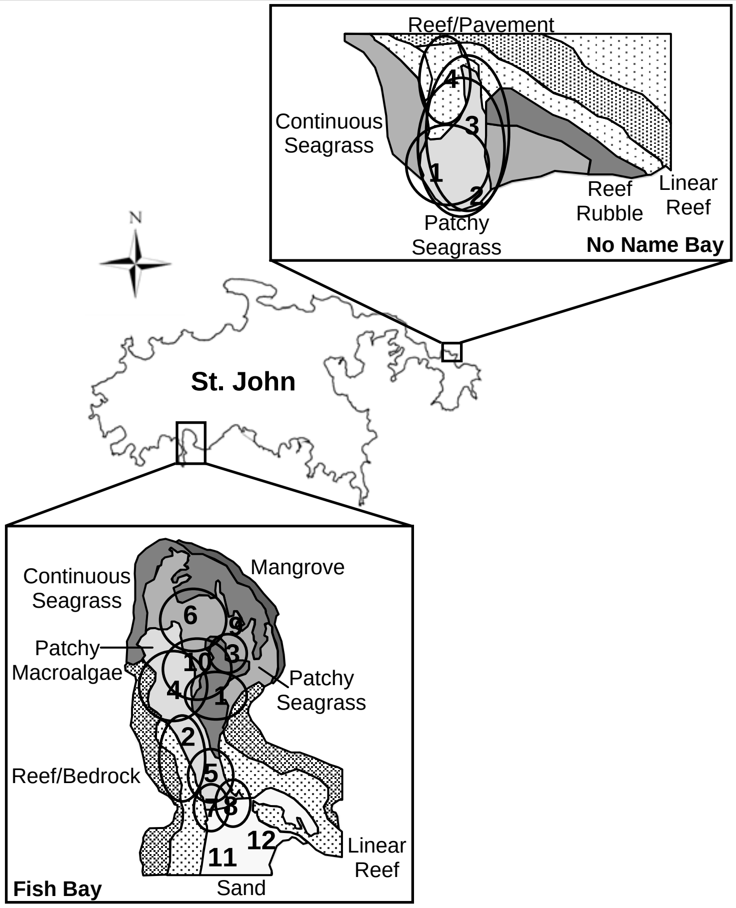

Figure 1. Map of St. John, USVI, showing study locations of Fish and No Name Bays. General habitat categories as defined by the NOAA maps are shown. Letters in each bay are individual hydrophone receivers with their respective detection zones indicated by circles or ellipses. Detection zones for hydrophones B, K, and L were not tested.

On each field trip, data files were downloaded from the receivers using an underwater cable. Temperature loggers were downloaded by temporarily removing them from the anchors, downloading, and replacing them in their previous location. After 12 months of continuous deployment, receivers were removed from their anchors, cleaned, and batteries replaced to ensure no gaps in data collection. Data files were converted to MS Excel spreadsheets and transferred into ArcView 9.1. Spatial locations of tagged conch were overlaid onto categorized NOAA benthic habitat maps to examine distributions through habitat types. Movement patterns and position estimates for queen conch with acoustic tags were interpreted by combining locational data collected from the capture/recapture study and detection patterns in hydrophone data. Linear regressions of conch size by water depth were completed using Statview 5.0 (SAS Institute).

RESULTS

We tagged 57 queen conch with acoustic transmitters during a 3-year period (Figure 2). Thirty-three of these were deployed on 20 juveniles (range = 109 – 223 mm) and 13 adults (range = 235 – 270 mm in Fish Bay. In No Name Bay, 24 conch were tagged, 21 juveniles (range = 145 – 227 mm) and three adults (range = 230 – 265 mm).

All acoustic tags were detected by at least one receiver after deployment with the exception of one in No Name Bay that was never recorded (Table 1). The mean detection time for conch in Fish Bay was 65.4 days, with a range of 1 to 302 days. Between May 26, 2005, and August 27, 2007, receivers in Fish Bay recorded 213,677 individual detections. Hydrophone E recorded the largest number of detections with 69,262 (32.4%), followed closely by hydrophone A at 66,224 (31.0%), and hydrophone C with 50,149 (23.5%, see Figure 3). Conch in No Name Bay had a slightly longer mean detection time of 85 days (range = 0 to 438 days). Hydrophones in No Name Bay logged 542,229 detections from July 13, 2005, to August 26, 2007. Hydrophone M recorded the most detections with 224,139 (41.5%), followed by 193,693 (35.7%) for hydrophone N (Fig ure 3).

Table 1. Summary of data on queen conch, *Strombus gigas*, tagged with coded acoustic transmitters in Fish Bay and No Name Bay, St. John, U.S. Virgin Islands, listed in order of tagging date. "J" designates a juvenile of <229 mm shell length and <9.5 mm lip thickness; "A" represents an adult of >229 mm shell length or >9.5 mm lip thickness. No Name Bay conch marked by asterisks indicate undersized juveniles lost to illegal fishing activity during the study period.

Conch Number	Initial Shell Length (mm)	Age Category (Juv. or Adult)	Date Tagged	Last Date of Detection	Total Days Detected	Nearest Hydrophone
Fish Bay:						
130	181	J	5/26/05	6/1/05	7	E
006	218	J	5/26/05	6/17/05	22	F
136	250	A	5/26/05	7/6/05	42	G
024	222	J	5/26/05	7/18/05	54	C
022	109	J	5/26/05	7/24/05	60	C
068	215	J	5/26/05	8/8/05	74	A
104	135	J	5/26/05	6/8/06	302	A
082	240	A	7/14/05	7/14/05	1	A
032	143	J	7/14/05	10/14/05	93	A
028	192	J	8/31/05	9/11/05	12	F
245	270	A	8/31/05	9/15/05	16	G
096	168	J	8/31/05	10/25/05	56	D
018	172	J	8/31/05	10/26/05	57	C
8066	189	J	3/29/06	4/20/06	23	E
8076	203	J	3/29/06	4/23/06	26	F
8070	270	A	3/29/06	4/25/06	28	E
8018	142	J	3/29/06	5/12/06	45	A
8315	245	A	6/14/06	7/20/06	37	E
8086	235	A	6/14/06	7/25/06	42	F
8232	140	J	6/14/06	8/23/06	67	D
8104	151	J	6/14/06	9/15/06	94	F
8526	265	A	8/14/06	8/28/06	15	I
8585	235	A	8/14/06	9/12/06	29	G
8600	164	J	8/14/06	1/16/07	75	A
8550	265	A	8/14/06	4/2/07	242	E
8757	241	A	4/28/07	5/7/07	10	A
8758	212	J	4/28/07	6/12/07	46	A
8371	223	J	4/29/07	6/22/07	54	E
8555	253	A	4/29/07	7/5/07	67	E
8617	238	A	4/29/07	8/16/07	109	E
8756	151	J	4/28/07	8/21/07	116	B
8755	147	J	4/28/07	8/23/07	118	A
8488	193	J	4/29/07	8/24/07	118	E
No Name Bay:						
152	227	J	7/13/05	8/15/05	34	P
151	191	J	7/13/05	8/18/05	37	P
138	164	J	7/13/05	9/2/05	52	N
150	230	A	7/13/05	11/8/05	119	N
147	173	J	7/13/05	11/13/05	124 *	M
153	160	J	7/13/05	9/23/06	438	P
334	250	A	9/1/05	9/10/05	10	P
336	220	J	9/1/05	9/22/05	22	P
320	205	J	9/1/05	11/8/05	69 *	M
340	171	J	9/1/05	11/11/05	72	O
8055	146	J	3/27/06	4/15/06	20	O
8054	145	J	3/27/06	4/30/06	35	M
341	190	J	3/27/06	5/5/06	40	P
327	166	J	3/27/06	5/23/06	58	M
137	265	A	6/11/06	7/10/06	30	P
8248	163	J	6/11/06	7/29/06	49	N
313	150	J	6/11/06	8/7/06	58 *	N
8056	148	J	6/11/06	9/4/06	86	N
8262	187	J	8/13/06	---	0	M
8265	162	J	8/13/06	8/26/07	379	N
8266	202	J	8/13/06	9/23/06	42	N
301	220	J	8/13/06	2/9/07	181	P
8245	225	J	4/23/07	5/26/07	34	M
8603	168	J	4/23/07	6/11/07	50	P

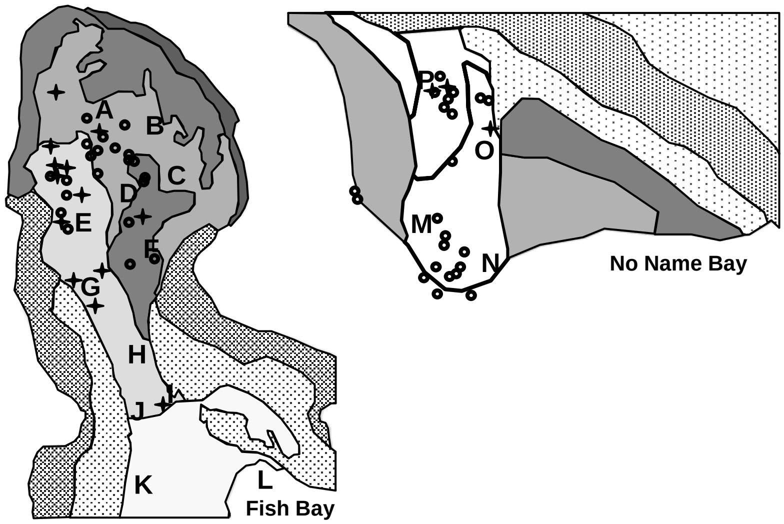

Figure 2. Locations of acoustic tag deployment on queen conch in Fish and No Name Bays. Release locations are shown for tagged adults (+) and juveniles (o).

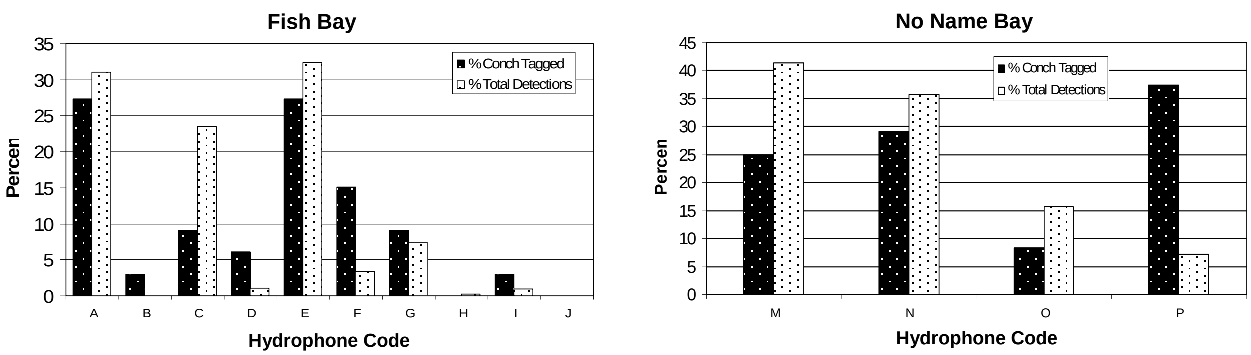

Figure 3. Relationship between the percent of queen conch receiving acoustic tags near each receiver and the relative percent of total detections recorded by each receiver.

The majority of adult conch that received acoustic tags (69.2%) were originally found in habitat classified as patchy macroalgae (NOAA maps) dominated by *Avrainvillea spp*., *Acanthophora spp*., *Halimeda spp*., and *Penicillus spp.* (J.C.D., Unpubl. data). Nearly half of these individuals remained in this habitat for as long as their tags were detected. Juveniles that received acoustic tags were more evenly distributed among habitat types with 45% in patchy seagrass (mixtures of *T. testudinum*, *Syringodium filiforme*, and *Halodule wrightii*), 30% in patchy macroalgae, and the remaining 25% in continuous seagrass beds (either *T. testudinum* or *S. filiforme*).

The results of a linear regression (Figure 4) showed a significant relationship between total shell length and water depth ($p < 0.05$, $R^2 = 0.164$). Juvenile conch were found mainly in depths of 1 - 3 m, while adults were more likely to be found in depths from 3 - 9 m.

Movement rates were calculated for individuals that migrated from Fish Bay. Of the 20 tagged juveniles in Fish Bay, 19 remained near their initial tag locations and one was detected leaving the bay. This individual (conch #032, 143 mm) remained in the central portion of the bay for nearly 5 months (from May 21 – October 5), before traveling approximately 474 m south and exiting in nine days at a rate of 52.7 m/day. Six of the tagged adults showed very little movement within the bay, while the other seven were detected leaving the bay. During their migration out of the bay, these conch (#245, #8070, #8488, #8526, #8550, #8585, and #8757) traveled an average of 414 m in 17 days, for an overall rate of 24.4 m/day. The maximum rate was detected from conch #8070 that traveled 144 m in a single day.

Acoustic tracking data collected from No Name Bay showed low movement patterns for all conch. Two adults left the bay shortly after they were tagged, while the signal from the third disappeared without evidence of exiting the bay. This conch was never recaptured on subsequent field trips. Three juveniles were detected leaving the bay and did not return. The other 17 tagged juveniles remained within the bay, the majority in close proximity to their original capture locations for the duration of their tag life.

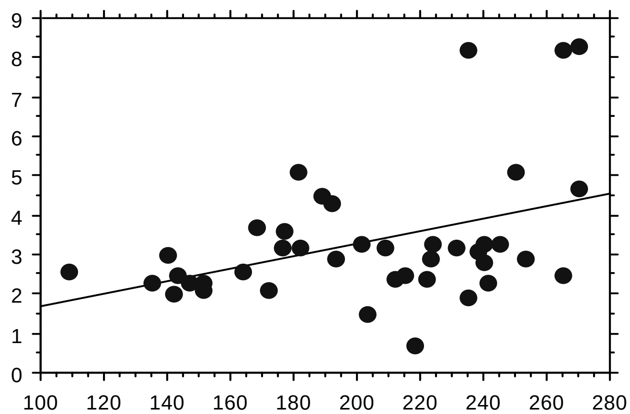

Figure 4. Regression lines for the relationship between shell length (mm) and water depth (m) for acoustic tagged queen conch in Fish Bay ($p < 0.05$, $R^2 = 0.164$).

DISCUSSION

Acoustic telemetry studies can effectively collect data on habitat utilization patterns of both juvenile and adult conch. Juveniles in Fish Bay were evenly distributed among patchy seagrass, continuous seagrass beds, and patchy macroalgal plains in the inner-central portion of the bay in 1 - 3 m of water nearest to hydrophones C and A. Aside from the single juvenile that moved out of Fish Bay and the three that left No Name Bay, the majority of small conch remained near their initial tag locations and habitats for several months until no longer recorded by any receivers. These remaining conch accounted for 98% of the total detections recorded by hydrophones C and A over the course of this study. As larger juveniles grew closer to adult size, their rate of movement increased, and they moved to the western side of the bay into deeper water (4 - 6 m, near hydrophone E) and occupied a mixed zone of sand and patchy macroalgae. They either remained in this area or began outward migration, following a sand channel running south into water 8 - 12 m deep until no longer detected by our outermost hydrophones. Two additional hydrophones have been added in deeper water to improve detection of direction as conch leave the bay.

Migrating adults generally exhibited a linear direction of movement, moving quickly between hydrophone locations. Two adults increased their rate of movement in late March and were gone by early to mid-April, coinciding with a 2^{o}C increase in bottom water temperature. Another adult began moving quickly almost immediately after it was tagged, beginning in early May and exiting the detection area within nine days. The other adults left later during the months of July and August. Spawning activity in the U.S. Virgin Islands has been reported as early as February (Randall 1964) and has been shown to increase with increasing water temperatures until reaching a peak in June through August (Coulston *et al*. 1987). Our data suggest that adults migrating from Fish Bay were likely prompted by elevated water temperatures signaling the start of reproductive activity, although no spawning activity was witnessed.

Conch #032 was the only juvenile detected leaving Fish Bay, remaining in the central portion of the bay until early October before leaving in approximately nine days. This movement may have been triggered by changing environmental conditions as water temperature dropped by 1^{o}C followed by a sudden decrease in barometric pressure (http://www.tidesandcurrents.noaa.gov). Similar movements have been recorded for blacktip sharks leaving shallow nursery areas for deeper water in response to falling barometric pressures (Heupel *et al*. 2003).

Acoustic data can also provide insight into hourly activity levels, particularly for slow-moving animals. Previous studies on young juvenile conch have reported diurnal burial rhythms thought to be associated with increased feeding activity at night (Appeldoorn and Ballantine 1983, Randall 1964, Sandt and Stoner 1992). Diel patterns in tag detection can provide information on activity levels, if we assume that burial into the substrate affects the probability of tag detection. Where there were consistent detection data useful for this analysis (nearly half of our tagged conch), juveniles and adults showed stronger activity patterns from 0600 to 1900 hours before weakening and occasionally disappearing completely until 0600 the following morning. Factors expected to affect signal detection such as wind energy, wave action, and increased turbidity (Heupel *et al*. 2006, Thorstad *et al*. 2000) were reduced at night and unlikely to produce this pattern.

While temperature fluctuations and weather events may influence annual patterns of migration and diel activity, patterns show day-night differences, our data only suggest a weak connection between tidal or lunar cycles. Individuals that were continuously detected for extended periods of time showed evidence that nocturnal activity increased around the new moon and decreased around the full moon. This will require a more complete analysis of additional tagged individuals.

Tracking conch movements in shallow-water environments presents a unique set of challenges from initial study design to data analysis. Detection ranges and tag lives were highly variable and not as expected; equipment failures during annual battery changes resulted in loss of data. Topographic variability, dynamic environmental conditions, extraneous sources of biological noise (i.e. fish and crustaceans), and biofouling continually alter the probability of tag detection. In addition, we found that tag detection was substantially reduced in shallow (< 2 m) water limiting information from shallow shelf areas.

Acoustic tracking can provide valuable information on site fidelity of various size classes of queen conch, their daily movement patterns, timing and distance of migration patterns, and general habitat use. In spite of some technical limitations in this application, the techniques provide data at a scale that cannot reasonably be gained any other way. The continued collection and analysis of acoustic data, combined with our mark-and-recapture study, will provide information necessary to further understand habitat utilization and needs and movement patterns of queen conch in the U.S. Virgin Islands.

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