Preliminary Investigation of the Movements, Density, and Growth of Juvenile Queen Conch in a Nursery Area in Barbados

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ABSTRACT

Conservation and sustainable use of queen conch (*Strombus gigas*) is a topic of considerable importance in the Caribbean and is supported by international (CITES) and regional (SPAW Protocol) treaties. Barbados, a conch range state with a small artisanal conch fishery and signatory to both legally binding treaties has recently begun investing in research and development of management plans for this species. To date, the fishery has been described, an island-wide conch abundance survey has been completed and on-going research is examining the reproductive characteristics and movement patterns of adult conch. The current pilot study compliments these efforts by investigating the movement patterns, density and growth of juvenile conch in a nursery area in Barbados over a 10-week period. Three juvenile conch aggregations within a nursery area were selected for study and over 100 individuals (mean shell length: 19.5 cm) from each aggregation were tagged using numbered disc tags (Floy Tag and Manufacturing Inc). A 'key informant' animal in each aggregation was also fitted with a Lotek MM-S-8-SO acoustic tag to assist in relocating the group. Animals were acoustically tracked and visually re-located every few days for 10 weeks. Position (depth, habitat and GPS co-ordinates) and density (number of individuals within 5m-radius) were recorded for key informants and a subsample of individuals within the aggregation were measured for shell length on each tracking dive. Summer home ranges, minimum distance travelled and movement speed were estimated for two key informants, and growth rates of the juvenile cohort within the aggregations were estimated. This preliminary study will inform the design of a larger scale study of the connectivity of juvenile and adult conch aggregations.

KEY WORDS: Queen conch, *Strombus gigas*, acoustic telemetry, juvenile aggregation, Barbados

La Investigación Preliminar de los Movimientos y Uso del Hábitat de las Agregaciones de Juveniles De Caracol

Conservación y uso sostenible de la caracol (*Strombus gigas*) es un tema de considerable importancia en el Caribe y con el apoyo de internacional (CITES) y regionales (Protocolo SPAW) tratados. Barbados, un Estado del área de la caracol con una caracol de la pesca artesanal y de pequeña signatario de ambos instrumentos jurídicamente vinculantes recientemente ha empezado a invertir en investigación y desarrollo de planes de manejo para esta especie. Hasta la fecha, la pesquería se ha descrito, una encuesta de la caracol abundancia en toda la isla se ha completado y en la investigación en curso examina las características de reproducción y patrones de movimiento de la concha de adultos. El estudio complementa estos esfuerzos mediante el examen de la ecología espacial de la caracol juvenil en Barbados. Tres agrupaciones de caracol de menores han sido seleccionados para el estudio y más de 100 personas de cada agrupación han sido marcadas con etiquetas numeradas disco (Floy Tag Inc y Fabricación)."Informantes clave" un animal en cada uno de agregación también ha sido etiquetado con un Lotek MM-S-8-etiquetas acústicas que presten asistencia en la reubicación del grupo. Los animales están siendo rastreados acústicamente y visualmente reubicados dos veces por semana durante 10 semanas. Posición (co profundidad, hábitat, y el GPS-ordenadas) y la densidad (número de individuos dentro de 5 m de radio) se recogen datos de informantes clave y las caracols que se encuentran etiquetados dentro de una barrida metódica de la zona. Estos datos serán utilizados para examinar la amplitud de los movimientos individuales (distancia, velocidad, rango en el hogar) y rastrear los patrones de la cohesión y el movimiento de la agregación. Este estudio preliminar se informará de un estudio a mayor escala de la conectividad de las agregaciones de caracol de menores y adultos.

PALABRAS CLAVE: Caracol, *Strombus gigas*, telemetría acústica, Barbados

L'Enquête Préliminaire de l'Utilisation de l'Habitat et les Mouvements des Agrégations de Strombes Géants pour Mineurs

MOTS CLÉS: Strombes, *Strombus gigas,* hábitat, Barbados

INTRODUCTION

Conservation and sustainable use of the valuable queen conch (*Strombus gigas*) resource is a topic of considerable importance in the Caribbean today as once abundant stocks have dwindled and many conch fisheries throughout the region have collapsed or been closed following overfishing (Theile 2001, FAO 2007). Conservation and sustainable use of queen conch is supported by international (CITES) and regional (SPAW Protocol) treaties, and fishery management efforts throughout much of the region (Theile 2001, 2005).

Barbados, a conch range state with a small, unregulated, artisanal conch fishery, is a signatory to both legally binding treaties and has recently begun investing in research and development of management plans and regulations for this species (GOB 2004, Oxenford and

Parker 2008). To date the fishery has been described (Oxenford et al. 2008), an island-wide conch abundance survey has been completed (Oxenford et al. 2010) and on-going research is examining the reproductive characteristics and movement patterns of adult conch (Bissada-Gooding and Oxenford 2010, Bissada-Gooding In prep.). Further research to investigate the connectivity between the remaining juvenile and adult aggregations in Barbados' low density conch population will be important in developing a conservation strategy for this species in Barbados. The current pilot study is a first step in this research, and investigates characteristics (conch density, individual movement patterns, habitat use and growth rates) of juvenile conch aggregations in a nursery area, over a 10-week period.

METHODS

Site Selection

This study was conducted in a presumed nursery ground: a predominantly coral rubble and sand area in Carlisle Bay, southwest coast of Barbados; known by several fishers to be favoured by juvenile conch; and where juvenile densities were very high at the time of the study. Three sites with significant juvenile aggregations were selected within this area, with the assistance of a local conch fisher (Figure 1).

Tagging and Tracking

A combination of acoustic transmitters and conventional tags were used in the study, and the animals were tracked every 2 - 4 days (weather and sea conditions permitting) following the protocol of Bissada-Gooding and Oxenford (2010) for a period of 10 weeks (July 14 – September 23, 2010).

One juvenile conch at each of the three sites was randomly selected as a 'key informant' and fitted with an acoustic transmitter (Lotek MM-S-8-SO tag, 8.5 x 38 mm in size, 5.5g weight in air). The transmitters were pre-programmed to pulse every five seconds (12 bpm), from 6 am to 6 pm, for an expected longevity of 135 days (Lotek Wireless Inc). The transmitters were attached lengthwise to the dorsal surface of the shell spire with twisted stainless steel wire and yellow cable ties (Figure 2), the latter helping to make the animals more conspicuous for visual re-sighting. A conventional tag (uniquely numbered, brightly coloured, oval disc tag measuring 29 x 5 mm from Floy Tag and Manufacturing Inc.) was also attached to each key informant with twisted stainless steel wire.

All juveniles found within a 10 m radius of the key informant at the time of fitting the acoustic transmitter, were also marked with conventional tags in a single tagging event, in order to monitor whether or not the juveniles stayed together.

The key informant conch were acoustically tracked from a small open boat using a wired HPA-O hydrophone and a LOTEK SRX-400 receiver with a 150 MHz sonic up-converter. Once located from the surface, the exact location, depth (to the nearest 0.1 m) and habitat type was confirmed by SCUBA divers, and coordinates were recorded using a handheld Garmin eTrex Legend geospatial positioning unit.

Biological and Environmental Data Collection

The density of conch around each key informant was recorded on each tracking dive by counting the number of individuals (both tagged and untagged) found within a 5 m radius. Habitat characteristics were also noted and categorised into one of six basic groups (Table 1).

Growth of the juvenile cohort was monitored over the 10-week study by measuring the shell length (to the nearest mm with a flexible tape) of the first five animals encountered in each quadrant of the 5 m survey circle on each tracking dive.

Water temperature was monitored *in situ* every four hours throughout the study period with a HOBO® Water Temp Pro data logger (Onset Computer Corp.) attached to the substrate.

Data Analysis

Mapping — Positions of key informants were mapped using ArcGIS 9.2. Distance moved was measured as the shortest distance between chronologically recorded positions. Total minimum distance travelled by any given animal was measured as the cumulative distances between all consecutive positions. Minimum movement speed was then derived from the distance covered in the given number of days.

Home range — The home range of key informants was delineated by the minimum convex polygon enclosing all recorded positions, following the method of Glazer et al. (2003) and using the 'Hawth's Analysis Tools' extension for ArcGIS. A fixed kernel home range for each was also generated using the 'Animal Space Use 1.3 Beta' software

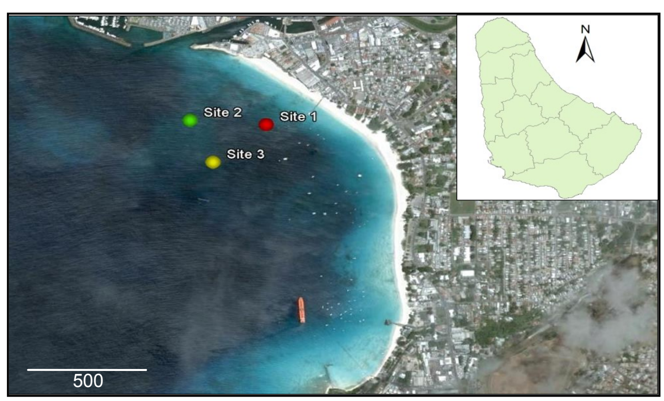

Figure 1. Aerial image of Carlisle Bay, Barbados, showing the locations of the three initial study sites. Insert map shows location of Carlisle Bay on the southwest coast of Barbados. Image source: Google Earth.

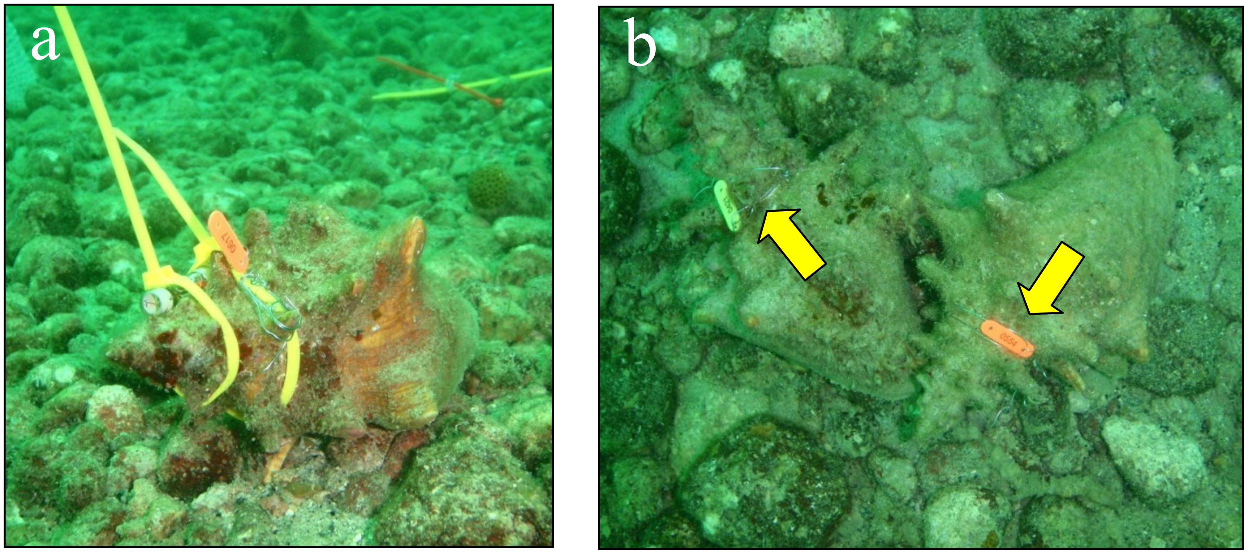

Figure 2. Photographs of juvenile queen conch showing tag attachments for (a) a 'key informant' conch carrying both an acoustic transmitter and a numbered disc tag attached to the shell spire with cable ties and twisted wire, and (b) two conventionally tagged conch carrying numbered disc tags attached to the shell spire with twisted wire.

Table 1. Habitat categories used during visual surveys of juvenile queen conch in Carlisle Bay. Modified from Danylchuk et al. (2003).

Category	Code	Description
Algal Plain	AP	Coarse or fine sand with benthic macroalgae
Seagrass	SG	Coarse sand bottom with seagrass
Sand Plain	SP	Coarse sand or fine coral rubble with little or no macroalgae or seagrass
Coral Rubble	CR	Coarse coral rubble with benthic algae and/or seagrass cover
Gorgonian/ Sponge	GS	Coral rubble and Sand substrate dominated by gorgonians and sponges
Coral Heads	CH	Small coral heads surrounded by other habitat types; living coral

to find appropriate smoothing factors (h values) according to the Least Squares Cross Validation method ($LSCV_h$), and Hawth's Analysis Tools.

RESULTS

Tracking and Tag Performance

Acoustic transmitters were placed on three juvenile conch (one at each site) in mid July (Table 2) and tracking was attempted thereafter every 2 - 4 days. However, the occurrence of bad weather and several failures to locate key informants meant that data collection was uneven over the 10-week study (Table 3).

None of the acoustic tags transmitted for the expected 135 day longevity, although their actual longevity was highly variable (Table 2). AC6, the key informant for Site 1, transmitted signals for 62 days before failing on September 13, 2010. This animal was consistently located visually on every attempt. The small data gaps resulted from adverse weather and aborting tracking due to time constraints. AC7, the key informant for Site 2, could not be visually located on August 4 or August 10, despite a clear signal. A weak, intermittent, signal was picked up on August 16 and the animal was visually located. Thereafter the tag failed to transmit (33 days after deployment) and the animal was subsequently visually tracked by increasing the SCUBA search effort to every two days and conducting a concentric outward sweep from its last known location. AC8, the key informant for Site 3, stopped transmitting a signal on July 20, 2010, only four days after being deployed. The animal was fortuitously located again on August 2, 2010 after dedicated SCUBA searches. Unfortunately, it was again lost after that date. As a result, only three positions were recorded for this animal and only limited analyses were conducted for this site.

Site and Aggregation Characteristics

Habitat and temperature — The study sites were essentially quite similar with gentle slopes from shallow (5 - 10 m) to deeper (10 - 15 m) areas, relatively low relief substrate comprising a mixture of *Porites porites* coral rubble, sand, and gorgonian and sponge habitats. Turf algae was prevalent at all sites on any hard substrate and the dominant macroalgae were Dictyota sp. and *Galaxora* sp. Common fauna included sea urchins (*Diadema antillarum*, *Meoma ventricosa*, *Astropyga magnifica*), sea cucumbers (*Holothuria mexicans*) and fishes (*Dactylopterus volitans*, *Scorpaena plumieri*, *Rypticus saponaceus*, *Bothus lunatus*, *Gymnothoraz moringa*). Some differences were apparent between Sites 1 and the other two, the former having the lowest relief and predominantly sand habitat, and being the only site where sparse seagrass (*Halophila decipiens*) was

Table 2. A Summary of key informant conch size and tagging data, and study site characteristics within the Carlisle Bay conch nursery area. Habitat codes are defined in Table 1. Conch density measured in 5m-radius circle area.

Site name	Initial density (no. conch m^{-2})	Key informant conch	Shell length (cm)	Start date	End date	Tag longevity (d)	No. re-sightings	Depth range (m)	Habitat categories		Rugosity
									Dominant	Others	
Site 1	0.51	AC 6	19.0	14-Jul-10	13-Sep-10	62	16	6.4 - 14.0	SP	CR, SG, GS	Low
Site 2	0.59	AC 7	21.5	15-Jul-10	23-Sep-10	33	14	7.0 - 12.5	GS	SP, CH, CR	Moderate
Site 3	0.42	AC 8	19.0	16-Jul-10	2-Aug-10	4	3	9.4 - 10.1	GS	SP, CR	Moderate

found (Table 2). Water temperatures rose from around 29 °C in mid July to over 30 °C in mid August and September (Figure 3).

Conch density — All three sites had high initial densities of juvenile conch (Table 2) and these persisted throughout the 10-week study at the two sites monitored (Table 3, Figure 3). Overall, juvenile conch densities ranged from 0.09 – 1.46/m^2 with a mean of 0.55/m^2 (range: 892-14,650/ha, mean 5,458/ha) (Table 3).

Individual size and growth — The aggregations appeared to comprise a single age cohort of presumed year 1+ juveniles, that were first observed by fishers in the same area in early November 2009. Fortnightly progression of overall size frequencies showed a steady increase in mean shell size by 2.2 cm over the 10-week study, and indicated a mean overall growth rate of approximately 0.03 cm/day (Figure 4).

Movement Patterns of Key Informants

Distance and speed — The key informant conch at Site 1, AC6, was recorded to travel a total minimum distance of 481 m in 62 days indicating an overall minimum average speed of 7.75 m/day. This juvenile conch exhibited a range of speeds, with a maximum average speed of 23.7 m/day (Table 3, Figure 3).

The key informant at Site 2, AC7, was recorded to travel a total minimum distance of 323 m in 70 days indicating an overall minimum average speed of 4.42 m/day. This juvenile conch exhibited a similar range of speeds and maximum average speed (26.0 m/day) as AC6 (Table 3, Figure 3).

The key informant for Site 3, AC8, was recorded to travel a total minimum distance of just 29 m in 17 days indicating an overall minimum average speed of 1.72 m/day. Since there were only three re-sightings for this animal, no other metrics were calculated, nor comparisons made.

A standard density survey conducted around each recorded key informant position, after an initial tagging of all neighbours, revealed that other juveniles within the aggregation were also moving, but not as a cohesive unit with the key informant. This was indicated by the relatively small proportion of conventionally tagged conch recorded in subsequent surveys (Table 3), and the change-over of uniquely numbered tagged individuals recorded in successive surveys.

Depth Range — The key informants at both sites were observed to move between shallow (5 - 10 m) and deep (10 - 15 m) areas several times throughout the 10-week study (Table 3, Figure 3). AC6 at Site 1 ranged between 6.4 and 14.0 m (mean depth; 9.8 m), whilst AC7 at Site 2 ranged between 8.2 and 12.5 m (mean depth: 9.1 m).

Home Range: Over the 10-week study AC6 at Site 1 had an estimated minimum convex polygon home range measuring approximately 215 x 86 m and covering an area of 11,654.5 m^2 (1.17 ha) (Figure 5). The fixed kernel density home range calculated for this animal indicated two higher-use areas (Figure 5). For AC7 at Site 2 the estimated minimum convex polygon home range was smaller, measuring 151 x 62 m and covering an area of 5,535 m^2 (0.55 ha), but in common with AC6, the fixed kernel density home range also indicated two higher-use areas (Figure 5).

DISCUSSION AND CONCLUSIONS

Tracking and Tag Performance

The acoustic tags were found to be of an appropriate size and weight for the size class of juvenile queen conch

Table 3. Summary of data collected on juvenile conch densities, and key informant conch (carrying acoustic transmitters) depths and speeds recorded at Sites 1 and 2, over the 10-week study of a conch nursery area in Carlisle Bay, Barbados.

	Site 1 – Key informant AC6						Site 2 – Key informant AC7					
			Density						Density			
Date	Speed (m d^{-1})	Depth (m)	No. conch (5m-radius)	No. tagged conch (5m-radius)	No. conch per m^2	No. conch per ha	Speed (m d^{-1})	Depth (m)	No. conch (5m-radius)	No. tagged conch (5m-radius)	No. conch per m^2	No. conch per ha
14-Jul-10		7.4	40	40	0.51	5096						
15-Jul-10								7.6	46	46	0.59	5860
16-Jul-10	6.5	7.0					26.0	9.0				
20-Jul-10	5.3	11.9	14	2	0.18	1783	9.3	8.7	91	7	1.16	11592
24-Jul-10	6.5	12.8	42	2	0.54	5350	10.0	7.6	64	11	0.82	8153
27-Jul-10	12.3	11.9	51	2	0.65	6497	6.0	8.8	34	1	0.43	4331
04-Aug-10	5.4	8.8	48	4	0.61	6115						
10-Aug-10	8.5	7.6	55	3	0.70	7006						
16-Aug-10	4.2	8.5	115	8	1.46	14650	1.9	9.1	18	0	0.23	2293
19-Aug-10	7.0	6.4	91	10	1.16	11592	0.0	7.0	12	0	0.15	1529
23-Aug-10	8.0	9.1	110	12	1.40	14013						
25-Aug-10							2.3	8.5	25	1	0.32	3185
27-Aug-10	1.8	10.7	7	0	0.09	892	5.5	7.6	17	0	0.22	2166
30-Aug-10	6.7	11.3	11	0	0.14	1401	11.0	8.8	29	1	0.37	3694
01-Sep-10							6.5	7.6	24	0	0.31	3057
03-Sep-10	9.3	7.9	80	1	1.02	10191	2.0	9.1	24	1	0.31	3057
06-Sep-10	23.7	9.1	96	4	1.22	12229	6.7	8.5	31	0	0.39	3949
08-Sep-10	12.2						6.0	9.8	22	0	0.28	2803
11-Sep-10		11.6	30	1	0.38	3822						
13-Sep-10	5.0	14.0	66	7	0.84	8408	2.2	10.7	27	0	0.34	3439
15-Sep-10							5.5	12.5	15	0	0.19	1911
17-Sep-10							6.0	11.0	15	0	0.19	1911
23-Sep-10							2.7	10.7	21	0	0.27	2675
Mean	8.1	9.8	57	-	0.73	7270	6.4	9.1	30	-	0.39	3859

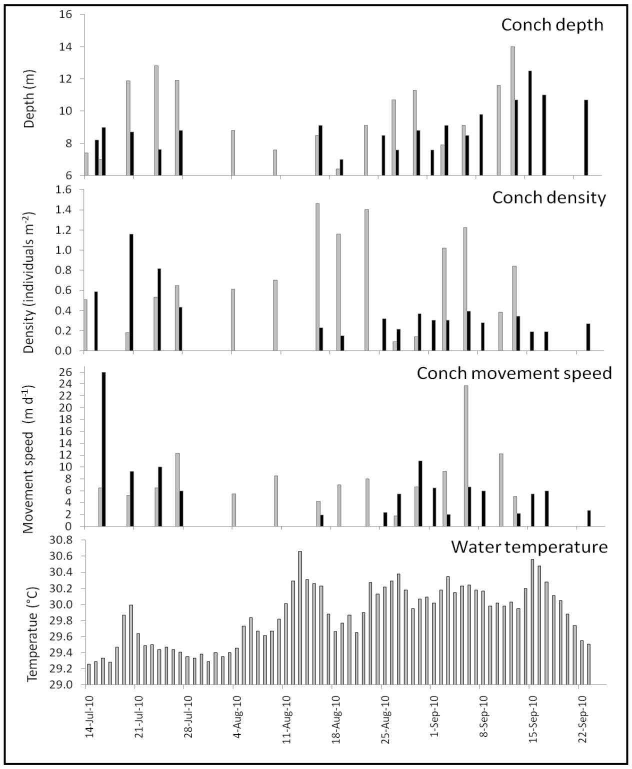

Figure 3. Composite chart showing temporal variation in depth, aggregation density, speed and temperature experienced by the key informant conch AC6 (grey) and AC7 (black) over the summer (July 14 – Sept 23, 2010).

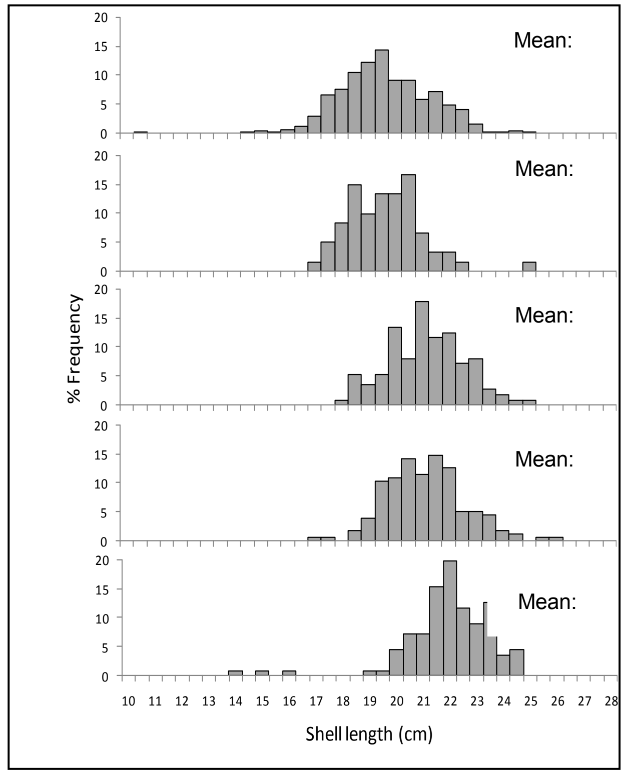

Figure 4. Modal progression of size frequencies for juvenile conch from the nursery area in Carlisle Bay (all sites combined), shown fortnightly. Fortnight 1: July 14 – 28; 2: July 29 – Aug 11; 3: Aug 12 – 25; 4: Aug 26 – Sep 8; 5: Sep 9 - 23, 2010.

studied here, appearing to have no effect on their ability to move normally. The transmission strength and frequency were also adequate, facilitating relatively accurate tracking of acoustically tagged conch in the low relief environment. However, all of the tags ceased transmission long before the expected longevity of 135 days. This severely compromised the data collection in the current study, causing temporal variation and large gaps in the data time series, increasing the required sampling effort, and resulting in the loss of one of three key informants near the beginning of the study.

Future studies should preferably seek to use more reliable, and a greater number of acoustic tags, or at least stock extra tags for speedy replacement of failed tags. Increasing survey effort to every two days to keep track of failed tags is unlikely to be cost effective or feasible, especially for a longer-term study. The use of autonomous static hydrophone arrays and acoustic tags, as used by Doerr and Hill (2008) could be used to overcome the issue of manpower, especially if larger numbers of acoustic tags were deployed. This technology has already proven to perform well for conch in a low relief environment, such as that of Carlisle Bay (Doerr and Hill 2008). However, the technology is relatively expensive, and based on the experience of Doerr and Hill (2008) would still require careful maintenance (frequent cleaning) of the fixed

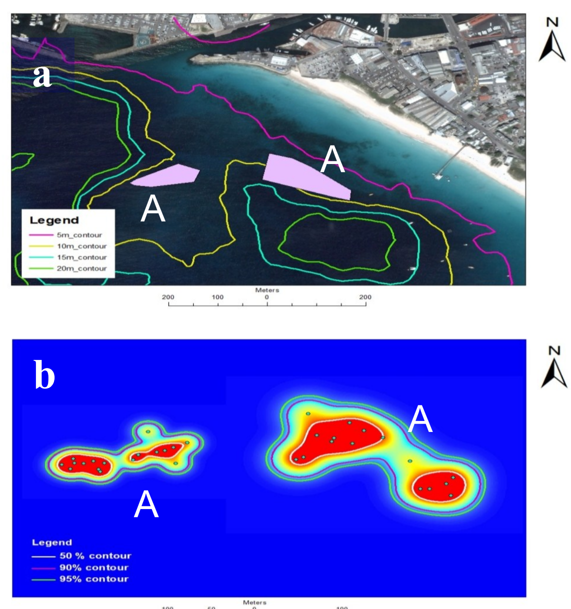

Figure 5. Maps showing (a) minimum convex polygon home ranges and (b) kernel density estimation of home ranges for key informant juvenile conch (AC6 and AC7) in Carlisle Bay, Barbados over the summer (July 14 – Sept 23, 2010). Image source: Google Earth.

receivers. The high level of boat traffic and frequent turbidity at the Carlisle Bay site would also need to be taken into account when interpreting the data from receivers, since underwater noise and turbidity can both effect the efficacy of transmissions (Doerr and Hill 2008).

The conventional tags and their attachment worked well, although fouling made them hard to detect after several weeks. However, they would not be suitable for detailed movement studies in this case, given the depth of water which requires the use of SCUBA gear to visually detect tags, and the considerable search effort required to re-find individuals after just a few days.

Characteristics of Juvenile Nursery Area

Habitat utilization patterns for queen conch juveniles vary across the region (Doerr and Hill, 2008), making it difficult to generalise about the characteristics of a 'high quality habitat' for queen conch nursery areas. Danylchuk et al. (2003) suggest that the 'highest quality habitat' at a given location may be defined as the habitat which exhibits the highest densities of juvenile conch.

The area studied in Carlisle Bay was reported by fishers to be frequented by small juvenile conch and was therefore considered to be a nursery area, although it is not known whether or not this is a 'persistent' nursery. The sites examined in this area were found to have consistently high densities (greater than 0.2 conch/m^2) of juvenile conch and were therefore considered to be suitable juvenile habitats capable of supporting dense aggregations. These aggregations were utilising a variety of low to medium relief habitat categories, including sand plain, sparse seagrass, coarse coral rubble with macroalgae, coral rubble dominated by gorgonians and/or sponges, and sand/rubble areas with small live coral heads, at depths between 6.4 - 14.0 m (Tables 2,3; Figure 3). These habitat categories were found to be typical of other queen conch nurseries in the region, although they were somewhat deeper than most (Randall 1964, Hesse 1979, Stoner and Ray 1993, Stoner and Lally 1994, Appeldoorn 1997, Danylchuck et al. 2003, Stoner 2003, Glazer and Kidney 2004).

This finding, together with a detailed bathymetric map of shallow marine habitats in Barbados (available from the Coastal Zone Management Zone) will help in the search for other suitable conch nursery habitats around the island. A longer-term study could also determine the persistence of the nursery area studied here.

Attributes of Aggregated Juveniles

Densities — Densities of 0.1 to 0.2 conch/m are considered typical for juvenile queen conch aggregations (Hesse 1979, Stoner and Ray 1993, Stoner et al. 1996). The juvenile conch aggregations in this study were found to have significantly higher densities (overall mean: 0.6/m; range: 0.1 to 1.5 conch/m) using a similar survey grain size to that of Stoner and Ray (1993), where 4m-radius circles were used to quantify conch density.

Size and Growth Rates — The aggregated juveniles appeared to be from a single 1+ yr cohort, which first emerged in November 2009 (Kamal Abdal-Jabbar, conch fisher, Bridgetown Fisheries Complex, pers. com.; at a mean shell length of 11.3 cm, Unpubl. data), and had a mean shell length in mid-July of 19.7 cm. They grew steadily over the summer at a mean rate of 0.03 cm/day. This appears to be at the high end of the range of growth rates reported in the literature for juvenile conch of this size (e.g. Randall 1964, Hesse 1979, Stoner and Ray 1993) and may be explained by the high water temperatures (29 – 30.5°C) during the study period and/or a particularly high quality habitat. Conch growth is known to be highly dependent on parameters such as density of conspecifics (Stoner and Ray 1993, Stoner and Lally 1994), micro-scale habitat quality and water depth (Theile 2001, Ehrhardt and Esquivel 2008), but would be expected to result in lower than average growth rates for our juveniles given their high densities and relatively deep water.

Movement and Home Range — Key informants indicated that the juvenile conch were capable of moving considerable distances (meandering approximately 0.3 – 0.5 km in 2 ½ months) and at maximum speeds of 24 - 26 m per day. Again these movement speeds are higher than most previous reports for medium-sized juveniles (Randall 1974, Hesse 1979, Stoner and Lally 1994), although Doerr and Hill (2008) reported a single juvenile to travel 53 m/day during a 9-day migration out of a monitored bay.

The two key informants utilised a summer (July 14 – Sept 23) home range area of 0.6 and 1.2 ha repectively. Again these are larger than the few previous reports of home range for medium sized juveniles. For example, Hesse (1979) reported annual home ranges of between 0.15 – 0.5 ha for medium-sized conch in the Turks and Caicos Islands, and Doerr and Hill (2008) reported very limited movement of 17 juveniles within two bays in St. John, USVI over a period of 10 months.

The aggregations did not move 'on masse' during the period of study, as has been observed by several authors (Stoner et al. 1988, Lipcius et al. 1991, Stoner and Lally 1994), although both key informants were observed to meander in a general westerly direction away from shore. Others (Stoner and Lally 1994, Lipcius et al. 1991) have suggested that the orientation of movement of high density juvenile conch aggregations is influenced by the direction of ebbing tidal movement. In this study, tidal currents were not measured, although they are known to be fairly weak in this part of the bay. It is possible that their westerly migration could eventually lead the juvenile conch to a known adult habitat situated approximately 1 km west of their current location.

Determining the connection between nursery and adult areas will be important for determining 'essential habitat' and for informing the design of a conservation and management plan for Barbados, but will require a longer-term study of movement patterns to detect ontogenetic migrations, and should be guided by lessons learnt in this pilot study. With abundance surveys revealing critically low population densities of queen conch in Barbados (Oxenford et al. 2010), such research should be a matter of priority to ensure that appropriate action is taken to safeguard the remaining aggregations.

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