Estimating Home Range and Density of a Queen Conch Aggregation Using Acoustic Telemetry and Conventional Tagging

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ABSTRACT

Understanding the behaviour of queen conch aggregations in Barbados is vital to developing plans for their protection to ensure the sustainability of the small scale fishery. This pilot study tests the efficacy of a combination of acoustic and conventional tags to evaluate the home range size, monthly movement patterns, site fidelity and density of individuals in an aggregation located in a high relief coral community. Three adult conch in the aggregation were tagged using acoustic transmitter tags and others were marked with conventional tags to investigate the feasibility of simultaneously tracking many individuals within one aggregation. Individual conch were followed biweekly using a combination of surface tracking with telemetry and SCUBA observation. Positions of acoustically tagged conch were obtained using a handheld GPS and verified initially by divers using a survey tape and compass to record their positions relative to known markers at the site. All position and biological data were recorded and analysed in a geographic information system (GIS). Both observational tracking by SCUBA and acoustic tracking in such a high relief coral environment is difficult, but the acoustic tags have proven highly beneficial in re-finding individual conch that have demonstrated large movements away from the aggregation centre.

KEY WORDS: Queen conch, *Strombus gigas*, acoustic telemetry, tagging, home range, GIS

Estimando el Rango de Origen y Densidad de Agregaciones de Caracol Reina Utilizando Telemetria Acustica y Etiquetado Convencional

Comprender el comportamiento de agregación del caracol reina en Barbados es de vital importancia para el desarrollo de planes para su protección y para garantizar la sostenibilidad de la pesca a pequeña escala. Este estudio piloto pone a prueba la eficacia de una combinación de etiquetas convencionales y rastreadores acústicos para evaluar el rango de tamaño de origen, patrones de circulación mensual, fidelidad de sitio y la densidad de los individuos en agregación situados en una comunidad coralina de alto relieve. Tres caracoles adultos en un sitio de agregación fueron etiquetados utilizando rastreadores acústicos LOTEK CAFT11-4 y otros diez fueron marcados con etiquetas convencionales para investigar la viabilidad de rastrear varios individuos simultáneamente dentro de una agregación. Los caracoles fueron rastreados a diario individualmente durante los primeros 10 días y posteriormente cada dos semanas utilizando una combinación de rastreo superficial con telemetría y observación con buceo SCUBA. Las posiciones de los caracoles marcados con rastreadores acústicos se obtuvieron utilizando un GPS de mano y luego fueron verificados por los buceadores utilizando una cinta de reconocimiento y una brújula para registrar la ubicación en relación con marcadores conocidos en el sitio. Todas las ubicaciones y datos biológicos se registraron y analizaron en un sistema de información geográfica (SIG). La observación con buceo y por rastreo acústico en sitios de alto relieve coralino es difícil. Sin embargo los rastreadores acústicos han demostrado ser altamente beneficiosos en reencontrar aquellos caracoles que han mostrado grandes movimientos fuera del centro de agregación.

PALABRAS CLAVES: Caracol reina, *Strombus gigas*, telemetría acústica, etiquetas, rango de origen, GIS

Determination du Domaine Vital et de la Densité D'Agregation de Lambis en Utilisant la Télémétrie Acoustique et L'Etiquettage Conventionnel

Comprendre le comportement d'agrégations de lambis à la Barbade est essentiel au développement de plans pour leur protection pour assurer la viabilité de la pêche à petite échelle. Cette étude pilote teste l'efficacité d'une combinaison d'étiquettes acoustiques et conventionnelles pour évaluer la taille du domaine vital, les types de mouvements mensuels, la fidélité de sites et la densité d'individus dans une agrégation située dans une communauté de corail de haut-relief. Trois lambis adultes dans l'agrégation ont été étiquetés avec des étiquettes acoustiques LOTEK CAFT11-4 et dix autres ont été marqués avec des étiquettes conventionnelles pour examiner la faisabilité de suivre simultanément beaucoup d'individus dans une agrégation. Les lambis individuels ont été suivis quotidiennement pendant les 10 premiers jours et deux fois par semaine ensuite en utilisant une combinaison de suivi de surface avec télémétrie et observation en plongée. Les positions des lambis munis d'étiquettes acoustiques ont été obtenues en utilisant un GPS portatif et vérifiées par des plongeurs à l'aide d'un enregistrement d'enquête et d'une boussole pour enregistrer leurs positions relatives à des marqueurs connus sur le site. Toutes positions et données biologiques ont été enregistrées et analysées dans un système d'information géographique (SIG). Le suivi d'observation par plongée et le suivi acoustique dans un tel environnement de corail haut-relief est difficile, mais les balises acoustiques se sont révélées très bénéfiques pour retrouver des lambis individuels qui ont démontré d'importants mouvements du centre de l'agrégation.

MOTS CLÉS: Lambis, *Strombus gigas*, télémétrie acoustique, étiquetage, domaine vital

INTRODUCTION

Patterns of movement and space use are fundamental factors that influence ecological patterns of populations, communities and species (Zeller 1997). Understanding these is essential for effective management of exploited species. For marine species, population-specific information on daily, seasonal and ontogenetic movements, including site fidelity and migration patterns of individuals is key for designing management strategies, including marine protected areas, that will be effective in conserving or aiding in the sustainable use of exploited populations (Zeller 1997, Posada *et al* 1999, Eristhee and Oxenford 2001, Roberts *et al* 2001, 2005). This information can be very difficult and time-consuming to obtain, particularly for marine species. However, conventional tagging and recapture or re-sighting is a commonly used tool and has proven highly effective in many cases e.g. Oxenford 1994, Corless *et al* 1996, Glazer *et al*. 1997. The development of acoustic and archival tags has greatly improved the accuracy of this technique, allowing an enormous amount of critical information on life history dynamics and ecological requirements of marine species to be gathered (White and Garrott 1990, Eristhee and Oxenford 2001, Horrocks *et al*. 2001, Block *et al*. 2005), and many studies are now using a combination of acoustic and conventional tags (Glazer *et al* 2003, Glazer and Delgado 2006, Delgado and Glazer 2007, Luckhurst 2007). Technology in passive acoustic telemetry has evolved rapidly with tags becoming smaller and battery life longer, so that smaller species are now being fitted with acoustic tags resulting in an increase in the extent of information available to managers, particularly in reef environments (e.g. Tulevech and Recksiek 1994, Zeller 1997, Eristhee and Oxenford 2001, Glazer *et al*. 2003, 2006). When tagging is used in conjunction with a global positioning device, an animal's movement patterns can easily be viewed in a geographical Information System (GIS). Adding information on habitat type and depth can provide a robust tool for understanding the holistic requirements of a population (Jones and Stoner 1997, Glazer *et al*. 2003, Glazer and Delgado 2006).

Queen conch, *Strombus gigas,* is one of the most valuable fisheries resources in the Caribbean, yet at risk of collapse due to overexploitation throughout its range (Chakalall and Cochrane 1997, Aiken *et al.* 1999, Theile 2001, FAO 2007). Although some level of management is already in place in most of the range states (Theile 2001, FAO 2007), there remains a strong need for improved conservation to ensure the continuance of breeding populations, which in turn requires comprehensive information on home range size, critical habitat use and the minimum density of individuals for successful reproduction (Stoner and Sandt 1992, Appeldoorn and Lindeman 2003, Stoner and Lally 1994, Appeldoorn 1994, Gascoigne and Lipcius 2004, FAO 2007). In some countries, particularly the small islands of the eastern Caribbean (e.g. Tobago, Grenada, Barbados, St Vincent and the Grenadines) there is almost no information on the biology and ecology of the local conch populations, and very little or no management of the conch fisheries (Theile 2005, FAO 2007, Oxenford *et al* 2008a, Georges *et al.* 2009).

Barbados has a small conch fishery (Oxenford *et al*. 2008a) and is striving to meet its obligations to the international Convention on International Trade in Endangered Species of flora and fauna (CITES) and the regional Cartagena Convention protocol on Specially Protected Areas for Wildlife (SPAW), by assessing the status of its conch resource and initiating management of the fishery. Queen conch were included in the 2004 - 2006 fishery management plan (Barbados Fisheries Division 2004), and a species-specific management plan was recently drafted in consultation with stakeholders (Oxenford and Parker 2008). The Fisheries Division has also produced a public information brochure on conch and the Environment Division (CITES Authority) formed a scientific working group on queen conch and is funding conch surveys (Oxenford *et al*. 2008b).

The current study complements the ongoing research on queen conch in Barbados by attempting to obtain an understanding of the movement patterns and habitat use of individuals from an aggregation, using a combination of acoustic telemetry and conventional tags.

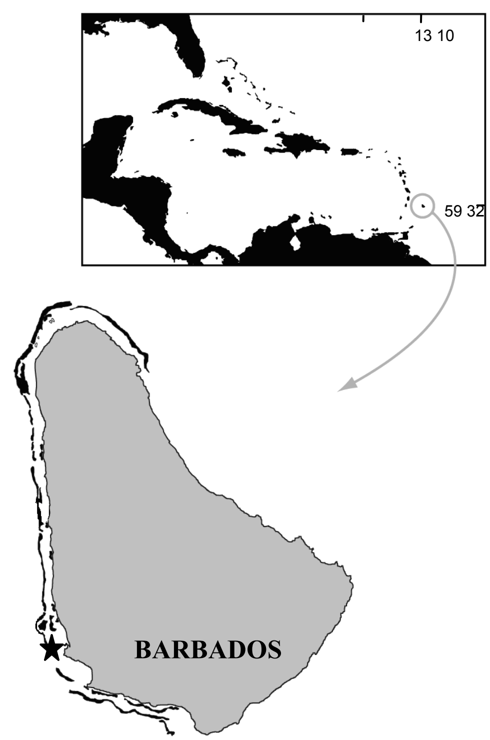

Figure 1. Map of Barbados showing the study site located on the west coast.

METHODS

Site Selection and Preparation

Queen conch aggregation sites were located with the assistance of a local conch fisher and a single site was selected for this preliminary study to test the efficacy of the research methodology in examining individual conch movements and habitat use. The site was primarily selected because: it is typical of the high relief, coral reef environments inhabited by conch on the west coast of Barbados; it is relatively easy to access; and is not heavily used by conch fishers, being close to the Bridgetown Port (Figure 1). The site was first surveyed by SCUBA divers to describe the habitat type, the approximate density of conch and to establish several permanent stakes with known geospatial coordinates to use as markers.

Tag Descriptions and Attachment

A combination of acoustic transmitter and conventional tags are being used in this study. Three mature adult conch have been selected as 'key informants' and fitted with acoustic transmitters, whilst all other conch in the vicinity (within a 20 m radius) of the key informants are being tagged using conventional tags.

Acoustic transmitters are pre-coded Lotek CAFT11-4 tags, measuring 11x 55 mm and weighing 5.1 g (in seawater). These transmitter tags have been preset to pulse every 20 seconds (3 bpm) for an estimated battery life of 380 days (Lotek Wireless Inc.) (Figure 2). Each transmitter tag is wrapped in a non-slip rubber mesh and attached to the apex of the conch shell with the pulsing end of the transmitter protruding beyond the tip of the spire, to prevent interference in the propagation of the signal (Figure 3). The transmitter tag is fastened with nickel-copper alloy, non magnetic, corrosion-resistant wire (80 lb monel, 3 mm diameter). Tag visibility has been enhanced by affixing a cable tie and conventional tag that extend vertically from the transmitter. Conventional tags, made initially from cut sections of a measuring tape were subsequently replaced by brightly coloured, numbered laminated oval disc tags measuring 29 x 5 mm (Floy Tag and Manufacturing Inc.; Figure 2) and attached around the base of the spire with the same monel wire (Figure 3).

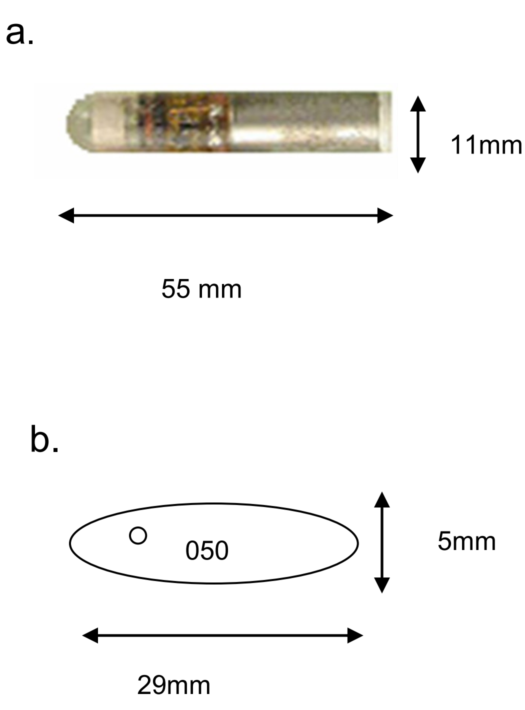

Figure 2. Acoustic and conventional tags used on conch showing: (a) Lotek CAFT11-4 acoustic transmitter; and (b) Floy laminated numbered oval disc tag

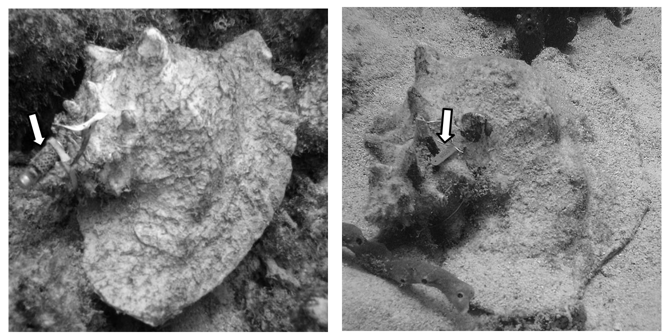

Figure 3. Underwater photos of tagged conch *Strombus gigas* in Barbados showing: (a) 'key informant' conch with an acoustic transmitter tag wrapped in a non-slip rubber mesh attached near the top of the conch shell spire with monel wire; and (b) adult conch with conventional Floy tag attached with monel wire to shell spire. White arrows indicate tag positions

Biological and Environmental Data Collection

For each conch tagged, shell length was measured with a soft tape from the apex of the spire to the siphonal notch to the nearest 0.1 cm, lip thickness was measured with callipers to the nearest mm (after Appeldoorn 1988), and presence of shell flare is recorded at the time of tagging. Sex of the animal was noted opportunistically, to avoid disturbing the animals unnecessarily during the study. Environmental parameters (weather conditions, water clarity, current, sea condition) are noted qualitatively each sampling day and water temperature was monitored continuously *in situ* with a HOBO Water Temp Pro logger (Onset Computer Corp.). Information on depth to the nearest 0.1 m, habitat type and conch behaviour (e.g. feeding, resting, actively moving, mating, spawning *inter alia*) was recorded for each new conch position.

Tracking

The key informant conch was acoustically tracked from a small open boat using a wired HPA-O hydrophone placed in the water connected to a LOTEK SRX-400 receiver with a 150 MHz sonic up-converter. The hydrophone receiver picked up the acoustic pulse from the transmitter tag, the up-converter converts the pulse to an audible sound that was emitted by the SRX receiver and to digital data that were displayed on the receiver screen (see Eristhee *et al*. 2000, for a full description of the set-up and operation of the equipment). The conventionally tagged conch were tracked via visual re-sightings by SCUBA divers.

Conch are being tracked biweekly (weather and sea conditions permitting). Tracking always begins in the area where an acoustically tagged conch was last found, slowly covering the area whilst 'listening' for the transmitter signal. Once a combination of a loud clear signal, a code-in of the transmitter identification number, and a high signal strength are obtained, a weighted buoy is thrown into the water to mark the location of the best signal.

Divers make visual confirmation by conducting concentric circular sweeps of increasing diameter around the buoy until the key informant is located. Once found, the marker buoy is moved and placed next to the key informant such that the exact position (within 3 - 4 m) can be recorded at the surface using a handheld Garmin Legend geospatial positioning unit (GPS).

Each conch within a 20 m radius of the key informant is noted and tagged with a conventional tag. Their position relative to the key informant is then recorded by taking a compass bearing and distance measurement to the nearest cm using a 30 m tape. The geospatial co-ordinates are subsequently generated in ArcGIS 9.2 (ESRI).

Positions of all conch are mapped using ArcGIS 9.2. Distance moved is measured as the shortest distance between chronologically recorded positions. Total minimum distance travelled by any given animal represents the cumulative distances between all consecutive positions. Home range is delineated by the minimum convex polygon enclosing all recorded positions following the method of (Glazer *et al*. 2003).

RESULTS AND DISCUSSION

The first conch were tagged on May 13, 2009 and tracking began immediately and has continued biweekly. Here we report on the efficacy of the tracking method and the data collected over the first 12 weeks of the study (May 13 to August 3, 2009).

Number of Tagged Animals

Two large adult 'key informant' conch (shell length 29 and 27 cm, lip thickness16 and 11 mm respectively) were tagged on May 13, 2009 and a third (shell length 28 cm, lip thickness 14 mm) was tagged on June 9, 2009. The number of conventionally tagged conch has been increasing throughout the study, as new individuals move into the vicinity of the key informants, and by the end of week 12 totalled 17 individuals (Table 1).

Description of Habitat

The study site is on an offshore shoal area between 8-15 m depth, comprising patches of highly rugose hard coral reef dominated by the star coral, *Montastrea annularis* with several large mounds of pencil coral, *Madracis mirabilis.* The reef is interspersed with areas of lower relief, coarse, coral rubble and isolated coral heads and sponges, and areas of low relief sand and fine coral rubble. Being on the leeward coast of Barbados, sea conditions have been typically calm throughout the study, and tidal currents have been minimal except around full and new moon. Water temperature has been within the normal summer range, rising from 27.7 to 29.0 ^{o}C over the 12 weeks.

Efficacy and Comparison of Tracking Techniques

Transmitter tags — Time spent searching for the acoustically tagged key informant conch is largely dependent on the rugosity of the habitat and distance travelled from their previous known position. On sand and low relief coral rubble areas, the signal can be picked up from as far away as 200 m in any direction and increases in strength linearly as the animal is approached, often reaching > 150 dB. Underwater search time is also relatively short in this low relief habitat, as the animals can be spotted quite easily. For example, when an individual has been detected in this type of habitat with a signal strength of > 150 dB, the animal is usually found within a few metres of the marker buoy, whilst a signal strength of >120 < 150 dB might require a broader search of up to 20 m from the marker. However, in the high relief, hard coral habitat, where the conch appear to be spending much of their time, tracking is far more challenging. The acoustic signal may not be detected until the hydrophone is within 50 m or less of the transmitter tag. Furthermore, the strength of the signal is highly variable depending on the direction of approach and does not increase in a consistent manner, making it difficult to anticipate the appropriate search direction and position of the animal. As such the signal is often lost during the approach, as a result of it being masked by, or reflected off one or more coral heads. Under these conditions a more rigorous search pattern at the surface is required. Furthermore, the search time underwater is greatly increased in highly rugose coral reef habitat, with the tagged animals occasionally not being found at all.

Signal strength and direction from the transmitter tags is also influenced by water current and particles in the water column, which affect how the signal propagates through the water. Strong currents deflect the signal, so that it can only be reliably detected when approaching the tagged animal from down stream, and turbid water appears to muffle the signal. Furthermore, manoeuvring the boat in a strict search pattern is complicated by strong currents, high winds and choppy seas, and underwater searching is much more difficult and time-consuming in conditions of

Table 1. Summary of movement, home range and density data for queen conch, *Strombus gigas*, in an aggregation off the west coast of Barbados over a 12 week period from May 13 to August 3, 2009 shown separately for the three informant conch carrying acoustic tags and for all other conch marked with conventional tags. Data on number of conch tagged, number of re-sightings, minimum distance travelled and home range size are shown cumulatively from week one. Home range area is calculated using minimum convex polygon of 4 or more re-sightings. Minimum and maximum values

Week	Acoustically tagged key informant conch					Conventionally tagged conch			
	No. conch tagged	No. re-sight ings	Mean minimum distance (m) travelled by individuals (min - max)	Mean individual home range (m^2) (min - max)	Density of conch in 20 m radius (min max)	No. conch tagged	No. re-sight-ings	Mean minimum distance (m) travelled by individuals (min - max)	Mean individual home range (m^2) (min - max)
1	2	4	29.0 (23.1 - 34.9)	-	4.25 (3 - 5)	3	6	23.2 (13.2 - 31.7)	-
2	2	8	55.5 (41.4 – 69.6)	338.1 (138.3 – 538.0)	2.5 (2 - 3)	3	12	26.8 (15.7 - 36.0)	75.2 (9.2 - 133.8)
3	2	9	65.5 (41.4 – 89.7)	381.8 (138.3 – 625.3)	2 (1 - 3)	3	15	29.1 (17.7 - 38.7)	76.0 (11.5 – 133.8)
4	3	14	80.2 50.0 – 89.8)	381.8 (138.3 – 625.3)	4 (2 - 6)	3	17	40.5 (22.9 - 67.9)	126.3 (26.9 – 269.2)
5	3	17	76.3 (28.3 – 129.8)	1058.7 (664.5 – 1453.0)	4 (3 - 5)	8	28	60.9 (41.1 - 91.5)	166.3 (58.0 – 302.0)
6	3	17	76.3 (28.3 – 129.8)	1058.7 (664.5 – 1453.0)	-	8	28	60.9 (41.1 - 91.5)	166.3 (58.0 – 302.0)
7	3	20	144.6 (78.3 – 357.7)	1117.9 (782.9 – 1452.9)	5.5 (5 - 6)	8	31	51.1 (14.7 – 91.5)	170.2 (58.0 – 302.0)
8	3	21	147.8 (78.3 – 357.7)	1160.1 (803.5 – 1516.7)	1 (1 - 1)	9	36	54.0 (15.0 - 91.5)	253.0 (182.0 – 302.0)
9	3	27	230.6 (78.3 – 671.8)	5705.8 (892.7 – 15107.9)	3.7 (1 - 8)	16	55	87.4 (3.3 - 535.2)	211.9 (138.7 – 302.0)
10	3	30	265.7 (154.7 – 728.9)	7292.1 (892.7 – 17631.9)	3.3 (1 - 5)	16	59	93.5 (3.3 - 544.2)	224.5 (138.7 – 302.0)
11	3	36	316.1 (207.5 – 817.1)	8784.5 (1060.6 – 21255.7)	4.2 (1 - 8)	16	71	120.7 (3.3 - 576.6)	365.7 (91.7 – 871.9)
12	3	41	367.1 (214.8 – 880.1)	11031.1 (1131.0 – 21255.7)	3.1 (1- 8)	17	76	122.3 (3.3 - 576.6)	411.5 (91.7 – 877.6)

low visibility and strong currents. Another complication is that boats with active depth sounders as far as 300 m from the hydrophone can cause interference with the acoustic signal and tracking must be halted until the vessel has passed. Given the proximity of the port to our sampling site, this can be a significant source of disturbance.

Setting the transmitter tags to a shorter time interval between pulses would make tracking considerably easier at times, but would significantly diminish the battery life of the transmitter and thus the length of the tracking study. As such, the compromise is justified. Likewise, increasing the frequency of visits to the site would lower the search time on any given day, since individuals would have less time to move away from their previously tracked position, and would increase the detail of the data collected. However, cost and overall time constraints would make daily tracking impractical, so that biweekly sampling is considered an appropriate compromise in this study.

The number of transmitter tags was limited to three in the first instance, primarily because of the relatively high cost of these tags. A greater number would allow a higher proportion of the conch aggregation to be monitored, especially as individuals have now become quite dispersed, but would require a significant increase in man hours and boat time to track them. Furthermore, tracking several acoustically tagged conch at the same time can be challenging if they are in close proximity since the individual ID code does not reveal itself until a very strong signal is obtained. Until then they can only be differentiated by the timing of the pulse.

Conventional tags — Tracking of individuals with conventional tags using visual re-sighting by SCUBA divers was easy in the beginning, but soon proved to be very labour intensive and time consuming as individuals began to disperse in the high relief environment. After five weeks it was no longer possible to re-find them within the time constraints imposed on divers at depth. As such, the use of conventional tags alone would not provide sufficient data in this study, given the relatively low density of conch and the low re-sighting rate in such a rugose environment, even if a high proportion of individuals in the initial aggregation were tagged. However, the use of conventional tagging in combination with acoustic tagging of a few key informants has allowed additional coarse movement data to be collected for a relatively large number of other individuals from the aggregation. The tape tags initially used became unreadable after a matter of weeks due to epiphytic growth, which could not be wiped off without destroying the identification number. The laminated disc tags have proven to be longer lasting.

Conch Movements, Home Range and Density

Cumulative data on minimum distance travelled and home range area for all tagged conch are shown in Table 1 over the 12 week study period. At the end of 12 weeks we have a total of 41 re-sightings for the three acoustically tagged key informant conch (mean of 13.6 per individual) and 76 re-sightings for a total of 17 conventionally tagged conch (mean of 4.5 per individual).

The key informant conch have moved continuously around the study site throughout the study period with recorded mean minimum distance travelled of 29 m by the end of the first week and 367.1m per individual by end of week 12. The least recorded distance travelled by an individual over the 12 weeks is 214.8 m and the maximum almost one kilometre (880.1 m) (Table 1). These values are considerably higher than reported for conch in the Florida Keys in studies using acoustic transmitters over an equivalent time frame (Glazer *et al*. 2003, Glazer and Delgado 2006, Delgado and Glazer 2007). This is perhaps surprising given the high rugosity of our site, but total distances are largely a result of the number of re-sightings, which are more frequent in our own study. Recorded home ranges for these key informants have continued to expand over time across all habitat types including sand, coral rubble and high relief coral reef, and the current mean home range area is 11,031m^2 with one individual covering as much as 21,255.7m^2 (Table 1). These values are consistent with the previous studies (Glazer *et al*. 2003, Glazer and Delgado 2006, Delgado and Glazer 2007), and are expected to expand as the animals are monitored over a full year. Mean density of conch around the key informants has fluctuated from 1 to 8 individuals within a 20 m radius (i.e. 0.08 to 0.64 conch per 100 m^2) indicating a fairly dispersed or low density aggregation similar to those being monitored in the Florida Keys (Delgado and Glazer 2007). Information for conventionally tagged conch is less detailed, but covers more animals, with mean minimum distance travelled of 23.2 m by week one and 122.3 m by end of week 12 (Table 1). The distance values are lower than those so far recorded for the key informants, but the data are clearly influenced by the number of re-sightings per individual. Key informant conch have been re-sighted more than three times as often and tracked over more days than most of the conch with conventional tags, and therefore provide a greater level of accuracy in determining movement patterns over the 3-month study. There is greater similarity in estimated home ranges, which appear less sensitive to the number of re-sightings (Glazer *et al*. 2003). Nevertheless, data for conventionally tagged conch are accumulating exponentially as greater numbers of conch are being tagged and re-sighted over time, albeit with much lower frequency. We therefore believe that a representative database for the conventionally tagged conch will be obtained using the current methodology, although it will take longer to build than for the key informants.

Preliminary Conclusions

Overall, the use of a small number of acoustic transmitter tags has been effective in simultaneously evaluating the home range size and movement patterns of a small number of individual conch in an aggregation. Given the challenges of using acoustic telemetry in a high relief coral reef environment, it would be very difficult to monitor a larger number of individuals simultaneously. However, tagging other conch with conventional tags and relying on *ad hoc* visual re-sightings by SCUBA divers, has added valuable complementary information, helping to build a database that is more representative of the movement patterns of individuals in the aggregation. The tracking methodology is also allowing a significant amount of additional information to be collected, particularly on reproductive behaviour, individual interactions with other members of the aggregation, and associated densities.

ACKNOWLEDGEMENTS

This research was supported by grants from The University of The West Indies (UWI), Cave Hill Campus, Graduate Research Fund to CB-G; the Centre for Resource Management and Environmental Studies (CERMES), UWI; and the Ministry of Environment, Water Resources and Drainage, Government of Barbados. We are grateful for the invaluable technical support from Mitch Sisak of Lotek Fish and Wildlife Monitoring Systems and for the expert knowledge provided by local conch fisher, Kamal Abdul-Jabbar. Fieldwork would not have been possible without the help of R. Goodridge, J. Walcott, D. Gill and numerous other volunteers.

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