The following supplements accompany the article

A groundwater-fed coastal inlet as habitat for the Caribbean queen conch *Lobatus gigas*—an acoustic telemetry and space use analysis

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Supplement 1:

Animal Position Calculation by VEMCO Positioning System (VPS)

Typically, acoustic telemetry operates on a presence-absence principle; an animal is detected if it is located within the detection range of a receiver (Heupel 2006). This method is commonly applied for studies where animal movement ranges are larger than receiver location spacing. On small spatial scales, a higher spatial resolution and geographic positioning as opposed to presence-absence will yield a higher accuracy in space use patterns. The VEMCO Positioning System (VPS) is a fine-scale positioning system that uses a time-difference-of-arrival algorithm to determine geographic locations of tagged animals from detections concurrently received at three or more receivers. The positioning accuracy of typically less than few metres inside the array is usually higher than that of other methods commonly used to track marine species (e.g. Argos or Fastloc-GPS, Espinoza et al. 2011; Smith 2013; Dujon et al. 2014). VPS has been successfully used to study high-resolution movement of benthic fish (*Ophiodon elongatus*; Andrews et al. 2011), benthic shark species (*Mustelus californicus*; Espinoza et al. 2011) as well as abalone (Coates et al. 2013).

In a VPS field setup, acoustic transmitters identical to those mounted on the animals are permanently installed at fixed locations throughout the acoustic array in order to synchronize receiver clocks (Fig 1d). VPS positions are calculated by in-house software at VEMCO. Processed data include time, calculated position and a unit-less Horizontal Position Error (HPE), similar to Dilution of Precision for GPS calculations (Smith 2013). Calibrated positioning error in metres (HPEm) is calculated as distance of VPS position to true location, and compared to the HPE value provided by the VPS algorithm. Following methods described in Smith (2013), HPE data was binned in steps of one, and compared to twice the root mean square (2DRMS) of HPEm of a fixed-location tag. A relationship of calibrated error HPEm with HPE of $HPEm = (-1.2 \pm 0.2) + (1.5 \pm 0.1) * HPE$ was established. In other words, on average computed VPS positions with an HPE of 10 and 20 have an absolute positioning error HPEm of 14 m and 28 m respectively.

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Supplement 2: Preliminary study of animal movement with a low-cost, low-resolution telemetric accelerometer

Methods

Accelerometer data is widely used to gain an understanding of short-term movement behaviour, including that of queen conch (e.g. Brownscombe et al. 2015). In the closely spaced acoustic receiver array, where detection of an animal on at least one receiver is effectively continuous with time, a preliminary study on low-resolution telemetric accelerometer was carried out. In this study, at a small additional cost, a standard tag was replaced with a sensor tag that incorporate a triaxial accelerometer. An average value for overall dynamic body acceleration (ODBA, expressed in *g*) is transmitted to and stored on the receivers in pre-programmed intervals, resulting in a long-term time series of ODBA. The main advantage of this method over traditional accelerometer methods is that the data is stored on the receiver network and thus does not require recovery of the animal, which is useful when the animal is difficult to locate (e.g. buried in the sediment) or is susceptible to leave the study zone.

One conch was equipped with a VEMCO V9AP transmitter in order to evaluate this approach for slow-moving animals. The on-board accelerometer measures mean 3D acceleration over a 30-seconds period acquired at a rate of 10 Hz. The tag transmitted one ODBA record every 15 minutes from 28 April to 13 October 2011. The gravitational component of acceleration was corrected for on-board. Here, the (unitless) 'movement rate' is defined as the ratio of the number of detections at which the animal was detected to move to the total number of detections in three-hour time steps. For this specific pilot study, the animal was considered as moving when the ODBA was greater than 0.01 *g* (to account for noise generated by waves and currents). Throughout the observation period, the tracked animal (T86) remained in the north arm and centre section of the inlet, and its trajectory and home range was highly consistent with that of other tracked animals. Overall, its movement is thus considered representative for animals in Xel-Há.

To illustrate an application of this accelerometry approach and to understand potential environmental drivers for the animals' movement, the statistical relationships between movement rate and key environmental parameters were investigated by applying a series of logistic regressions fitted to the data using a generalized linear model (Zuur et al. 2009). Odds ratios were used to compare the relative odds of the occurrence of the outcome of interest. If the odds ratio equals 1, the exposure to an environmental parameter does not affect the movement ratio, if <1 exposure is associated with lower movement ratio, and if >1 exposure is associated with higher movement ratio.

Results & Discussion

A total of 15 947 ODBA values were recorded between April and October 2011. The data demonstrates that sub-daily variations in movement can be resolved and recorded for long periods of time (months, Fig S1), in addition to the daily and monthly time scale studied by VPS data. At little extra cost and no additional work load, significant additional information on the animals' movement behaviour can thus be gathered on sub-daily scale that is not necessarily available from positioning data alone, in particular for slow-moving animals. This pilot data thus suggests that this tool should be considered in future telemetry studies.

With view of future investigations in order to better understand habitat usage patterns and their drivers, it is interesting to explore temporal patterns of telemetric-accelerometer-derived movement and their potential relationship with the key environmental drivers dissolved oxygen concentration, temperature, salinity and ambient light level / day – night cycles) (e.g. Jolivet et al. 2015). Statistical analyses indicate that dissolved oxygen concentration and temperature explain the observed movement rate better than salinity and light level (Table 2). Dissolved oxygen concentration as a driver of short-term movement is well documented in gastropods and other marine organisms (e.g. Houlihan & Innes 1982; Bell et al. 2003; Froehlich et al. 2014). Queen conchs commonly inhabit marine habitats where oxygen concentration is usually high and where temperature, salinity and oxygen concentrations show long-term stability (Stoner 2003), and it is therefore perhaps not surprising that oxygen supply in a highly variable estuarine-like environment like Xel-Há may affect the rate of movement.

Whilst Sandt and Stoner (1993) observed an effect of the light cycle on the movement in early juvenile queen conchs, both VPS and accelerometer data do not show a clear pattern associated with light levels, and statistical relationships with oxygen are stronger than with light. It is interesting to note that the episodic considerable freshening of bottom water (to a salinity <30) does not appear to considerably affect the animals' movement behaviour, which is perhaps surprising considering their marine provenance.

In summary, on sub-daily time scales, queen conchs appear to respond to the ambient dissolved oxygen variations by reducing their movement rate during periodic daily low-oxygen conditions. Despite being exposed to these estuarine conditions on a daily basis however, they not only remain in this habitat for extended periods as indicated by their home range, but also show growth rates comparable to those of 'less stressful' marine habitats where no oxygen constraints persist (Peel & Aldana-Aranda, 2012). Assuming the same food intake is required to achieve the same growth rate, this is perhaps indicating that the 'time-out' for foraging during low-oxygen conditions is made up for during the remainder of the day, and overall food intake is not compromised by this environmental constraint of movement.

These results must be regarded as preliminary given that they were obtained from a single animal. This study illustrates the usefulness of this tool, but further research is needed to fully understand the animals' short-term response to environmental drivers.

Table S1: Results of generalized linear model regressions of movement rate with four key environmental parameters (DO = dissolved oxygen concentration; T = Temperature; S = Salinity; L = Light; AIC = Akaike Information Criterion; β = regression coefficient). The more the odd ratio deviates from 1 the more explicative effect the associated parameter has. Individual parameters as well as combinations DO+T, DO+S and DO+T+S were tested.

Model	**β ± SE**	**p-value**	**Odds Ratio**	**AIC**
MR ~ DO	DO: 0.303 ± 0.059	<0.001	1.35	923
MR ~ T	T: -0.262 ± 0.046	<0.001	0.77	919
MR ~ S	S: -0.056 ± 0.016	<0.001	0.95	940
MR ~ L	L: 0.002 ± 0.001	0.004	1.00	936
MR ~ DO+T	DO: 0.159 ± 0.075	0.03	1.17	917
	T: -0.179 ± 0.060	<0.001	0.84	
MR ~ DO+S	DO: 0.272 ± 0.059	<0.001	1.31	920
	S: -0.041 ± 0.016	0.01	0.90	
MR ~ DO+T+S	DO: 0.164 ± 0.074	0.03	1.18	916
	T: -0.148 ± 0.063	0.02	0.86	
	S: -0.029 ± 0.017	0.08	0.97	

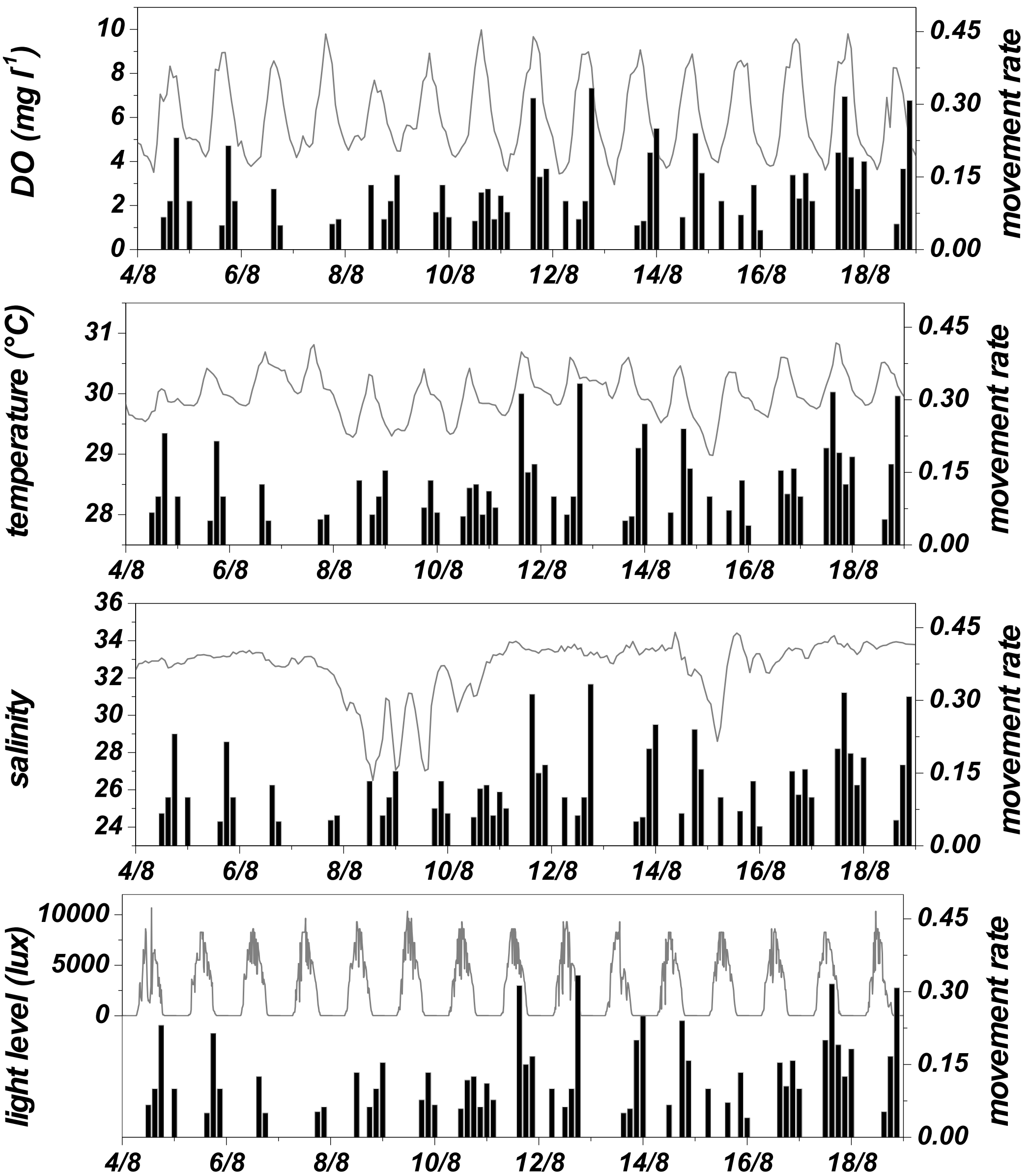

Figure S1: Time series of dissolved oxygen concentration, temperature and salinity in bottom water as well as ambient light level, together with conch movement rate (shown as bar graph) as derived from ODBA. For clarity, representative data covering a two-week period (of a total of 5.5 months) are shown. Dissolved oxygen exhibits important daily variations with low-oxygen conditions in the early morning hours. Daily temperature variations are comparatively small; salinity varies little on a daily basis, but shows important excursions on a multi-day time scale, driven by temporary vertical mixing events caused by strong wind events.

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