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Author(s): Erik Maitz Boman, Martin De Graaf, Leo A. J. Nagelkerke, Jimmy Van Rijn, Melanie Meijer Zu Schlochtern and Aad Smaal


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**UNDERWATER TOWED VIDEO: A NOVEL METHOD TO ESTIMATE DENSITIES OF QUEEN CONCH (LOBATUS GIGAS; STROMBIDAE) ACROSS ITS DEPTH RANGE**

ERIK MAITZ BOMAN,1,2* MARTIN DE GRAAF,1 LEO A. J. NAGELKERKE,2 JIMMY VAN RIJN,2 MELANIE MEIJER ZU SCHLOCHTERN2 AND AAD SMAAL1,2

1IMARES Wageningen UR–Institute for Marine Resources and Ecosystem Studies, PO Box 68, 1976 CP IJmuiden, The Netherlands; 2Aquaculture and Fisheries Group, Wageningen Institute of Animal Sciences (WIAS), Wageningen University, De Elst 1,6708 WD Wageningen, The Netherlands

**ABSTRACT** Queen conch (Lobatus gigas) populations living deeper than 20 m are rarely studied, because of the limitations of conventional survey methods using divers [i.e., belt transect (BT), towed-diver]. A crucial management goal for conch populations is to maintain adult densities at adequate levels to ensure reproduction, which is highly density dependent. Therefore, accurate estimates of adult conch densities, both in shallow and deep areas, are essential. The rapid technical progress of video systems has made it possible to develop new cost-effective ecological sampling tools, which can be used to survey areas previously hardly accessible. A lightweight towed video array was used, which was able to survey adult conch throughout the species entire depth range (ca. 0–60 m depth), in a safe and efficient manner. The towed video method (TVM) was compared with a conventional BT method using scuba divers, in its ability to identify adult live and dead conch. A series of intercalibration transects was conducted in a high-complexity (HC) and in a low-complexity (LC) habitat by having the towed video followed by a diver conducting a concurrent standard BT, covering the exact same surface area as the towed video. In both the HC and LC habitat, adult live queen conch had similar counts with both methods. Adult dead conch were not mistaken for live conch but were significantly underestimated with the towed video compared with the BT. The results validate the use of TVM as a reliable sampling tool to estimate densities of live adult conch in both HC and LC habitats throughout the species depth range.

**KEY WORDS:** density estimate, video survey, deep-water populations

**INTRODUCTION**

Queen conch (Lobatus gigas (Linnaeus, 1758)) is a large marine gastropod, which is widely distributed throughout the Caribbean region, where it supports one of the most important fisheries (Appeldoorn 1994, Acosta 2002). It has been heavily exploited throughout large parts of its distribution range (Stoner 1997, Acosta 2002), which resulted in concerns for the species’ future and its listing in Appendix II of the Convention on International Trade of Endangered Wild Fauna and Flora in 1992. Queen conch occurs to a depth of 60 m (Randall 1964), but is most commonly found from 0 to 25 m (Ehrhardt & Valle-Esquivel 2008). Although most common in depths below 25 m, deep-water (>25 m) conch populations can be found throughout the Caribbean, for example, Bahamas, Belize, Martinique, Turks and Caicos, Jamaica, People’s Republic of China (Berg Jr 1975, Berg & Olsen 1989, Stoner & Sandt 1991, Appeldoorn 1997, Reynal et al. 2009, García-Sais et al. 2012). Unfished deep-water adult populations are believed to provide significant recruitment to shallow-water stocks and are considered critical spawning stock refugia (Appeldoorn 1997). Such unfished deep-water populations are sometimes assumed to exist and to replenish fished shallow-water populations without proper confirmation of their presence (MRAG 2013).

A crucial management objective for queen conch populations is to maintain adult densities at adequate levels to ensure successful reproduction (Appeldoorn et al. 2011), as reproductive success in queen conch is highly dependent on adult conch densities (Stoner & Ray-Culp 2000). Stoner and Ray-Culp (2000) demonstrated that mating and spawning behaviors reach maximum levels at approximately 200 conch per ha and that reproductive behavior decreases below this level, until they cannot be observed below 48 conch per ha. Furthermore, the Queen Conch Expert Workshop Group Report (2012) advised to set harvest quota at no more than 8% of the adult conch stock. Accurate estimations of live adult conch densities, in shallow and deep areas alike, are thus essential to set sustainable harvest quotas.

Because of safety limitations of survey methods using scuba, areas below 20 m are rarely surveyed and areas below 30 m are generally excluded from biomass estimates (Queen Conch Expert Workshop Group Report 2012, MRAG 2013). In addition, dive surveys can be logistically demanding and relative expensive, in particular when remote offshore areas are surveyed (Queen Conch Expert Workshop Group Report 2012). The rapid technical progress of video systems has made it possible to develop new cost-effective sampling tools to study benthic organisms, beyond depths safe for diving, using video technology (Stevens 2003, Sheehan et al. 2010). This study describes the suitability of a light and affordable towed video method (TVM) to determine densities of adult (flared lip) queen conch throughout its entire depth range (ca. 60 m depth), in a safe and cost-effective manner. This study aims to assess the ability of the TVM to (1) correctly identify live adult queen conch, and (2) accurately estimate adult queen conch densities. Simultaneous towed video and diver belt transects (BT) were conducted to test the following hypothesis: the TVM does not differ in its ability to accurately estimate live adult queen conch densities from conventional methods using scuba in high-complexity (HC) and low-complexity (LC) habitats.
MATERIALS AND METHODS

Study Site

St. Eustatius is a small island (21 km²) located between 17° 28’ and 17° 32’ N latitude and 62° 56’ and 63° 0’ W longitude (Fig. 1). The St. Eustatius National Marine Park (SNMP) surrounds the entire island and extends from the high-tide level to a depth of ca. 30 m. The total surface area of the SNMP is 27 km². The Marine Park, which includes the Northern Reserve (163 ha) and the Southern Reserve (364 ha), was established in 1996. In these two reserves, fishing or anchoring is not allowed. Low-relief gorgonian reefs amount to 22% of the SNMP and are concentrated to the shallow (<20 m) eastern part of the island.

The reef habitats and seagrass beds are concentrated at depths of about 24 m and each cover ca. 4% of the SNMP. Rocky reef areas are limited to the southern and southwestern shelf areas, whereas seagrass beds are confined to the north (Debrot et al. 2014).

Towed Video Method

The hovering towed video array was based on a design of Stevens (2003) and Sheehan et al. (2010) and consisted of a polyvinyl chloride (PVC) frame with a live view camera (Seaview super mini; Seaviewer Cameras Inc., Tampa, FL, www.seaviewer.com) and a transect camera (GoPro Hero 2; GoPro, San Mateo, CA, www.gopro.com) (Figs. 2A and 3). The live view camera was mounted on the frame in a forward and downward (30°) position, sending a real-time feed to the operator on the boat through a cable. The feed was continuously monitored by the operator to avoid high-relief habitat and to adjust for changes in depth. The transect camera was mounted on the frame in a forward and more downward (45°) position than the live view camera. This position allowed for an optimal angle for video analysis. The 1 m width of the transect was indicated by two green laser (Z-bolt SCUBA-1 Underwater green laser; Beam of Light Technologies Inc., Happy Valley, OR, www.z-bolt.com) mounted parallel on a PVC bar on top of the frame at a fixed distance of 1 m apart. The two green lasers were angled in the same forward and downward position as the transect camera. The laser dots were visible on the video recordings (Fig. 2B). Two sealed and air-filled PVC pipes attached on top of the frame kept the array slightly positively buoyant. Total weight of the array including cameras and lasers was <10 kg. A length of chain attached to the bottom of the frame secured the downward position of the frame and allowed the array to hover over the bottom. The array was towed behind a 6-m-long vessel with a 115-hp-outboard engine, using a tow-line, which was connected to the frame. The length of the towline was adjusted depending on depth. A 10 kg drop weight was attached to the towline 10 m in front of the frame to ensure that the frame was kept in a horizontal forward position and helped to absorb some of the movements caused by surface waves. The drop weight was kept at a height of 1–2 m above the seafloor and by adjusting the height of the drop weight above the seafloor, the array was kept at the preferred height of ca. 1 m above the substrate.

Calibration Transects

The calibration of the TVM was conducted in two different benthic habitats with different levels of complexity and where adult queen conch commonly occurred. The HC habitat, found at a depth range of 20–33 m, consisted of rubble and algae (Fig. 2C) and the LC habitat, found at 10–26 m depth, consisted of sand, seagrass, and algae (Fig. 2D). Habitat complexity was expected to potentially influence results of the TVM, because, based on previous experience, adult queen conchs are slightly
more difficult to identify in HC habitats. During the calibration transects, an experienced conch research diver, used to identify adult conch in different habitats, followed the towed video array and at the same time conducted a standard BT (CRFM 2013) covering exactly the same area (equal width and length) as the transect made by the TVM. Belt transects are a common method used to estimate the distribution of organisms within a specified area. All individuals of the species of interest are recorded within an area with a set length and width (CRFM 2013). The towed method was operated by two individuals, the first monitored the live view feed and the second adjusted the length of the towline to keep the array at the preferred height above the bottom. The video array was towed at low speeds (0.25–0.5 m/s) or when possible, the vessel drifted with the current and/or the wind. Keeping the speed lower than 0.5 m/s was critical as at higher speeds, the transect video recordings became blurry and unsuitable for analysis. The 1 m width of the transect was indicated by the lasers attached to the towed video array. To have the same transect length for both methods, hand signals in front of the video camera and live view camera by the
diver were used to indicate begin and endpoint in the video recordings. Based on the divers hand signals, visible through the live view feed, global positioning system points of the begin and endpoint were determined with a handheld global positioning system (Garmin GPSmap 78, Garmin Ltd., Olathe, KS, www.garmin.com), which was set to track the position every 10 sec to accurately follow the transect and calculate transect length. Begin and end depths were also recorded for each transect and determined by the vessel’s depth sounder. The video recordings of the transects were saved on secure digital cards and converted to audio video interleave-files using Xilisoft video converter (Xilisoft Corporation, San Diego, CA, www.xilisoft.com). All adult conch inside the transect as well as all adult conch which were only partially inside the transect were counted by the diver conducting the BT and the video analyst. After conversion, videos were analyzed for the occurrence of adult queen conch by an independent researcher not involved in the BT to avoid bias, using TransectMeasure computer software (SeaGIS Pty. Ltd., Bacchus Marsh, VIC, Australia, www.seagis.com.au). To distinguish live from dead conch, the diver turned over each animal in the transect, whereas the video analyst determined live from dead based on visual cues (e.g., position of the conch, damage to shell, tracks on the sea bottom, and movement).

**Statistical Analysis**

To test the difference between the two survey methods, the conch counts (X, in numbers) were first transformed to \( X = \sqrt{X + 0.5} \), which is the preferred method in case of dealing with small numbers, including zero values in the data (Zar 1996). The transformed counts were first tested for differences using a Student’s paired \( t \)-test, if their variances were not significantly different (\( P > 0.05 \)) according to a Levene’s test (which was never the case). Next a major axis regression was carried out to investigate the relationship between the results of both survey methods. This method is preferred if neither of the variables can be considered independent, when they are in the same units and if the variance of error is approximately the same for both variables (Legendre 2013). Data analysis was performed using the software environment R (R Development Core Team 2016) and the packages car and lmde2.

**RESULTS**

Eighteen transects were conducted in the HC habitat and 19 transects in the LC habitat covering a total area of 1.8 ha. Transects varied in length from 130 to 982 m and ranged from 10 to 33 m in depth. In the HC habitat, both survey methods recorded similar counts of adult live queen conch (Table 1), with mean counts of 31.94 with the BT and 30.06 with the TVM (paired \( t \)-test: \( t = 1.623, df = 17, P = 0.122 \)). In the LC habitat, adult live queen conch counts were also similar with both methods (Table 1), with mean counts of 6.84 with the BT and 6.54 with the TVM (paired \( t \)-test: \( t = 0.90, df = 18, P = 0.380 \)). In addition, the major axis regression showed that the numbers of adult live conch recorded by the TVM and BT in the HC habitat were similar (slope not significantly different from one) and had a high explanatory level (\( R^2 = 0.89 \)) (Table 2, Fig. 4A). In the LC habitat, both methods were even more similar (slope not significantly different from one) with a very high explanatory level (\( R^2 = 0.99 \)) (Table 2, Fig. 4B). Adult dead conch counts were consistently underestimated with the TVM (Table 1) in the HC habitat, with mean counts of 5.72 with the BT and 2.22 with the TVM (paired \( t \)-test: \( t = 4.97, df = 17, P = 0.0005 \)). No dead adult conchs were found in the LC habitat (Table 1). The number of recorded adult dead conch in the HC habitat was lower with the TVM than with BT (slope significantly different from 1) with only a moderate explanatory level (\( R^2 = 0.50 \)) (Table 2, Fig. 4C).

**DISCUSSION**

In this study, a lightweight and effective towed video array was developed capable of surveying adult queen conch populations in both HC and LC habitats throughout the species’ entire depth range (ca. 0–60 m). The TVM proved to be effective in accurately identifying live adult conch, in both the HC and the LC habitats tested, and both methods yielded overall the same counts. Especially in the LC habitat, the results of both methods appeared interchangeable (Fig. 4A). This also applied for the HC habitat, although the variability in the estimates was larger, resulting in more spread around the intercalibration line and a slightly lower \( R^2 \) (Fig. 4B). It is likely that the slightly larger variability in the more complex habitat is caused by the overall greater difficulty in detecting conch in this habitat.

Accurately distinguishing between live and dead conch is important to produce reliable density estimates, which is critical for queen conch management (Ehrhardt & Valle-Esquível 2008). Concerns have been raised that the identification of live versus dead conch could be a potential problem for the TVM.

**TABLE 1.** Summary of the result from the calibration transects.

<table>
<thead>
<tr>
<th>Group</th>
<th>Habitat</th>
<th>Method</th>
<th>Number of T</th>
<th>Count</th>
<th>Mean Count</th>
<th>SD</th>
<th>0–T</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult live</td>
<td>HC</td>
<td>BT</td>
<td>18</td>
<td>575</td>
<td>31.94</td>
<td>12.62</td>
<td>0</td>
</tr>
<tr>
<td>Adult live</td>
<td>HC</td>
<td>TVM</td>
<td>18</td>
<td>541</td>
<td>30.06</td>
<td>10.84</td>
<td>0</td>
</tr>
<tr>
<td>Adult live</td>
<td>LC</td>
<td>BT</td>
<td>19</td>
<td>132</td>
<td>6.94</td>
<td>4.97</td>
<td>2</td>
</tr>
<tr>
<td>Adult live</td>
<td>LC</td>
<td>TVM</td>
<td>19</td>
<td>130</td>
<td>6.84</td>
<td>4.94</td>
<td>2</td>
</tr>
<tr>
<td>Adult dead</td>
<td>HC</td>
<td>BT</td>
<td>18</td>
<td>103</td>
<td>5.72</td>
<td>4.79</td>
<td>1</td>
</tr>
<tr>
<td>Adult dead</td>
<td>HC</td>
<td>TVM</td>
<td>18</td>
<td>40</td>
<td>2.22</td>
<td>2.01</td>
<td>4</td>
</tr>
<tr>
<td>Adult dead</td>
<td>LC</td>
<td>BT</td>
<td>19</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>19</td>
</tr>
<tr>
<td>Adult dead</td>
<td>LC</td>
<td>TVM</td>
<td>19</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>19</td>
</tr>
</tbody>
</table>

Summary of the results for transects in the HC and LC habitat with the TVM counts and the divers counts during the BT [counts, mean counts per transect, SD, and number of transects with 0-counts (0–T)].

**TABLE 2.** Summary of the results from the major axis regression.

<table>
<thead>
<tr>
<th>Group</th>
<th>Habitat</th>
<th>Mean slope</th>
<th>Lower CI</th>
<th>Upper CI</th>
<th>( R^2 )</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult live</td>
<td>HC</td>
<td>0.869</td>
<td>0.718</td>
<td>1.048</td>
<td>0.888</td>
<td>P &lt; 0.01*</td>
</tr>
<tr>
<td>Adult live</td>
<td>LC</td>
<td>0.995</td>
<td>0.940</td>
<td>1.044</td>
<td>0.991</td>
<td>P &lt; 0.01*</td>
</tr>
</tbody>
</table>

Major axis regression analysis of the squared root (\( X + 0.5 \)) transformed TVM counts and the squared root (\( X + 0.5 \))-transformed BT counts in the HC and LC habitat [lower (lower CI) and upper confidence interval (upper CI) of the slope] (* = significant).
The key advantage of the TVM over other conventional survey methods using scuba is the ability to accurately determine live adult conch densities throughout the species' entire depth range (ca. 0–60 m), with essentially unlimited bottom time (Stevens 2003, Spencer et al. 2005). The two most common methods to study the abundance and distribution of queen conch populations are towed scuba diver (Wood & Olsen 1983, Stoner et al. 2012) and BT by scuba divers (Clark et al. 2005, CRFM 2013). Both methods use scuba and are thus restricted to limits of safe diving, although for practical reasons areas below 20 m are rarely surveyed with methods using scuba (Queen Conch Expert Workshop Group Report 2012). During this study, the TVM was only used to a depth of 33 m to be able to conduct the concurrent BT. However, the TVM has been used to determine adult queen conch densities to a depth of 58 m (unpublished data) on the Saba Bank, an offshore bank located 20 miles west of St. Eustatius. With methods using scuba, costs increase with survey depth (Prada et al. 2014), however, the TVM is equally cost-effective at any depth. Further advantages of the TVM is its capability of covering large distances (Sheehan et al. 2010) and make permanent records of the surveys (Spencer et al. 2005), which can be reanalyzed if necessary. Furthermore, the recorded transects can be used to quantify habitat characteristics on a fine and broadband scale (Spencer et al. 2005, Sheehan et al. 2010). The TVM was accurate in identifying adult live conch in both the HC and LC habitat with a high R² in both habitats (Fig. 4A, B). In high-relief habitats, such as coral reefs, the TVM is, however, not capable of safely navigating. Although these areas are not usually preferred by queen conch (Acosta 2006), conch surveys in such areas will require methods using divers. Controlling the speed over the seafloor is also important, with the transect camera (GoPro Hero 2) used in this study, speeds above 0.5 m/s resulted in blurry video unsuitable for quantitative analysis.

The results of this study verify the TVM ability in making accurate density estimates of live adult queen conch. With this verification and the advantages of the TVM, especially at greater depth, over conventional survey methods using divers, managers now have a new survey tool at their disposal. The entire depth range of adult queen (0–60 m) can be surveyed and accurate density estimates of live adult conch can be made with the TVM, without an increase in costs or risks to field staff.

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