Recent survey results indicate *Trochus niloticus* (seum) populations increased since 2016

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Abstract

The objective of this study was to provide needed information to the Bureau of Marine Resources (BMR) under the Ministry of Natural Resources, Environment and Tourism (MNRET) for which they can make recommendations to the Palau National Congress on the status of the *Trochus niloticus* (seum) in Palau. These recommendations will be weighed in the decisions on whether or not to open the harvest season for trochus in Palau. The study was conducted in 122 sites from Kayangel to Peleliu, on the fore reef and reef crest habitats. At each site three 50-m transects were laid and observers counted and measured any trochus found within a 2 m belt within each transect. This was the second follow up of the same study done by BMR in 2016. Results showed a significant increase in density, population abundance, and size in each habitat through time (2016 to 2019). Within the fore reef habitat the average density of trochus per 100m² was 3.63 ± 0.63, while the reef crest had a higher density of 7.57 ±1.4 trochus per 100m². As a result, the total density found per ha (in both fore reef and reef crest habitats) was found to be 515.03 amounting to a total population abundance of 3,385,995.83. The mean size of all trochus counted was 9.34±0.04 cm. About 86% of the population of trochus was greater than the legal harvest size of 3 inches (7.62 cm), while 48% of the population was greater than 4 inches (10 cm). Based on past studies on sustainable stocks of trochus where a density of 600 individuals per ha is recommended for harvest. Since the reef crest habitat had 754 trochus individuals per ha, it is recommended that the harvest season for trochus be open for a limited time of 2-3 weeks. This ensures that people are able to participate in the fishery, but also retain a sustainable population of trochus for further reproduction. Finally, a monitoring protocol should be established to ensure continued surveys that inform decisions made by resource managers and the national congress.
1. Introduction

_Trochus niloticus_ (seum) is a valuable marine species due to its use in the manufacturing of products like buttons, jewelry, handicrafts and more (Gilett, 1997). _Trochus niloticus_ has been overharvested in the past throughout the Pacific, as well as in Palau (Kitalong, 1992; Gilett, 1997). Because of this, the national government has imposed strict regulations on the harvest of _T. niloticus_ in Palau in an effort to create a more sustainable fishery. Now, the species has a harvest season determined by the Palau National Congress, the Olbiil er a Kelulau (OEK), where congress can open the harvest season through resolution.

To make this decision, the OEK is advised by the Bureau of Marine Resources (BMR) under the Ministry of Natural Resources, Environment and Tourism (MNRET). As per regulations on trochus harvest policy, during open harvest season for trochus, only individuals with a basal diameter that is greater than three inches (7.62 cm) can be harvested, the size that correlates to reproductive maturity. In line with this decision-making process, in 2016, the 9th OEK requested that BMR conduct a trochus stock assessment to determine whether the population is stable enough to reopen the harvest season. In 2016, BMR, along with its partner agency – the Palau International Coral Reef Center (PICRC) – conducted stock surveys at 122 sites across Palau to assess the current population status of _T. niloticus_ in Palau. The first round of assessments were conducted and a report was produced that illustrated the population density and size distribution of _T. niloticus_ in Palau (Gouezo et al, 2016). As a result of that 2016 survey, the 9th OEK decided to keep the harvest season closed. In 2019-2020, BMR conducted a second assessment to advise the 10th OEK on the trochus harvest closure. This report is an update to the one done in 2016, where the population density and size distribution is compared through time. This report will also be used as the basis for any recommendations that will be made by the Bureau of Marine Resources.
2. Methods

2.1. Site Selection

As requested by BMR, PICRC prepared the survey design for this *T. niloticus* stock assessment. The study focused on two main habitats where *T. niloticus* are mostly found: fore reef and reef crest habitats. The total area of each reef habitat found in Palau was obtained from the Office of the Palau Automated Land Resources Information System (PALARIS) under the Ministry of Finance (Appendix 1). Palau was split into four different regions that were about the same area to ensure a good spatial coverage of survey sites within the regions (Figure 1). In addition to random selection of sites, collection hotspots (where trochus are historically found in abundance) were identified on the reef map by PICRC staff, and polygons were drawn on the map in orange to signify hotspot areas (Figure 1).
Figure 1: Map of trochus stock survey sites all over Palau main archipelago.
The number of survey sites identified within each region and habitat was proportional to the size of the habitat and region. As such, one random survey site per 600,000 m² was allocated per habitat type. Additionally, twenty survey sites were allocated to hotspot areas (Figure 1; Table 1). In 2016, 121 sites were identified to be surveyed; however, due to weather conditions, only 94 sites were surveyed (Table 1). In 2019, these same sites were surveyed with a new addition of 1 more site (Table 1).

**Table 1.** Number of sites in each region in 2016 and 2019.

<table>
<thead>
<tr>
<th>Year</th>
<th>Habitat</th>
<th>Region</th>
<th>Number of Sites Surveyed</th>
<th>Year</th>
<th>Habitat</th>
<th>Region</th>
<th>Number of Sites Surveyed</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>Fore_Reef</td>
<td>HS</td>
<td>9</td>
<td>2019</td>
<td>Fore_Reef</td>
<td>HS</td>
<td>10</td>
</tr>
<tr>
<td>2016</td>
<td>Fore_Reef</td>
<td>NE</td>
<td>13</td>
<td>2019</td>
<td>Fore_Reef</td>
<td>NE</td>
<td>22</td>
</tr>
<tr>
<td>2016</td>
<td>Fore_Reef</td>
<td>NW</td>
<td>12</td>
<td>2019</td>
<td>Fore_Reef</td>
<td>NW</td>
<td>13</td>
</tr>
<tr>
<td>2016</td>
<td>Fore_Reef</td>
<td>SE</td>
<td>12</td>
<td>2019</td>
<td>Fore_Reef</td>
<td>SE</td>
<td>21</td>
</tr>
<tr>
<td>2016</td>
<td>Fore_Reef</td>
<td>SW</td>
<td>9</td>
<td>2019</td>
<td>Fore_Reef</td>
<td>SW</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td><strong>2016 Fore_Reef Total</strong></td>
<td><strong>55</strong></td>
<td></td>
<td></td>
<td><strong>2019 Fore_Reef Total</strong></td>
<td><strong>75</strong></td>
<td></td>
</tr>
<tr>
<td>2016</td>
<td>Reef_Crest</td>
<td>HS</td>
<td>8</td>
<td>2019</td>
<td>Reef_Crest</td>
<td>HS</td>
<td>10</td>
</tr>
<tr>
<td>2016</td>
<td>Reef_Crest</td>
<td>NE</td>
<td>6</td>
<td>2019</td>
<td>Reef_Crest</td>
<td>NE</td>
<td>8</td>
</tr>
<tr>
<td>2016</td>
<td>Reef_Crest</td>
<td>NW</td>
<td>7</td>
<td>2019</td>
<td>Reef_Crest</td>
<td>NW</td>
<td>8</td>
</tr>
<tr>
<td>2016</td>
<td>Reef_Crest</td>
<td>SE</td>
<td>6</td>
<td>2019</td>
<td>Reef_Crest</td>
<td>SE</td>
<td>11</td>
</tr>
<tr>
<td>2016</td>
<td>Reef_Crest</td>
<td>SW</td>
<td>12</td>
<td>2019</td>
<td>Reef_Crest</td>
<td>SW</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td><strong>2016 Reef_Crest Total</strong></td>
<td><strong>39</strong></td>
<td></td>
<td></td>
<td><strong>2019 Reef_Crest Total</strong></td>
<td><strong>47</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>2016 Total</strong></td>
<td><strong>94</strong></td>
<td></td>
<td></td>
<td><strong>2019 Total</strong></td>
<td><strong>122</strong></td>
<td></td>
</tr>
</tbody>
</table>

### 2.2. Data Collection and Entry

With a GPS with the plotted sites, the survey team travelled to the designated sites. Due to shallow nature of the sites, the team had to get as close as possible to the chosen sites and swim to the allotted survey area (Figure 1; Appendix 2 & 3). At each survey site, 3 transects measuring 50 meters long were laid at the same depth, with about 2-3 meters separating each transect tape (see illustration below). At each site, the total surveyed area was 300 m². The maximum depth at each site was about 2-3 meters deep. Swimming along the length of the three transects, the observers counted and measured all observed *T. niloticus* that were found within 1 meter on each side of the transect tape. For measurements of the trochus, the observer measured the
basal diameter of each individuals found in the survey area using a ruler (Gouezo et al, 2016). All data was entered into Microsoft Excel Spreadsheets.

<table>
<thead>
<tr>
<th>Site</th>
<th>Transect #1</th>
<th>Transect #2</th>
<th>Transect #3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>50 m</td>
<td>50 m</td>
<td>50 m</td>
</tr>
<tr>
<td></td>
<td>2-3 m</td>
<td>2-3 m</td>
<td>2 m</td>
</tr>
</tbody>
</table>

2.3. Data Analysis

In order to decrease the variation in the data among the sites, the average abundance among the three transects was to calculate the number of individuals per 100 m² for calculations of population density. For each habitat (fore reef and reef crest), the total area surveyed was calculated by multiplying the surveyed area (100 m²) per site by the total number of sites. Within each habitat, the count of *T. niloticus* at each site was summed to get the number of individuals per total surveyed area. This was then converted into number of individuals per hectares (ha; 1ha = 10,000 m²) to make interpretations and comparisons with past studies easier. The total area of the two habitats (fore reef and reef crest) was obtained from the PALARIS Office and was converted into hectares. The number of *T. niloticus* was then estimated within each habitat depending on their total size. The size distribution of *T. niloticus* was explored graphically using histograms and calculation of mean size within each habitat. Data analysis was done using MS Excel (pivot tables and analysis tools) and the R statistical software (R Development Core Team 2015, R version 3.6.3).
3. Results

Results are presented in the following categories: (1) density, (2) population abundance, and (3) size. Averages of density and size by habitat (fore reef and reef crest) are presented in each subsection. Further breakdown of density and size by region is also presented.

3.1. Density

3.1.1. Density by habitat

In 2016, the average density of trochus found in an area of 100m$^2$ was 1.39 (±0.32) on the fore reef, while on the reef flat, it was 1.44 (±0.38). In 2019, the average density of trochus found on the fore reef increased to 3.63 (±0.63) trochus found in 100m$^2$ and on the reef crest, 7.57 (±1.40) trochus was found per 100m$^2$ (Figure 2). On the reef crest, there was a significant increase in density from 2016 to 2019 (Kruskal-Wallis, p<0.01).

Figure 2: Density of T. niloticus per 100m$^2$ through time in fore reef and reef crest habitats. (Error bars (±) signify standard error; 2016, n=94 and 2019, n=122)
3.1.2. Density by Region

In both 2016 and 2019 the region with the highest average density of trochus was the SE region with 2.48±0.75 and 9.15±1.75 individuals per 100m$^2$ respectively. In both 2016 and 2019, the SW region had the least trochus density with 0.87 (±0.40) 2.16 (±0.90) trochus per 100m$^2$ respectively. In 2016, the NE region also had the least trochus density with 0.77 (±0.18) and in 2019, the NW region had 2.32 (±1.26) trochus per 100m$^2$. In 2016 and 2019, the hotspot regions had an average density of 1.61 (±0.73) and 6.90 (±1.61) per 100m$^2$, respectively. (Figure 3).

![Figure 3: Average density of T. niloticus per 100m$^2$ through time in each region](image)

3.2. Population Abundance

In 2016, the total reef area (both fore reef and reef crest) that was surveyed was 9,400 m$^2$ (number of sites multiplied by the 100m$^2$), where a total of 132.33 T. niloticus were counted. This total density was converted into number of individuals per hectares (ha), amounting to approximately 140.78 individual T. niloticus found in 1 ha or 10,000 m$^2$ (Table 2). However, in 2019, the total reef area that was surveyed was 12,200 m$^2$, where a total T. niloticus individuals found were 628.33. Converting to hectares, a total of 515.03 T. niloticus individuals were recorded per 1 ha (Table 2).
### Table 2: Total density of *T. niloticus* within each habitat through time.

<table>
<thead>
<tr>
<th>Year</th>
<th>Habitat</th>
<th>Number of sites surveyed</th>
<th>Reef area surveyed (m²)</th>
<th>Total count of individuals within surveyed area</th>
<th>Ind/ha (10,000m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>Fore Reef</td>
<td>55</td>
<td>5,500</td>
<td>75.33</td>
<td>136.97</td>
</tr>
<tr>
<td></td>
<td>Reef Crest</td>
<td>39</td>
<td>3,900</td>
<td>57</td>
<td>146.15</td>
</tr>
<tr>
<td></td>
<td><strong>Overall</strong></td>
<td><strong>94</strong></td>
<td><strong>9,400</strong></td>
<td><strong>132.33</strong></td>
<td><strong>140.78</strong></td>
</tr>
<tr>
<td>2019</td>
<td>Fore Reef</td>
<td>75</td>
<td>7,500</td>
<td>272.33</td>
<td>363.11</td>
</tr>
<tr>
<td></td>
<td>Reef Crest</td>
<td>47</td>
<td>4,700</td>
<td>356</td>
<td>757.45</td>
</tr>
<tr>
<td></td>
<td><strong>Overall</strong></td>
<td><strong>122</strong></td>
<td><strong>12,200</strong></td>
<td><strong>628.33</strong></td>
<td><strong>515.03</strong></td>
</tr>
</tbody>
</table>

To estimate the total population abundance of *T. niloticus* in Palau’s waters, the overall abundance was used to multiply by the total reef area (\(\text{Ind/ha} \times \text{total reef area in Palau (ha)}\)). The total area of reef (including fore reef and reef crest) is 6,574.40 hectares. In 2016, the total estimated number of *T. niloticus* found in Palau was 925,545.02 and in 2019, the estimated number increased to 3,385,995.83 (Table 3).

### Table 3: Total estimated population density of *T. niloticus* in Palau by habitat through time.

<table>
<thead>
<tr>
<th>Year</th>
<th>Habitat</th>
<th>Total reef area in Palau (m²)</th>
<th>Total area of reef in Palau (ha)</th>
<th>Estimated number of <em>T. niloticus</em> in Palau</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>Fore Reef</td>
<td>42,719,637</td>
<td>4,271.96</td>
<td>585,129.57</td>
</tr>
<tr>
<td></td>
<td>Reef Crest</td>
<td>23,024,367</td>
<td>2,302.44</td>
<td>336,509.98</td>
</tr>
<tr>
<td></td>
<td><strong>Overall</strong></td>
<td><strong>65,744,004</strong></td>
<td><strong>6,574.40</strong></td>
<td><strong>925,545.02</strong></td>
</tr>
<tr>
<td>2019</td>
<td>Fore Reef</td>
<td>42,719,637</td>
<td>4,271.96</td>
<td>1,551,197.49</td>
</tr>
<tr>
<td></td>
<td>Reef Crest</td>
<td>23,024,367</td>
<td>2,302.44</td>
<td>1,743,973.33</td>
</tr>
<tr>
<td></td>
<td><strong>Overall</strong></td>
<td><strong>65,744,004</strong></td>
<td><strong>6,574.40</strong></td>
<td><strong>3,385,995.83</strong></td>
</tr>
</tbody>
</table>
3.3. Size Distribution

The size distribution of *T. niloticus* is described in this section using histograms and averages. Size distribution are further categorized by habitat (fore reef, reef crest, and overall) through time. Further analysis of size classes are also presented showing total populations for each size class (undersized (≤7.5 cm) and legal sized (≥7.6 cm)).

3.3.1. Fore Reef

On the fore reef in 2016, the mean size of the *T. niloticus* was 8.16 (±0.15) cm and in 2019, the mean size was 9.36 (±0.06) cm in diameter (Figure 4; Table 4). Through time, there was a significant increase in mean size of trochus within the fore reef habitat (Kruskal-Wallis, p<0.001). In both years, the mean size was greater than the legal harvest size of 7.62 cm (3 inches) within the fore reef.

![Figure 4: Histograms showing the size distribution of *T. niloticus* on the fore reef habitat through time. (Dashed red line signifies the mean size)](image_url)
In terms of the overall distribution of trochus on the fore reef according to each size class, in 2016, about 39% of the trochus counted were undersized (7.5 cm or smaller) and 61% was of legal harvest size (7.6 or greater). Furthermore, in 2019, only 12.6% of the trochus counted measured less than 7.5 cm and 87.4% were greater than 7.6 cm (Table 4). In 2016, about 27% of the trochus counted had measured 10 cm (4 inches) or greater and in 2019, the count nearly doubled accounting for 28% of trochus measured.

<table>
<thead>
<tr>
<th>Year</th>
<th>Size Class</th>
<th>Count per size class</th>
<th>Total counted</th>
<th>Percent of each size class</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>≤7.5cm</td>
<td>89</td>
<td>226</td>
<td>39.4%</td>
</tr>
<tr>
<td></td>
<td>≥7.6cm</td>
<td>137</td>
<td>226</td>
<td>60.6%</td>
</tr>
<tr>
<td>2019</td>
<td>≤7.5cm</td>
<td>103</td>
<td>817</td>
<td>12.6%</td>
</tr>
<tr>
<td></td>
<td>≥7.6cm</td>
<td>714</td>
<td>817</td>
<td>87.4%</td>
</tr>
</tbody>
</table>

3.3.2. Reef Crest

On the reef crest habitat, the mean size of *T. niloticus* was 7.8 (±0.16) cm in 2016, and increased in 2019 to a mean size of about 9.33 (±0.05) cm in basal diameter (Figure 5; Table 5). From 2016 to 2019, there was a significant difference in mean size within the reef crest habitat, where in 2019 the mean size was significantly greater than in 2016 (Kruskal-Wallis, p<0.001). In 2016, the mean size of trochus was slightly higher (7.8 cm) than the legal harvest size of 7.62 cm (3 inches), and in 2019, the mean size was higher at 9.3 cm on the reef crest.
Figure 5: Histograms showing the size distribution of *T. niloticus* on the reef crest habitat through time. (*Dashed red line signifies the mean size*)

On the reef crest, in 2016, 45% of the trochus measured and counted were less than the legal harvest size (7.5 cm and smaller), while 54% of the trochus counted were greater than the legal size. Moreover, in 2019 only 15.2% of the trochus counted were 7.5 cm or smaller and 84.8% were 7.6 cm or greater (Table 5). In 2016, only 19% of trochus counted and measured were 10 cm (4 inches) or greater, but in 2019, this percentage doubled, amounting to about 48% of the trochus counted measuring 10 cm or greater.

<table>
<thead>
<tr>
<th>Year</th>
<th>Size Class</th>
<th>Count per size class</th>
<th>Total counted</th>
<th>Percent of each size class</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>≤7.5 cm</td>
<td>77</td>
<td>171</td>
<td>45%</td>
</tr>
<tr>
<td></td>
<td>≥7.6 cm</td>
<td>94</td>
<td>171</td>
<td>54%</td>
</tr>
<tr>
<td>2019</td>
<td>≤7.5 cm</td>
<td>162</td>
<td>1068</td>
<td>15.2%</td>
</tr>
<tr>
<td></td>
<td>≥7.6 cm</td>
<td>906</td>
<td>1068</td>
<td>84.8%</td>
</tr>
</tbody>
</table>
3.3.3. Overall

In 2016, the overall mean size was 8 (±0.11) cm and in 2019, the mean size increased to 9.34 (±0.04) cm in basal diameter (Figure 6; Table 6). This increase in mean size from 2016 to 2019 was found to be significant (Kruskal-Wallis, p<0.001). Over both habitats through time, the mean size was consistently greater than the legal harvest size.

Figure 6: Histograms showing the overall size distribution of T. niloticus through time. (Dashed red line signifies the mean size)

Overall, in 2016, on average, across both habitats, about 42% of the trochus that were counted were 7.5 cm or smaller and 58% were of legal harvest size. In 2019, 14% are undersized while 86% are measured 7.6 cm or greater (Table 6).

<table>
<thead>
<tr>
<th>Year</th>
<th>Size Class</th>
<th>Count per size class</th>
<th>Total counted</th>
<th>Percent of each size class</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>≤7.5cm</td>
<td>166</td>
<td>397</td>
<td>41.8%</td>
</tr>
<tr>
<td></td>
<td>≥7.6cm</td>
<td>231</td>
<td>397</td>
<td>58.2%</td>
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<tr>
<td>2019</td>
<td>≤7.5cm</td>
<td>265</td>
<td>1885</td>
<td>14.0%</td>
</tr>
<tr>
<td></td>
<td>≥7.6cm</td>
<td>1620</td>
<td>1885</td>
<td>86.0%</td>
</tr>
</tbody>
</table>
4. Discussion

Since the 2016 trochus stock assessment, the trochus population in Palau has significantly increased, from an estimated total population density of 925,545 individual trochus per hectare in 2016 to 3,385,995.83 individuals per hectare. Additionally, the mean sizes of the trochus recorded in 2019 (9.34 cm) were significantly greater than those recorded in 2016 (8 cm).

The most abundant region in 2019 was the SE region with 9.15 $\pm$ 1.26 trochus per 100 m$^2$, as well as the hotspot regions with a density of 6.9 $\pm$ 1.61 trochus per 100 m$^2$. The least abundant region was found to be the NW region with a density of 2.32 ($\pm$1.26) and the SW region with 2.16 ($\pm$0.9) trochus per 100 m$^2$. Historically, the SE region of Palau had always had a greater density of trochus, while the SW region had the least density, which coincides with findings from 2019 (Palau Marine Resources Profile, SPREP).

The objective of this study was to determine whether or not the trochus population in Palau was stable enough for the harvest season to reopen by the Palau National Congress. In a study conducted in 1985, the estimated trochus density was 119 per ha (Heslinga at al., 1985); and in a study conducted by Ngiramolau and others (1991), the estimated trochus density in 1991 was 155 trochus per hectare. In 2002, Kitalong (2002) estimated a density of 961 trochus per ha. Since 2002, the density had decreased to 341 trochus individuals per ha in 2010 (BMR data) and 140.8 trochus per ha in 2016; while an increase in density came in 2019 with 515.03 trochus individuals per ha (Table 7).

<table>
<thead>
<tr>
<th>Year</th>
<th>Total reef area in Palau (m$^2$)</th>
<th>Total area of reef in Palau (ha)</th>
<th>Individuals per ha</th>
<th>Estimated number of T. niloticus in Palau</th>
</tr>
</thead>
<tbody>
<tr>
<td>1985</td>
<td>65,744,004</td>
<td>6,574.4004</td>
<td>119</td>
<td>782,353.6476</td>
</tr>
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<td>1991</td>
<td>65,744,004</td>
<td>6,574.4004</td>
<td>155</td>
<td>1,019,032.062</td>
</tr>
<tr>
<td>2002</td>
<td>65,744,004</td>
<td>6,574.4004</td>
<td>961*</td>
<td>6,317,998.784</td>
</tr>
<tr>
<td>2010</td>
<td>65,744,004</td>
<td>6,574.4004</td>
<td>341.1*</td>
<td>2,242,527.976</td>
</tr>
<tr>
<td>2016</td>
<td>65,744,004</td>
<td>6,574.4004</td>
<td>140.78</td>
<td>925,545.0209</td>
</tr>
<tr>
<td>2019</td>
<td>65,744,004</td>
<td>6,574.4004</td>
<td>515.027</td>
<td>3,385,995.834</td>
</tr>
</tbody>
</table>

Table 7. Estimated total population of T. niloticus in Palau through time, 1985-2019. (Asterisk (*) signify only legal sized individuals counted)
A study by Adams and others (1992) in the Cook Islands recommends harvest to take place when *T. niloticus* stocks were more than 600 individuals per ha. As such, though the population estimates in 2019 show a dramatic increase since 2016, the 2019 data show only 515 individuals per ha, 85 individuals less than recommended. However, on the reef crest, the total population density was 757 individuals per ha, which is 157 more than the recommended. Based on this number, it is recommended that this reef crest population is stable enough for a small window of harvest during the harvest season (2-3 weeks). While the stock is estimated to be about 3 million, the ratio of adult to juvenile trochus is skewed, where there are significantly more adult than juvenile (see table 8 below). By limiting harvest time to a short amount of time, allows for residents to participate in this activity, but also curbs exploitation of the resource. If all adults are taken (2.9 million), few juvenile trochus (476,000) are left to repopulate the lost stock. This window of opportunity for harvest will ensure that residents are able to harvest, yet ensure that the stock of *T. niloticus* remain sustainable to support further reproduction and future harvest.

### Table 8. Estimated total population of *T. niloticus* in each size class in each habitat through time.

<table>
<thead>
<tr>
<th>Habitat</th>
<th>Year</th>
<th>Size Class</th>
<th>Count per size class</th>
<th>Total counted</th>
<th>Percent of each size class</th>
<th>Total population</th>
<th>Estimated Total Population in each size class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fore Reef</td>
<td>2016</td>
<td>≤7.5cm</td>
<td>89</td>
<td>226</td>
<td>39.4%</td>
<td>585,129.57</td>
<td>230,427.13</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≥7.6cm</td>
<td>137</td>
<td>226</td>
<td>60.6%</td>
<td>585,129.57</td>
<td>354,702.44</td>
</tr>
<tr>
<td></td>
<td>2019</td>
<td>≤7.5cm</td>
<td>103</td>
<td>817</td>
<td>12.6%</td>
<td>1,551,197.49</td>
<td>195,561.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≥7.6cm</td>
<td>714</td>
<td>817</td>
<td>87.4%</td>
<td>1,551,197.49</td>
<td>1,355,636.48</td>
</tr>
<tr>
<td>Reef Crest</td>
<td>2016</td>
<td>≤7.5cm</td>
<td>77</td>
<td>171</td>
<td>45.0%</td>
<td>1,551,197.49</td>
<td>698,492.44</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≥7.6cm</td>
<td>94</td>
<td>171</td>
<td>55.0%</td>
<td>1,551,197.49</td>
<td>852,705.05</td>
</tr>
<tr>
<td></td>
<td>2019</td>
<td>≤7.5cm</td>
<td>162</td>
<td>1068</td>
<td>15.2%</td>
<td>1,743,973.33</td>
<td>264,535.28</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≥7.6cm</td>
<td>906</td>
<td>1068</td>
<td>84.8%</td>
<td>1,743,973.33</td>
<td>1,479,438.05</td>
</tr>
<tr>
<td>Overall</td>
<td>2016</td>
<td>≤7.5cm</td>
<td>166</td>
<td>397</td>
<td>41.8%</td>
<td>925,545.02</td>
<td>387,003.71</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≥7.6cm</td>
<td>231</td>
<td>397</td>
<td>58.2%</td>
<td>925,545.02</td>
<td>538,541.31</td>
</tr>
<tr>
<td></td>
<td>2019</td>
<td>≤7.5cm</td>
<td>265</td>
<td>1885</td>
<td>14.1%</td>
<td>3,385,995.83</td>
<td>476,015.33</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≥7.6cm</td>
<td>1620</td>
<td>1885</td>
<td>85.9%</td>
<td>3,385,995.83</td>
<td>2,909,980.50</td>
</tr>
</tbody>
</table>
Conclusions

Based on the 2019 *T. niloticus* stock assessment, below is a list of all recommendations:

1. Allow harvest of *T. niloticus* for at least 2 weeks to enable residents to harvest, but also limit exploitation of the resource, allowing for a sustainable stock of trochus for further reproduction and future harvesting.

2. Establish a monitoring protocol for *T. niloticus* to continually assess the stocks at least every two years. This will help keep the Congress and resource managers informed on the status and trends of trochus stocks through time, and to make informed decisions and find ways to sustainably manage the resources.
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Appendix

1. Palau Reef Map - PALARIS
2. NW and NE Survey Site Map
3. SW and SE Survey Site Map