Age-based Growth Variation of Green-blotched Parrotfish *Scarus quoyi* in the Southern Philippine Seas

Merlene E. Elumba¹*, May Anne E. Mata², Muhammad Monzer Abpi³, and Cleto L. Nañola, Jr.¹

¹Department of Biological Sciences and Environmental Studies, University of the Philippines Mindanao, Davao City 8000 Philippines
²Department of Mathematics, Physics and Computer Sciences, University of the Philippines Mindanao, Davao City 8000 Philippines
³Davao Doctors Hospital, Davao City 8000 Philippines

Age structures of *Scarus quoyi* populations among three different bays (Davao Gulf, Pujada Bay, and Sarangani Bay) within a spanning distance of ~300 km in the southern Philippine seas were estimated by analyzing sagittal otoliths of 264 individuals. Growth from each study location was fitted using von Bertalanffy growth functions (VBGF) and the derived size-at-age trajectories for the three populations were compared. The 95% confidence interval ellipses around least squares estimate of $K$ and $L_\infty$ showed non-overlapping regions, indicating strong differences among the examined populations. The difference in growths among Davao Gulf ($K=1.00941$), Pujada Bay ($K=1.35561$), and Sarangani Bay ($K=0.98114$) populations are statistically significant. The Davao Gulf population achieved larger mean asymptotic size than populations from Pujada Bay and Sarangani Bay. These variations could possibly suggest that growth rate differences are related to monsoon-driven seasonal changes, level of nutrient load and food availability, and habitat structure – including the type of substrate on the reef.

Keywords: age, growth, otolith, parrotfish, *Scarus quoyi*, von Bertalanffy equation, Southern Philippines

**INTRODUCTION**

Fishes exhibit variation in life history in response to environmental distinction (Atkinson 1994) such as locality and habitat variables (Gust *et al.* 2002), temperature (Choat and Robertson 2002) and population density (Weatherley 1976), and resource availability (Clifton 1995). Among the most diverse and abundant groups found on coral reefs, parrotfishes are considered both ecologically and commercially important – having the capacity to modify the benthic biota (Bellwood and Choat 1990, Stockwell *et al.* 2009, Comeros-Raynal *et al.* 2012) and having strong influence in the structuring of some reef fish assemblages (Taylor *et al.* 2018). Parrotfishes exhibit dynamic and distinctive life histories. They have high growth variation and display complex sexual ontogenies, as well as inter-specific and conspecific demographic variability (Gust *et al.* 2002, Taylor *et al.* 2018).

In recent years – while there has been an increase in research interest on the impacts of parrotfishes on coral reef biota, particularly on their function and role in the trophic ecology (Clements *et al.* 2016) – a disparity with studies on the demography and population dynamics of parrotfishes exists (Taylor *et al.* 2018). Life-history and age-based demographic studies of parrotfishes on the spatial and temporal scale have remained relatively few.
(Taylor et al. 2018). Oceanic regions of the Indo-Pacific where parrotfishes are harvested still exhibit gaps in age-based studies, possibly brought about by research funding limitations and lack of access to appropriate laboratory facilities (Choat and Robertson 2002, Houk et al. 2012, Taylor and Choat 2014).

In the Philippines, an archipelagic country with vast water and fisheries resources, age-based studies on fishes is almost absent. A few reported studies from the Philippines are from Mamauag et al. (2000) on age data of Plectropomus leopardus (Lacepède, 1802) to demonstrate the effects of exploitation on the fish stocks. Otolith increment validation for golden-spotted rabbitfish Siganus guttatus (Bloch, 1787) was first reported by Soliman et al. (2009). Palla et al. (2016) investigated the age, growth, and mortality rates of a brown stripe snapper Lutjanus vitta (Quoy and Gaimard, 1824) from the West Sulu Sea, while Fortaleza and Nañola (2017) investigated the age and body length relationship of two-spot red snapper (Lutjanus bohar; Forsskål, 1775) in the Davao Gulf. Most recently, a study of Fortaleza et al. (2019) reported the first attempt of providing age-growth parameters of crescent grunter, Terapon jarbua (Forsskål, 1775) collected from Iligan Bay and Davao Gulf in Mindanao. To date, no recorded age-growth studies have been reported on parrotfishes from the Philippines.

The green-blotched parrotfish – Scarus quoyi Valenciennes, 1840 – is widespread in the Indo-Pacific region. It inhabits coral-rich areas of outer channels, including reef flats. It occurs singly or in small groups from depths of 1–18 m (Lieske and Myers 1994) with a recorded maximum length of 40 cm total length (Kuiter and Tonozuka 2001). This species is primarily utilized as a subsistence food resource in local and regional scales in Micronesia (Myers et al. 2012) and in the Philippines (Stockwell et al. 2009). However, it is reported to have 60% population reduction due to heavy fishing in the central Philippines (Stockwell et al. 2009).

While there is an abundance of this fish species globally – reported as least concerned in the IUCN red list (Myers et al. 2012) – there is, however, limited information on S. quoyi in the primary literature, especially on its life-history traits. The length-weight information, which is essential for management of fisheries or conservation and estimation of biomass (Froese et al. 2014), has been provided by a study of Gumanao et al. (2016) in Davao Gulf, Philippines. An earlier study on this species included a standardized karyotype and idiogram analyses reported from Southern Thailand (Kaewsri et al. 2014). A most recent report on this fish species was by Cabasan et al. (2017), which is on its morphological differentiation from the southern Philippine seas. Using land-mark based geometric morphometrics, their study found morphological differentiations observed from different populations of S. quoyi.

Given the dearth of information on life-history traits of S. quoyi, the present study provides an initial report on the age growth parameters of S. quoyi by analyzing sagittal otoliths of fish sampled from three embayed areas of the southern Philippine seas. These embayments span a distance of ~300 km, reach a latitudinal gradient of ~2°, and are mainly influenced by the Mindanao current.

In the present study, we hypothesize that fish populations from these areas will have similar age-growth structures given the close proximity of the areas and common major current influencing them.

MATERIALS AND METHODS

Sampling sites were in Davao Gulf, Pujada Bay, and Sarangani Bay – which are all embayed areas located in the Southern part of Mindanao, the Philippines with a spanning distance of around ~300 km (Cabasan et al. 2017) (see Figure 1). Davao Gulf has a total surface area of about 6600 km², making it one of the biggest embayment in the country (Villanoy 2009). Pujada Bay has an area of about 168 km², whereas Sarangani Bay has an area of 480 km². Davao Gulf is a fairly deep body of water with its deepest part at 2.8 km near its mouth. Sarangani Bay is generally shallower at 2 km depth with the bottom substratum dominated by mud (De Jesus et al. 2001, Alcala et al. 2008). In contrast, Pujada Bay is the shallowest among the three sites.

Fish individuals were collected from different local wet markets between Apr 2013 and May 2016. Prior to collection, it was validated that the fish were caught locally using spear fishing aided by an air compressor. Fish collected were processed by measuring the individual standard length to the nearest centimeter using a 45 cm x 18 m cutting mat and wet weight to the nearest gram using a 3000 g x 0.1 g auto calibration electronic digital scale.

**Figure 1.** Scarus quoyi sampling areas located in the Southern Philippine Seas. Inset shows the whole Philippine map.
Sagittal otoliths were extracted using open-the-hatch method following Secor et al. (1992). Otolith length and width were measured to the nearest millimeter (0.01 mm) using a digital Vernier caliper. Otolith weight was measured to the nearest milligram (0.0001 g) using an analytical weighing balance.

Only one of each pair of the sagittal otolith was used for aging purposes. Modified otolith processing of Choat et al. (1996) was carried out by embedding pre-cleaned and weighed otolith on the edge of a glass slide using thermoplastic glue (Crystal Bond 509), followed by manual polishing using wetted sandpaper with grit numbers 600, 1500, and 2000. Alternating opaque and translucent bands were counted as annual growth following Lou (1992). Samples with incomplete data on otolith morphometrics and age were not included in the otolith analysis.

Regression analysis was carried out to examine the relationship between otolith weight and age per study location. Size-at-age data obtained from the analysis of 264 sagittal otoliths from the three study locations were fitted with the VBGF using R statistics.

Box plots were done for standard length and otolith weight against age in order to determine the outliers. The age and size data without the outliers were used in fitting the growth curves.

Comparison of the VBGF curves for all three study locations was fitted with 95% confidence regions following Kimura (1980) using R statistics. All growth curves were constrained by adding dummy fish settlement length at 1.5 cm (SL), following the recruitment of fish length data observed by Abesamis and Russ (2010) per sampling site, to allow for the missing juvenile data.

RESULTS AND DISCUSSION

Results

Table 1 shows the total number of samples from each study location, size range sampled, the asymptotic standard length $L_\infty$, curvature parameter $K$, with standard errors. Out of the 563 individuals, 264 were successfully analyzed for sagittal otoliths. The size class distribution with successful otolith readings is presented in Figure 2. Strong correlations ($r^2$ ranging from 0.81 to 0.85) were observed for sagittal weight and age regression for the three study locations (Figure 3) to check consistency in the aging criteria. Furthermore, box plots were performed to check for the outliers (Figures 4 and 5) of age estimates.

Size-at-age plots showed faster growth trajectory for fish populations in Davao Gulf ($K=1.00941$) followed by Pujada Bay ($K=1.35561$) – with Sarangani Bay population ($K=0.98114$) having the slowest growth rate (Figure 6). Furthermore, the plots of 95% confidence ellipses show a significant difference in growth parameters $K$ and $L_\infty$ among the three study locations (Figure 7).

Histograms show the high distribution of samples with size class of 17–21 cm and high age distribution of 1–3 years old (Figure 2).

<table>
<thead>
<tr>
<th></th>
<th>Davao Gulf</th>
<th>Pujada Bay</th>
<th>Sarangani Bay</th>
</tr>
</thead>
<tbody>
<tr>
<td>All samples</td>
<td>340</td>
<td>116</td>
<td>107</td>
</tr>
<tr>
<td>Size range (SL cm)</td>
<td>13–26</td>
<td>11–22</td>
<td>14–23</td>
</tr>
<tr>
<td>Samples used for otolith analysis</td>
<td>145</td>
<td>51</td>
<td>50</td>
</tr>
<tr>
<td>Size range (SL cm)</td>
<td>15–26</td>
<td>13–22</td>
<td>14–21</td>
</tr>
<tr>
<td>$L_\infty$</td>
<td>20.40003 ± 0.16455 &amp; 18.94212 ± 0.26562 &amp; 18.83066 ± 0.23313</td>
<td></td>
<td></td>
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<tr>
<td>$K$</td>
<td>1.00941 ± 0.07233 &amp; 1.35561 ± 0.10122 &amp; 0.98114 ± 0.09769</td>
<td></td>
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<tr>
<td>$t_0$</td>
<td>-0.16873 ± 0.08115 &amp; -0.07402 ± 0.02944 &amp; -0.11151 ± 0.04378</td>
<td></td>
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</tbody>
</table>

Figure 2. Age and size distribution of *Scarus quoyi* sampled from three study locations.
DISCUSSION

The observed wound in all samples confirmed our assumption that all fish individuals were collected by spearfishing (Nañola et al. 2013). With this evidence, the selectivity of the gear used is dependent on the available fish in the area. Despite of this limitation, representative samples were obtained for all size classes greater than 13 cm SL from all three sites, with no suggestion of sampling bias during collection (Figure 2).

Strong otolith weight and age correlation ($r^2$) were observed among populations examined in this study, suggesting consistency in the aging criteria (Figure 3). These findings support the idea of Choat et al. (1996) that sagittae continue to increase in weight over the lifetime of the fish. In addition, the use of box plot technique employed in this study is one way of checking the quality of age estimates and can be used a guide to exclude outliers of age estimations (Figures 4 and 5).

Size-at-age plots among Davao Gulf, Pujada Bay, and Sarangani Bay populations revealed similar growth trajectories. However, *Scarus quoyi* from Davao Gulf reached a greater size at a given age compared to those from Pujada Bay and Sarangani Bay (Figure 6). Furthermore, plots of 95% confidence regions (Figure 7) show non-overlapping of regions among the three locations, suggesting the variation among populations. Primary

![Figure 3. Otolith age-weight regression for *Scarus quoyi* from three study locations.](image1)

![Figure 4. Boxplots of standard length vs. age from three study locations.](image2)
Figure 5. Boxplots of otolith weight vs. age from three study locations.

Figure 6. Size-at-age plots of Scarus quoyi fitted with VBGF curves. All curves constrained by imputing length at settlement at 1.5 cm.

Figure 7. Comparison of von Bertalanffy growth curves for three populations of Scarus quoyi showing 95% confidence regions around least squares estimate of $K$ and $L_\infty$, following Kimura (1980).

differences lie in the larger asymptotic length of Davao Gulf populations than the other locations (Figure 7). As indicated in an earlier study of Cabasan et al. (2017), morphological differentiation on body shape, mouth fins, and operculum positioning of Scarus quoyi from populations of Davao Gulf, Pujada Bay, and Sarangani Bay was observed. Many factors can be attributed to growth profile variations of reef fishes. Temperature as a function of latitude was observed in Acanthurus bahianus (Choat and Robertson 2002), habitat structure for Scarus frenatus (Gust et al. 2002), fishing pressure for Sparisoma viride (Choat et al. 2003), and resource availability for Scarus iserti (Clifton 1995). In the Philippines, all these factors except temperature most likely can cause the variations observed.

As suggested by T. Qu (personal communication, 21 Feb 2018) – given the proximity of the three study sites – physical parameters such as ocean circulation and water properties (including salinity) are highly variable both in space and time, and so it is difficult to include these factors as attributes for growth variation in this study.

Although this study did not directly examine the diets and estimates at resource levels of parrotfishes as they have been known as microphages (Clements et al. 2016), conditions affecting the resource are possible factors that can be attributed to the observed variations in their growth profiles among Davao Gulf, Pujada Bay, and Sarangani Bay populations. Clifton (1995) found differences in growth rates of Scarus iserti populations separated by 3 km distance, which he attributed to contrasting seasonal algal availability on the reefs. In a study of David et al. (unpublished), Pujada Bay was categorized under Type VII configuration and mainly influenced by Northeast monsoon, while Davao Gulf and Sarangani Bay were categorized under Type VI being strongly influenced by Southwest monsoon. These two contrasting seasonal patterns could have influenced the resource patterns in the areas and, hence, influenced the growth among the three
populations. Furthermore, reproductive seasonal peaks can also be determined by reef-associated environmental conditions as described by Clifton (1995). Lastly, environmental disturbances either anthropogenic or natural can modify the abundance and demographic traits of parrotfishes (Taylor et al. 2018).

CONCLUSION
Age-growth variation was observed on populations of *Scarus quoyi* across the southern Philippine seas. Differences in habitat structure, fishing pressure, fish density, and food availability were not directly examined in this study but these factors have the potential to influence fish growth patterns. Although fishes have plasticity in growth, it is noteworthy that variations in age-growth profiles were observed in populations of *S. quoyi* in the southern Philippine seas spanning ~300 km apart. Otolith microchemistry can be done to further assess this variation and complete the picture of how and at what level *S. quoyi* populations in the southern Philippine seas have differentiated in spatial and demographic scales.

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STATEMENT ON CONFLICT OF INTEREST
The authors declare no conflict of interest.

REFERENCES


