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# Length-weight relationship and morphological studies of the *Polydactylus sextarius*, *Nemipterus japonicus* and *Pampus argenteus* from the Fiery Cross Reef, South China Sea

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**Abstract** This paper reports the length-weight relationships and morphological characters of three fishes namely, *Polydactylus sextarius*, *Nemipterus japonicus* and *Pampus argenteus*, collected from the Fiery Cross Reef (9° 37' N, 112° 58' E) of South China Sea during November 2013. The length-weight relationships of the studied fishes can be expressed as $W_{Po}$=1.17$L^{1.46}$ for *P. sextarius*, $W_{Ne}$=0.07$L^{2.73}$ for *N. japonicus* and $W_{Pa}$=0.04$L^{3.05}$ for *P. argenteus*. Growth of *P. argenteus* was found to be positive ($b$ > 3) and *N. japonicus* ($b$ = 2.73) was negative allometric. Body length of *P. sextarius* varied from 100.36 to 119.43 mm, and the wet weight ranged from 10.04 to 45.42 g. Body length of *N. japonicus* varied from 88.37 to 159.54 mm, wet weight ranged from 22.42 to 128.39 g. Body length of *P. argenteus* varied from 75.13 to 92.07 mm, and wet weight ranged from 20.58 to 42.27 g. The study provides first biological reference in these species in Fiery Cross Reef, South China Sea. In addition, the results of the present study will offer fundamental information for resource assessment as well as for taking up further aquaculture practices of these three species.
**Keywords** Length-weight relationship; Morphometry; *Polydactylus sextarius*; *Nemipterus japonicas*; *Pampus argenteus*; Truss network

## Introduction

Morphometric and meristic characters are frequently used to identify or define the purpose of stock, and thus is of strong interest in ichthyology (Tudela, 1999). Among the morphometric measurement systems, truss network analysis is a conventional method performed in parallel with genetics because of easy operation, and it can be used to re-evaluate past study data and test their reliability in genetic data. The truss network system is a powerful tool for the analysis of shape, and designed to cover the animal's body (Strauss and Bookstein, 1982). Ideally, truss length measurement between desired landmarks points should be curved vectors (Humphries et al., 1981). Because of the complicated calculations (Nie et al., 2013), Hockaday et al. (2000) assumed that all distances measured represented straight lines lying on the same plane to simplify the method.

Length-weight relationship has been used to estimate weight from length for individual fish, fish length classes and the standing-crop biomass (Anderson and Gutreuter, 1983) when the length frequency distribution is known. And it can also be used to calculate the selected species condition index as well as the life history and morphological difference between populations from different regions (Peterakis and Stergiou, 1995; Goncalces et al., 1997). Therefore, length-weight relationship plays an important role in fishery science and population dynamics.

*Polydactylus sextarius* belongs to the family of Polynemidae and is a common seawater species widely distributed in Indo-Pacific Ocean, northern Indian Ocean and South China Sea. It has a large-scale commercial fishery value and also is a potentially lucrative product for Hawaiian aquaculture because of its delicate flavor (Kam et al., 2003). Due to overfishing, the wild resources of *P. sextarius* have dramatically decreased in recent years, which have depressed the thriving local market (Ostrowski and Molnar, 1998).

*Nemipterus japonicus* was first recorded in the Mediterranean Sea by Fisher and Whitehead (Fisher and Whitehead, 1974), and then by Golani and Sonin (2006). Recently, its biological characters have been studied in different regions (ElHaweet, 2013). *N. japonicus* is widely distributed in the Indo-Pacific Ocean, and Mediterranean Sea, and can be fished all year around in coastal areas of the South China Sea. *Pampus argenteus* is widely distributed along the coastal areas of the Indo-West Pacific (Azad et al., 2007) which is an economically important fishery species of China Sea, Bay of Bengal and Arabian Sea (Almatar and James, 2007; Shi et al., 2009). However, the wild resource of this species is under threatened due to over fishing. Long term survey indicates that the market size of *P. argenteus* reduced dramatically, and the resources are deteriorating in China (Liu and Zhan, 1999).

The present study measured basic morphological characters and estimated the length-weight relationship of wild collected *P. sextarius*, *N. japonicas* and *P. argenteus* from the Fiery Cross Reef, South China Sea. Results from this study can provide biological information to conserve the natural resource of these species in South China Sea.

## 1 Materials and methods

In November 2013, a total of 187 samples of three fish species were collected from Fiery Cross Reef of the South China Sea (9$^{o}$ 37’ N, 112$^{o}$ 58’ E). Samples were kept in ice after collection, and taken to the South China Sea Fisheries Research Institute, Chinese Academy of Fishery Sciences. Upon samples’ arrival, morphological studies were immediately conducted (Table 1).

Table 1 Numbers and sizes of samples collected from Fiery Cross Reef

| | | Length(mm) | | Weight(g) | |
|---|---|---|---|---|---|
| Species | Numbers | Min-max | Mean ±SD | Min-max | Mean ±SD |
| *Polydactylus sextarius* | 66 | 100.36-119.43 | 110.10 ±4.89 | 10.04-45.42 | 38.44 ±17 |
| *Nemipterus japonicus* | 52 | 88.37-159.54 | 132.08 ±19.48 | 22.42-128.39 | 86.01 ±32.71 |
| *Pampus argenteus* | 69 | 75.13-92.07 | 81.53 ±3.32 | 20.58-42.27 | 26.70 ±3.99 |

### 1.1 *Measurement procedure*

The fishes’ weights were measured using an electronic balance (accurate to ± 0.01g). A SONY (NEX-F3) digital camera was used to capture the images of the 187 fish samples with a calibration ruler placed in down-side view in each image. The image analysis software of Matlab (R2011a) was used to perform the morphometric data analyses. The truss network consisted of 12 landmarks to describe the major features of those fishes including (A) origin of the pectoral fin, (B) tip of maxillary, (C) origin of the pelvic fin, (D) top of operculum, (E) origin of the anal fin, (F1 or F) origin of the first dorsal fin, (F2) origin of the second dorsal fin, (G) end of the anal fin, (H1 or H) end of the first dorsal fin, (H2) end of the second dorsal fin, (I) ventral attachment of the caudal fin to the tail, and (j) dorsal attachment of the caudal fin to the tail. Morphometric character including (1) body length, (2) height, (3) head length, (4) head height, (5) snout length, (6) eye diameter, (7) caudal peduncle length, (8) caudal peduncle height, (9) the first dorsal fin length(or dorsal fin length), (10) pectoral fin length, (11) pelvic fin length, (12) anal fin base length, (13) anal fin length, and (14) the second dorsal length. The selection criteria for these landmarks must be linked closely to the skeletal structure of *P. sextarius*, *N. japonicus* and *P. argenteus*, easily observed and assessed by eye. Lengths of the truss between these landmarks were measured according to the method of Hockaday et al. (2000), where all the distance measured in the study were assumed to represent straight lines lying on the same plane.

### 1.2 *Statistical analysis*

The relationship between body length (*L*) and wet weight (*W*) were calculated by the power regression $W = aL^b$ (PASW Statistics 19.0). Values of the exponent *b* provide information of fish growth. When $b = 3$, the increase in weight is isometric. When the exponent value of $b > 3$, the weight increase is positive allometric, and when $b < 3$ the weight increase is negative allometric (LeCren, 1951). All the truss measurements were log transformed and tested for normality using the SPSS 19.0.

Significant correlations between body size and truss measurements were found in this study. The absolute measurements were transformed into size-dependent shape variable to perform further analysis. The transformation method was done following Nie et al. (2014), using the equation:

$$\text{Dtrans} = \text{D} \times \left(\frac{\text{BLmean}}{\text{BL}}\right)$$

$^{b}$, where *Dtrans* is the transformed truss measurement, *D* is the original truss measurement, *BL* is the body length of fish, *BL* mean is the overall mean of the body length, and *b* is the within-group slope of the geometric mean regression calculated with log-transformed variables, *D* and *BL*.

## 2 Results and Discussion

### 2.1 *Length-weight relationship*

The length-weight relationship of *P. sextarius* was found to be $W_{Po}=1.17L^{1.46}$, while for *N. japonicus* and *P. argenteus* was estimated as $W_{Ne}=0.07L^{2.73}$ and $W_{Pa}=0.04\times L^{3.05}$ respectively (Table 2).

Table 2 Length-weight relationship of *P. sextarius, N. japonicas* and *P. argenteus* collected from Fiery Cross Reef, South China Sea

| Fish species | a | b | $R^2$ |
|---|---|---|---|
| *Polydactylus sextarius* | 1.17 | 1.46 | 0.78 |
| *Nemipterus japonicus* | 0.07 | 2.73 | 0.69 |
| *Pampus argenteus* | 0.04 | 3.05 | 0.80 |

Wang et al. (2011) found that the *b* value of *P. sextarius* was 2.90, and suggested that the fish followed a negative allometric growth pattern (*b* < 3). In the present study, we got the same conclusion despite Wang et al. (2001)'s exponent 'b' value was greater than ours (*b* = 1.46). In the present study smaller 'b' values (b=1.46) was due to the analysis of restriced length range (119.43-100.36=19. 7 mm) and low fish number (66), which not covered all the size groups. The *b* values in the length-weight relationship of *N. japonicus* from Jizan Region of Red Sea, Suez Gulf-Red Sea and Afshari in the Northren Oman Sea were ranged from 2.6 to 2.8 (Bakhsh, 1996; Amine, 2012; Afshari et al., 2013). In this study, the *b* value of *N. japonicus* obtained from Fiery Cross Reef was 2.73, which showed similarities with their study suggesting a negative allometric growth in this species. However, Manojkumar et al. (2004) (*b* = 2.9902), and Raje (2003) (*b* = 3.00437) were isometric and highly differed with the present study.

Siyal and Amir (2012) estimated the length-weight relationship in *P. argenteus* from Pakistan waters and got the exponent b value 3.15, which was closer to present study, and the growth was found to be isometric. However, the *b* value in the length-weight relationship of *P. argenteus* estimated in the Bay of Bengal Large Marine Ecosystem was 2.841 (Siyal and Amir, 2012). The *b* value of this species collected along the southern coast of Karnataka, India was 2.485 (Abdurahiman et al., 2004). Both results indicated that the growth of *P. argenteus* followed negative allometric trend. The difference between 'b' values of our study and other researchers' study might be due to the fish growth phase, size range, small and big data range, seasonal effect, general fish condition and size selectivity of the sampling gear (Tesch et al., 1971).

### 2.2 *Truss network analysis*

Body length of *P. sextarius* varied from 100.36 to 119.43 mm, and the wet weight ranged from 10.04 to 45.42 g. Body length of *N. japonicus* varied from 88.37 to 159.54 mm, wet weight ranged from 22.42 to 128.39 g. Body length of *P. argenteus* varied from 75.13 to 92.07 mm, and wet weight ranged from 20.58 to 42.27 g (Table 1). All models of truss networks are presented in Figure 1. Morphometric trait has been used for the identification of fish stock units as a powerful measurement tool (Cadrin and Friedland , 1999). Cadrin (2000) suggested that morphmetric variations can be used to discriminate the stock units, as the result may be different when locations are changed. Furthermore, Nie et al. (2014) successfully removed the size effect by allometric transformation of their study data.

In conclusion, our study identified the morphological characters of *P. sextarius, N. japonicus* and *P. argenteus* collected from Fiery Cross Reef of South China Sea, we measured 39 morphological characters between 12 landmarks of *P. sextarius*, 29 characters between 10 landmarks of *N. japonicus* and 23 characters between 9 landmarks of *P. argenteus* for academic work. For detail measurement, all characters from significant loadings obtained shown in Table 3, and all of these may be be useful as primary measurement characters.

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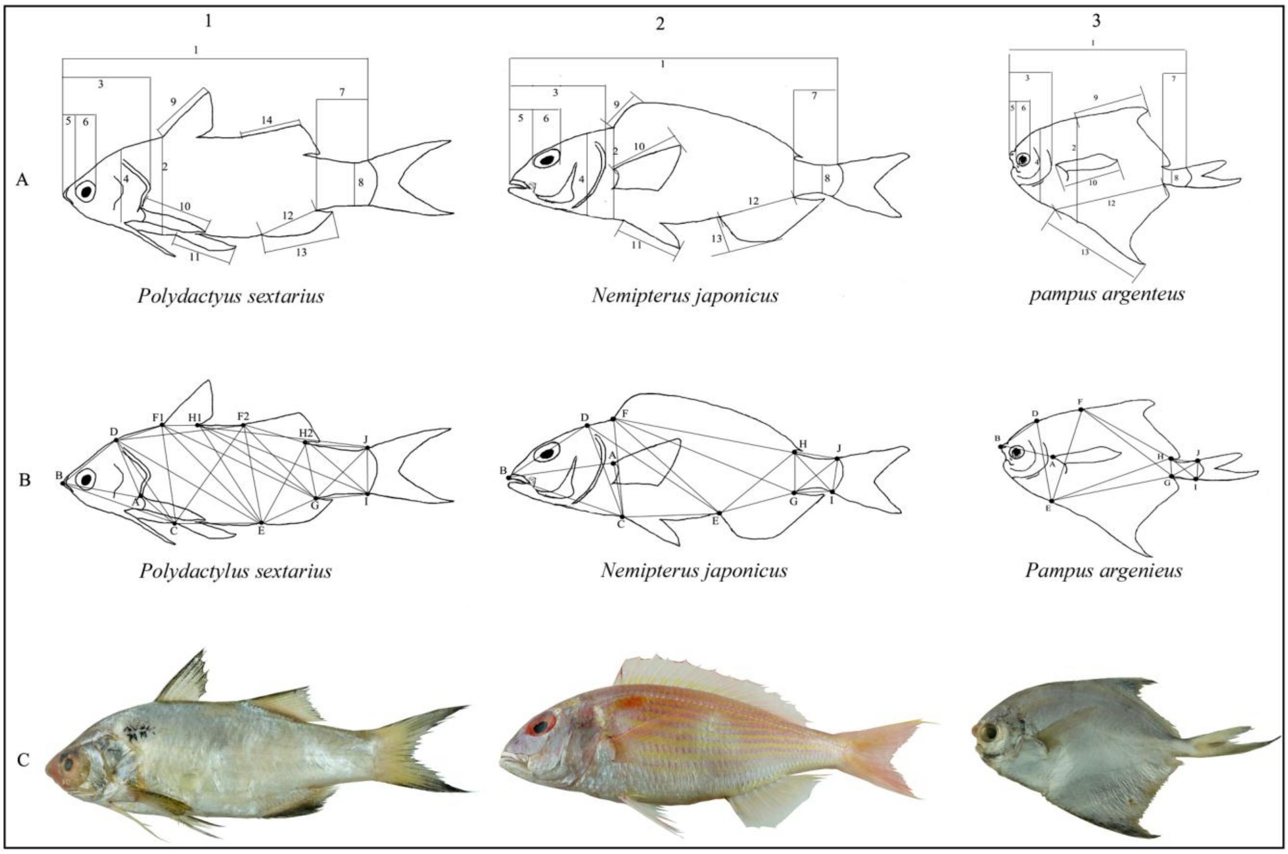


Figure 1 Diagrams and pictures of the three fishes' truss network models

Table 3 Truss network of distance ratio of *Polydactylus sextarius*, *Nemipterus japonicus* and *Pampus argenteus*

| Character (×100%) | *Polydactylus sextarius* | *Nemipterus japonicus* | *Pampus argenteus* |
|---|---|---|---|
| 2/1 | 0.32±0.01 | 0.34±0.01 | 0.67±0.03 |
| 3/1 | 0.30±0.01 | 0.31±0.02 | 0.25±0.01 |
| 4/3 | 0.80±0.05 | 0.93±0.06 | 0.36±0.02 |
| 6/3 | 0.21±0.03 | 0.30±0.02 | 0.04±0.00 |
| 7/1 | 0.18±0.02 | 0.15±0.01 | 0.08±0.01 |
| 8/1 | 0.15±0.01 | 0.11±0.00 | 0.09±0.00 |
| 9/1 | 0.20±0.01 | 0.10±0.00 | 0.29±0.02 |
| 10/1 | 0.22±0.01 | 0.30±0.02 | 0.34±0.02 |
| 11/1 | 0.16±0.01 | 0.25±0.02 | —— |
| 13/1 | 0.17±0.01 | 0.12±0.01 | 0.42±0.04 |
| 14/1 | 0.17±0.01 | —— | —— |
| BD/1 | 0.22±0.01 | 0.32±0.01 | 0.21±0.01 |
| AD/1 | 0.20±0.01 | 0.16±0.02 | 0.23±0.02 |
| EF1/1 | 0.45±0.02 | 0.46±0.03 | 0.63±0.02 |
| EF2/1 | 0.33±0.01 | —— | —— |
| DF1/1 | 0.19±0.01 | 0.09±0.00 | 0.40±0.04 |
| DF2/1 | 0.49±0.01 | —— | —— |
| CE/1 | 0.26±0.01 | 0.30±0.02 | —— |
| CD/1 | 0.33±0.01 | 0.33±0.02 | —— |
| F1H1/1 | 0.14±0.00 | 0.55±0.04 | 0.50±0.02 |
| F2H2/1 | 0.21±0.02 | —— | —— |
| IJ/1 | 0.15±0.00 | 0.11±0.00 | 0.10±0.00 |

Continued Table 1

| Character (×100%) | *Polydactylus sextarius* | *Nemipterus japonicus* | *Pampus argenteus* |
|---|---|---|---|
| GJ/1 | 0.24±0.02 | 0.21±0.01 | 0.13±0.00 |
| GH1/1 | 0.43±0.02 | 0.17±0.01 | 0.10±0.00 |
| GH2/1 | 0.19±0.01 | —— | —— |
| AC/1 | 0.14±0.01 | 0.17±0.01 | —— |
| H1I/1 | 0.58±0.02 | 0.18±0.02 | 0.14±0.01 |
| H2I/1 | 0.27±0.02 | —— | —— |
| EH1/1 | 0.37±0.02 | 0.31±0.01 | 0.67±0.02 |
| EH2/1 | 0.30±0.02 | —— | —— |
| DE/1 | 0.54±0.01 | 0.51±0.01 | —— |
| BC/1 | 0.39±0.01 | 0.12±0.02 | —— |
| H1J/1 | 0.54±0.02 | —— | 0.10±0.01 |
| H2J/1 | 0.21±0.03 | —— | —— |
| F1G/1 | 0.55±0.03 | 0.58±0.01 | 0.58±0.02 |
| F2G/1 | 0.33±0.04 | —— | —— |
| GI/1 | 0.18±0.02 | 0.16±0.00 | 0.10±0.01 |
| AB/1 | 0.27±0.01 | 0.34±0.02 | 0.58±0.02 |
| CF1/1 | 0.33±0.03 | 0.33±0.02 | —— |
| CF2/1 | 0.39±0.03 | —— | —— |

Note: Where: *Polydactylus sextarius* have two dorsal fin, *Pampus argenteus* have no pelvic fin, and '——' represent empty, (1) body length, (2) height, (3) head length, (4) head height, (5) snout length, (6) eye diameter, (7) caudal peduncle length, (8) caudal peduncle height, (9) the first dorsal fin length(or dorsal fin length), (10) pectoral fin length, (11) pelvic fin length, (12) anal fin base length, (13) anal fin length, and (14) the second dorsal length (Figure 1)


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