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# Morphometric Analysis of Malaysian Oxudercine Goby, *Boleophthalmus boddarti* (Pallas, 1770)

[1]SITI KHALIJAH DAUD, [1]MEHDI MOHAMMADI, [1]SITI SHAPOR SIRAJ &
[2]MOHAMAD PAUZI ZAKARIA
*[1]Department of Biology, Faculty of Science,*
*[2]Department of Environmental Science,*
*Faculty of Environmental Studies*
*Universiti Putra Malaysia,*
*43400 UPM, Serdang, Selangor, Malaysia*
*Email: sitikd@fsas.upm.edu.my*

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**ABSTRAK**

*Ikan gobi Oxudercine dikenali sebagai ikan belacak atau tembakul. Ikan eurihalin ini merupakan antara ikan belacak di Malaysia yang boleh bernafas di udara. Boleophthalmus boddarti merupakan satu daripada ikan belacak yang biasa terdapat di kawasan pamah pasang surut, paya bakau, kuala sungai dan pesisir pantai. Data morfometrik biasa, morfometrik truss dan meristik yang diperolehi daripada 85 sampel lima populasi B. boddarti (Pulau Pinang, Kuala Selangor, Banting, Port Dickson dan Melaka) dianalisis dengan menggunakan kaedah statistik ANOVA sehala dan Analisis Komponen Prinsipal (PCA). Lima belas ciri morfometrik, 28 ciri morfometrik truss dan 9 ciri meristik dianalisis untuk menentukan darjah keserupaan antara kelima-lima populasi ini. Semua ciri morfometrik mempunyai perbezaan bererti ($P<0.05$) bagi dalam dan antara populasi. Berdasarkan analisis komponen prinsipal ke atas ciri morfometrik biasa, populasi B. boddarti dikelompokkan kepada 3 kumpulan, di mana populasi Banting dan Melaka berada dalam satu kumpulan, Pulau Pinang dan Kuala Selangor dalam kumpulan lain, manakala populasi Port Dickson dalam satu kumpulan lain yang berbeza dengan kumpulan lain. Berdasarkan kepada ciri morfometrik truss, tiga kumpulan juga dihasilkan tetapi kelompoknya adalah berbeza di mana populasi Kuala Selangor dan Banting dalam satu kumpulan, Port Dickson dengan Melaka dalam satu kumpulan lain, manakala Pulau Pinang pula jauh berbeza dengan kumpulan-kumpulan lain. Keputusan kajian ini menunjukkan bentuk badan ikan belacak di kawasan utara sangat berbeza dengan yang terdapat di kawasan tengah dan selatan Semenanjung Malaysia. Berdasarkan kepada ciri mersitik, semua populasi belacak adalah memusat dan tiada kelompok yang boleh dikenal pasti. Hubungan panjang-berat bagi B. boddarti dinyatakan sebagai: $\log W = \log 0.754 + 1.029 \log TL$.*

**ABSTRACT**

*The Oxudercine gobies or mudskippers are locally known as "belacak" or "tembakul". These euryhaline fish are amongst the air breathing gobies found in Malaysia. Boleophthalmus boddarti is one of the common mudskippers inhabiting tidal flats, mangrove swamps, estuarines and coastal areas. Conventional and truss morphometrics as well as meristic data from 85 samples in five populations (Pulau Pinang, Kuala Selangor, Banting, Port Dickson and Melaka) of B. boddarti were analyzed using one-way ANOVA and Principal Component Analysis (PCA). Fifteen morphometric, 28 truss morphometric and 9 meristic data were analyzed to examine the degree of similarity among the five populations. All morphometric characters within and between the populations were significantly different ($P<0.05$). Using the conventional morphometric data analysed by PCA, the populations of B. boddarti are clustered into 3 groups, where Banting and Melaka populations form the first group, Pulau Pinang and Kuala Selangor populations the second group and Port Dickson population the third group. In contrast, 3 groups were also clustered based on the truss morphometric data but the grouping was different. The three groups from the truss morphometric data consist of Kuala Selangor and Banting populations in the first group, Melaka and Port Dickson populations the second group and the Pulau Pinang population the third group which is distantly separated from the other two groups. The results indicate that the shape of mudskippers*

*in the northern part is distinct from the middle and southern parts of Peninsular Malaysia. Based on meristic data, all populations were centric and no grouping was identified. The length-weight relationship for B. boddarti in this study was described as log W = log 0.754 + 1.029 log TL.*

## INTRODUCTION

Oxudercine gobies are most notable among the amphibious air breathing gobies, consisting of at least 40 species (Murdy 1989). All oxudercine are at least occasional burrow dwellers and several genera are known as mudskippers or locally named as "Belacak" or "Tembakul". *Boleophthalmus boddarti* (Pallas, 1770) is one of the mudskippers that spend much of its time out of water. It is also known as Boddart's goggle-eye goby or blue spotted mudskipper. This species is widely distributed in the Indo-West Pacific, from India to New Guinea and north to China. *B. boddarti* is characterised by an elongated and laterally compressed body covered with cycloid scales. The head is slightly flat, warty skin and entirely covered with scales. The eyes are very close, movable to dorsal profile of head, and having well developed lower eyelids. The snout is blunt with slightly oblique mouth. There are two dorsal fins, fused pelvic fins, scaled base muscular pectoral fins, and an asymmetrical caudal fin where the upper half is slightly longer than the lower half. *B. boddarti* is marked by lighter colour of the first dorsal fin, the dark edge of the pectoral fins, large blue spots on the head and a number of darker dorso-ventrally stripes along the body.

A large number of *B. boddarti* inhabit brackish water of estuaries, mangrove swamps and intertidal mudflats in Malaysia. During low tides, *B. boddarti* are often aggregated at the water edge. During high tide, they hide themselves in the submerged burrows to avoid being attacked by predatory fish that forage for food on the mudflats (Takita *et al.* 1999). The submerged burrows made by this species have directly or indirectly increased the productivity of mangrove swamp and mudflat areas.

Morphological characters are commonly used in fisheries biology to measure discreteness and relationships among various taxa and have long been used to delineate stocks of fish. Morphometric characters are continuous characters describing the body shape, which have provided evidence for stock discreteness as documented by Corti *et al.* (1988) and Murta (2000). Meristic characters are the number of discrete serially countable structures, and often being used for species identification because they are considerably less affected by environmental changes. Morphometric and meristic analyses can thus be a first step in investigating the stock structure of species with a large sized population.

However, there is a major limitation in using morphological characters at the intra-specific level, in which phenotypic variation is not directly controlled by genetic factors but rather subject to environmental changes (Ihssen *et al.* 1981). However, both environmental and genetic components are now believed to contribute to phenotypic variation in organisms. To improve the use of morphometric analysis, truss morphometry has been developed especially for stock differention (Corti *et al.* 1988; Roby *et al.* 1991). Truss morphometry has proven to be more powerful in describing morphological variation between closely related fish taxa (e.g. stock) than conventional morphometry (Strauss and Bookstein 1982; Rohlf 1990). The size of a fish population is best estimated by length-weight relationship, which can also be used in determining allometric growth in a fish species. Thus, this study was carried out to examine morphological variation and length-weight relationships of *B. boddarti* in Peninsular Malaysia.

## MATERIALS AND METHODS

A total of 85 samples of *B. boddarti* were collected from five different locations, namely Pulau Pinang, Kuala Selangor, Banting, Port Dickson and Melaka. Samples were collected

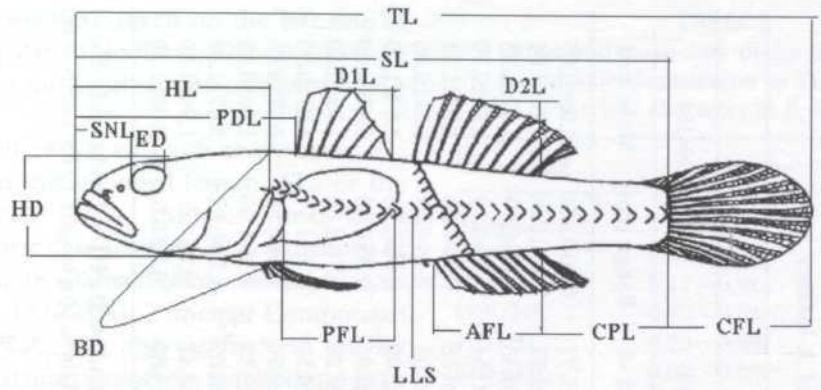


*Fig. 1: Morphometric characters used for* Boleophthalmus boddarti

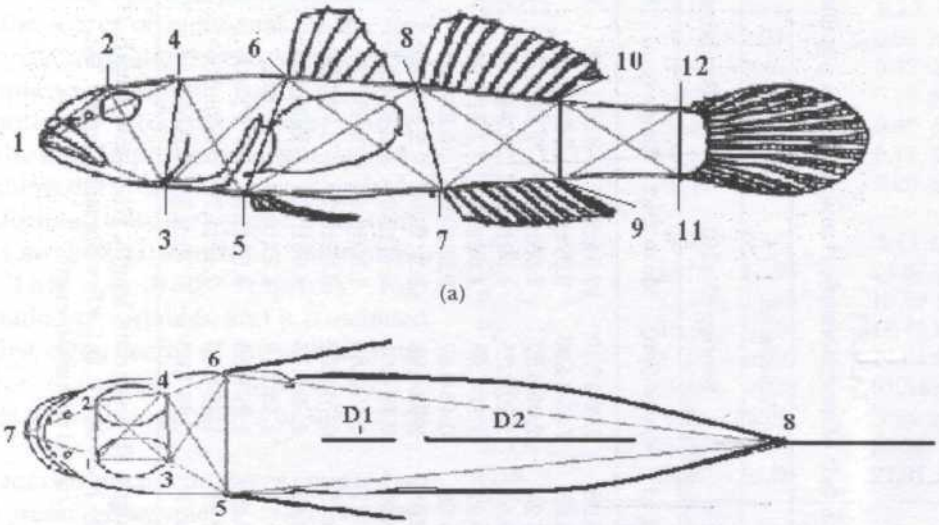


*Fig. 2: The body landmarks used for the truss morphometric characters in* B. boddarti*: (a) body section (b) head section*

by hook and line, casting net and traps as well as by hand and scope net. The measurements taken for mophometric (to the nearest 0.01 cm), and meristic studies follow the methods of Murdy (1989). Sexes were pooled for all analyses since the sexual dimorphism was unknown in this species.

Fifteen selected conventional morphometric characters were measured using vernier calipers for each sample (*Fig. 1*). The following morphometric characters were measured: total length (TL), standard length (SL), head length (HL), head width (HW), head depth (HD), snout length (SNL), predorsal length (PDL), eye diameter (ED), body depth (BD), first dorsal fin length ($D_1L$), second dorsal fin length ($D_2L$), pectoral fin length (PFL), anal fin length (AFL), caudal fin length (CFL), and caudal peduncle length (CPL) (*Fig. 1*). To reduce the allometric effects and make the results more comparable, each measurement was expressed as a ratio to the standard length or head length.

For truss morphometric data, 12 landmarks were chosen based on the methods described by Strauss and Bookstein (1982). All

TABLE 1
Range and mean ± standard deviation (sd) of morphometric characters in five populations of *B. boddarti*

| MC | Population | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | P. Pinang (N=16) | | K. Selangor (N=15) | | Banting (N=20) | | N. Sembilan (N=18) | | Melaka (N=16) | |
| | Range (cm) | Mean ± sd | Range (cm) | Mean ± sd | Range (cm) | Mean ± sd | Range (cm) | Mean ± sd | Range (cm) | Mean ± sd |
| TL | 8.80-12.90 | 10.53±1.07 | 7.71-11.50 | 9.61±0.96 | 9.00-17.10 | 12.04±2.47 | 8.50-14.50 | 10.75±1.77 | 9.00-18.50 | 13.05±2.85 |
| SL | 7.05-11.30 | 8.44±1.08 | 6.14-9.50 | 7.71±0.85 | 7.55-14.90 | 9.99±2.14 | 7.05-12.50 | 9.11±1.57 | 7.15-16.00 | 10.79±2.84 |
| HL | 1.78- 2.50 | 2.16±0.18 | 1.67-2.66 | 2.11±0.21 | 2.02-3.57 | 2.58±0.43 | 1.89-3.76 | 2.44±0.55 | 2.00-6.50 | 3.07±1.23 |
| HW | 1.08-1.75 | 1.32±0.16 | 0.99-1.68 | 1.19±0.51 | 1.20-2.25 | 1.59±0.70 | 1.04-2.66 | 1.52±0.51 | 1.20-3.10 | 1.93±0.70 |
| HD | 1.00-1.55 | 1.25±0.70 | 0.90-1.45 | 1.12±0.47 | 1.12-1.98 | 1.62±0.27 | 1.11-2.90 | 1.35±0.18 | 0.94-2.23 | 1.68±1.51 |
| SNL | 0.30-0.53 | 0.42±0.07 | 0.27-0.59 | 0.47±0.08 | 0.43-0.67 | 0.52±0.09 | 0.27-0.61 | 0.43±0.01 | 0.43-0.59 | 0.51±0.05 |
| PDL | 1.80-4.30 | 2.48±0.07 | 2.12-2.96 | 2.50±0.03 | 2.02-4.90 | 3.32±0.08 | 2.00-4.80 | 3.89±0.09 | 0.60-6.60 | 3.83±1.75 |
| ED | 0.27-0.49 | 0.37±0.06 | 0.32-0.47 | 0.39±0.04 | 0.33-0.61 | 0.47±0.09 | 0.32-0.57 | 0.39±0.06 | 0.35-0.63 | 0.44±0.09 |
| BD | 0.84-1.63 | 1.30±0.21 | 0.84-1.63 | 1.20±0.17 | 1.15-2.68 | 1.60±0.40 | 0.85-1.86 | 1.26±0.28 | 0.76-2.86 | 1.75±0.60 |
| $D_1L$ | 0.61-1.47 | 1.09±0.21 | 0.58-1.02 | 0.99±0.13 | 0.76-2.02 | 0.89±0.29 | 0.73-1.96 | 1.11±0.34 | 0.75-1.74 | 1.21±0.29 |
| $D_2L$ | 2.26-4.21 | 3.42±1.38 | 2.75-3.80 | 3.25±0.42 | 2.99-5.43 | 4.08±0.25 | 2.98-6.00 | 3.73±0.96 | 1.11-6.50 | 4.07±0.96 |
| PFL | 1.40-1.98 | 1.59±0.19 | 1.45-1.89 | 1.67±0.14 | 1.42-2.10 | 1.72±0.23 | 0.70-2.17 | 1.33±0.37 | 1.30-1.95 | 1.56±0.22 |
| AFL | 2.60-4.22 | 3.42±0.37 | 2.43-3.90 | 3.08±0.39 | 1.92-5.66 | 3.03±1.20 | 1.92-5.06 | 3.10±0.09 | 1.78-6.90 | 3.87±1.39 |
| CFL | 0.39-2.30 | 1.35±0.55 | 1.38-2.24 | 1.80±0.21 | 1.33-6.50 | 2.41±1.79 | 0.38-2.05 | 1.31±0.47 | 0.38-6.5 | 1.98±1.50 |
| CPL | 0.50-2.20 | 0.90±0.65 | 0.41-1.02 | 0.66±0.16 | 0.48-1.06 | 0.79±0.02 | 0.55-2.50 | 1.64±0.65 | 0.82-6.5 | 2.80±1.39 |

Abbreviations: MC = Morphometric character, TL = total length, SL = standard length, HL = head length, HW = head width, HD = head depth, SNL = snout length, PDL = predorsal length, ED = eye diameter, BD = body depth, $D_1L$ = first dorsal fin length, $D_2L$ = second dorsal fin length, PFL = pectoral fin length, AFL = anal fin length, CFL = caudal fin length, CPL = caudal peduncle length.

measurements were taken on the left side of the fish (*Fig. 2a*). In addition, 8 landmarks were also taken in the head section as shown in *Fig. 2b.*

Data on ratios of each morphometric character to the standard length (SL) or the head length (HL), meristic and truss morphometric characters in all populations of *B. boddarti* were analysed using one-way analysis of variance (ANOVA). Principal Component Analysis (PCA) was also performed on the conventional morphometric, meristic and truss morphometric data. The mean values (centroids) and 95% asymptotic confidence limits of the scores of individual on the first two principal components were computed for each sample to classify the fish into one of several mutually exclusive groups and to establish the most important characteristics for distinguishing the groups. The truss variables (log-transformed) were corrected for size using Burnaby's method (Darroch and Mosimann 1985). This method requires log-transformation of variables, and it is assumed that the first eigen vector of the within-group covariance matrix of log-morphometric variables is a multivariate index of the size of fish

Nine meristic characters were counted on fresh and preserved samples. These characters include the numbers of first dorsal fin rays ($D_1$), second dorsal fin rays ($D_2$), pectoral fin rays ($P_1$), pelvic fin rays ($P_2$), anal fin rays (A), lateral line scales (LLS), upper lateral line scales (ULLS), lower lateral line scales (LLLS), and predorsal scales (PDS).

Linear regression analysis was also performed to describe length-weight relationship of *B. boddarti* in Malaysia using logarithmic transformation. The relationship is expressed as: $\log W = \log a + b \log L$, where W is the weight (g), L is the total length (cm), a is the intercept of the regression curve and b is the regression coefficient (slope). The statistical significance of the regression was assessed using analysis of variance (ANOVA).

TABLE 2
Range and mean ± sd of the ratios of each morphometric character to TL or HL and meristic character in *B. boddarti*

| Characters | Range | Mean ± sd |
|---|---|---|
| *Morphometric* | | |
| SL/TL | 0.79 - 0.90 | 0.83 ±0.026 |
| HL/TL | 0.17 - 0.42 | 0.22 ±0.033 |
| HW/HL | 0.49 - 0.85 | 0.62 ±0.067 |
| HD/HL | 0.23 - 0.89 | 0.58 ±0.099 |
| SNL/HL | 0.09 - 0.28 | 0.20 ±0.040 |
| ED/HL | 0.08 - 0.26 | 0.17 ±0 .037 |
| PDL/TL | 0.07 - 0.29 | 0.12 ±0.038 |
| BD/TL | 0.05 - 0.16 | 0.13 ±0.017 |
| $D_1L$/TL | 0.08 - 0.09 | 0.09 ±0.023 |
| $D_2L$/TL | 0.40 - 0.46 | 0.42 ±0.014 |
| PFL/TL | 0.10 - 0.22 | 0.16 ±0.024 |
| AFL/TL | 0.38 - 0.47 | 0.42 ±0.024 |
| CFL/TL | 0.11 - 0.21 | 0.17 ±0.025 |
| CPL/TL | 0.12 - 0.24 | 0.20 ±0.020 |
| *Meristic* | | |
| $D_1$ | 5.00 – 7.00 | 5.11 ±0.420 |
| $D_2$ | 23.00 – 27.00 | 24.62 ±0.816 |
| $P_1$ | 15.00 – 20.00 | 18.39 ±0.914 |
| $P_2$ | 15.00 – 19.00 | 18.42 ±0.971 |
| A | 24.00 – 26.00 | 24.61 ±0.709 |
| LLS | 59.00 – 78.00 | 67.54 ±4.314 |
| ULLS | 6.00 – 10.00 | 7.66 ±0.919 |
| BLLS | 8.00 – 13.00 | 10.54–± 0.814 |
| PDS | 25.00 – 35.00 | 27.91 ±2.831 |

*Abbreviations:* TL = total length, SL = standard length, HL = head length, HW = head width, HD = head depth, SNL = snout length, PDL = predorsal length, ED = eye diameter, BD = body depth, $D_1L$ = first dorsal fin length, $D_2L$ = second dorsal fin length, PFL = pectoral fin length, AFL = anal fin length, CFL = caudal fin length, CPL = caudal peduncle length, $D_1$ = first dorsal fin ray, $D_2$ = second dorsal fin ray, $P_1$ = pectoral fin ray, $P_2$ = pelvic fin ray, A = anal fin ray, LLS = lateral line scale, ULLS = upper lateral line scale, BLLS = below lateral line scale, PDS = predorsal scale.

## RESULTS

*Morphometric*

The range and mean ± standard deviation values of morphometric characters for *B. boddarti* are presented in Table 1. The total

TABLE 3
Summary of one -way ANOVA for each ratio of morphometric data to the TL in *B. boddarti*

| Variable | Between populations | | Within population | |
|---|---|---|---|---|
| | F value | P | F value | P |
| SL/TL | 7.101 | .000** | 2.476 | .067 |
| HL/TL | 1.845 | .128 ns | .237 | .870 |
| HW/HL | 2.934 | .026* | 1.747 | .164 |
| HD/HL | 3.115 | .020* | 4.148 | .009* |
| SNL/HL | 3.032 | .022* | 1.943 | .129 |
| ED/HL | 2.091 | .090 ns | 1.464 | .231 |
| PDL/TL | .658 | .623 ns | .827 | .429 |
| BD/TL | 2.024 | .099 ns | 2.624 | .056 |
| $D_1$/TL | 3.548 | .010* | 3.237 | .026* |
| $D_2$/TL | 2.067 | .093 ns | 2.447 | .068 |
| PFL/TL | 4.611 | .002** | 3.567 | .018* |
| AFL/TL | 3.715 | .008* | 3.688 | .015* |
| CFL /TL | 5.800 | .000** | 2.486 | .067 |
| CPL/TL | 1.061 | .381ns | .851 | .470 |

ns= not significant (P>0.05); * significant at p < 0.05; ** highly significant at p < 0 .005

length of the 85 samples of *B. boddarti* ranged from 7.71 to 18.5 cm with a mean of 11.268 ± 4.214 cm and the standard length ranged from 6.14 to 16.0 cm with a mean of 9.327 cm. The weight ranged from 41 to 82 g, with a mean of 54.28 ± 9.461 g. The biggest individual was found in the Melaka population whilst the smallest was from Kuala Selangor population. The ratios of each morphometric character to TL or HL for *B. boddarti* are shown in Table 2. The standard length (SL) is about 80-90% of the total length (TL). The body depth (BD) was about 5-16% of the TL.

The ANOVA showed that the ratios of standard length (SL), pectoral fin length (PFL) and caudal length (CFL) to TL showed highly significant differences (P<0.005) among the populations. The ratios of head width (HW), head depth (HD), snout length (SNL) to the head length (HL), and the ratios of first dorsal fin length ($D_1$L) and anal fin length (AFL) to TL were also significantly different (P<0.005) among the populations.

Head length (HL), predorsal length (PDL), body depth (BD), second dorsal fin length ($D_2$L) and caudal fin length (CFL) to TL, and the ratio of eye diameter (ED) to HL were not significantly different among the populations of *B. boddarti.*

The values of the first four principal components performed on the 15 raw morphometric data and weight of *B. boddarti* are presented in Table 4. The positive and negative values indicate shape variation. The negative value was not considered a good discriminant as shown by predorsal length (-0.177) in the first component. The total correct classification rate was 80.43% which is considered a good discrimination. The component loadings (Table 4) were also not very high for most of the variables accounted for by the first principal component, which described 54.43% of the cumulative variance within the samples.

Based on Principal Component Analysis (PCA) on morphometric data, the populations of *B. boddarti* are clustered into 3 groups, wherein Banting and Melaka populations are clustered in one group, Pulau Pinang and Kuala Selangor populations in another group, and both groups are well separated from the Port Dickson population (*Fig. 3*).

TABLE 4
Values of the first four components obtained through a PCA performed on raw morphometric data of *B. boddarti*

| Morphometric character (cm) | Component | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| Weight (g) | .835 | .199 | -.066 | .299 |
| TL | .957 | -.055 | .039 | .046 |
| SL | .959 | -.149 | .004 | .007 |
| HL | .713 | -.107 | .563 | .059 |
| HW | .877 | -.213 | .202 | -.196 |
| HD | .907 | -.030 | -.115 | -.204 |
| SNL | .550 | .364 | -.060 | .594 |
| PDL | -.177 | .388 | -.533 | .002 |
| ED | .514 | .489 | .382 | -.140 |
| BD | .907 | -.027 | -.188 | .062 |
| $D_1L$ | .539 | -.277 | .331 | -.487 |
| $D_2L$ | .778 | -.001 | -.464 | -.165 |
| PFL | .483 | .628 | .155 | -.063 |
| AFL | .918 | -.108 | -.199 | .072 |
| CFL | .498 | .512 | -.079 | -.211 |
| CPL | .564 | -.526 | .460 | .423 |
| Eigen value | 8.710 | 1.658 | 1.048 | 1.453 |
| Variance explained (%) | 54.435 | 10.365 | 9.081 | 6.549 |
| Cumulative variance (%) | 54.435 | 64.800 | 73.881 | 80.430 |

*Truss Morphometry*

Of 28 truss morphometric characters, only 5 did not differ significantly ($P<0.05$) among the five populations of *B. boddarti* as shown in Table 5. Highly significant differences ($P<0.005$) of truss morphometric characters among the populations were mostly found in the head region.

Three components were extracted from the 28 truss morphometric data (Table 6). The first component accounted for 68.6% of the total variance. The component loadings were also higher (81.6%) than those of morphometric and meristic characters. Based on these data, populations of *B. boddarti* were also clustered into 3 groups although the grouping is slightly different from that of the conventional morphometric data. In this grouping, Kuala Selangor and Banting populations are in the first group, while Port Dickson and Melaka populations in the second group, and the Pulau Pinang population by itself is distantly isolated from the other two groups (*Fig. 4*).

*Meristic*

These five populations were significantly different ($P<0.05$) in their meristic characters except for the second dorsal fin ray count ($D_2$) (Table 7).

Three principal components were extracted from 7 meristic data. The component loadings were not very high for most variables in the first component (26.9%) of the total variance within the samples (Table 8). As expected there was an overlap among Pulau Pinang, Kuala Selangor and Banting populations as shown in *Fig. 5*.

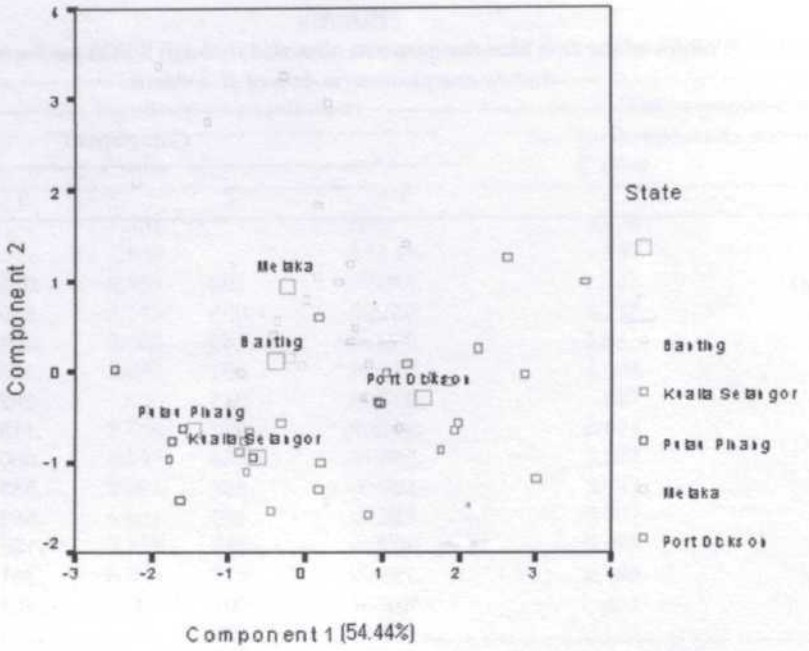


*Fig. 3: Plots of the coordinates of individuals of* B. boddarti *according to the first two discriminant functions, obtained from morphometric data*

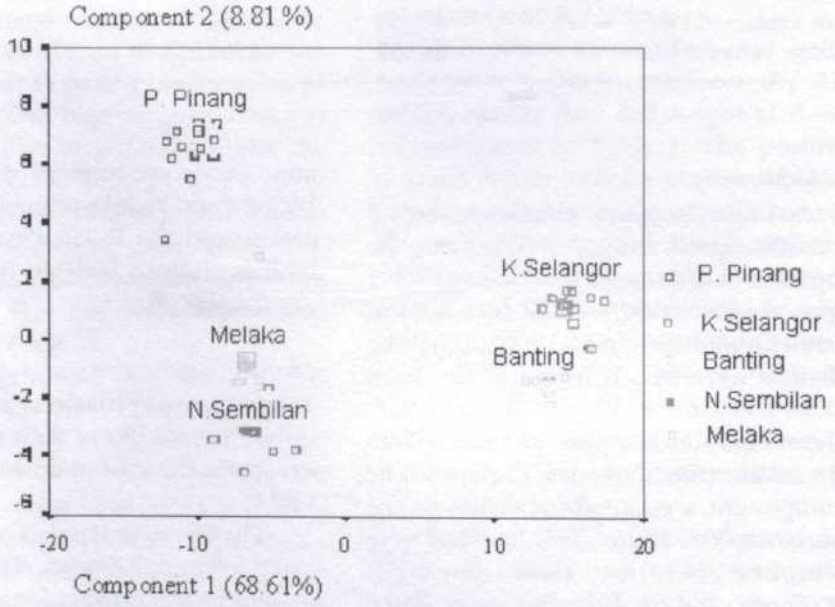


*Fig. 4: Plots of the coordinates of individuals of* B. boddarti *according to the first two discriminant functions, obtained from truss morphometric data*

TABLE 5
Summary of One -Way ANOVA for each truss character in *B. boddarti* populations. The variables are referred to *Fig. 2a*

| Variable | Between populations | | Within population | |
|---|---|---|---|---|
| | F value | P | F value | P |
| B1 to 2 | 5.823 | .001** | 21.008 | .000** |
| B2 to 4 | 10.646 | .000** | 15.956 | .000** |
| B2 to 6 | 78.984 | .000** | 30.682 | .000** |
| B1 to 4 | 7.532 | .000** | 19.287 | .000** |
| B1 to 6 | 4.871 | .002** | 10.949 | .002** |
| B6 to 5 | 6.045 | .000** | 14.745 | .000** |
| B4 to 5 | 2.178 | .084 ns | .029 | .866 |
| B6 to 8 | 5.165 | .001** | 9.009 | .003** |
| B8 to 7 | 2.048 | .100 ns | 2.551 | .116 |
| B7 to 5 | 3.093 | .023* | 4.659 | .035* |
| B6 to 7 | 4.882 | .002* | 12.095 | .001** |
| B5 to 8 | 6.957 | .000** | 19.923 | .000** |
| B8 to 10 | 1.128 | .351ns | .816 | .370 |
| B10 to 9 | 4.289 | .004** | 10.890 | .002** |
| B9 to 7 | 2.803 | .034* | 6.747 | .012* |
| B8 to 9 | 2.898 | .030* | 6.482 | .014* |
| B7 to 10 | 3.455 | .014* | 8.776 | .001** |
| H7 to 2 | 7.808 | .000** | 13.165 | .001** |
| H7 to 1 | 5.409 | .001** | 8.883 | .004** |
| H1 to 2 | 6.512 | .000** | 22.437 | .000** |
| H2 to 4 | 2.979 | .027* | 7.652 | .008* |
| H4 to 3 | 4.582 | .027* | 9.278 | .004** |
| H3 to 1 | 2.913 | .029* | 7.675 | .008* |
| H2 to 3 | 1.650 | .031* | 3.909 | .053 |
| H1 to 4 | 1.386 | .251ns | 4.613 | .036* |
| H4 to 6 | 1.692 | .165ns | 2.154 | .104 |
| H6 to 8 | 3.210 | .019* | 8.051 | .006* |
| H5 to 8 | 4.540 | .003** | 11.369 | .001** |

ns = not significant (P>0.05); * significant at $p < 0.05$; ** highly significant at $p < 0$ .005

TABLE 6
Values of the first three components obtained through a PCA performed on raw 26 truss morphometric data of *B. boddarti*

| Truss character | Component | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| B1 to 2 | 865 | -.161 | .110 |
| B2 to 4 | .901 | -.223 | .054 |
| B2 to 6 | .962 | -.126 | -.077 |
| B1TO4 | .956 | -.171 | .023 |
| B1TO6 | .822 | .433 | -.065 |
| B6TO5 | .836 | -.121 | -.034 |
| B1TO5 | .460 | -.072 | .761 |
| B4TO5 | .903 | .165 | -.181 |
| B6TO8 | .804 | .049 | .181 |
| B8TO7 | .968 | -.074 | .013 |
| B7TO5 | .932 | -.200 | .069 |
| B6TO7 | .869 | .306 | -.255 |
| B5TO8 | .936 | .052 | -.166 |
| B8TO10 | .953 | .062 | -.097 |
| B10TO9 | .903 | -.154 | -.118 |
| B9TO7 | .678 | .004 | -.005 |
| B8TO9 | .827 | -.271 | .016 |
| B7TO10 | .863 | -.267 | -.134 |
| H7TO2 | .667 | -.272 | -.040 |
| H7TO1 | .753 | .512 | -.067 |
| H1TO2 | .727 | .440 | .341 |
| H2TO4 | .621 | .680 | -.024 |
| H3TO1 | .387 | .602 | .289 |
| H2TO3 | .930 | -.042 | -.131 |
| H4TO6 | .962 | -.106 | -.036 |
| H6TO5 | .688 | -.507 | .221 |
| Eigen value | 17.839 | 2.299 | 1.085 |
| Variance explained (%) | 68.610 | 8.841 | 4.173 |
| Cumulative variance (%) | 68.610 | 77.45 | 81.624 |

TABLE 7
Summary of One-Way ANOVA for each meristic character in *B. boddarti*

| Variable | Between population | | Within population | |
|---|---|---|---|---|
| | F value | P | F value | P |
| $D_1$ | 3.390 | .013* | 4.391 | 0.007* |
| $D_2$ | 1.655 | 169 ns | 2.193 | 0.095ns |
| $P_1$ | 4.490 | .037* | 4.490 | 0.037* |
| $P_2$ | 4.304 | .003** | 4.192 | 0.008* |
| A | 7.482 | .000** | 9.975 | 0.000** |
| LLS | 6.084 | .000** | 8.045 | 0.000** |
| ULLS | 2.834 | .030* | 3.503 | 0.019* |
| BLLS | 3.082 | .021* | 3.352 | 0.023* |
| PDS | 6.876 | .000** | 8.880 | 0.003** |

ns = not significant (P>0.05); *significant at p < 0.05; ** highly significant at p < 0 .005

TABLE 8
Values of the first three components obtained through a PCA performed on 7 raw meristic data of *B. boddarti*

| Meristic character | Component | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| $D_1$ | .720 | - .513 | .202 |
| $D_2$ | .548 | .480 | .533 |
| A | .447 | .480 | - .448 |
| $P_1$ | - .262 | .077 | .696 |
| $P_2$ | .665 | - .624 | .115 |
| LLS | - .125 | .210 | .639 |
| PDS | .583 | .605 | - .088 |
| Eigen value | 1.885 | 1.528 | 1.439 |
| Variance explained (%) | 26.925 | 21.835 | 20.560 |
| Cumulative variance (%) | 26.925 | 48.760 | 69.320 |

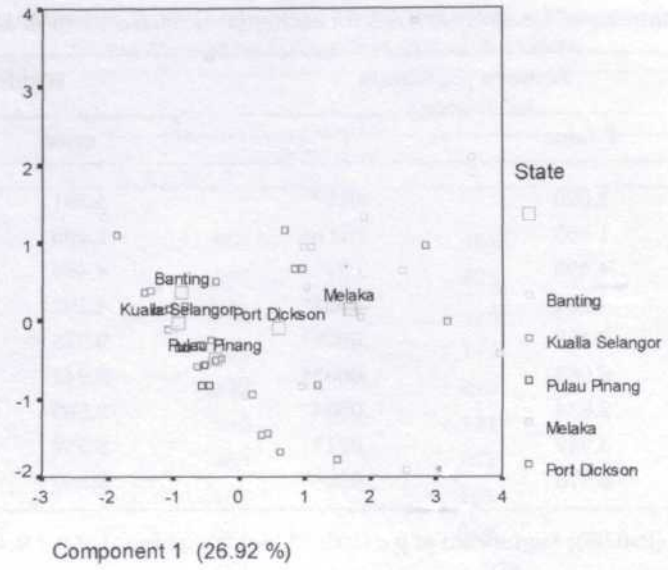


*Fig. 5: Plots of the coordinates of individuals of* B. boddarti *according to the first two discriminant functions, obtained from meristic data*

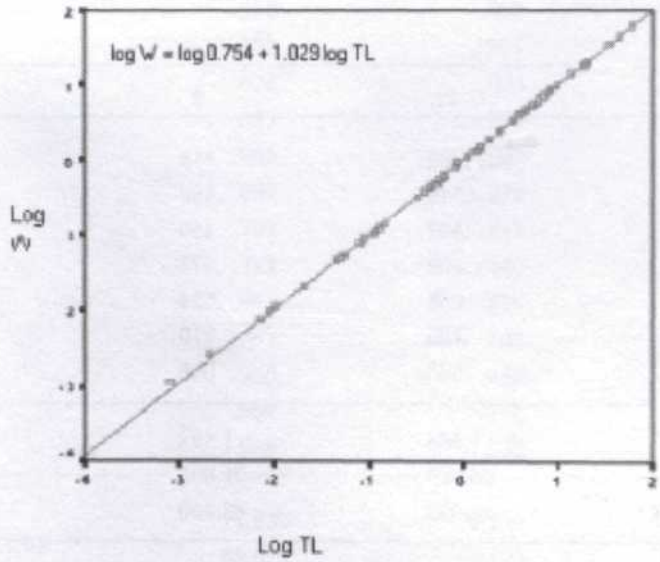


*Fig. 6: Length-weight relationship for* B. boddarti *populations in Peninsular Malaysia ($R^2$ = 0.937; n = 85)*

*Length-weight Relationship*

The length-weight relationship for *B. boddarti* in this study is described as: log W = log 0.754 + 1.029 log TL and the regression curve is presented in *Fig. 6*. The linear regression between total length and weight for *B. boddarti* was highly significant (P<0.005) with a $R^2$ value of 0.937.

## DISCUSSION

Some morphometric and meristic characters of *B. boddarti* have been recorded by Murdy (1989) based on samples from India, Indonesia, Thailand and Malaysia. In this study, more comprehensive conventional morphometric, truss morphometric and meristic data were collected and analysed to determine the most appropriate method to be used for handy fish stock identification and assessment.

The size of *B. boddarti* varies from one population to another. Of the five populations, the Melaka population had the biggest sized individuals ranging from 9.0 to 18.5 cm with a mean of 13.05 cm in TL, whilst the population of Kuala Selangor comprised the smallest sized individuals, ranging from 7.7 to 11.5 cm with a mean of 9.61 cm in total length. Various factors may be responsible for the differences such as food availability, environmental conditions, stage of maturity and seasonal changes, such as dry and rainy seasons.

The results of ANOVA and PCA are complementary to each other as shown by the results of the predorsal length of *B. boddarti*. The ANOVA showed that the PDL/TL was not significantly different ($P>0.05$) in the populations, and similarly for PCA, the predorsal length value was negative, suggesting that this character was not a good criterion to discriminate populations of *B. boddarti*.

The first component coefficient of morphometric data had positive and negative values, indicating shape variation. Based on PCA, the populations of *B. boddarti* are clustered into 3 groups (*Fig. 3*). Although the populations of *B. boddarti* were also clustered into 3 groups based on truss morphometric data, the grouping was different from that for the conventional morphometric data. The grouping based on truss morphometric data was more reasonable and meaningful as the geographically closer populations were grouped together. The results support the hypothesis that the shape of *B. boddarti* in the northern part is distinct from the middle and the southern parts of Peninsular Malaysia. These differences could be based on physical characteristics of each habitat, such as water temperature and currents (McElroy and Douglas 1995).

The first component of meristic characters only consists of 26.5% of the cumulative variance which is not good enough for stock identification (Doherty and McCarthy 2004). All populations were centric and no grouping was identified. Thus the populations of *B. boddarti* could not be differentiated using meristic characters.

In the length-weight relationship study, the estimated value of b was less than 3 ($b = 1.029$), indicating that allometric negative growth occurred in *B. boddarti*. In general, the exponent b from length-weight regression equation in fish and other invertebrates often lies between 2.5 and 3.5, and usually close to 3 for symmetrical or isometric growth (Gonzales *et al.* 2000; Atar and Secer 2003). In contrast, the length-weight relationship recorded for *B. boddarti* is $\log W = \log 0.0156 + 3.0 \log SL$ (*http://www.fishbase.org*).

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