Meristic characters and length-weight relation of climbing perch (Anabas testudineus) from wetlands in Sigi District, Central Sulawesi, Indonesia

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Abstract. The climbing perch, Anabas testudineus Bloch 1972, is a valued freshwater fish with a wide distribution in South and Southeast Asia. This study examined the meristic counts and length-weight relation of climbing perch from Sigi District, Central Sulawesi, Indonesia, close to the eastern extremity of the species distribution. Specimens collected from wetlands in Sigi District were weighed and measured (total length) to derive length–weight relation (n = 265) and meristic counts (n = 140). Length (L, in mm) – weight (W, in g) relation (W = aLb) parameter b = 2.98 overall; for females b = 3.06 while for males b = 2.88. Maximum length Lmax was 163 mm. The meristic formula using median values was D, XVII+8; A, X+9; P, 13; V, I+5; C, 16. Mean scale counts for both male and female climbing perch were: longitudinal 31 and vertical 15. There was no significant between-sex difference in meristic characters. Although the average growth pattern was isometric, males exhibited a slight allometric negative tendency. Low maximum size is consonant with other indications of a population under pressure, reinforcing the need for sustainable, holistic wetland management. In the context of domestication, high variability in meristic characters may indicate high genetic diversity and/or plasticity, which could provide scope for selective breeding.

1. Introduction

The climbing perch, Anabas testudineus Bloch 1972, is a valued freshwater fish with a wide distribution in South and Southeast Asia [1]. The Indonesian island of Sulawesi is at or close to the eastern extremity of the A. testudineus native distribution [2]. Once a favourite source of protein for several indigenous peoples in Central Sulawesi, A testudineus is now regaining popularity as a food fish. This is partly due to increased awareness of health benefits from the consumption of A. testudineus such as those reported by [3]. A. testudineus is increasingly recognized as a species with nutraceutical potential, in particular due to its high content of docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA) [4], high protein content, high omega-3 content and omega3/omega 6 ratio [5]. In 2013, surveys in Central Sulawesi, Indonesia indicated declining populations of once abundant native fishes including A. testudineus [6]. These surveys found widespread habitat loss and degradation, mainly due to wetland conversion for agriculture (e.g. intensive rice farming and palm oil plantations), aquaculture of introduced species, and urban development; increasingly heavy fishing
pressure including the illegal use of high-voltage electricity; and a general perception among respondents that these fish were harder to find and generally smaller in size than formerly.

An obligate air breather, *A. testudineus* is capable of surviving, even thriving, in harsh conditions such as higher temperatures, lower dissolved oxygen and pH [7,8], which are predicted to become increasingly prevalent due to climate change and other human impacts [9,10]. In addition, as predators on mosquito larvae, climbing perch can be effective in mosquito control [11]. Sustainable management of wild populations and local domestication of this native fish could thus contribute to regional climate change adaptation and food security.

Population characteristics or parameters are important as a basis for both the management of wild populations and development of domestication. Although data on *A. testudineus* population characteristics are limited, several studies indicate between-population variability in life-history and phenotypic characters. These include reproductive parameters such as fecundity and total length at first maturity [12–14] as well as differences in morphometric and meristic characters [15,16]. High genetic variation has been reported between *A. testudineus* populations, although within population variability is sometimes low [16,17].

The only District in Central Sulawesi Province with no coastline, Sigi does have significant freshwater fishery potential and has initiated a freshwater aquaculture development policy, with the climbing perch as one species proposed for aquaculture development, including domestication. A program for the domestication and sustainable management of *A. testudineus* in Sigi District was initiated in 2014, however there were no data on the characteristics of *A. testudineus* populations in Central Sulawesi Province in general, and the wetlands of Sigi District in particular. This study is a first step towards remedying this lack of data. Specific research objectives were to determine the length-weight relation and meristic formula and to evaluate within population variability of meristic counts (fin rays/spines) of climbing perch from Sigi District, Central Sulawesi, Indonesia.

2. Materials and Methods

2.1. Sample collection and measurement

Climbing perch *Anabas testudineus* (*n* = 265) were captured from wetland habitat in Sigi District, Central Sulawesi Province, Indonesia by local fishermen and fish farmers. The specimens were transported live, and humanely euthanized in the laboratory. A plastic tag labelled with a unique code (using a 2B pencil) was attached (with raffia) to each specimen after euthanasia and temporarily removed when taking measurements. Total length (*L*) was measured to the nearest millimetre (mm) using a standard fish measurement board (Cadwell ruler), and total body weight (*W*) was measured to the nearest 0.1 g using digital scales (Adam CQT1501). Sex was determined through dissection of the abdominal cavity and observation of the gonads. Samples for meristic analysis (*n* = 140; 69 males and 71 females) were preserved in 70% alcohol.

2.2. Length-weight relation and *L*\(_{\text{max}}\)

The parameters *a* and *b* of a length–weight relation of the form *W* = *a*·*L*\(^b\) (Keys 1928 in [18]), where *W* is the wet weight in g and *L* is the total length in mm, were determined from the analysis of all climbing perch specimens (*n* = 265). Weight was averaged within each 1 mm length class and a linear regression was fitted to the log-transformed variables (*L* and mean class weight), leading to an equation of the form log(*W*) = log(*a*) + *b* · log(*L*). Similar analyses were performed on subsets comprising specimens identified as female (*n* = 71) and male (*n* = 69). Values of *b* were used to determine average growth pattern of the Sigi District population (isometric if *b* ≈ 3, allometric positive/negative for *b*> 3 and *b*< 3 respectively). *L*\(_{\text{max}}\) was, by definition, the length of the longest specimen within the total sample.

2.3. Meristic formula and meristic diversity

For each specimen (*n* = 140), the number of spines and rays (dorsal, anal, pectoral, ventral and
caudal fins) were counted through visual inspection. Longitudinal and vertical scale rows were also counted. Where necessary, a magnifying glass (magnification × 2) was used. Mean and median values of each meristic variable were computed for the sample as a whole and by sex. The meristic formula (D = dorsal fin, A = anal fin, P = pectoral fin, C = caudal (tail) fin; spine counts in Roman numerals, ray counts in Arabic numerals) was determined using median values for each parameter.

2.4. Data analysis
Data were tabulated in Microsoft Excel (Microsoft Office 2010). Statistical data analyses were performed and graphics produced in R for Windows v.3.4.2 [19], implemented in RStudio v.1.1.456 [20]. The values of b and Lmax, meristic formula data, and meristic diversity were compared with data on other climbing perch populations.

3. Results

3.1. Length-weight relation and Lmax
The total length (L) of climbing perch used in this study (n = 265) ranged from 40–163 mm; body weight (W) range was 1.3–88.6 g. The longest specimen (female, weight 88.6 g) gave Lmax as 163 mm. The largest male specimen measured 143 mm and weighed 51.0 g. The mean length and weight of male A. testudineus (9.6 mm; 16.9 g) were significantly lower (Student’s t-test, p < 0.01) than those of females (11.6 mm; 31.3 g). Linear regression (Table 1) yielded the L-W relation equations:

- All specimens (n = 265): W = 1.782×10^-05 L^2.997
- Females only (n = 71): W = 1.396×10^-05 L^3.055
- Males only (n = 69): W = 2.875×10^-05 L^2.878

Table 1. Length-weight regression parameters for Sigi District climbing perch

| Sex   | N    | b    | SE   | Log(a) | SE   | a    | L in mm | r²    | Growth pattern | p-value (a&b) |
|-------|------|------|------|--------|------|------|---------|-------|----------------|---------------|
| Both  | 265  | 2.997| 0.028| -10.935| 0.128| 1.782×10^-05 | 0.993 | Isometric | <2×10^-16 |
| Female| 71   | 3.055| 0.068| -11.179| 0.321| 1.396×10^-05 | 0.967 | Isometric | <2×10^-16 |
| Male  | 69   | 2.878| 0.046| -10.457| 0.210| 2.875×10^-05 | 0.983 | Allometric negative | <2×10^-16 |

3.2. Meristic Count Analysis
Minimum, maximum, mean and median values of meristic counts of the A. testudineus from Sigi District (n = 140) (Table 2, Figure 1) indicate significant within-population phenotypic diversity in meristic traits. None of the meristic differed significantly between males and females (Students t-test, p > 0.05). The meristic formula (median count values) was D, XVII + 8; A, X + 9; P, 13; V, I + 5; C, 16 (Figure 2).

Table 2. Meristic parameters of climbing perch from Sigi District (n = 140)

| Parameter¹ | D    | d    | V    | v    | A    | a    | P    | C    | LS   | VS   |
|------------|------|------|------|------|------|------|------|------|------|------|
| Maximum    | 20   | 10   | 1    | 6    | 13   | 12   | 15   | 19   | 37   | 20   |
| Minimum    | 15   | 6    | 1    | 4    | 8    | 5    | 9    | 12   | 28   | 12   |
| Mean       | 17.9 | 8.4  | 1.0  | 5.1  | 10.0 | 8.9  | 13.1 | 15.5 | 31.4 | 15.2 |
| Median     | 18   | 8    | 1    | 5    | 10   | 9    | 13   | 15   | 31   | 15   |

¹ Fins: D = dorsal; A = Anal; P = pectoral; V = Ventral; C = Caudal (upper case = spines; lower case = rays). Scale rows: LS = longitudinal; VS = vertical

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4. Discussion

4.1. Length-weight relation and $L_{\text{max}}$

Values of length-weight relation ($W = a \cdot L^b$) parameter $b$ and $L_{\text{max}}$ for *A. testudineus* in this and other studies (Table 3) are within the range reported from *A. testudineus* populations from other sites and countries. The majority of studies in Table 3 indicate an allometric negative growth pattern; however, higher values of $b$ indicating isometric growth patterns (as in this study) have been reported from wild populations in Indonesia [21] and Thailand [22] as well as cultured climbing perch in Bangladesh [23]. Conversely the observed $L_{\text{max}}$ for the Sigi District *A. testudineus* population can be considered low (Table 2). Such a condition can be considered indicative of a population under pressure [24]. Threats observed during sampling included wetland habitat conversion (rice paddies and aquaculture ponds), competition from alien species (introduced as aquaculture commodities) and high fishing pressure (including illegal electric fishing), similar to those reported in [6].

Higher values of $b$ for females than males [21] and a tendency for adult female *A. testudineus* to become both longer and heavier than adult males [12] have been reported from other populations. The length/weight regression models for males and females indicate that initially males tend to be heavier than females, and reach maturity at slightly shorter lengths; however once most fish are mature (around 9-10 cm total length) females tend to be heavier than males and grow faster.

Growth patterns in *A. testudineus* can be influenced by environmental factors [21, 25]. Individual weight at a given length (and hence observed $b$ values) could be influenced by transient factors such as nutritional status (e.g. related to food availability and water quality) and reproductive activity (e.g. gonad development), as well as intrinsic characteristics such as sex and genetically determined phenotypic variation. The relatively high values of $b$ in this study, especially for females, may have been influenced by the presence of mature fish with ripe gonads in our sample.

With respect to potential competition and predation from alien species, introduced species observed during this study included carp (*Cyprinus carpio*), tilapia (*Oreochromis niloticus* and *O. mossambicus*), catfish (*Clarias* sp.) and a species locally called *bawal air tawar*, voracious fast-growing fish from South America, most likely pacu of the genus *Piaractus*. All are known or
suspected to be invasive and to have adverse effects on native fish and invertebrate communities, largely through various forms of competition [26].

**Table 3.** Reported values of the length-weight parameter \( b \) and \( L_{\text{max}} \) for *A. testudineus* in Sigi District and other climbing perch populations

| Sample origin | \( n \) | value | \( b \) SE | \( R^2 \) | Growth pattern<sup>1</sup> | \( L_{\text{max}} \) (mm) | Reference/Remarks |
|---------------|--------|-------|---------|---------|----------------|----------------|-----------------|
| Indonesia,    | 265    | 2.997 | 0.028   | 0.993   | I              | 163            | This study - all |
| Sigi District,| 71     | 3.055 | 0.068   | 0.963   | I              | -              | This study - female |
| Sulawesi      | 69     | 2.878 | 0.046   | 0.983   | A-             | -              | This study - male |
| Indonesia,    | 400    | 2.754 | -       | -       | A-             | 195            | [21] - All |
| Kalimantan    | 165    | 2.818 | -       | -       | I              | -              | [21] - Females |
|               | 235    | 2.674 | -       | -       | A-             | -              | [21] - Males |
| Sigi District | 30     | -     | -       | -       | > 250          | -              | [27] |
| Philippines   | -      | 2.67  | -       | 0.91    | A-             | -              | [28] |
| Thailand      | 34     | 2.507 | 0.112   | 0.951   | A-             | 165            | [30] |
|               | 155    | 3.015 | 0.113   | 0.988   | I              | -              | [22] |
| Malaysia      | 70     | -     | -       | -       | 192            | -              | [13] |
| Bangladesh    | 6 x 12 | 1.53-3.08 | - | > 0.9 | A- to I | - | [23] (cultured) |
|               | -      | 2.7-2.8 | - | - | A- | - | [31] |
| India         | 149    | 2.621 | 0.12    | 0.76    | A-             | -              | [25] cage |
|               | 257    | 2.769 | 0.037   | 0.95    | A-             | -              | [25] tank |
|               | 238    | 2.770 | 0.09    | 0.87    | A-             | -              | [25] pond |
|               | -      | -     | -       | -       | 182            | -              | [32] |
|               | 319    | -     | -       | -       | 190            | -              | [12] |
| FishBase      | -      | 2.77<sup>2</sup> | 0.06 | - | A- | 250 | [1] |

<sup>1</sup> I = Isometric; A- = Allometric negative; - = no data.<sup>2</sup> mean of 6 values

Recently introduced to the Sigi area, pacu are still less widespread in aquaculture than carp, tilapia or catfish. Pacu have opportunistic omnivorous feeding habits and consume a wide variety of plant material, zooplankton and invertebrates, including molluscs and insects [33,34]. In aquaria, pacu are reported to prey on small fish, as illustrated by the quote: “small fish [in the same aquarium] will likely be eaten” (http://www.seriouslyfish.com/species/piaractus-brachypomus/ref). There are reports of piscivory and even serious biting of humans by captive and feral pacu, which can readily become invasive (e.g. https://bassfishing-gurus.com/pacu-invasive-species/). It would seem possible, and even likely that, in addition to competition for food and space, feral pacu could potentially become significant predators of *A. testudineus* and other native wetland fish in Sigi District, especially during early life stages. The Philippine experience in particular [26,33,34] indicates a need for extreme caution, as pacu can have severe deleterious impacts on biotic communities in wetland ecosystems.

### 4.2. Meristic Count Analysis

Mean and median values of Sigi District *A. testudineus* meristic counts (Table 1) were within the ranges reported for other climbing populations in Indonesia (e.g. Kalimantan) and other Asian countries (e.g. Bangladesh and India) (Table 4). However variability was high (Table 1), and some outliers had meristic counts outside the range reported from other studies, such as fifteen (XV) dorsal spines, 12 or 13 anal rays, four and six ventral fin rays.

The caudal ray counts (12-19, mean 15.5 and median 15), were mostly lower than 17, the value given in the only reference found for this character [2]. Some exceptionally low counts (such as the one dorsal ray outlier) could be linked to intra-species aggression, and the authors have observed aggressive behaviour between *A. testudineus* that resulted in fin damage. However, in most meristic
counts there was no noticeable bias to low values, and it seems likely that a wide range and high diversity in meristic traits are characteristic of this population. A correlation between meristic and genetic characteristics is reported by [25]. Thus, the observed meristic variability may denote intra-specific genetic diversity within the Sigi climbing perch population.

5. Conclusion
Although the average growth pattern was isometric, A. testudineus males exhibited a slight allometric negative tendency. Low maximum size is consonant with other indications of a population under pressure, including reports of native fish population declines due to habitat conversion and growing fishing pressure, reinforcing the need for sustainable, holistic wetland management in Sigi District. There was no significant between-sex difference in meristic counts. The Sigi District climbing perch population exhibit relatively high intra-specific variation in several meristic traits compared to other populations for which data are available. This may be related to genetic diversity and/or plasticity and might indicate potential for selective breeding as part of domestication efforts. Further research is needed to investigate possible correlations of meristic traits with genetic diversity and life history traits important to aquaculture.

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