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Assessing Morphometric Diversity and Growth Patterns of *Channa punctatus* in Distinct Freshwater Ecosystems of Tamil Nadu, India

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ABSTRACT

The present study investigates the morphometric, meristic, and length–weight relationships of *Channa punctatus* populations from two freshwater habitats in Tamil Nadu — Madurai (Sakkimangalam) and Virudhunagar (Kullursandhai). A total of 207 specimens were analyzed to assess intra-specific variation and population differentiation. Standard morphometric measurements and meristic counts were recorded and statistically analyzed using Principal Component Analysis (PCA) and cluster analysis through PAST software (version 1.89). The length–weight relationship for the combined sexes was expressed as Y = 7.9616x – 80.664, indicating a negative allometric growth pattern where weight increased less proportionally than length. PCA results revealed that the first three principal components accounted for approximately 70% of total variance, highlighting significant morphological differentiation between the two populations, particularly in head and fin morphometry. Cluster analysis further indicated slight segregation between Madurai and Virudhunagar populations, possibly reflecting environmental influences such as water quality, food availability, and habitat structure. Despite partial overlap in morphometric traits, population-level distinctions were evident, suggesting adaptive divergence under localized ecological conditions. The findings underscore the value of integrating morphometric and meristic analyses in stock discrimination and fisheries management of *C. punctatus*.

Keywords *Channa punctatus*, Morphometric analysis, Meristic characters, Length–weight relationship, PCA, Population variation, Tamil Nadu.

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INTRODUCTION

Aquaculture has emerged as one of the fastest-growing industries worldwide due to the significant

increase in global demand for fish and seafood. It is expanding more rapidly than other segments of the animal culture industry (Katiha *et al.* 2005). Fish play an important role in the development of a nation, serving as a relatively inexpensive source of highly nutritious protein, as well as providing other essential nutrients required by the human body. The identification of species is a fundamental step in any biological research, forming the basis for behavioral, ecological and physiological studies. Morphometric measurements refer to the quantification of various external body parts of an organism, while meristic counts include all countable features such as fin rays or scales (Talwar and Jhingran 1991). The length–weight relationship is of vital importance in Fisheries Science, as it helps establish a mathematical relationship between the two variables. This enables the conversion of one variable into the other (Abohweyere 2009, Jannat *et al.* 2022), facilitates the detection of differences among stocks of the same species (King 2007), and aids in delineating stocks for comparative growth studies (Urbanski *et al.* 2016). Morphometric relationships between length and weight are often used to assess the well-being of individuals and to identify potential differences between distinct unit stocks of the same species (King 2007). Additionally, length–length relationships are important in fisheries management for comparative growth analyses (Moutopoulos and Stergiou 2002). The study of morphometric characteristics has significantly enhanced our understanding of fish biology. The field of morphometrics focuses on methods for describing and statistically analyzing shape variation within and among samples of organisms (Farooq 2019). These methods allow for the quantitative comparison of organismal shapes or specific body structures (Thompson 1992). The knowledge of the length–weight relationship plays a crucial role in fisheries biology and population dynamics, as it assists in estimating standing stock or biomass, thereby facilitating yield estimation by converting one growth variable into another (Petakis and Stergiou 1995). In population studies, morphometric analysis serves as a powerful complement to genetic and environmental stock identification approaches (Cadrin 2000). Moreover, length–weight relationships enable the conversion of growth-in-length equations to growth-in-weight for use in stock assessment models (Moutopoulos and Stergiou 2002). The genus Channa, commonly known as snakeheads, comprises several economically and ecologically significant species. *Channa punctatus* exhibits a wide distribution across rivers, canals, lakes, swamps, marshes, and rice fields (Mirza 1982), reflecting its remarkable ecological adaptability to diverse freshwater environments in South Asia (Wee 1982, Singh *et al.* 2021). It is abundantly found in open water bodies of Pakistan, Bangladesh, Thailand, India and Nepal (Rahman 1989). In Tamil Nadu, it is locally known as Koravai. Morphometric and meristic characters have been extensively used in species discrimination and classification studies through various statistical techniques (Ahmad *et al.* 2024, Santanumurti *et al.* 2024, Huang *et al.* 2026, Fatle *et al.* 2025). Considering this background, the present study was undertaken to compare the morphometric and meristic variations of *Channa punctatus* stocks collected from Virudhunagar and Madurai districts of Tamil Nadu. Principal Component Analysis (PCA) was performed to assess differences in morphological and meristic traits between the populations.

MATERIALS AND METHODS

The present study was carried out in two freshwater ecosystems located in Tamil Nadu, India, namely Sakkimangalam in Madurai District (Site I) and Kullursandhai in Virudhunagar District (Site II). These sites differed in hydrological characteristics, with Site I representing a relatively stable perennial habitat and Site II representing a seasonal system subjected to greater environmental fluctuations. The geographical coordinates of both locations were recorded using a handheld GPS, and basic water quality parameters were measured during each sampling visit. A total of 207 specimens of *Channa punctatus* were collected during the study period through monthly sampling. Cast nets with a mesh size of 10–15 mm and gill nets were used for fish collection. The live specimens were transported to the laboratory in aerated containers to minimize stress, and species identification was confirmed using standard taxonomic keys. All specimens were handled carefully to avoid physical damage. Morphometric observations included fifteen characters such as total length, standard length, head length, body depth, eye diameter, predor-

sal length, postdorsal length, caudal peduncle length and depth, dorsal and anal fin base lengths, pectoral and pelvic fin lengths, snout length, and interorbital distance. These measurements were taken using a digital caliper with an accuracy of 0.01 cm. Meristic counts including dorsal, anal, pectoral, and pelvic fin rays, as well as lateral line scales, were recorded under a stereomicroscope. To minimize size-related variation, morphometric measurements were standardized using an allometric transformation formula.

All statistical data analyses were conducted using the software PAST (Hammer *et al.*, version 1.89). Descriptive statistics were generated for all morphometric and meristic variables and differences between sites were assessed using t-tests or ANOVA depending on data distribution. Pearson's correlation was applied to examine the relationship between length and weight, while multivariate analyses such as Principal Component Analysis and Cluster Analysis were employed to explore population-level variation. A significance level of $p < 0.05$ was adopted throughout the analysis.

RESULTS

Morphometric variation between populations

The proportional morphometric measurements of *Channa punctatus* collected from Madurai (Sakkimangalam) and Virudhunagar (Kullursanthai) are presented in Table 1 and Table 2, respectively.

Table 1. Proportional values of morphometric measurements with minimum, maximum mean and standard deviation on *Channa punctatus* collected from Madurai (Sakkimangalam).

Parameter	Range (cm)	Mean ± SD
Total length	13.5–21.4	16.7 ± 1.61
Standard length	1.0–15.4	12.4 ± 1.18
Head length	3.5–5.8	4.32 ± 0.48
Caudal peduncle depth	1.2–2.1	1.72 ± 0.21
Body depth	1.5–3.1	2.4 ± 0.41
Caudal peduncle length	0.4–0.5	0.43 ± 0.05
Pectoral fin length	2.3–3.3	2.69 ± 0.23
Pectoral fin height	2.1–3.4	2.85 ± 0.26
Pelvic fin length	1.4–2.2	1.69 ± 0.15
Pelvic fin height	1.3–2.0	1.68 ± 0.18
Anal fin length	4.6–6.3	5.51 ± 0.50
Anal fin height	1.5–2.6	2.06 ± 0.35
Caudal fin length	2.0–3.4	2.68 ± 0.40
Caudal fin height	3.1–4.9	3.79 ± 0.38
Dorsal fin length	6.0–9.6	7.75 ± 0.89
Dorsal fin height	1.2–2.1	1.72 ± 0.24
Distance between pectoral and pelvic fins	0.7–1.1	0.98 ± 0.11
Girth	6.2– 10.2	8.00 ± 0.84
Weight	30.12–96.91	50.8 ± 14.4
Head depth	2.0–3.1	2.46 ± 0.29
Head width	2.0–3.2	2.57 ± 0.31
Eye diameter	0.5–0.6	0.53 ± 0.05
Snout length	2.8–3.9	3.39 ± 0.28

Table 2. Proportional values of morphometric measurements with minimum, maximum mean and standard deviation on *Channa punctatus* collected from Virudhunagar (kullursanthai).

Parameter	Range	Mean ± SD
Standard length	10–15.8	12.6 ± 1.12
Head length	3.0–5.7	4.29 ± 0.53
Caudal peduncle depth	1.2–2.1	1.68 ± 0.20
Body depth	2.0–3.1	2.40 ± 0.28
Caudal peduncle length	0.3–0.6	0.47 ± 0.08
Pectoral fin length	2.2–3.5	2.66 ± 0.28
Pectoral fin height	2.0–3.6	2.64 ± 0.33
Pelvic fin length	1.1–2.5	1.78 ± 0.24
Pelvic fin height	1.0–1.8	1.31 ± 0.21
Anal fin length	4.6–7.6	5.75 ± 0.53
Anal fin height	1.1–2.5	1.39 ± 0.24
Dorsal fin length	6.0–10.5	8.22 ± 0.88
Dorsal fin height	1.0–2.5	1.55 ± 0.31
Distance between pectoral and pelvic fins	0.6–1.5	1.01± 0.14
Girth	6.5–10.6	8.54 ± 0.62
Weight	27.2–94.92	53±12.7
Head depth	1.8–3.0	2.28 ± 0.32
Head width	2.0–3.3	2.46 ± 0.36
Eye diameter	0.5–0.6	0.54 ± 0.05
Snout length	2.2–4.2	3.26 ± 0.39

In the Madurai population, total length ranged from 13.5–21.4 cm (16.7 ± 1.61 cm), while standard length varied from 10.0–15.4 cm (12.4 ± 1.18 cm). Head length ranged between 3.5–5.8 cm (4.32 ± 0.48 cm). Body depth varied from 1.5–3.1 cm (2.40 ± 0.41 cm), and caudal peduncle depth ranged from 1.2–2.1 cm (1.72 ± 0.21 cm). Dorsal fin length averaged 7.75 ± 0.89 cm, anal fin length 5.51 ± 0.50 cm, and caudal fin length 2.68 ± 0.40 cm. Girth ranged from 6.2–10.2 cm (8.00 ± 0.84 cm). Body weight ranged

from 30.12–96.91 g, with a mean of 50.8 ± 14.4 g (Table 1).

In the Virudhunagar population, standard length ranged from 10.0–15.8 cm (12.6 ± 1.12 cm), and head length varied from 3.0–5.7 cm (4.29 ± 0.53 cm). Body depth ranged from 2.0–3.1 cm (2.40 ± 0.28 cm), and caudal peduncle depth from 1.2–2.1 cm (1.68 ± 0.20 cm). The mean dorsal fin length was 8.22 ± 0.88 cm, anal fin length 5.75 ± 0.53 cm, and caudal fin length 2.83 ± 0.40 cm. Girth ranged from 6.5–10.6 cm (8.54 ± 0.62 cm). Body weight ranged from 27.2–94.92 g, with a mean of 53 ± 12.7 g (Table 2). Overall, morphometric measurements of the two populations were largely comparable. Slight differences were observed in dorsal fin length, anal fin height, girth and body weight, indicating minor regional variation.

Length–weight relationship

The standard length and body weight ranges were as follows:

Males: 14.2–21.0 cm / 31.8–91.1 g

Females: 13.4–21.5 cm / 27.2–96.9 g

Combined sexes: 13.4–21.5 cm / 27.2–96.9 g

The length–weight relationship was expressed using the following regression equations:

Male: Y = 7.9076x – 81.608

Female: Y = 7.2435x – 72.406

Combined sexes: Y = 7.9616x – 80.664

The pooled length–weight relationship is illustrated in Fig. 1, showing a positive linear relationship between length and weight. This indicates that body weight increases proportionally with increasing body length across the sampled size range.

Meristic characters

Meristic counts of *Channa punctatus* are presented in Table 3. All specimens from both Madurai and Virudhunagar exhibited identical meristic characteristics. The number of lateral line scales was consistently 41. Dorsal fin rays numbered 32, anal fin rays 21, pectoral fin rays 15, pelvic fin rays 5, and caudal fin rays 14. No variation in meristic characters was observed between the two populations.

Table 3. Meristic counts in different length groups of *Channa puntatus*.

Sl No	Character	No of fin rays
1	Lateral line scales	41
2	Caudal fin rays	14
3	Dorsol fin rays	32
4	Pectoral fin rays	15
5	Pelvic fin rays	5
6	Anal fin rays	21

Table 4. PCA scores for the four components, vaiance explained and eignvalues.

PC	Eiguvalue	Variance
1	19.14	78.77
2	2.28	71.44

Principal component analysis (PCA)

Principal Component Analysis (PCA) was performed using morphometric and meristic data, and the eigenvalues and percentage variance explained are presented in Table 4. The first principal component (PC1) showed a high eigenvalue of 19.14 and accounted for 78.77% of the total variance. The second principal component (PC2) had an eigenvalue of 2.28. Together, the principal components explained a substantial proportion of the observed morphological variation. The PCA scatter plot (Fig. 2) revealed partial overlap between specimens from Madurai and Virudhunagar, indicating strong morphometric similarity with slight differentiation between populations.

Cluster analysis

Cluster analysis using Ward's method is presented in Fig. 3. The dendrogram showed that specimens from Madurai and Virudhunagar formed two closely related clusters. Although the populations were not

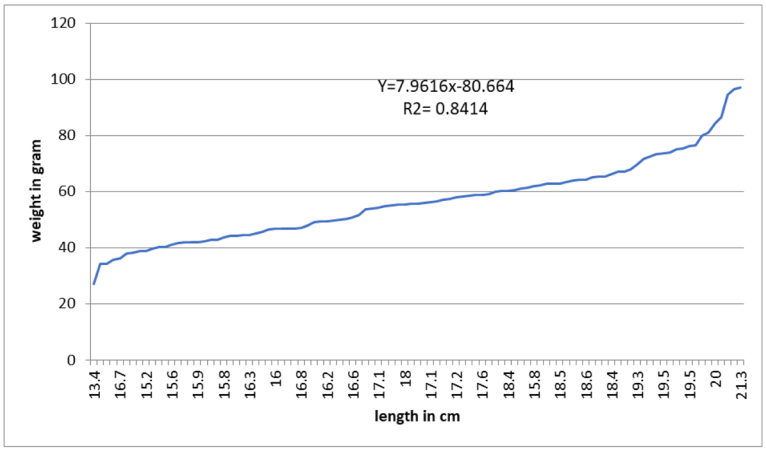

Fig. 1. length weight relationship of *C. Puntatus* (pooled).

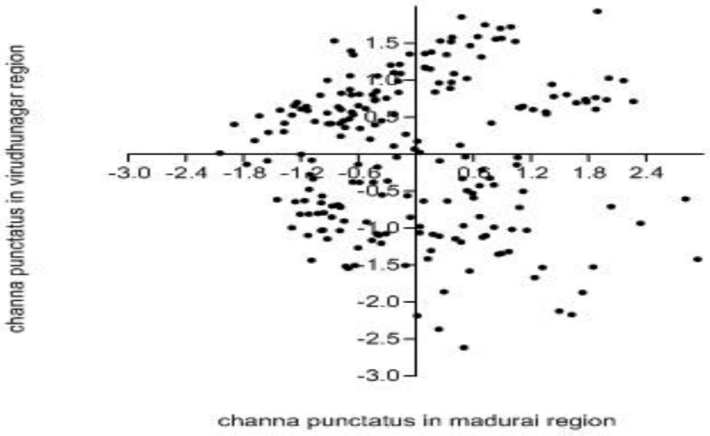

Fig. 2. Principal Component Analysis of morphometric data of two different populations of *C. punctatus* by Ward's method.

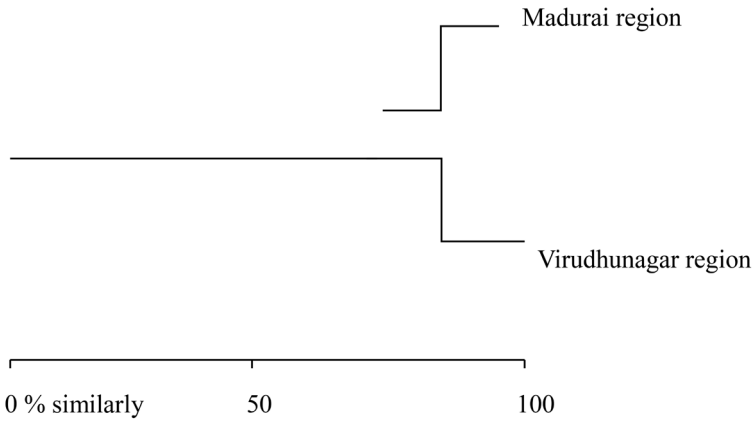

Fig.3. Cluster analysis of two populations of *C. punctatus* by Ward's method.

completely separated, minor clustering differences were evident, suggesting slight morphometric variation between the two geographic regions.

DISCUSSION

Snakeheads (Family Channidae) are a diverse group of air-breathing freshwater fishes represented by two genera, *Channa* and *Parachanna*. They are characterized by an elongated body, large plate-like scales on the head, and long dorsal and anal fins supported only by rays. Their distinctive morphology, color variation, economic value, and environmental tolerance have attracted significant scientific interest (Choure *et al.* 2025, Rahman *et al.* 2023, Bordoloi *et al*. 2024). The length–weight relationship (LWR) of *C. punctatus* in this study exhibited a curvilinear pattern, showing negative allometric growth—weight did not increase proportionally with length at all stages. Similar findings have been reported for other fishes such as channa punctatus (Begum *et al.* 2025), *Channa striatus* (Manikandaraja and Ananth Kumar (2024), and Ilisha Africana. Principal Component Analysis revealed morphometric differentiation between populations, particularly in fin ray counts and lateral line scales, consistent with findings of Mohammed *et al.* (2025). While Madurai specimens were relatively distinct, overlap in Virudhunagar samples indicated possible intermixing between populations due to similar environmental conditions. Differences in certain traits—such as eye diameter, head length, and fin position—may relate to habitat features such as depth, flow, turbidity, and prey type (Rahman *et al.* 2023). For instance, dorsal eye placement suggests a benthic lifestyle, while robust pectoral fins and compact bodies aid adaptation to strong currents and the morphometric relationships observed in the present study are comparable to those reported for *Channa orientalis* from Northwestern Bangladesh, where multi-linear morphometric analysis revealed significant correlations among total length, standard length, head length and body depth. Similar positive allometric growth patterns suggest that morphometric traits in *Channa* species are strongly influenced by ecological conditions and habitat structure. (Chowdhury *et al*. (2021). Overall, *C. punctatus* populations from Madurai and Virudhunagar exhibited minor morphometric differences, likely influenced by environmental variability (Manikandaraja and Ananth Kumar 2024, Bano *et al.* 2022 . To confirm these phenotypic observations, genetic tools such as molecular markers (Carvalho and Hauser 1994, Singh and Sejauddin 2019, Singh *et al.* 2021) should be employed for precise stock discrimination. This study concludes that length–weight studies, coupled with morphometric and meristic analyses, are essential for species identification, taxonomic resolution, and understanding population structure in *Channa punctatus*.

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