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Morphological discrepancies of three *Garra* (Teleostei: Cyprinidae) in Arunachal Pradesh, India- a possible evolutionary process

Bungdon Shangningam[1]*, Shibananda Rath[2], Asha Kiran Tudu[2] and Laishram Kosygin[2]

[1] *Wildlife & GIS Section, Zoological Survey of India, Prani Vigyan Bhawan, Kolkata-700053*
[2]*Freshwater Fish Section, Zoological Survey of India, 27 JL Nehru Road, Kolkata-700016*

Abstract

The present study appraises the discrepancies patterns of morphometry for the first time on the three species of *Garra*. *Garra arunachalensis*, *G. birostris,* and *G. quadratirostris* were collected from various locations of the Siang River in Arunachal Pradesh, India. The results of the morphological analysis revealed that *G. arunachalensis*, *G. birostris,* and *G. quadratirostris* hold many similar characteristics compared to the type species, which confirms its speciation. However, they parade distinct variations in morphological and meristic characters which indicate genetic variation as time lapsed. Certain morphometric characters overlapped. Hence the variations in many morphometric characters point towards a possible continuous evolutionary process. Details of the morphological discrepancies of the three species and possible hypotheses of climatic, geographical, and habitat changes are discussed.

Keywords: Pisces, Cypriniformes, *Garra*, Variations, Brahmaputra drainage

Introduction

The oxygen-rich mountainous streams of Northeast India form an ideal habitat for the genus *Garra* (Shangningam *et al.*, 2019). The snout modification viz., development of the proboscis, distribution pattern of the tubercles, and the transverse lobe are of taxonomic significance in distinguishing species of the genus. Based on the snout morphology, Nebeshwar and Vishwanath (2013) described *Garra arunachalensis*, *G. birostris,* and *G. quadratirostris* from the Brahmaputra River drainage of Arunachal Pradesh. Furthermore, on the basis of the snout and oromandibular morphology, Nebeshwar and Vishwanath (2017) has categorized the genus *Garra* occurring in India, Sri Lanka, China, and Southeast Asia into five distinct aspects: snout smooth; snout with a transverse lobe; snout with a proboscis and transverse lobe; snout with a pair of rostral flaps and snout with a pair of rostral lobes.

A collection of fishes from the Siang River, a tributary of the Brahmaputra River drainage in Arunachal Pradesh, India included three species viz., *Garra arunachalensis*, *G. birostris,* and *G. quadratirostris.* Further detail examination revealed morphometric variations from the original description directing towards a possible continuous evolutionary process. Hence, the present study appraises the discrepancies patterns of morphometry on *Garra arunachalensis*, *G. birostris,* and *G. quadratirostris* for the first time.

Material and Method

The specimens were collected from the Siang River, a tributary of the Brahmaputra drainage, upper Siang district, Arunachal Pradesh, India. Specimens were fixed in 10 %formalin and subsequently transferred to 70 % ethanol for storage. GPS coordinates and elevations of the sampling sites were recorded using a Garmin Oregon750GPS. Measurements were taken point-to-point, with digital calipers, on the left side of the specimens, and recorded to the nearest 0.1mm. Counts, measurements, and terminology follow Nebeshwar & Vishwanath (2013).

*Author for correspondence : bdshangningam@gmail.com
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Gular disc terminology follows Kottelat (2020). Counts for dorsal and anal-fin rays follow Kottelat (2001). Fin rays and the number of scales were counted using a Leica stereo-zoom microscope. Head length and measurements of the body are expressed as a percent of standard length (% SL). Specimens are deposited in the Zoological Survey of India, Freshwater Fish Section, Kolkata, India.

Systematic accounts

Class Actinopterygii

Order Cypriniformes

Family Cyprinidae

Genus *Garra* Hamilton, 1822

***Garra arunachalensis* Nebeshwar & Vishwanath, 2013**

(Figure 1)

Material examined. ZSI FF 9259, 2 exs, 152.1-161.8 mm SL, India: Arunachal Pradesh: upper Siang District, Gobuk village, Siang River: 28. 576831 N, 95.145417 E: Coll. S. D. Gurumayum, 20 December 2021.

Diagnostic characters. *Garra arunachalensis* belongs to the members of the snout with a proboscis and transverse lobe species group. It is characterized in having an elongate body, slightly compressed laterally, more compressed in the region of caudal peduncle. Snout with a transverse lobe with 17-18 small- to medium-sized tubercles and a prominent quadrate proboscis. Dorsal fin with iii, 8 rays, origin midway between snout tip and caudal-fin base. Pectoral fin with i, 15 rays, reaching beyond midway to pelvic-fin origin when adpressed. Pelvic fin with i,8 rays, reaching beyond midway to anal-fin origin, origin closer to anal fin origin than to pectoral-fin origin. Anal fin short with iii 5 rays, origin closer to caudal-fin base than to pelvic-fin origin. Anus closer to anal-fin origin than to pelvic-fin origin. Caudal fin forked, tip of lobes pointed; lower lobe slightly longer. Lateral line complete with 35 scales. Circumpeduncular scale rows 12. Predorsal scales 12. Chest and belly scaled. One long axillary scale at the base of pelvic fin, its tip reaching posterior end of pelvic-fin base.

Distribution. *Garra arunachalensis* is distributed in Upper Siang, West Siang, East Kameng and Lower Divang valley districts of the upper Brahmaputra basin in Arunachal Pradesh.

***Garra birostris* Nebeshwar & Vishwanath, 2013**

(Figure 2)

Material examined.ZSI FF 9258, 2 exs, 117.1-123.4 SL, India: Arunachal Pradesh: upper Siang District, Gobuk village, Siang River: 28. 576831 N, 95.145417 E: Coll. S. D. Gurumayum, 20 December 2021.

Diagnostic Characters. *Garra birostris*, a member of the snout with a proboscis and transverse lobe species group. It is distinguished from its congeners in the following: snout morphology with a transverse lobe with 16-17 small- to large-sized uni- to tetracuspid acanthoid tubercles; a prominent bilobed proboscis, moderately elevated upwards, each lobe forwardly protruding and tapering; the tip of each lobe with a large, anteriorly-directed tri- or tetracuspid acanthoid tubercle; the anterior margin of the proboscis sharply delineated by a deep groove from the depressed rostral surface; 1-2 small tubercles on the lateral margin of the proboscis. Dorsal fin with iii, 8 rays; its origin nearer to snout tip than to caudal-fin base, inserted anterior to vertical from pelvic-fin origin. Pectoral fin with 1, 14 rays, reaching beyond midway to pelvic-fin origin when adpressed; length slightly shorter than head length. Pelvic fin with 1, 8 rays, reaching beyond midway to anal-fin origin, origin closer to anal fin origin than to pectoral-fin origin. Anal fin short with iii, 5 rays. Caudal fin forked; lobe tips pointed; lower lobe slightly longer; tenth ray shortest. Lateral line complete, with 34 scales. Circumpeduncular scale rows 16. Predorsal scales 11 scales regularly arranged, same size as flank scales. Chest and belly scaled. One long axillary scale at the base of the pelvic fin, its tip reaching beyond the posterior end of pelvic-fin base.

Distribution. *Garra birostris* is widely distributed in Upper Siang, West Kameng, and Papum Pare districts of the upper Brahmaputra basin in Arunachal Pradesh.

***Garra quadratirostris* Nebeshwar & Vishwanath, 2013**

(Figure 3)

Material examined. ZSI FF 9260, 2 exs, 95.7-107.6 mm SL, India: Arunachal Pradesh: upper Siang District, Gobuk village, Siang River: 28. 576831 N, 95.145417 E: Coll. S. D. Gurumayum, 20 December 2021.

Diagnostic characters. *Garra quadratirostris* is distinguished from its congeners in having the following combination of characters: snout morphology with a prominent transverse lobe with 13-14 small to large-sized tubercles; a prominent

quadrate proboscis, moderately elevated towards the anterior margin of the proboscis truncate, and sharply delineated from the depressed rostral surface by a narrow transverse groove; and small to medium-sized tubercles on the margins of the proboscis in a single row. Dorsal fin with iii, 8 rays, origin inserted anterior to vertical from pelvic-fin origin. Pectoral fin with 1, 15 rays, reaching beyond midway to pelvic-fin origin when adpressed; length equal or shorter than head length. Pelvic fin with 1, 8 rays, reaching beyond midway to anal-fin origin, surpassing anus; second branched ray longest, not extending to the base of anal fin; origin closer to anal fin origin than to pectoral-fin origin, inserted below the base of third branched dorsal-fin ray; distal margin almost truncate or slightly convex. Anal fin short with iii, 5 rays, reaching the base of caudal fin; distal posterior margin straight; origin closer to caudal-fin base than to pelvic-fin origin. Anus closer to anal-fin origin than to pelvic-fin origin. Caudal fin forked; tip of lobes pointed; lower lobe slightly longer. Lateral line complete with 37 scales. Circumpeduncular scale rows 12. Predorsal 11 scales regularly arranged same size as flank scales. Chest and belly scaled.

Distribution. *Garra quadratirostris*is widely distributed in Upper Siang, West Kameng, and Papum Pare districts of the upper Brahmaputra basin in Arunachal Pradesh.

Results and Discussion

Nebeshwar & Vishwanath (2013) described *Garra arunachalensis*, *G. birostris,* and *G. quadratirostris* from the Brahmaputra River Drainages of Arunachal Pradesh, India (Figure 4) in having a prominent proboscis, a transverse lobe on the snout with tubercles and black spots on the base of the dorsal-fin rays. *Garra arunachalensis* is distinguished in having a prominent quadrate proboscis with two large unicuspid acanthoid tubercles, one on each anterolateral marginal corner and one small tubercle in between; and in the absence of an anterolateral lobe. *Garra birostris* is distinguished in having a prominent bilobed proboscis with one large tri- or tetracuspid acanthoid tubercle on each lobe, and a distinct black spot at the upper angle of gill opening. *Garra quadratirostris* is distinguished in having a prominent quadrate proboscis with three or four small- to medium-sized tubercles on the anterior margin, and a faint blackish spot immediately anterior to the upper angle of the gill opening.

These three species are abundantly present in various water bodies of the Brahmaputra River drainage of Arunachal Pradesh, India. They slightly differ in their morphological features but certain characters overlap each other. Morphometric measurement values obtained for the three species of *Garra* are shown in Table 1. *Garra arunachalensis* exhibited distinct variations in the morphological character such as head depth, caudal peduncle depth, dorsal fin base length, dorsal fin length, pre pectoral length, eye diameter, and other minor variations in meristic. *G. birostris* shows distinct variations in the morphological character such as head depth, caudal peduncle depth, dorsal fin base length, pelvic anal distance, pre-anus length, vent to anal fin origin pre pectoral length, and a few variations in meristic including caudal peduncle and lateral line scale count. *G. quadratirostris* also depicts distinct variations in the morphological character such as body depth, body width at anal-fin origin, and a few minute variations in meristic including lateral line scale count.

Many fish species are now facing increasing threats by exploitation, pollution, habitat destruction, dispersal barriers, overfishing, and ongoing climatic changes that bring modified novel move variable and extreme condition as well as selection regimes. Changes in the river connectivity associated with removal of dispersal barriers such as dams and construction of fishways together with compensatory breeding and supplemental stalking impact on gene flow and selection. However, this in terms affects dynamics genetic structure, and genetic diversity evolutionary potentials (Tamario *et al.*, 2019). The statement given is true for migratory fishes but this might also importantly factor in evolutionary process for non-migratory fishes like *Garra.* Further, harvesting can induce rapid evolution in animal populations yet the role of economic change in buffering or enhancing that response is poorly understood (Gobin *et al.*, 2018). Human activity can induce rapid evolutionary change in animal populations with resulting ecological consequences and impacts on society (Hendry *et al.*, 2017). Sometimes evolution is also evident owing to heavy pollution and changes in the food habitats. Intensive and trait-selective mortality of fish can cause an evolutionary change in the range of life history and behavior traits. This change might in terms alter the sub-cardian system due to co-evolutionary mechanism and co-related selection response both at behavioral and molecular levels with a note on effects on daily physiological processes and behavior

output (Sbragaglia *et al.*, 2020).

Darwin's competitive speciation of the gradual expansion into a new niche occurs in response to competitive pressure within the old niche. So, the variation observed in the present *Garra* species may lead to a new species in the course of the ontogeny changes. Expansion of the population niche and adaptation to novel resources may result in sympatric speciation. Variations in size and shape may be influenced by various factor which include habitat changes, water temperature, food habitat, genetic variation, maturity, and adaptive characteristics of fishes. Often, this character may lead to species changes and tends to new species. There is the probability that after repeated changes, natural selection of fitness arises. Hence, the reported three species of *Garra* maybe in an evolutionary process, to the patterns of morphological variation in the primary range of the species.

Table 1. Morphometric variation for *Garra arunachalensis*, *G. birostris,* and *G. quadratirostris.*

	Garra arunachalensis		***Garra birostris***		***Garra quadratirostris***	
	ZSI FF 9259	Nebeshwar & Vishwanath (2013)	ZSI FF 9258	Nebeshwar & Vishwanath (2013)	ZSI FF 9258	Nebeshwar & Vishwanath (2013)
Standard Length	152.1-161.8	84-140	117.1-123.4	40-143	117.1-123.4	73-132
% SL						
Body Depth	20.3-28.7	22.3-25.4	18.0-18.2	21.3-24.6	17.6-18.2	20.3-28.2
Head Length	25.1-25.5	24.6-27.1	21.6-22.9	22.8-25.3	24.1-25.3	23.8-26.7
Head Depth	14.9-15.6	17.1-18.8	14.6-15.4	16.8-18.4	15.2-16.6	15.9-18.7
Body width at anal fin origin	8.8-10	9.6-12.6	7.9-10.3	9.7-11.5	7.1-8.8	11.0-12.5
Caudal Peduncle depth	13.1-13.2	11.7-12.9	8.6-12.6	12.7-14.4	12.6-13.4	12.9-14.4
Dorsal-fin base Length	19.7-19.8	16.4-17.6	15.9-16.6	17.5-19.7	16.3-17.2	17.1-18.4
Dorsal-fin Length	25.2-26	16.4-20.1	23.5-25.0	21.7-27	24.0-25.1	24.1-27.1
Pectoral-fin Length	21.6-23.9	22.3-26.5	19.8-20.9	21.0-23.9	13.5-23.8	21.0-24.6
Prepectoral Length	22.1-23.5	21.4-21.9	19.9-21.8	20.5-23.8	21.5-25.0	19.8-23.3
Pelvic-anal distance	24.8-25.3	24.1-26.9	22.8-23.7	25.7-30.0	24.2-25.1	23.7-26.1
Pre anus length	71.1-72.1	69.6-75.0	68.0-69.3	71.1-73.0	67.9-68.7	66.8-72.3
Vent to anal fin origin	19.9-21.5	19.0-25.0	39.7	21-30	37.1-39.6	37-44

Figure 1. *Garra arunachalensis*, ZSI FF 9259, 161.8 mm SL, Siang River near Gobuk village, Upper Siang District, Arunachal Pradesh, India.

Figure 2. *Garra birostris,* ZSI FF 9258, 123.4 SL, Siang River near Gobuk village, Upper Siang District, Arunachal Pradesh, India.

Figure 3. *Garra quadratirostris*, ZSI FF 9260, 95.7, Siang River near Gobuk village, Upper Siang District, Arunachal Pradesh, India.

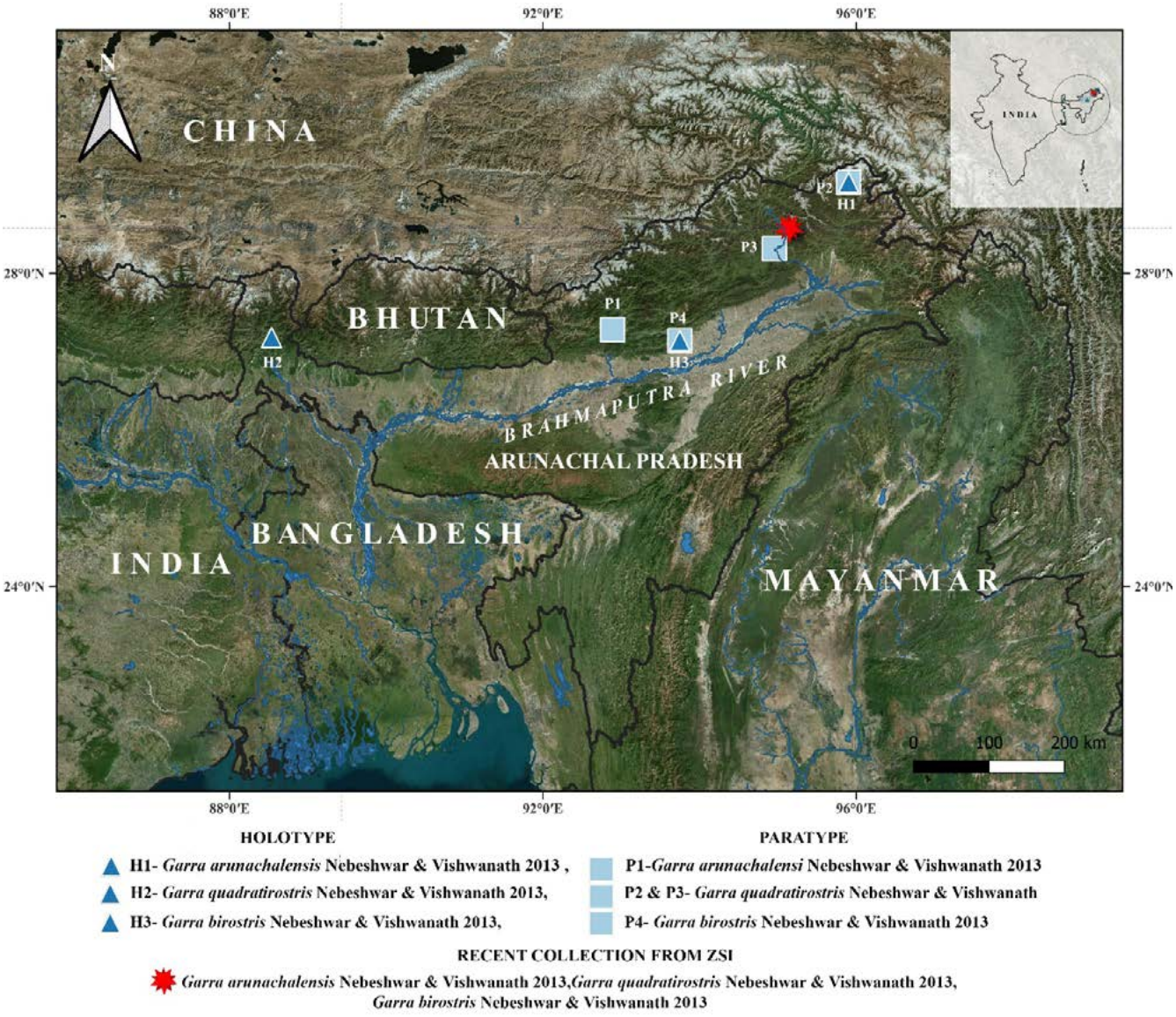

Figure 4. Distributional map of *Garra arunachalensis, G. birostris* and *G. quadratirostris.*

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