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Article

Taxonomic account of genus *Scylla* (de Haan, 1833) from Gujarat State, India with two new records of species

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Abstract
The present study describes the taxonomic account of genus *Scylla* from Gujarat state, India. Specimens of crab were collected from 11 different marine sites/ habitats along the coastal region of the state. Of the several specimens examined on site, 30 morphologically distinct samples were selected for the study, and total 47 different morphological characters were measured. Three different species of genus *Scylla* were identified viz. *Scylla serrata*, *Scylla tranquebarica* and *Scylla Olivacea*. We report *Scylla tranquebarica* and *Scylla Olivacea* for the first time from the state. In general, *S. serrata* is reported as a dominant species with wide spread distribution while rest of the species show patchy distribution.

Keywords *Scylla*; Gujarat; taxonomy; morphology; marine habitat.

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1 Introduction
Mud crabs of genus *Scylla* de Haan, (1883) (Decapoda, Brachyura, Portunidae) are a very important part of marine fisheries resources in many countries for aquaculture purposes (Fukunga and Fukumoto, 1960; Cowan, 1984; Oshiro, 1988). Genus *Scylla* has wide spread distribution in Indo Pacific region from Australia, Japan to South Africa (Chhapgar, 1957; Hill, 1975; Sakai, 1976; Dai and Yang, 1991). Species of the genus *Scylla* inhabit mangrove swamps, estuaries, and intertidal mudflats (Hill, 1980; Keenan, 1999). Taxonomic studies on Genus *Scylla* have created much confusion in the past. Estampador (1949) collected specimens from Philippines and identified three species and one subspecies that included *Scylla serrata*, *Scylla ocenica*, and *Scylla tranquebarica*. Molecular studies of the genus were also carried out and three distinct species *Scylla serrata*, *Scylla ocenica*, and *Scylla tranquebarica* were identified (Fuseya and Watanabe, 1996). In later nineties, Keenan et al. (1998) revised the taxonomy using genetic and morphometric analysis and identified four different species viz. *Scylla serrata*, *Scylla tranquebarica*, *Scylla paramamosain*, and *Scylla Olivacea*. Taxonomic studies on *Scylla* along the Indian coast have suggested the occurrence of two species *Scylla*

serrata and *Scylla tranquebarica* and one subspecies (Alcock, 1899; Kemp, 1915; Gravely, 1927; Chopra and Das, 1937; Pannikar and Aiyar, 1937; Chhapagar, 1957; Radhakrishnan and Samuel, 1982).

Gujarat is the western proximity of India and occupies longest coastline in the country (1650 km). The coastal area has different kinds of marine habitats that include 29% of muddy flats, 28% of sandy beaches, 22% of marshy coast and 21% of rocky coast (Vaghela, 2010). Earlier studies reported 42 species of brachyuran crabs from Gujarat (Chhapagar, 1957). Recent studies from our lab reported 19 species of brachyuran crabs from the Gulf of Kachchh, 25 species from Saurashtra coast and 13 species from Gulf of Khambhat (Trivedi and Vachhrajani, 2012; Trivedi et al., 2012; Shukla et al., 2013). These studies reported occurrence of only one species of genus *Scylla* from the state. Therefore, present study was carried out to check the species diversity and distribution of genus *Scylla* from Gujarat state.

2 Materials and Methods

2.1 Study area

Specimens of crabs were collected from 11 different sites along the coast of Gujarat state, India (Fig. 1). The study sites were selected to cover variety of habitats like rocky shores: 1. Okha (22°28′46″N, 69°04′35″E); 2. Veraval (20°54′37″N, 70°21′04″E); 3. Sutrapada (20°49′53″ N, 70°29′17″E); 4. Dhamlej (20°46′29″N, 70°36′19″E); 5. Kodinar (20°45′29″N, 70°39′39″E), Mudflats; 6. Gopnath (21°12′16″N, 72°06′20″E); 7. Sartanpur (21°16′50″N, 72°06′50″E); 8. Alang (21°25′34″N, 72°13′24″ E); 9. Gogha (21°41′ 05″N, 72°17′33″E) and mangroves: 10. Nada (21°54′38″N, 72°34′43″E), 11. Gandhar (21°54′02″N and 72°37′35″E). The studies were carried out from November 2011 to April 2013.

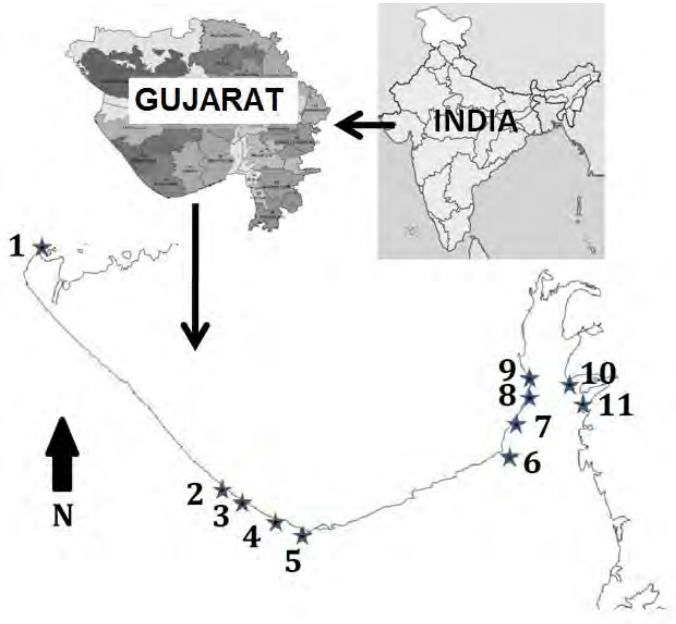

Fig. 1 Map of study area.

2.2 Sampling methods

Hand picking and burrow digging methods were adopted for the collection of the specimens in the field. Local fishermen assisted in collection of crab specimens from mangrove and mudflat regions of different study sites.

During the field surveys at different locations most of the samples observed belonged to *S. serrata* while only a few exhibited character differences. Therefore, few of those different specimens were collected for comparison with the specimen of *S. serrata*. Thirty specimens were selected from the collection and examined for differences in morphological characters. Selected specimens were preserved in 10% formalin, brought to the laboratory for further study, and deposited in the Department of Zoology museum. The specimens were identified to the species level using different identification keys and monograms (Chhapgar, 1957; Sethuramalingam and Khan, 1991; Jeyabaskaran, et al., 2000; Keenan et al., 1998). Total 47 different morphological measurements were recorded using calibrated instruments. For further confirmation of species, all the specimens were examined and compared with the photographs and identification information available on Marine Species Identification Portal website (www.speciesidentification.org) and NIO marine fauna information website (Jeyabaskaran et al., 2002). The classification of brachyuran crabs was adopted from WORMS website (www.marinespecies.org). Principal Component Analysis analysis was carried out to find the species variation on the bases of measurements of different morphological characters.

3 Results

In present study, total three different species belonging to genus *Scylla* were identified that includes *Scylla serrata, Scylla tranquebarica* and *Scylla Olivacea*. Amongst three species identified *Scylla tranquebarica* and *Scylla Olivacea* were reported for the first time from Gujarat state. The detail description about identification and morphometry is discussed below:

Order Decapoda Latreille, 1802

Super family Portunoidea Rafinesque, 1815

Family Portunidae Rafinesque, 1815

3.1 Genus *Scylla* de Haan, 1833

Description

Carapace, glabrous and broader than long; carapace shape oval and slightly convex; carapace surface smooth; grooves of gastro cardiac regions more or less well defined; prominent front separated from supra orbital angles; from divided into four teeth; shape of front teeth varies from rounded lobes to sharp spines; width of the front varies between species; antennal flagellum not excluded from orbits; antero external corner of the third maxilliped rounded; antero lateral margins convex in shape with nine sub equal teeth; anterolateral margins longer than posterolateral margin; posterolateral margins smooth; supra orbital margins ornamented with fissures; infra orbital margins significantly toothed.

Chelipeds massive in shape; longer than walking legs; merus ornamented with three large spines on anterior border and two small spines on the posterior border; carpus with one acute spine present on the inner angle; one to two spines present on the outer margin varying in shape from strong to obsolete; propodus with strong spine on carpal articulation; two spine present above the base of dactylus varying from strong to obsolete in shape.

Walking legs strong and slightly compressed; first three pair of walking legs similar in shape; dactylus of fourth pair peddle shaped; Male abdomen narrow in shape with 3-5 fused segments; female abdomen oval and broad in shape; color of the body and abdomen varies between species (Keenan et al., 1998).

3.2 *Scylla serrata* Forskal, 1775 (Fig. 2a)

Cancer serratus Forskal, 1775: 90.

Portunus serratus Rüppell, 1830: 10, pl. 2.

Portunus (Scylla) serrata de Haan, 1833-1849 (1835): 44.

Achelous crassimanus MacLeay, 1838: 61, Stebbing, 1910: 308.

Scylla tranquebarica var. *oceanica* Dana, 1852c: 270, Dana, 1855: pl. 16, fig. 6a-b

Scylla serrata Milne Edwards A., 1861: 349, Haswell, 1882c: 79., Miers, 1886: 185

Scylla oceanica (not Dana, 1852) Estampador, 1949: 101, pl. 1, fig. 2.

Scylla serrata var. *paramamosain* (not Estampador, 1949) Serène, 1952: 134, fig. 1D, pl. 1, fig. 4, pl. 2, figs 4, D.

Scylla tranquebarica (not Fabricius, 1798) Joel and Raj, 1980: 39, figs 1, 3, 5, 7, 9a-b.

3.2.1 Material examined

3 males and 2 females, Okha fish landing centre (6 October, 2012), 3 males, Sutrapada intertidal area (6 May, 2012), 1 female, Kodinar intertidal area (27 September, 2012); 2 males and 2 females, Ghandhar and Nada mangroves (3 March, 2013); 2 females, Gopnath mangrove area (19 November, 2012); 4 males and 2 females, Sartanpur mud flats (18 November, 2012). Details of morphological measurements are given in Table 1.

Table 1 Morphometric comparison of *Scylla* species.

NO.	Parameters	*Scylla serrata*	*Scylla tranquebarica*	*Scylla olivacea*
Carapace				
1	Carapace width	72.84 ± 24.7	62.62 ± 17.31	125.8 ± 3.38
2	Inner carapace width	69.82 ± 24.64	60.32 ± 17	122.2 ± 3.65
3	Carapace length	49.97 ± 16.8	43.89 ± 13.14	84.12 ± 0.59
4	Posterior carapace width	24.25 ± 8.79	19.77 ± 5.39	37.75 ± 0.68
5	Frontal width	21.83 ± 6.66	18.41 ± 5.85	32.825 ± 3.55
6	Abdominal width	25.375 ± 10.18	19.54 ± 5.59	38.38 ± 1.5
7	Abdominal length	28.42 ± 11.03	25.09 ± 7.79	47.05 ± 0.8
Chelipeds				
8	Merus length	26.42 ± 9.77	21.52 ± 4.69	52.75 ± 1.42
9	Merus depth	13.515 ± 4.82	10.43 ± 2.52	28.895 ± 0.91
10	Carpus length	18.115 ± 5.45	14.57 ± 3.37	41.92 ± 1.35
11	Carpus depth	9.19 ± 2.24	7.76 ± 1.42	23.25 ± 9.34
12	Palm length	46.56 ± 16.16	35.1 ± 7.02	100.765 ± 0.38
13	Palm depth	16.615 ± 5.89	12.18 ± 2.37	47.33 ± 7.11
14	Dactylus length	22.245 ± 6.88	17.75 ± 3.68	45.05 ± 0.36
15	Dactylus depth	6.715 ± 2.46	4.68 ± 1.45	21.54 ± 2.64
Periopod-1				
16	Merus length	25.55 ± 7.58	23.945 ± 3.93	44.55 ± 3.97
17	Merus depth	7.73 ± 3.17	6.84 ± 1.34	13.38 ± 0.48
18	Carpus length	15.2 ± 5.53	13.86 ± 1.35	28.4 ± 3.04
19	Carpus depth	5.08 ± 1.77	4.67 ± 0.7	9.54 ± 0.27
20	Propodus length	18.08 ± 5.74	16.82 ± 2.82	32.91 ± 1.64
21	Propodus depth	5.48 ± 2.41	4.98 ± 1.08	9.74 ± 0.36

22	Dactylus length	18.37 ± 6.55	17.05 ± 2.21	28.99 ± 6.46
23	Dactylus depth	2.95 ± 1.01	2.55 ± 0.48	5.05 ± 0.11
Periopod-2				
24	Merus length	27.81 ± 8.91	24.09 ± 8.2	51.5 ± 1.6
25	Merus depth	8.34 ± 3.3	7.17 ± 2.38	14.48 ± 0.304
26	Carpus length	5.56 ± 5.71	13.49 ± 4.45	32.42 ± 0.92
27	Carpus depth	5.07 ± 1.95	4.31 ± 1.53	10.12 ± 0.21
28	Propodus length	19.98 ± 6.34	16.86 ± 5.46	38.95 ± 0.16
29	Propodus depth	5.14 ± 2.05	4.5 ± 1.55	10.18 ± 0.94
30	Dactylus length	19.36 ± 6.34	17.21 ± 5.4	36.13 ± 1.9
31	Dactylus depth	2.57 ± 1.18	2.36 ± 0.79	5.61 ± 0.02
Periopod-3				
32	Merus length	22.53 ± 7.13	20.61 ± 6.26	41.7 ± 0.41
33	Merus depth	7.71 ± 3.13	6.77 ± 2.07	14.03 ± 0.035
34	Carpus length	12.99 ± 4.16	11.12 ± 3.42	25.54 ± 1.69
35	Carpus depth	4.79 ± 1.79	4.24 ± 1.39	9.88 ± 0.73
36	Propodus length	16.99 ± 5.34	14.54 ± 4.5	32.41 ± 0.26
37	Propodus depth	5.18 ± 2.07	4.59 ± 1.55	10.24 ± 0.46
38	Dactylus length	16.12 ± 4.3	14.18 ± 4.19	30.73 ± 0.06
39	Dactylus depth	2.54 ± 1.11	2.18 ± 0.74	4.93 ± 0.21
Periopod-4				
40	Merus length	12.23 ± 4.43	10.8 ± 3.44	23.29 ± 0.502
41	Merus depth	7.15 ± 2.58	6.4 ± 2.11	13.26 ± 0.53
42	Carpus length	8.66 ± 4.14	6.95 ± 2.31	14.94 ± 0.04
43	Carpus depth	6.23 ± 2.75	5.21 ± 1.81	11.21 ± 2.26
44	Propodus length	17.29 ± 6.28	14.93 ± 5.07	31.54 ± 1.15
45	Propodus depth	10.84 ± 4.73	9.16 ± 3.33	20.27 ± 0.96
46	Dactylus length	21.44 ± 7.34	18.36 ± 6.78	38.68 ± 2.92
47	Dactylus depth	11.13 ± 4.53	9.33 ± 2.87	18.99 ± 0.12

3.2.2 Description

Carapace oval and convex in shape; carapace surface smooth and glabrous; granular lines present on the gastric region and epibranchial region, line originates from last teeth of anterolateral region and ends at branchial region; ″H″ shape groove moderately carved in the centre of the carapace front ornamented with 4 subequal and equally spaced teeth(Fig. 3a); tips of the front teeth high in height and rounded in shape; the interspaces between front teeth rounded; anterolateral borders ornamented with 9 subequal teeth; last teeth is smallest; anterolateral tooth narrow with curved or straight outer margin; Basal antennal joint short and broad

with lobules on antero external angle.

Chelipeds massive and unequal in size (Fig. 4a); merus ornamented with 3 spines and 2 spines on the anterior and posterior region respectively; carpus with strong spine on inner part and small spine on the outer part (Fig. 5a); two distinct spines present on the distal upper part near the insertion of finger; cheliped color ranging from dark green to blue green; polygonal markings present on the chelipeds and female abdomen; fingers straight with slightly rounded claw shape tip; Walking legs strong and slightly compressed, polygonal markings present on the walking legs (Keenan et al., 1998).

Fig. 2 Species diversity of genus *Scylla* (a) *Scylla serrata* (b) *Scylla tranquebarica* (c) *Scylla olivacea*.

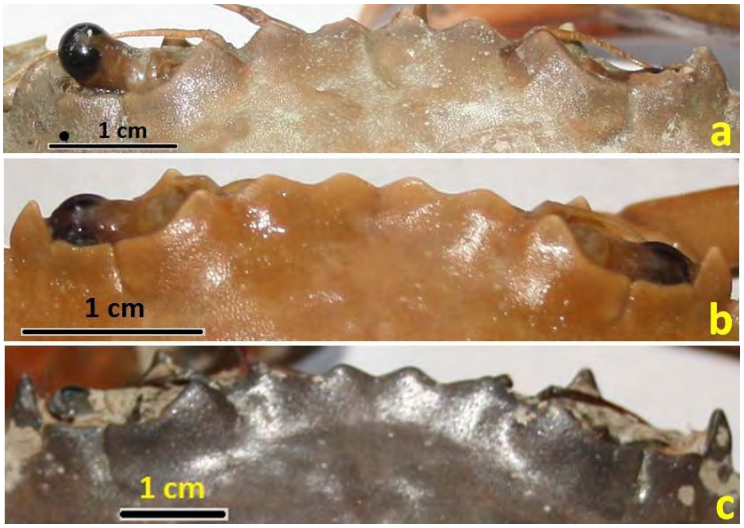

Fig. 3 Variation in shape of the front (a) *Scylla serrata* (b) *Scylla tranquebarica* (c) *Scylla olivacea*.

Fig. 4 Variation in shape and color of the chelipeds (a) *Scylla serrata* (b) *Scylla tranquebarica* (c) *Scylla olivacea*.

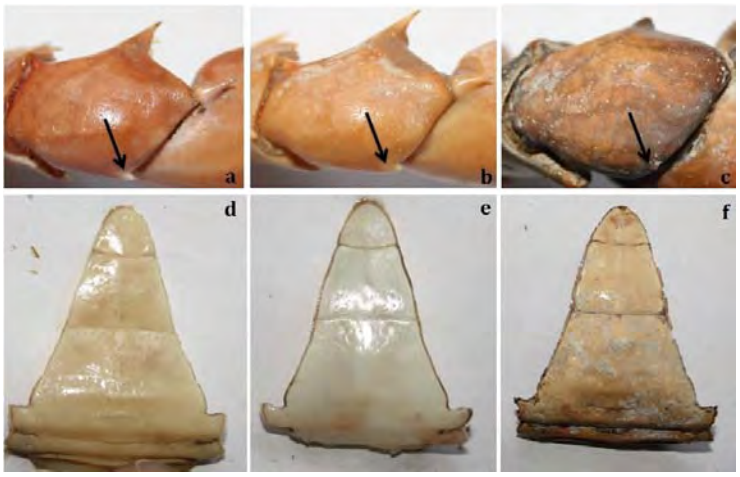

Fig. 5 Variation in spine shape of the crapus (a) *Scylla serrata* (b) *Scylla tranquebarica* (c) *Scylla olivacea* and male abdomen shape (d) *Scylla serrata* (e) *Scylla tranquebarica* (f) *Scylla olivacea*

3.2.3 Remarks

The specimens obtained in the study were showing some variation in the body and chelae color. Normal body and chelae color of *Scylla serrata* is dark green or blue green (Jirapunpipat et al., 2009) but body and chelae color of the collected specimen was observed as greenish orange. Polygonal markings on the legs and chelipeds were observed less prominent in the collected specimens.

In present study, the species was reported from Okha, Sutrapada, Dhamlej, Kodinar, Veraval, Gopnath, Sartanpur, Alang, Ghogha, Ghandhar, and Nada.

3.2.4 Distribution

The species has wide spread distribution ranging from Madagascar to Japan. The species is reported from Yemen (Keenan et al., 1998), Mozambique (Barnard, 1950), South Africa (Mac leay, 1838), Mauritius

(Keenan et al., 1998), Burma (Chopra and Das, 1937), Korea (Kamita, 1941), Taiwan (Sakai, 1939), China (Shen, 1932), Vietnam (Serene, 1952), Singaore (Shen, 1937), Phillippenes (Keenan et al., 1998) and Japan (de Haan, 1835).

In India the species is reported from West Bengal (Nandi and Pramanik, 1994), Orissa (Raj, 2002), Tamilnadu (Serebiah et al., 2008), Andaman and Nicobar islands (Santhankumar et al., 2010), Kerala (Khaleel, 2005), Goa (Padte et al., 2013), Maharashtra (Chhapagar, 1957) and Gujarat (Chhapagar, 1957, Trivedi et al., 2012).

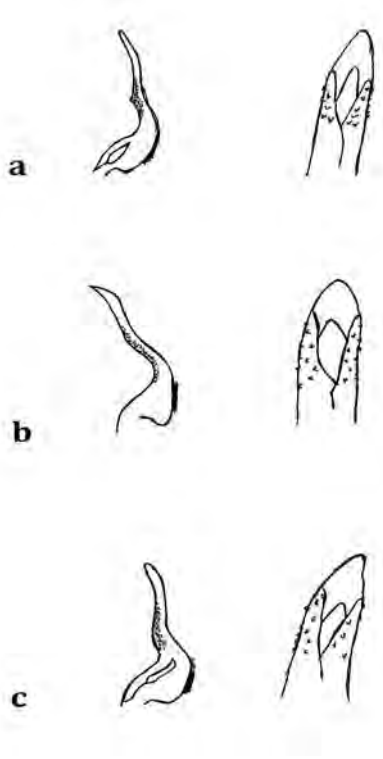

Fig. 6 Variation in shape of the first male gonopod
(a) *Scylla serrata* (b) *Scylla tranquebarica* (c) *Scylla olivacea*.

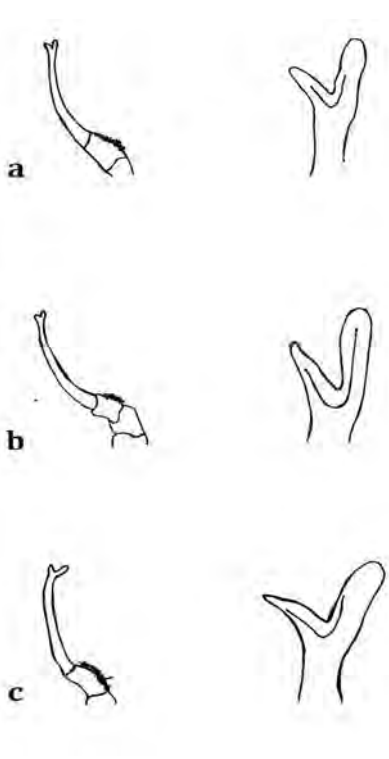

Fig. 7 Variation in shape of second male gonopod
(a) *Scylla serrata* (b) *Scylla tranquebarica* (c) *Scylla olivacea*.

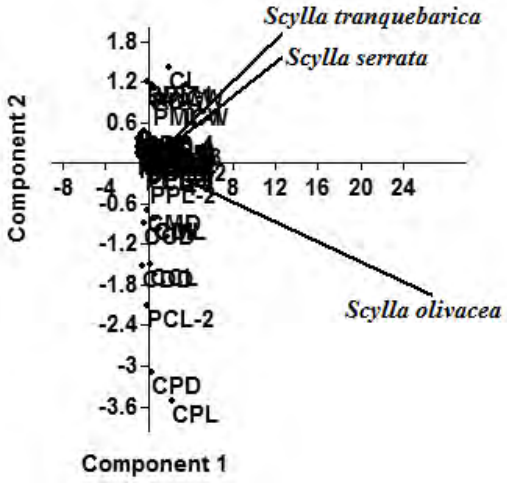

Fig. 8 PCA showing difference between three different species of Scylla.

3.3 *Scylla tranquebarica* Forskal, 1775 (Fig. 2b)

Portunus tranquebaricus Fabricius, 1798: 366.

Lupa tranquebarica Milne Edwards H., 1834: 448.

Lupa lobifrons Milne Edwards H., 1834: 453.

Scylla tranquebarica Dana, 1852c: 270, Estampador, 1949: 103, pl. 3, fig. 1, Serène, 1952: 134, fig. 1B, pl. 1, fig. 2, pl. 2, figs 2, B, Keenan et al., 1998: 230, figs 7B, 8B, 9B, 11, Apel & Spiridonov, 1998: 313, Ng, 1998c: 1118(key), 1128, fig.

3.3.1 Material Examined

Total 2 male, Sartanpur mud flats (18 November, 2012), 1 male and 1 female, Gopnath mangrove area (19 November, 2012), 1 male Sutrapada intertidal area (26 September, 2012). Detail morphological measurements are given in Table 1.

3.3.2 Description

Carapace oval and convex in shape; carapace surface smooth and glabrous; granular lines present on the gastric region and epibranchial region, line originates from last teeth of anterolateral region and ends at branchial region; H-shaped groove moderately carved in the centre of the carapace front ornamented with 4 subequal and equally spaced teeth (Fig.3b); front teeth moderately high in height and rounded in shape; the interspaces between front teeth rounded; anterolateral borders ornamented with 9 subequal teeth; last teeth is smallest; anterolateral tooth broad with convex outer margin; Basal antennal joint short and broad with lobules on antero external angle.

Chelipeds massive and unequal in size (Fig. 4b); merus ornamented with 3 spines and 2 spines on the anterior and posterior region respectively; carpus with strong spine on inner part and small spine on the outer part (smaller than *Scylla serrata*)(Fig. 5b); two distinct spines present on the distal upper part near the insertion of finger (Size of the spine smaller than *Scylla serrata*); cheliped color ranging from purple to dark orange; polygonal markings weak on chelae and first two pair of walking legs; Strong patterning observed on female abdomen and last two pairs of walking legs; fingers straight with slightly rounded claw shape tip (Keenan et al, 1998)

3.3.3 Remarks

The specimens obtained in the study were showing some variation in the body and cheale color. Normal body and chelae color of *Scylla tranquebarica* is olive green or purple green (Jirapunpipat et al., 2009) but body and chelae color of the collected specimen was observed as bright orange. In present study the species was reported from Sutrapada, Gopnath, and Sartanpur.

3.3.4 Distribution

The distribution of the species is ranging from Pakistan to Vietnam. The species is reported from Karanchi (Keenan et al., 1998), Taiwan (Keenan et al., 1998), Philippines (Keenan et al., 1998), Singapore (Dana, 1852), Malaysia and Vietnam (Serene, 1952).

In India the species has wide spread distribution on the eastern coast and some part of western coast. The species is reported from Tamilnadu (Soundarapandian et al., 2008), Orissa (Raj, 2006), Karanataka (Dineshbabu et al., 2011) and West Bengal (Raj, 2010)

3.4 *Scylla olivacea* Herbst, 1796 (Fig. 2c)

Cancer olivaceous Herbst, 1794: 157, pl. 38, fig. 3.

Scylla serrata (not Forskål, 1775) Estampador, 1949: 99, pl. 1, fig. 1, Serène, 1952: 134, fig. 1C, pl. 1, fig. 3, pl. 2, figs 3, C., Joel & Raj, 1980: 39, figs 2, 4, 6, 8, 10a-b.

Scylla olivacea Keenan et al., 1998: 233, figs 7D, 8D, 9D, 14., Apel & Spiridonov, 1998: 314. Jeng et al., 1998, Ng, 1998c: 1118(key), 1127, Sakai K., 1999: 40

3.4.1 Material Examined

Total 4 male, Sartanpur mud flats (18 November, 2012). Detail morphological measurements are given in Table 1.

3.4.2 Description

Carapace oval and convex in shape; carapace surface smooth and glabrous; H-shaped groove prominently carved in the centre of the carapace front ornamented with 4 subequal and equally spaced teeth (Fig.3c) ; front teeth low in height and rounded in shape; the interspaces between front teeth shallow; anterolateral borders ornamented with 9 subequal teeth; last teeth is smallest; anterolateral tooth broad with convex outer margin; Basal antennal joint short and broad with lobules on antero external angle.

Chelipeds massive and unequal in size (Fig.4c); merus ornamented with 3 spines and 2 spines on the anterior and posterior region respectively; no spines present on the inner and outer margin of the carpus (Fig.5c); two blunt spines present on the distal upper part near the insertation of finger (Size of the spine smaller than *Scylla serrata*); cheliped color ranging from red brown to dark brown; polygonal markings not present on any chelipeds, walking legs and female abdomen (Keenan et al., 1998).

3.4.3 Remarks

In the present study, the species was reported from the mangrove areas and mudflats of Sartanpur and Ghaogha areas respectively (The shopkeepers of local fish market collect the species from mangrove areas and mudflats of Sartanpur and Ghaogha study sites only).

3.4.4 Distribution

The distribution of the species is ranging from Asia to Australia. The species is reported from Karanchi, Thailand, China, Taiwan, Malaysia, Philippines, Indonesia, and Australia (Keenan et al., 1998). In India the species is recently reported from Goa, west coast of India (Padte et al., 2013).

4 Discussion

The present study was carried out to map the distribution and species diversity of the genus *Scylla* of Gujarat state, India. The results of the study revealed that Genus *Scylla* of the state contains three distinct species viz. *Scylla serrata*, *Scylla tranquebarica* and *Scylla olivacea*. Amongst the three species reported, *S. serrata* has wide spread distribution in the coastal areas of the state while rest of the two species show patchy distribution. Previously many researchers have studied distinguishing morphological characters for the proper identification of these three species, but due to the close similarities in the morphological characters, it has created huge confusion (Keenan et al., 1998). Joel and Raj (1980) stated that coloration difference between the *Scylla* species cannot be used as major identification character because the coloration in the species varies with the habitat, geographical location and water quality. *Scylla tranquebarica* reported from Pulicat lake shows dark grayish green color (Joel and Raj, 1980) while the specimens of the same species reported from Thailand shows olive green or purplish green color (Jirapunpipat et al., 2008) but in the present study the collected specimens show bright orange coloration. Keenan et al. (1998) have reported that morphological variation in first and second gonopod of males is an important character for the identification of the species. The first gonopod of all three species are almost same in the appearance except the shape of the apex and serration on the outer border. The serration on the outer border is high in *S. serrata* as compared to *S. tranquebarica* and *S. olivacea* (Fig. 6a–c). In the second male gonopod, the apex is divided into two branches and the angle between the branches is the most important character for species identification. The angle between the two branches of the apex is high in *S. olivacea* followed by *S. tranquebarica* and *S. serrata* (Fig. 7–c). Male abdomen also shows variation in shape of different segments in all three species (Fig. 5d–f). Principal component analysis was done to find out the variation between the species based on the morphological measurements and the

results have shown the presence of three different species (Fig. 8).

Joel and Raj (1980) reported that *S. serrata* utilizes a wide range of habitat while rest of the species requires specific kinds of micro habitat for survival. In the present study, it was observed that *S. serrata* lives in the complex system of the burrows in mudflats while on rocky shores it lives in rock crevices. *S. tranquebarica* was mostly observed residing in shallow mud or algal assemblage while *S. olivacea* mostly prefers the deep burrows near mangrove roots. It was observed that surface salinity of the water also play an important role in the distribution of *Scylla* species. Therefore, the effect of abiotic factors on the distribution of all three species in different marine habitats of the state needs to be studied in detail.

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