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Shell Utilization and Size Group Analysis of Two Intertidal Hermit Crabs *Clibanarius infraspinatus* and *Diogenes avarus* (Decapoda: Anomura) From Kathiawar Peninsular Coast of Gujarat, India

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ABSTRACT

Present study reports the shell utilization in relation to the body size of two hermit crab species that live in the same habitat and share the similar gastropod shell resources. The study was conducted at a rocky-muddy intertidal coast of western India where the gastropod shell resource for the hermit crabs is scanty. The hermit crabs *Clibanarius infraspinatus* and *Diogenes avarus* were collected and assigned to one of the three sized classes based on total body length of the hermit crab. Belt transect method was followed on monthly basis from January 2013 to December 2013. The parameters measured were: species of gastropod shell in which hermit crab resided, shell mass-length-width, shell aperture length and width, hermit crab species, mass and length of hermit crab, length of cephalic region, length of abdomen. Results revealed that *C. infraspinatus* and *D. avarus* were found inhabiting in the shells of 9 and 19 gastropod species respectively. Results revealed that 78% of *C. infraspinatus* selected the shells of *Calliostoma tranquebarica* followed by 9% *Trochus radiatus* and 1% *Cerithium scabridum* while 12% *C. infraspinatus* was also found in other shell species. 32% of *D. avarus* selected the *C. scabridum* shell followed by 26 % *Cerithium rubes*, 14% *Cerithium morus,* 11% *C. tranquebarica,* 5% *T. radiatus while* 12% *D. avarus* was also found in other shells. The exhibited shell utilization clearly indicated that larger animal size is a disadvantage for the sustainability of the population due to lack of big sized gastropod shells in the studied muddy shore. Demand for the large gastropod shells lead to both intra and interspecific competition. This study provides important ecological information supported by statistical validation on hermit crab shell utilization of the studied muddy intertidal zone.

Key Words: Morphometry; Shell Utilization; Muddy Shore; Western India; Shell Resource

INTRODUCTION

Hermit crabs are common inhabitants of coastal areas particularly the intertidal and sub-tidal zones where they represent a significant portion of the macro-benthic assemblage. Hermit crabs are represented by approximately 2002 described species worldwide (Appeltans et al. 2012). Hermit crabs depend on empty gastropod shells to protect themselves against physical stress and predation (Bertness 1982). The pattern of shell usage is known to be dependent on shell availability (Argüelles-Ticó et al. 2010, Arce and Alcaraz 2011) and shell preference (Meireles et al. 2008). Hermit crabs choose shells according to species or shape (Sato and Jensen 2005, Mantelatto et al. 2007), size (Hazlett 1992), shell condition (Pechenik et al. 2001), the previous experience of the crab (Alcaraz and Kruesi 2009), and the developmental and reproductive stage of the crab (Elwood et al. 1979). To eke out a life inside the empty gastropod shell, they have modified their body form to suit the shape of the shell (Ramesh et al. 2009). This behaviour of hermit crabs living in empty gastropod shells has intrigued naturalists down through the ages from Aristotle (Thompson 1910) to the present (Turra and Leite 2002, Raval 2015). Vance (1972) proved this experimentally by adding empty gastropod shells which increased the number of hermit crabs subsequently. More than 170 species from around the world are currently assigned to the genus *Pagurus* (Lemaitre and Cruz Castaño 2004, Mantelatto et al. 2009, McLaughlin et al. 2010). This genus is complex because there is high morphological variability and similarity among some species, and has it been divided in groups (eg., Ingle 1985 for European species and, Lemaitre and Cruz Castaño 2004 for eastern Pacific species) with difficulty (Ayón-Parente and Hendrickx 2012). This difficulty has led to taxonomic problems; although molecular techniques have been recently used to elucidate some species (Da Silva et al. 2011). Shells are the major limiting factor for hermit crab population. Shell availability has been demonstrated to be an important limiting factor in hermit crab populations (Shih and Mok 2000). The majority of hermit crabs found on the seashore are not housed in their preferred shell but inhabit shells that are either too small or too big, supporting the suggestion that adequate shells are a limiting factor for hermit crab populations (Michael 2013). The abundance of shells seems to be the major factor influencing shell utilization (Barnes 1999). Hermit crabs occupy empty gastropod shells, and these shells act as shelters from biotic factors including predation (Leonard et al. 2001) and abiotic factors such as desiccation (Brodie 1999) and osmotic stress (Pechenik et al. 2001). Marine species commonly found in low water dynamic environments, opportunistic species with different degrees of tolerance to organic enrichment, and typical brackish water species (Pati et al. 2015). By knowing a hermit crab's shell affection, the dynamics of hermit crab interactions among a species can be better reviled for shell choice and exchanges. The study of shell selection of hermit crab is crucial to know about hermit crabs ecology. Shell availability directly influences the hermit crab population. On the base of such study further hypothesis for hermit crabs can be formulated like for trend of increasing or decreasing populations, anthropogenic pressure, reproductive behavior and opportunistic behaviour. Alvarez et al. (2015) found the potential risk of atrazine for crustacean reproduction, both in terms of altered ovarian maturation and abnormal hatched larvae. According to Takeuchi et al. (2015) the burrowing ability can be one key trait for success or failure in the population establishment of clam species in an area with shifting sediment on intertidal sand flats. Present study reports the shell utilization in relation to the body size of two hermit crab species that live in the same habitat and share the same gastropod shell resource.

MATERIALS AND METHODS

Hermit crabs *Clibanarius infraspinatus* and *Diogenes avarus* (Decapoda: Anomura) and the gastropod shells occupied by them were studied every month from January 2013 to December 2013 at the coastal Gujarat, India, which occupies a total of 865 km coastal extend that provides diverse range of habitats (Raval 2011). The site, Koliyak (20° 35′ 51.226" N, 72° 17′ 33.259") is 30 km away from Bhavnagar city, Gujarat state (Figure 1). The entire intertidal zone of this area was surveyed beforehand. The coastline studied is muddy-rocky having calcareous eruptions. The site is predominantly muddy with scattered algal growth, sandy slopes and a lesser amount of pools and puddles. The upper intertidal zone is composed of sandy-muddy substratum. The intertidal area was frequently surveyed at regular intervals during the lowest tides. Belt transect method was followed for the collection of ecological data whereas random quadrat method (Misra 1968) was used to analyse the structural attributes of the intertidal fauna. Quadrats measuring 50 ×50 cm were laid by following an oblique direction to

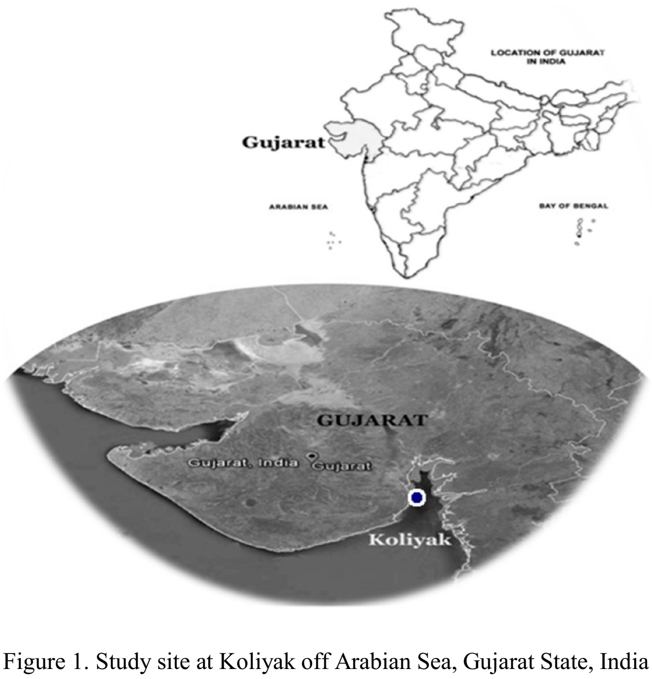

Figure 1. Study site at Koliyak off Arabian Sea, Gujarat State, India

cover maximum area on the intertidal zones. Fifty quadrats were laid every month starting from spray zone to lowest low tide mark. *In situ* photographs of live specimens were taken and voucher specimens of the species were collected for further identification. A total of 67 *Clibanarius infraspinatus* and 325 *Diogenes avarus* individuals were examined. Encountered hermit crab species and gastropod shells were identified up to species level by comparing differences in morphology, size, structure, patterns and color with available identification keys (Apte 1998), literature available in the form of books, manuals, research articles, and with help of specialized websites (WoRMS - World Register of marine Species). Shell lengths were measured manually by Warner caliper (±0.1 mm) and shells were weighed on a plate balance (accuracy ±0.1 g). Detailed data like gastropod shell in which hermit crab resided, hermit crab species, quadrat number, number of hermit crabs in a quadrat, mass of each hermit crab, mass of each shell utilized by that hermit crab, total mass of each hermit crab and shell utilized, shell length and width, length and width of hermit crab, lengths of cephalic region, abdomen, walking legs, right and left chelipad, shell aperture length and width and gastropod species were recorded. This study focused on *C. infraspinatus* and *D. avarus* two common species of hermit crab that are widely distributed throughout the intertidal and shallow sub-tidal waters. In the region both the species coexist and exhibit partial resource competition for the shells. The two species demonstrate some degree of microhabitat partitioning occupying upper intertidal areas comprising coarse sand, rocky substrates and muddy substrates characteristic of lower intertidal areas. It is noteworthy that the study area is not included in any notified or protected region as well as the species under consideration are not categorized for protection. Individual *C. infraspinatus* and *D. avarus* were collected and assigned to one of three size classes based on total body length of the hermit crab. The size classes for *C. infraspinatus* were: 15-25 mm (s1), 26-31 mm (s2) and 32-47 mm (s3), and for *D. avarus* the size classes were: 3-9 mm (s1), 10-15mm (s2) and 16-30 mm (s3).

RESULTS AND DISCUSSION

The results for population density of gastropod species (Figure 2) reveal that *Cerithium scabridum* displayed maximum density followed by *Calliostoma tranquebarica, Cerithium rubes, Cerithium morus, Trochus radiates,* and others. The other species of gastropod had a low occurrence. These gastropods of low frequency, grouped together as "Others" in the present communication, included 18 species: *Architectonica laevigata, Bursa granularis, Cantharus spirailis, Cerithidea cingulata, Epitonium lineolatum, Littorina intermedia, Littorina undulate, Lunella coronata, Nassarius eranea, Nassarius stolatus, Nassarius sufflatus, Nerita oryzarum, Planaxis sulcatus, Polia rubigenosa, Rhinoclavis sinensis, Thais lacera, Trochus niloticus* and *Turitella terebra.*

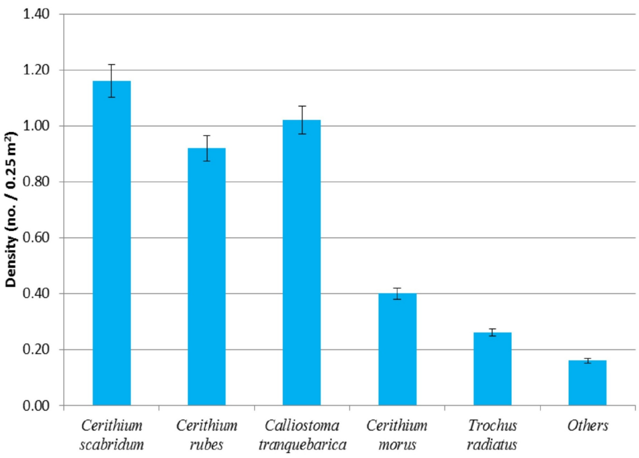

Figure 2. Overall density of gastropod species in the study area.

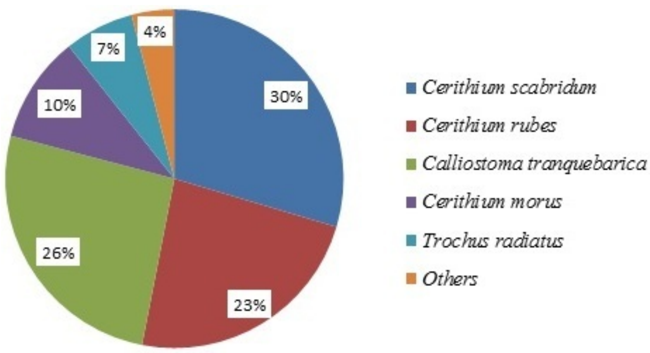

Figure 3. Composition of the gastropod community at the study site.

The following findings are based on initial survey of gastropod shells performed before the starting of the study (Figure 3). Out of total gastropod shells encountered, 30% were of *Cerithium scabridum*, 26% *Calliostoma tranquebarica,23% Cerithium rubes, 10% Cerithium morus, 7% Trochus radiates,* and 4% Others. A total of 392 hermit crabs were studied which includes 325 *Diogenes avarus* and 67 *Clibanarius infraspinatus* individuals. Morphometric details of shells selected by

Table 1. Morphometric details of shell selected by *Clibanarius infraspinatus*.
Names of the species follow WoRMS (November 2016).

Gastropod species	N	%	Shell Length (mm)	Shell Width (mm)	Hermit crab Mass (g)	Shell Mass (g)	Hermit crab Length (mm)
Size group 1 - s1c 15 to 25 mm							
Calliostoma tranquebaricum (Roding, 1798)	17	70.83	14-22	14-20	0.12-0.85	0.80-2.93	15-25
Cantharus spiralis (Gray, 1839)	2	8.33	20-21	15	0.22-0.38	1.44-2.62	17-19
Cerithium scabridum (Philippi, 1848)	1	4.17	24	12	0.18	1.04	24
Nerita oryzarum (Recluz, 1841)	1	4.17	23	18	1.06	3.66	25
Trochus cariniferus (Reeve, 1842)	3	12.50	17-22	16-19	0.11-0.41	1.19-2.13	15-22
Size group 2 - s2c 26 to 31 mm							
Calliostoma tranquebaricum (Roding, 1798)	15	75	18-26	13-23	0.12-0.90	1.33-2.42	27-31
Nassarius stolatus (Gmelin, 1791)	1	5	30	18	0.60	2.01	28
Tectus niloticus (Linnaeus, 1767)	1	5	18	18	0.72	1.86	30
Trochus cariniferus (Reeve, 1842)	3	15	17-22	17-20	0.52-0.93	1.78-3.16	28-31
Size group 3 - s3c 32 to 47 mm							
Bursa granularis (Roding, 1798)	1	4.35	30	20	0.63	1.50	35
Calliostoma tranquebaricum (Roding, 1798)	20	86.96	17-28	12-25	0.30-1.10	1.50-5.20	32-47
Cantharus spiralis (Gray, 1839)	1	4.35	25	18	0.50	3.81	32
Indothais lacera (Born, 1778)	1	4.35	32	22	1.07	4.69	42

Clibanarius infraspinatus and *Diogenes avarus* are shown in Tables 1 and 2 respectively, which elaborate the significant measurements of hermit crab and gastropod shells for all six size groups. Shell utilization of *Diogenes avarus* (Figure 4a) shows the shell selection frequency by *D. avarus* including others indicating that *Polia rubigenosa, Nassarius eranea, Lunella coronate, Littorina undulate, Epitonium lineolatum and Bursa granularis* had only 0.31% frequency. Figure 4b shows the shell utilization of *C. infraspinatus.* It was not found in the shell of *Cerithium rubes* and *Cerithium morus.* Figure 4b indicates that *Trochus niloticus, Thais lacera, Nerita oryzarum, Nassariusstolatus and Bursa granularis* had a frequency of 1.49% among others. Figure 4c shows the total shell utilization of *D. avarus* and *C. infraspinatus* together.

Figure 5a shows the shell utilization of *D. avarus* with three size groups. For other species, 20 hermit crabs were of s1, 9 of s2 and 10 of s3 size group. Shell utilization by three size groups of *Clibanarius infraspinatus* is shown in Figure 5b, and that of *D. avarus* and *C. infraspinatus* in Figure 5c. Figure 6a reveals the *Cerithium scabridum* shell utilization by *D. avarus* and *C. infraspinatus* for all 12 months and three size groups. In winter months, neither *D. avarus* nor *C. infraspinatus* had selected the *C. scabridum* shell (with single excep-

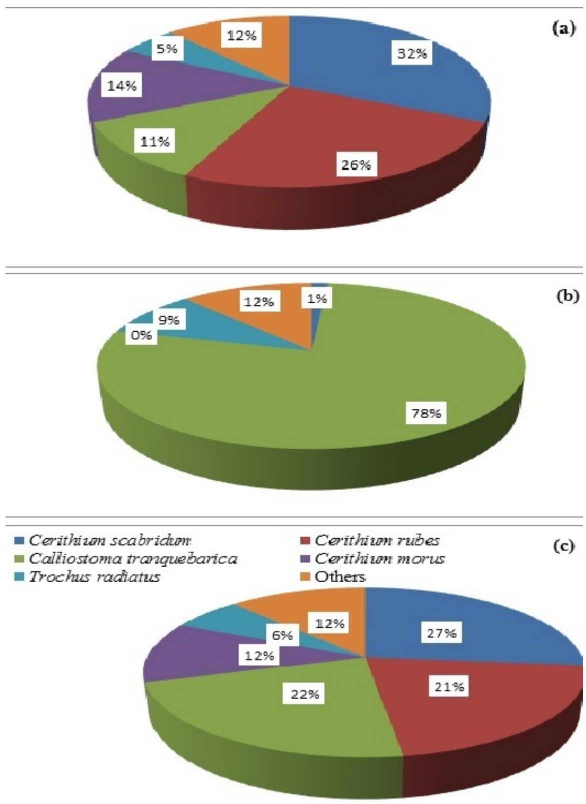

Figure 4. Shell utilizations of the two hermit crabs (a) *D. avarus* and (b) *C. infraspinatus* whereas, (c) denotes the shell utilizations by both the species combined.

tion of *D. avarus*). *Cerithium rubes* shell utilization by *D. avarus* and *C. infraspinatus* for all the twelve months and three size groups (Figure 6b) shows that in monsoon (with two exceptions of *D. avarus*) and early post-monsoon neither *D. avarus* nor *C. infraspinatus* had selected the *Cerithium rubes*. For s1z, s2z and s3z, no *C. infraspinatus* had selected the *C. rubes* shell in any of the seasons. Figure 6c shows the *Calliostoma tranquebarica* shell utilization by *D. avarus* and *C. infraspinatus* for all the months and three size groups. Utilization of

Table 2. Morphometric details of shell selected by *Diogenes avarus*. Names of the species follow WoRMS (November 2016).

Gastropod species	N	%	Shell Length (mm)	Shell Width (mm)	Hermit crab Mass (g)	Shell Mass (g)	Hermit crab Length (mm)
Size group 1 - s1d 3 to 9 mm							
Architectonica laevigata (Lamarck, 1816)	6	6.25	3-6	3-5	0.005-0.010	0.015-0.100	4-7
Calliostoma tranquebaricum (Roding, 1798)	5	5.21	2-9	2-5	0.005-0.03	0.005-0.15	3-8
Pirenella cingulata (Gmelin, 1791)	1	1.04	10	6	0.010	0.120	9
Cerithium morus (Bruguiere, 1792)	17	17.71	3-14	3-9	0.005-0.03	0.025-0.41	5-9
Cerithium rubus (Deshayes, 1843)	33	34.38	3-15	2-8	0.005-0.04	0.005-0.32	3-9
Cerithium scabridum (Philippi, 1848)	18	18.75	3-15	2-7	0.005-0.03	0.005	3-9
Epitonium lineolatum (G. B. Sowerby, 1844)	1	1.04	4	2	0.005	0.010	5
Littoraria intermedia (Philippi, 1846)	3	3.13	6-8	4-6	0.005-0.01	0.005	6-8
Littoraria undulata (Gray, 1839)	1	1.04	4	3	0.005	0.150	7
Nassarius sp. (Gmelin, 1791)	1	1.04	13	5	0.020	0.160	9
Nassarius sufflatus (Gould, 1860)	1	1.04	15	6	0.010	0.170	9
Pollia rubiginosa (Reeve, 1846)	1	1.04	6	4	0.005	0.030	6
Rhinoclavis sinensis (Gmelin, 1791)	1	1.04	4	4	0.010	0.060	7
Trochus cariniferus (Reeve, 1842)	4	4.17	4-5	1-6	0.005-0.01	0.005-0.08	3-8
Turritella terebra (Linnaeus, 1758)	3	3.13	8-14	3-5	0.005-0.010	0.03-0.080	7
Size group 2 - s2d 10 to 15 mm							
Architectonica laevigata (Lamarck, 1816)	2	1.45	9	8	0.020-0.040	0.070-0.150	12-13
Calliostoma tranquebaricum (Roding, 1798)	10	7.25	7-16	4-14	0.020-0.180	0.080-1.010	10-15
Pirenella cingulata (Gmelin, 1791)	2	1.45	10-15	4-9	0.011-0.090	0.060-0.410	10-12
Cerithium morus (Bruguiere, 1792)	21	15.22	10-18	5-10	0.010-0.090	0.130-0.650	10-15
Cerithium rubus (Deshayes, 1843)	39	28.26	8-20	5-12	0.010-0.110	0.080-0.810	10-15
Cerithium scabridum (Philippi, 1848)	56	40.58	7-20	4-32	0.010-0.110	0.039-0.630	10-15
Lunella coronata (Gmelin, 1791)	1	0.72	28	7	0.040	0.310	14
Planaxidae sp. (Gray, 1850)	2	1.45	14-16	7-8	0.030-0.050	0.280-0.570	11-14
Trochus cariniferus (Reeve, 1842)	4	2.90	8-15	7-12	0.010-0.12	0.170-0.380	10-15
Turritella terebra (Linnaeus, 1758)	1	0.72	23	7	0.070	0.320	12
Size group 3 - s3d 16 to 30 mm							
Bursa granularis (Roding, 1798)	1	1.10	25	15	0.130	0.960	18
Calliostoma tranquebaricum (Roding, 1798)	21	23.08	10-22	10-20	0.080-0.420	0.370-2.540	16-27
Cantharus spiralis (Gray, 1839)	2	2.20	10-20	6-12	0.060-0.200	1.040-1.400	17-19
Cerithium morus (Bruguière, 1792)	8	8.79	15-20	9-12	0.040-0.100	0.380-0.800	16-18
Cerithium rubus (Deshayes, 1843)	13	14.29	14-18	6-15	0.030-0.230	0.240-1.060	16-25
Cerithium scabridum (Philippi, 1848)	29	31.87	10-25	6-17	0.020-0.160	0.220-1.400	16-30
Nassarius sufflatus (Gould, 1860)	1	1.10	19	9	0.080	0.500	21
Planaxidae sp. (Gray, 1850)	3	3.30	17-18	9-15	0.060-0.170	0.470-1.000	17-18
Rhinoclavis sinensis (Gmelin, 1791)	1	1.10	18	12	0.080	0.600	20
Trochus cariniferus (Reeve, 1842)	10	10.99	10-20	8-18	0.050-0.400	0.400-1.620	17-25
Turritella terebra (Linnaeus, 1758)	2	2.20	22-28	8	0.050-0.060	0.250-0.320	18

Cerithium morus and *Trochus radiates* shells by *D. avarus* and *C. infraspinatus* for all the months and three size groups is shown in Figures 6d and 6e respectively. In monsoon (with one exception of *D. avarus* and one of *C. infraspinatus*) and post-monsoon neither *D. avarus* nor *C. infraspinatus* had selected the *T. radiatus*. Figure 6f shows the shell utilization by *D. avarus* and *C. infraspinatus* for all the 12 months and three size groups each for "Others" shells.

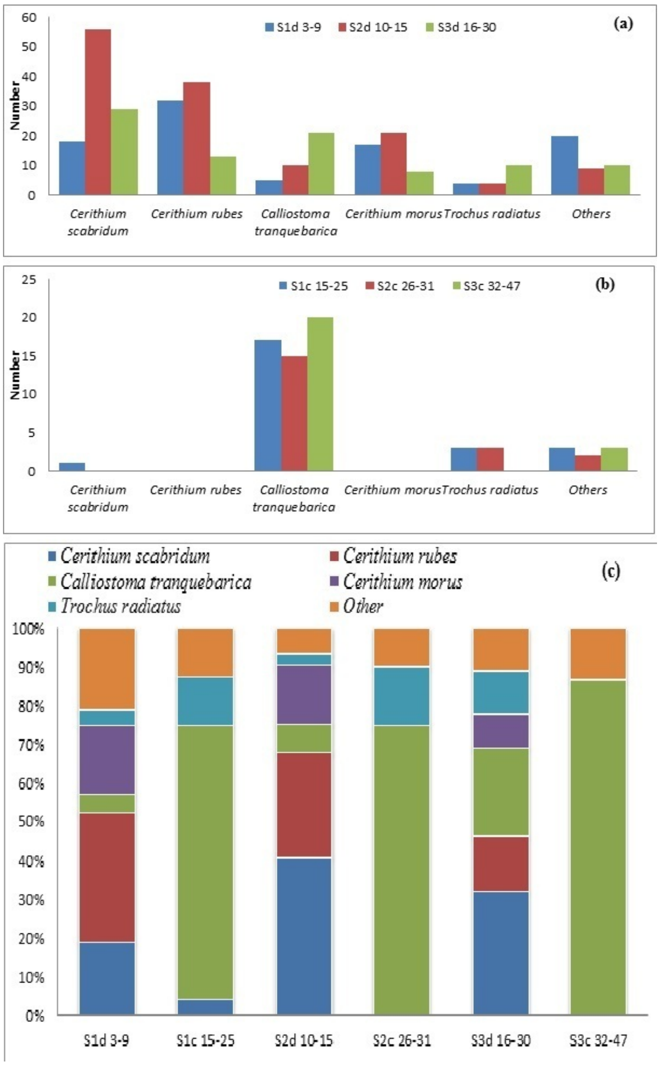

Figure 5. Size-group wise shell utilizations of the two hermit crabs. (a) *D. avarus* and (b) *C. infraspinatus* whereas, (c) denotes the shell utilizations by both the species combined.

The present study reveals that *Calliostoma tranquebarica* was preferred shell by both the species all through the year, possibly due to the availability of this shell throughout the study period. *T. radiatus* was used

Table 3. Comparison of shell utilization by *Diogenes avarus* and *Clibanarius infraspinatus*. Names of the species follow WoRMS (November 2016).

Gastropod species	*D. avarus* %	*C. infraspinatus* %
Size group 1	3 to 9 mm	15 to 25 mm
Architectonica laevigata (Lamarck, 1816)	6.25	-
Calliostoma tranquebaricum (Roding, 1798)	5.21	70.83
Cantharus spiralis (Gray, 1839)	-	8.33
Pirenella cingulata (Gmelin, 1791)	1.04	-
Cerithium morus (Bruguiere, 1792)	17.71	-
Cerithium rubus (Deshayes, 1843)	34.38	-
Cerithium scabridum (Philippi, 1848)	18.75	4.17
Epitonium lineolatum (G. B. Sowerby, 1844)	1.04	-
Littoraria intermedia (Philippi, 1846)	3.13	-
Littoraria undulata (Gray, 1839)	1.04	-
Nassarius sp. (Gmelin, 1791)	1.04	-
Nassarius sufflatus (Gould, 1860)	1.04	-
Nerita oryzarum (Recluz, 1841)	-	4.17
Pollia rubiginosa (Reeve, 1846)	1.04	-
Rhinoclavis sinensis (Gmelin, 1791)	1.04	-
Trochus cariniferus (Reeve, 1842)	4.17	12.50
Turritella terebra (Linnaeus, 1758)	3.13	-
Size group 2	10 to 15 mm	26 to 31 mm
Architectonica laevigata (Lamarck, 1816)	1.45	-
Calliostoma tranquebaricum (Roding, 1798)	7.25	75
Pirenella cingulata (Gmelin, 1791)	1.45	-
Cerithium morus (Bruguiere, 1792)	15.22	-
Cerithium rubus (Deshayes, 1843)	28.26	-
Cerithium scabridum (Philippi, 1848)	40.58	-
Lunella coronata (Gmelin, 1791)	0.72	-
Nassarius stolatus (Gmelin, 1791)	-	5
Planaxis sulcatus (Born, 1778)	1.45	-
Tectus niloticus (Linnaeus, 1767)	-	5
Trochus cariniferus (Reeve, 1842)	2.90	15
Turritella terebra (Linnaeus, 1758)	0.72	
Size group 3	16 to 30 mm	32 to 47 mm
Bursa granularis (Roding, 1798)	1.10	4.35
Calliostoma tranquebaricum (Roding, 1798)	23.08	86.96
Cantharus spiralis (Gray, 1839)	2.20	4.35
Cerithium morus (Bruguiere, 1792)	8.79	-
Cerithium rubus (Deshayes, 1843)	14.29	-
Cerithium scabridum (Philippi, 1848)	31.87	-
Nassarius sufflatus (Gould, 1860)	1.10	-
Planaxis sulcatus (Born, 1778)	3.30	-
Rhinoclavis sinensis (Gmelin, 1791)	1.10	-
Indothais lacera (Born, 1778)	-	4.35
Trochus cariniferus (Reeve, 1842)	10.99	-
Turritella terebra (Linnaeus, 1758)	2.20	-

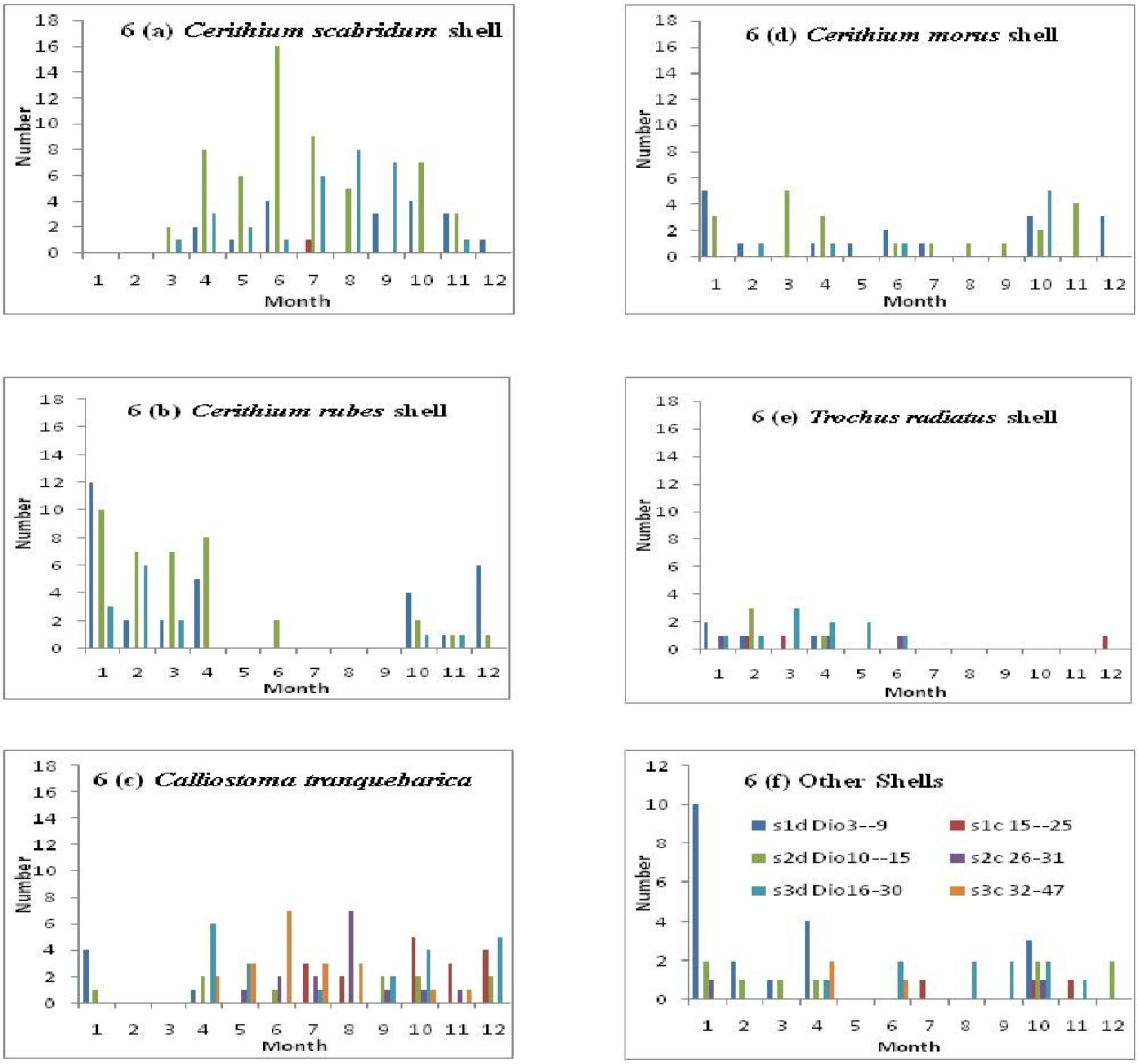

Figure 6. Monthwise and size group wise shell utilization of the two hermit crabs (a) *Cerithium scabridum* shell, (b) *Cerithium rubes* shell, (c) *Calliostoma tranquebarica* shell, (d) *Cerithium morus* shell, (e) *Trochus radiatus* shell (f) Other shells

during the winter and summer seasons only while *Cerithium scabridum* was used in summer and monsoon only. Utilizations of *Cerithium morus* shell was more or less similar throughout the year while that of *Cerithium rubes*shell was confined to winter, early summer and post monsoon seasons only. Both the species were also found in other gastropod shells in all the seasons. Gastropod species wise and size wise comparison of shell utilization by *D. avarus* and *C. infraspinatus* is represented in Table 3.

The study shows that majority of *D. avarus* selected the shell of *C. scabridum* followed by *C. rubes*. Shells of nineteen gastropod species were selected by *D. avarus,* of which first size group (3 to 9 mm) had selected fifteen, second size group (10-15 mm) had selected ten and third size group (16-30 mm) had selected shells of eleven gastropod species. Majority of *C. infraspinatus* selected the *C. tranquebarica* shell though shells of nine gastropod species were selected by *C. infraspinatus*. First size group (15 to 25 mm) had selected five, second size group (26-31 mm) had selected four and third size group (32-47 mm) had selected shells of four gastropod species. Similar results were obtained in other studies. *C. erythropus* was reported to utilize 19 species of gastropod shells (Botelho and Costa 2000). *D. moosai* and *D. lopochir* utilized the shells of 14 gastropod species but only four shell species were frequently utilized, or with more than 20% shell occupancy; these were *C. cingulata, N. jacksonianus, N. cf. olivaceus and T. malayensis* (Teoh and Chong 2014). Earlier studies on intertidal hermit crabs revealed that the crabs prefer to occupy shells of certain gastropod species to others, a utilization not necessarily based on previous experience with these shell species but on certain shell properties that vary among gastropod species (Ismail 2010). *Calcinus latens* occupied shells of 20gastropod genera represented by 30 species. The main gastropod genera occupied by *C. laten* were *Strombus* (32.8%), *Nerita* (18.2%) and *Cerithium* (12.6%). On the other hand, the highest occupation of common shells recorded 25.59% for *S. mutabilis*, followed by 11.46% for *N. albicilla*, 8.01% for *C. caeruleum* and 6.75% for *Neritapolita*. Also, *S. mutabilis* occupation showed a high significance than the remaining shell species. *C. signatus* occupied shells of 17 gastropod genera represented by 26 species. The main gastropod genera occupied by *C. signatus* were *Cerithium* (29.09%), *Nerita* (16.25%) and *Planaxis* (10.25%), respectively. The highest occupation of common shells recorded 17.18% for *C. caeruleum*, followed by 10.25% for *P. sulcatus*, 9.42% for *N. albicilla* and 8.18% for *Cerithium scabridum*. Occupation of gastropod *C. caeruleum* showed a high significance than the remaining shell species (Ismail 2010). *Pagurus criniticornis* utilized the shells of *Cerithium atratum* and *Olivella minuta* (Dominciano et al. 2009). Differences in shell use among sites have also been recorded for *Pagurus longicarpus* (Scullz 1979), *Clibanarius erythropus* (Botelho and Costa 2000; Benvenuto and Gherardi 2001), *Clibanarius antillensis* (Leite et al. 1998), *P. criniticornis* (Leite et al. 1998), *P. brevidactylus* (Leite et al. 1998), *Paguris testortugae* (Leite et al. 1998), and *Pagurus exilis* (Mantelatto et al. 2007).

Hermit crabs show a tendency to use the shells of the most abundant coexisting gastropods, revealing the importance of shell availability in shaping their shell utilization patterns (Reese 1969). The cost for a shell change behavior and the probability of its success has no relation to the optimal timing for the shell change, while with the small cost for a shell change, the optimality itself is high. Sufficiently large probability of the successful shell change could make the shell change behavior optimal. Hermit crabs choose shells based on a wide variety of features, including shell configuration, aperture size, and shell mass/crab mass and shell mass/shell volume indices (Grant and Ulmer 1974). Considering gastropod shells are very important to the hermit crabs' growth rate, reproduction, and population size, the ability of obtaining a shell as quickly as possible is crucial (Fotheringham 1976).The knowledge of utilization for shells is essential to understand the interactions of the hermit crab and the shell-use pattern in the wild (Arce and Alcaraz 2012).

CONCLUSION

The present study concludes that both *C. infraspinatus* and *D. avarus* showed marked shell utilization in the rocky-muddy shoreline of the west coast of India depending on their body size and the availability of preferred shell. However, *C. infraspinatus* was rather choosy in the selection of the shell as it resided in the shell of fewer gastropod species than *D. avarus*. It is possible that because *D. avarus* was the dominant species of this coastline, the interspecific competition restricted *C. infraspinatus* from occupying greater verities of shells. Various other factors like availability of appropriate shell, shell morphology, intra-specific and inter-specific competition, seasonal effect and prior experience of the shell species may also be responsible for shell utilization preference of the hermit crab species.

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