Indian Journal of Geo Marine Sciences
Vol. 53 (10), October 2024, pp. 669-678
DOI: 10.56042/ijms.v53i10.13187

Research Article

Feeding traits and diet diversity of *Heterocarpus chani* Li, 2006 (Decapoda: Caridea: Pandalidae) from southeastern Arabian Sea

R D Chakraborty*, A P Gayathri, G Kuberan, L Sreesanth, N Ragesh & A P Dineshbabu

Shellfish Fisheries Division, Central Marine Fisheries Research Institute, Ernakulam North, P.O., P.B. No. 1603, Cochin, Kerala – 682 018, India

*[E-mail: rekhadevi7674@gmail.com]

Received 16 August 2024; revised 22 October 2024

A comprehensive exploration into the diet diversity and feeding strategy of the deep-sea shrimp, *Heterocarpus chani*, involved the analysis of 274 specimens gathered from the southeastern Arabian Sea, revealing discernible differences in food preference based on factors such as sex, size, and season. Detritus emerged as the predominant dietary element, followed by crustaceans, foraminiferans, and fish remains. The index of preponderance revealed detritus accounting for 83.3 % in males, 71.5 % in berried females, and 67.9 % in non-berried females. It was noted that males exhibited a higher level of feeding intensity compared to females. The percentage of active feeders is higher in both males (48.2 %) and berried females (38.6 %) in comparison with moderately fed and poorly fed groups. During the post-monsoon season, both male and female *H. chani* showed peak feeding activity and intensity. Remarkably, within the female population, the highest feeding activity was noted among juvenile individuals, potentially contributing to accelerated somatic and ovarian development. Upon assessing the gastro somatic index, it became apparent that male *H. chani* exhibited greater efficiency as predators compared to their female counterparts. Throughout the entire study period, the average vacuity index remained consistent, standing at 22.8 % for males, 22.8 % for berried females, and 23.4 % for non-berried females. Instances of empty stomachs were observed across all seasons, with the highest proportion noted during the pre-monsoon period in both sexes.

[**Keywords**: Feeding activity, Foraminifera, Gastro somatic index, Index of preponderance]

Introduction

Deep sea caridean shrimp, *Heterocarpus chani* is being observed as one of the economically important, edible fishery resources in the southwestern and southeastern coast of India[1-6]. This caridean shrimp species exhibits a wide distribution, spanning the sandy and muddy slopes of the bottom regions from the southern South China Sea to the Philippines, Andaman Sea and the Bay of Bengal, with depths ranging from 200 to 888 meters. Notably, *H. chani*, contributing to 17.6 % of deep-sea fishery landings along the southwest coast of India from 2007 to 2020, showed a substantial presence in the region[7]. Several studies on *H. chani*, including species distribution[8-9], fishery status[10], taxonomical identification[4,11,12], molecular characterization[13] and phenotypic stock heterogeneity[14] have been conducted along the southern coast of India. Radhika & Kurup[15] conducted a comparative gut content analysis between *H. gibbosus* (as *H. chani*) and *Heterocarpus woodmasoni*.

In particular, Kuberan *et al.*[6] provided a comprehensive examination of the reproductive biology aspects of *H. chani* collected from the southeastern Arabian Sea and southwestern Bay of Bengal. Their study elucidated key aspects such as the period of reproduction, sex ratio, size at sexual maturity, and fecundity of this particular species. Despite its widespread occurrence and commercial importance, there has been a notable absence of studies focusing feeding ecology of *H. chani*, including aspects such as dietary affinity, feeding habits and the influence of external factors (such as season) and internal factors (sex and size).

Knowledge regarding the food and feeding habits of a species is fundamentally important for a comprehensive understanding of morphometric variation and metabolic activities. Furthermore, the feeding ecology is intricately linked with the reproductive biology of a species. Understanding prey composition contributes to defining feeding interaction within a trophic niche and the active role of the species in a food web. Therefore, studies on species food and feeding hold significant importance in maintaining a sustainable fishery for commercially valuable species like *H. chani*.

Materials and Methods

Sample collection

Samples of *H. chani* collected fortnightly during March 2017 to April 2022 from the fish landings centres, which were caught by the commercial deep sea trawlers operated from southeastern Arabian Sea (Long: 8°48'33.78" to 8°59'60.78" N & Lat: 75°27'34.27" to 76°35'34.27" E) were analysed to study the feeding traits and diversity of the species. Morphological characterisation of the specimens was carried out by following the taxonomic keys of Li[16], Yang *et al.*[17], and Li & Chan[18]. Male and female individuals were distinguished by the presence or absence of an appendix masculina on the second pleopod, respectively. Females were again segregated into berried and non-berried females[19] (Fig. 1). Morphometric measurements of the specimens (Total Length TL: the anterior edge of the rostrum to the tip of the telson; Carapace Length CL: the posterior margin of orbit to the outer end of carapace) were recorded to the nearest 0.01 mm using a vernier callipers and Body Weight (BW) was recorded with 0.0001 g accuracy by using a weighing balance (ME203E; Mettler Toledo, Greifensee, Switzerland). A total of 274 (182 females and 92 males) specimens were selected to study the species food and feeding habits. In the laboratory, the whole specimens were fixed in 10 % neutral formalin solution to dissect the gut for further studies.

Feeding intensity and feeding activity

The stomach was dissected out after removing the carapace and the contents were observed optically. The stomach fullness of each specimen based on the degree of distension of the anterior and posterior chambers of the proventriculus of stomach was visually classified as full, ¾ full, ½ full, ¼ full, trace and empty, and each one was assigned 100, 75, 50, 25, 10 and 0 points, respectively[20-21].

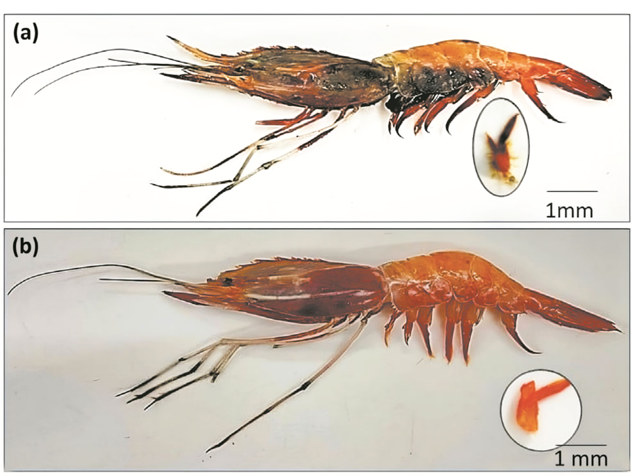

Fig. 1 — Sex identification characteristics of *H. chani*: (a) Berried female with Ist pleopod having pointed-tip endopod; and (b) Male with oval-leaf shaped endopod

To find out feeding condition, stomachs were grouped into actively fed (full and ¾ full stomachs), moderately fed (½ full and ¼ full) and poorly fed (trace and empty)[22].

Vacuity index and gastro-somatic index

The number of empty stomachs was expressed in terms of Vacuity Index (VI), which was estimated using the following formulae[23]:

$$VI = (ES/TS) * 100$$

Where, ES - Number of empty stomachs, and TS - Total number of stomachs examined.

Gastrosomatic Index (GaSI) was estimated using following formulae[24]:

$$GaSI\ (\%) = (Weight\ of\ gut/weight\ of\ body) * 100$$

Index of preponderance

To understand the diet components, the stomachs were cut open, and the contents were diluted with water. Mostly guts with full and ¾ full stages were used for gut content analysis. The prey items were examined under the stereomicroscope (Nikon SMZ1270, Japan). Crustacean particles were observed as undigested fragments of rostrum, carapace and appendages. Foraminifera were identified with the guide of Debenay[25]; whereas, the detritus and fish remains were considered separately.

In order to explore the preference to various food items, the stomach contents were quantified by prey occurrence as:

$$\%\ Oi = 100 * Oi / N$$

Where, Oi is the number of individuals consuming prey i, and N is the total number of specimens examined.

The stomach contents were also quantified by prey gravimetric method as:

$$\%Wi = 100 * Wi / W\ total$$

Where, Wi is the weight of prey i, and W is total weight of all prey items.

The total meal size was determined from prey biovolume or preponderance index[23], which was calculated as:

$$\%Vi = (100 * Oi * Wi) / (\sum Oi * Wi)$$

Where, Vi, Oi and Wi are percentages of biovolume, occurrence, and weight of prey i, respectively[23,26].

All the analysis related to the diet composition and feeding strategies was carried out in relation to sex (male and female), size (juvenile, sub-adult and adult), and seasons (pre-monsoon: January to May; post-monsoon: August to December)[27]. Three size groups were classified based on carapace length and denoted as juvenile (CL < 32 mm), sub-adult (CL between 32 and 36 mm), and adult (CL > 36 mm).

Data analysis

The assessment of *H. chani*'s diet components in relation to sex, size and season was performed with PERMANOVA (Permutational Multivariate ANOVA) in R statistical software (version 4.1.1))[28-29]. Principal Component Analysis (PCA) on gut content data was performed in the FactoMineR and factoextra in R software (version 4.2.2)[30].

Results

Diet diversity

The composition of the diet was analysed separately in males, berried females and non-berried females of *H. chani*. The gut contents observed were detritus, crustacean remains, foraminifera including *Bolivina* spp., *Globorotaloides* spp., and fish remains (Fig. 2). Detritus occupied the first position in males, berried and non-berried females, with the index of preponderance as 83.3 %, 71.5 % and 67.9 %, respectively. The detritus was followed by crustaceans (males 8.4 %, berried females 15.4 %, and non-berried females 20.8%), and foraminifera (males 8.3 %, berried females 13.1 %, and non-berried females 11.3 %) in stomach contents. Fish remains were found only in non-berried females and occurred relatively in a lowest percentage level (0.01 %) (Table 1).

Ontogenic variation in food preference

The detritus emerged as the predominant element across all male size categories, with its abundance diminishing as size increased. The preponderance index for detritus showed 88.7 % in size group CL < 32 mm, 80.7 % in size group having CL between 32 and 36 mm, and 78.9 % in size groups with CL > 36 mm. For lower-size groups, foraminifera held the foremost position among males, while crustaceans were notably abundant in the higher-size groups. In medium-sized groups, both crustaceans and foraminifera exhibited equal representation (Table 1).

Detritus asserted its dominance across all female size categories, with the highest index of preponderance value of 72.1 % in the higher-size groups and the lowest (69.3 %) in lower-sized groups.

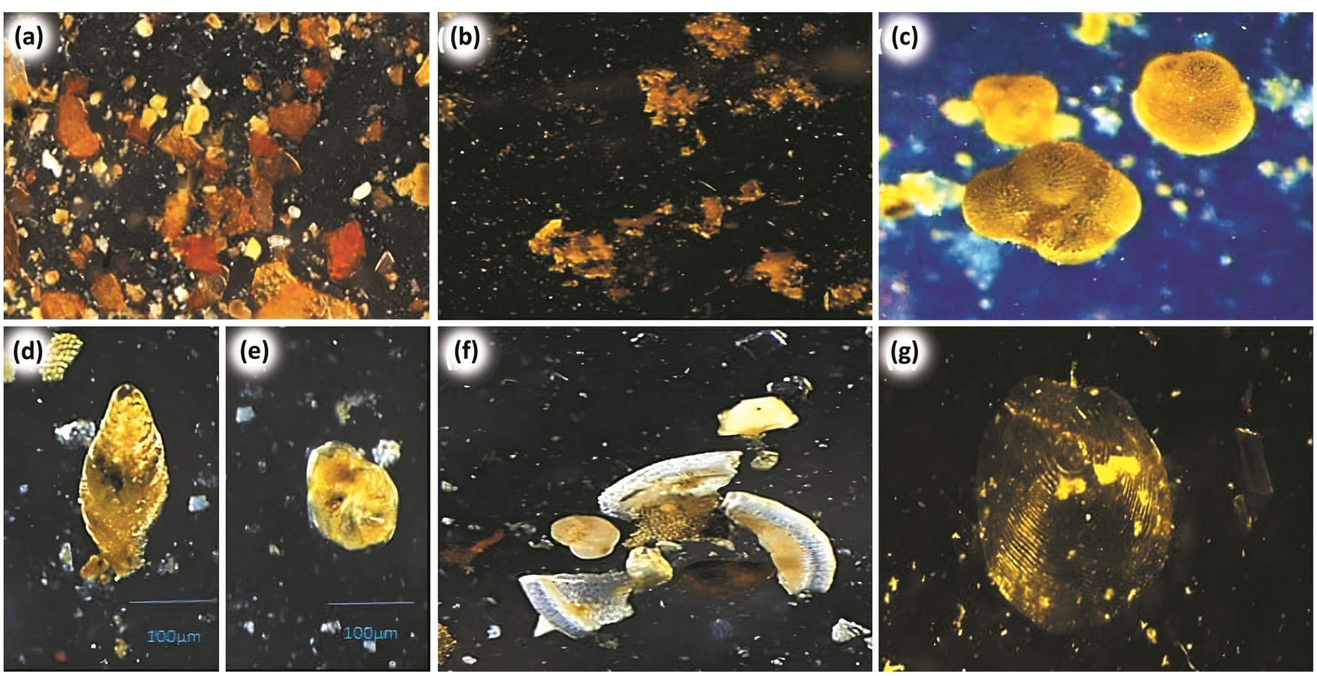

Fig. 2 — Diet composition of *H. chani*: (a) Assorted components; (b) Detritus; (c) *Bolivina* sp.; (d) *Globorotaloides* sp.; (e) Unidentified foraminifera; (f) Crustacean particles; and (g) Fish scale

Table 1 — Diet preference, feeding activity and feeding intensity of *H. chani*

Category	Subcategories	Index of preponderance (%)				Feeding activity (%)			Feeding intensity	No. of specimens
		Crustaceans	Foraminifera	Detritus	Fishes	AF	MF	PF		
Sex	Male	8.4	8.3	83.3		48.2	10.8	41.0	49.4	83
	Berried female	15.4	13.1	71.5		38.6	29.8	31.6	44.3	92
	Non-berried female	20.8	11.3	67.9	0.010	32.4	18.9	48.6	37.2	64
Size (M)	Lower	4.2	7.1	88.7		46.2	11.5	42.3	46.7	26
	Medium	9.8	9.5	80.7		43.8	12.5	43.8	45.8	30
	Higher	15.2	5.9	78.9		77.8	0.0	22.2	76.1	27
Size (F)	Lower	17.8	12.9	69.3	0.010	36.2	27.6	36.2	46.1	58
	Medium	18.1	12.0	69.9		34.9	18.6	46.5	41.9	58
	Higher	16.6	11.3	72.1		20.6	23.5	55.9	30.7	34
Season (M)	Pre-monsoon	8.2	11.2	80.6		40.6	15.6	43.8	43.3	32
	Post-monsoon	8.1	7.0	84.9		55.6	7.9	36.5	55.6	63
Season (F)	Pre-monsoon	21.9	17.7	60.4	0.006	26.5	22.9	50.6	35.4	83
	Post-monsoon	12.1	6.9	81.1		45.3	21.9	32.8	53.6	64

AF - Actively fed, MF - Moderately fed, and PF - Poorly fed

Crustaceans were dominant in all three female size groups, constituting 17.8 % in lower-sized groups, 18.1 % in medium-sized groups, and 16.6 % in higher-sized groups. Foraminifera secured the third position with indices of 12.9, 12.0, and 11.3 in lower-sized, medium-sized, and higher-sized groups, respectively. Fish remains were present in negligible quantities, registering an index value of 0.01 in the lower-sized groups of females (Table 1).

Seasonal variation

Detritus maintained its dominance as the primary gut content in males exhibiting indices of 80.6 and 84.9 in both the pre-monsoon and post-monsoon periods, respectively. In males, foraminifera secured the second position during pre-monsoon with an index of 11.22, while crustaceans took the second spot in post-monsoon with an index of 8.1. Similarly, in females, detritus prevailed as the leading gut content in all seasons.

Crustaceans were notably dominant in both pre-monsoon and post-monsoon periods for females, with the indices of 21.9 and 12.1, respectively. Foraminifera occupied the third position in females in seasonal analysis, constituting 17.7 % in the pre-monsoon and 6.9 % in the post-monsoon. Additionally, the presence of fish remains was observed in females during the pre-monsoon season (Table 1).

Diet preference in both sexes of *H. chani* with different size classes and seasons

The PERMANOVA analysis revealed that the diet preference of the deep-sea shrimp *H. chani* was significantly influenced by sex and season ($P < 0.05$). However, there was no significant regulation based on shrimp size. Moreover, the diet preference of this species remained consistent without notable changes in response to interactions between variables ($P_{sex×shrimp\text{-}size} = 0.765$, $P_{sex× season} = 0.07$). Notably, both males and females, across various sizes and seasons, exhibited a predominant preference for detritus, crustaceans, and foraminifera in their diet (Table 2).

Table 2 — PERMANOVA results for the effects of sex, size, season and their interactions on the diet components of *H. chani*

Source of variation	*df*	*F*	R^2	*Pr*
Size	2	0.15	0.002	0.933
Sex	1	5.49	0.46	0.020*
Sex × Size	2	0.35	0.006	0.765
Season	1	11.29	0.77	0.001**
Sex × Season	1	3.08	0.02	0.070

Significant codes: 0 '***', 0.001 '**', 0.01 '*', and 0.05 '.'

Figure 3, the loading plot derived from Principal Component Analysis (PCA) revealed that the initial two variables (foraminifera and crustaceans) explained approximately 94.3 % of the overall variability. Notably, the detritus was identified as a major gut component across three groups, namely male, berried, and non-berried females.

Feeding intensity

Feeding intensity exhibited notable variations among different groups, with males recording a rate of 49.4, berried females at 44.3, and non-berried females at 37.2. The feeding intensity peaked in higher-sized groups of males (76.1), while medium (45.8), and lower-sized groups (46.7) displayed

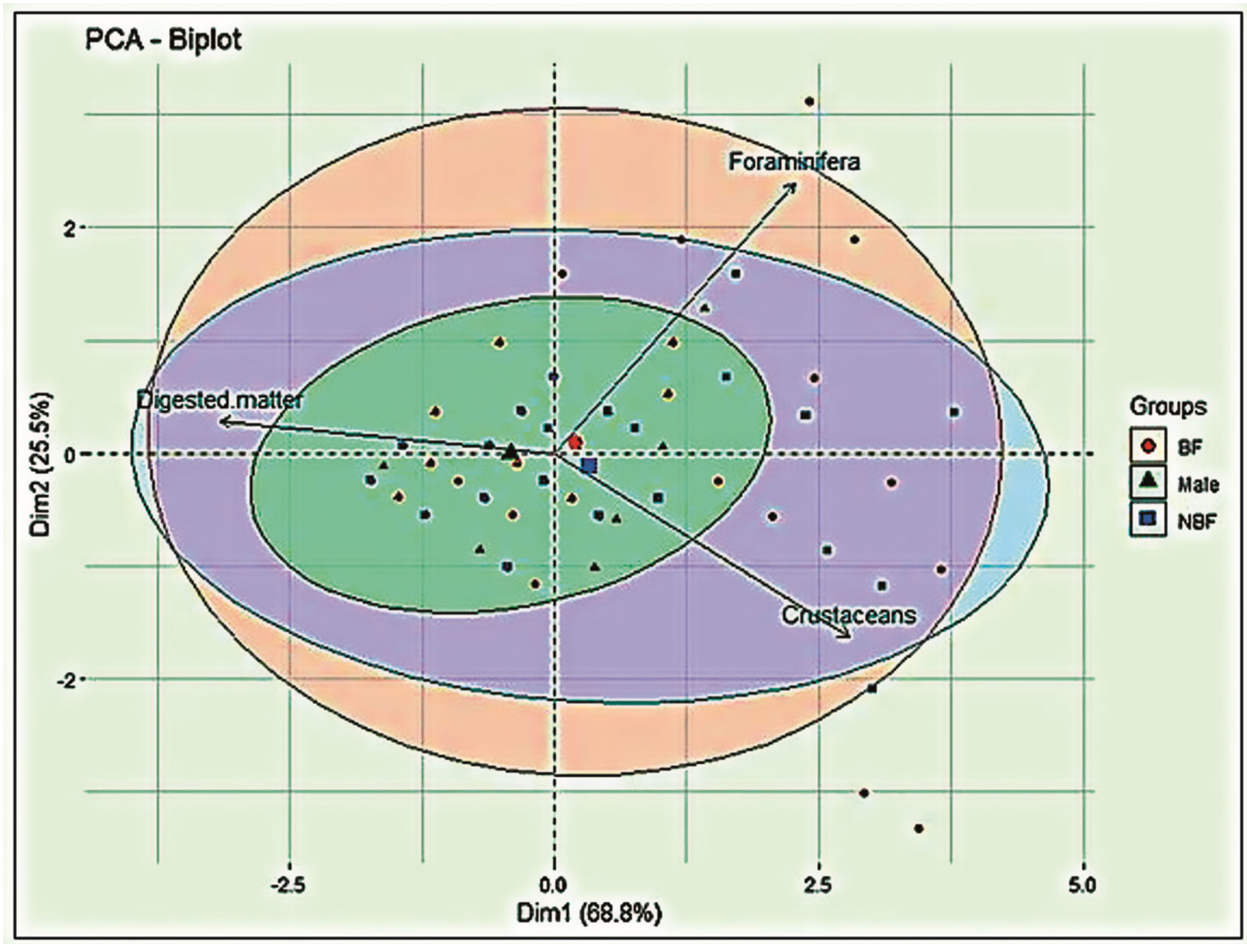

Fig. 3 — Principal Component Analysis (PCA) loading plot comparing the variability of gut composition among male, berried females, and non-berried females of *H. chani*

comparatively lower feeding intensities. Additionally, male feeding intensity during the pre-monsoon season was 43.3, with the highest intensity recorded during the post-monsoon season at 55.6.

The feeding intensity of *H. chani* females reached its peak value in lower-sized groups (46.1), exhibiting a decreasing trend from lower to medium (41.9) and higher-sized (30.7) groups. Notably, during the post-monsoon season, female shrimps displayed heightened feeding intensity of 53.6, surpassing the recorded pre-monsoon intensity (35.4; Table 1).

Feeding activity

Males exhibited a higher feeding activity rate at 48.2 %, surpassing berried females at 38.6 % and non-berried females at 32.4 %. Among berried females, a higher proportion was categorised as poor feeders compared to non-berried females and males. Additionally, more than half of the actively feeding male individuals belonged to the higher-size groups. In contrast, females in the lower-size groups showed greater feeding activity at 36.2 %, while medium (34.9 %), and higher-sized (20.6 %) groups displayed comparatively lower rates. Notably, the majority of both males and females demonstrated increased feeding activity during the post-monsoon season compared to the pre-monsoon period (Table 1).

Gastro Somatic Index (GaSI)

Within the three categories of *H. chani* (males, berried, and non-berried females), males exhibited the highest GaSI values at 1.4±0.83 %. Specifically, the GaSI value was elevated in higher-sized male group, recording 1.47±0.92 %, whereas a lower GaSI value was observed in females of similar size group. Among female individuals of *H. chani*, the highest GaSI values were documented in the lower-size group at 1.13±0.9 %. The GaSI of *H. chani* exhibited significant seasonal variations, with the highest values recorded during the post-monsoon period for both males (1.44±0.90 %) and females (1.02±0.93 %) (Table 3 & Fig. 4).

Vacuity index

The percentage of empty stomachs observed showed minimal variation among males (22.89 %), berried females (22.83 %), and non-berried females (23.44 %). Notably, the prevalence of empty stomach conditions was more pronounced in lower-sized group of males, accounting for 26.92 %. On the contrary, in females of *H. chani*, a higher incidence of empty stomachs was noted in higher-sized groups. Additionally, the vacuity index reached its peak during the pre-monsoon season, indicating a higher prevalence of empty stomachs during this period compared to the post-monsoon season (Table 3 & Fig. 5).

Discussion

In the current study, examination of the gut contents of *H. chani* revealed a diverse array of diet components, including detritus, crustacean remains, foraminifera, and fish remains. This observed food composition in *H. chani* aligns with findings from studies on other deep-sea caridean shrimps, such as *H. woodmasoni*[15,31]. Earlier study on food and feeding conducted in *H. gibbosus* (as *H. chani*) and *H. woodmasoni* revealed euphausiids as a major dietary component than detritus[15]. But similarities in dietary components suggest a shared ecological niche among deep-sea caridean shrimps *H. chani*, *H. woodmasoni*[15,31] and *Plesionika semilaevis*[32]. Similar diet composition was also observed in other deep-sea penaeid shrimp species, *Metapenaeopsis andamanensis*[33]. All these studies consistently reported the prevalence of detritus, crustacean remains, and foraminifera in higher quantities compared to other diet components. Detritus, in

Table 3 — Gastrosomatic Index (GaSI) and Vacuity Index (VI) of *H. chani*

Category	Subcategories	GaSI (%)	VI (%)
Sex	Male	1.4 ± 0.83	22.89
	Berried female	1.03± 0.89	22.83
	Non-berried female	0.97± 0.89	23.44
Size (M)	Juvenile	1.41±0.92	26.92
	Sub-adult	1.36±0.82	22.92
	Adult	1.47±0.92	11.11
Size (F)	Juvenile	1.13±0.9	18.97
	Sub-adult	0.92±0.61	27.91
	Adult	0.73±0.66	35.29
Season (M)	Pre-monsoon	1.08±0.87	25
	Post-monsoon	1.44±0.90	20.63
Season (F)	Pre-monsoon	0.99±0.85	27.71
	Post-monsoon	1.02±0.93	20.31

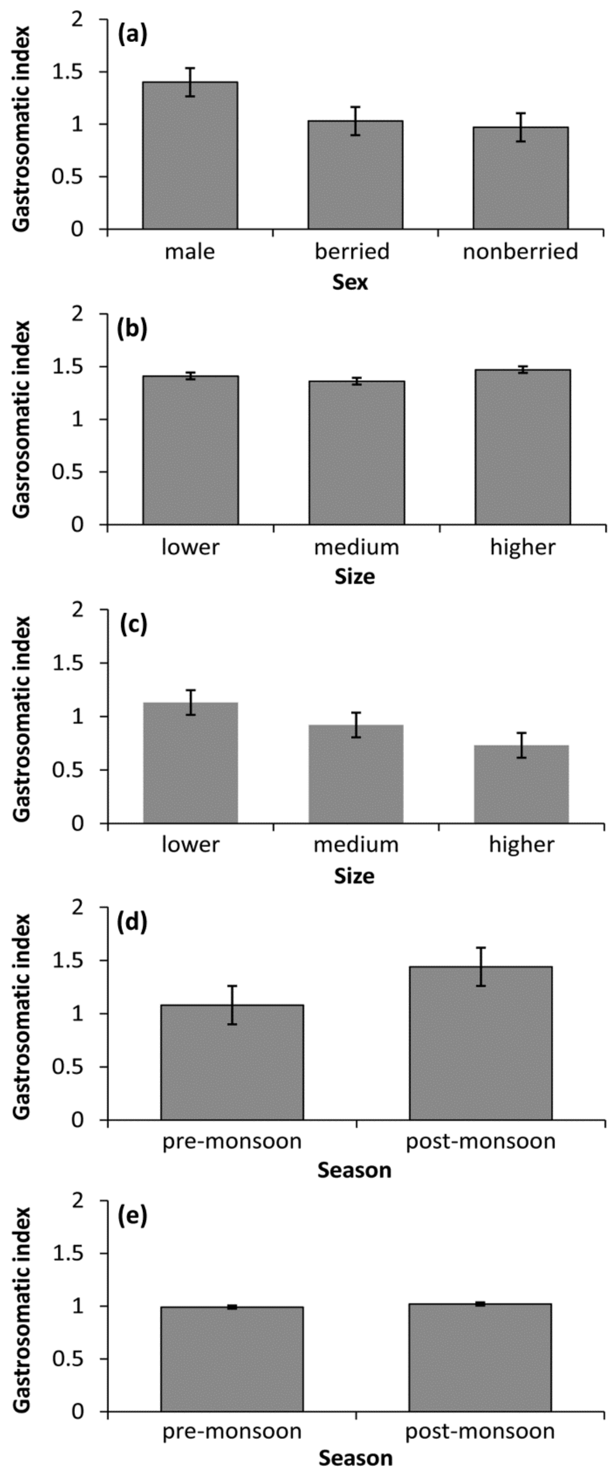

Fig. 4 — Gastrosomatic index of *H. chani*: (a) Sex; (b) Male shrimp - size; (c) Female shrimp - size; (d) Male - season; and (e) Female - season

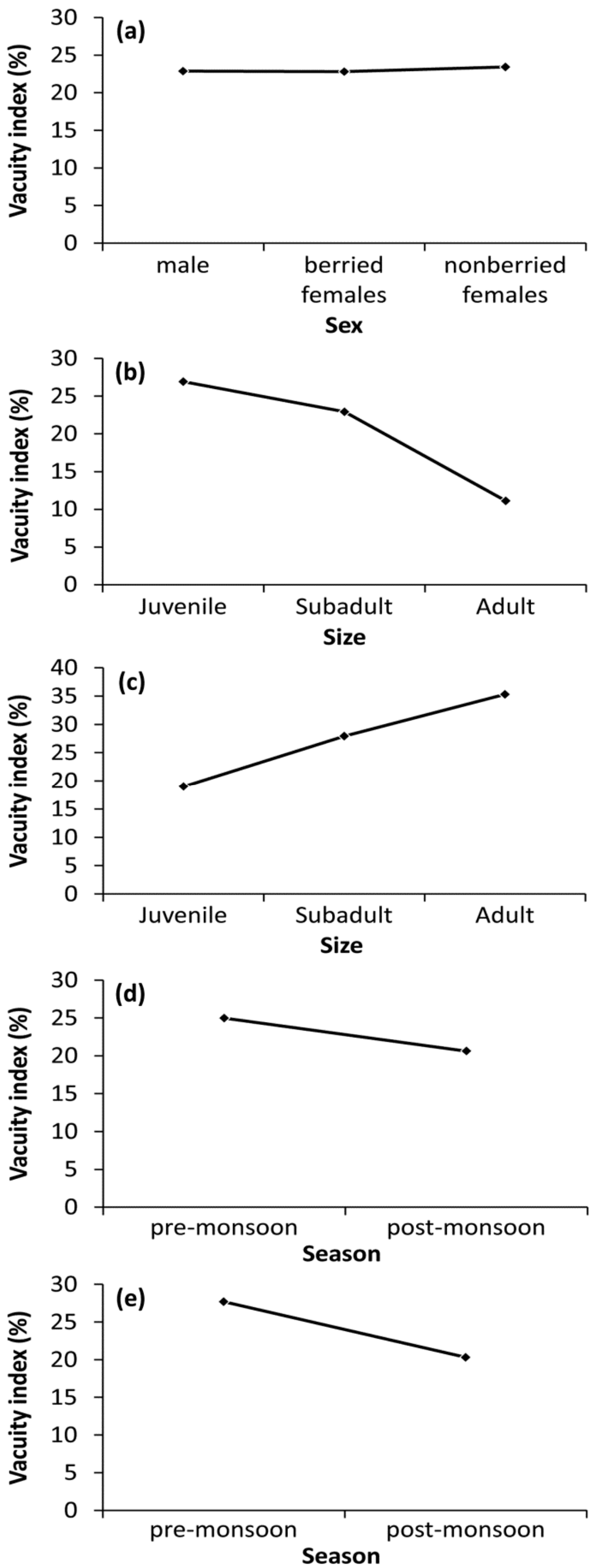

Fig. 5 — Vacuity index of *H. chani*: (a) Sex; (b) Male shrimp - size; (c) Female shrimp - size; (d) Male - season; and (e) Female - season

particular, was found to be the predominant dietary component in both sexes of *H. chani* throughout the entire study period. This pattern of detritus being a major component of the diet is in line with observations in other *Heterocarpus* species, such as *H. woodmasoni* collected from the southwestern coast of India[31]. These findings suggest a shared dietary preference among related species and emphasise the importance of detritus in the ecological context of these deep-sea caridean shrimps[15,31,32]. Detritus typically comprises decomposed animal and plant matter, along with their remains and unidentified components[34]. Some studies suggest that detritus also functions as a microbial networking of sediments[35], and detritus often considered only lightly nutritive, due to the associated bacterial biomass[34].

Karuppasamy & Menon[34] reported similar observations in *Oplophorus typus* from the west coast of India. Crustacean remains occurred in second position among the food items in *Oplophorus typus*, which showed similarity with the result of the present study. There was significant variation in food preference between berried and non-berried females of *H. chani* with reference to crustaceans. Differences in the preference for food contents among juveniles and the adults stages of *S. choprai* from Karnataka coast were also reported by Dineshbabu & Manissery[36]. In *H. chani*, variation in the gastrosomatic index was observed among different size groups of males and females. Highest GaSI value was observed in juveniles among females. This observation strongly corroborate with the highest GaSI values observed in small-sized immature females of *H. woodmasoni*[15,31] and *Plesionika semilaevis*[32]. The observed feeding intensity in *H. chani* indicates a higher level in lower-size group females, contrasting with lower intensity in higher-size group females. The correlation between the highest GaSI values observed in juvenile *H. chani* and their elevated feeding intensity suggests a potential link. It is plausible that the increased feeding activity among juvenile individuals contributes to the higher GaSI values, possibly aimed at acquiring more energy for rapid morphological and reproductive development. In some fish species, mature individuals approaching their reproductive period exhibit lower GaSI values, possibly due to the abdominal cavity being occupied by ripe gonads. Similarly, in *H. chani*, reduced feeding intensity and lower GaSI values observed during maturation may be attributed to their gonadal development[15]. This association underscores the intricate relationship between feeding behavior, size, and reproductive strategies in the ecology of *H. chani*.

The percentage of empty stomachs were more in the higher-sized group females of *H. chani.* Paturi & Myla[38] reported highest feeding intensity in immature and lowest in mature males of *Solenocera melantho.* They also observed a high vacuity index in mature males of *S. melantho.* Contrasting to this study, in *H. chani* higher-size group males showed more feeding activity than other two categories. All the size groups individuals of *H. chani* consumed similar prey items but in different quantities. Kapiris[39] in a study on the diet of deep-water red shrimps, *Aristaeomorpha foliacea* and *Aristeus antennatus* from Ionian Sea reported slight variation in feeding activity among small, medium and large female individuals. These variations were particularly observed in proportion of prey consumed while the prey components were the same.

Kapiris[31] observed that the feeding activity of *A. foliacea* and *A. antennatus* from the Ionian Sea increased during the spring–summer season for both sexes. He explained this with the support of increased reproductive activity observed during the same period in *A. antennatus*[40] and *A. foliacea*[41] from the Greek Ionian Sea. In the present study, *H. chani* showed a higher feeding activity and intensity during the post-monsoon season irrespective of the sex. Kuberan *et al*.[6] reported the presence of berried females in *H. chani* throughout the study period, and a peak in reproduction from October to February. The active reproduction period of *H. chani* overlaps post-monsoon season considered in the present study. This indicates that the reproductive process (maturation of gonad, spawning) plays an important role in the feeding activity of *H. chani*.

Conclusion

The current investigation yields a comprehensive account of the feeding habits of the deep-sea shrimp, *H. chani*, along the southeastern Arabian Sea. Through an analysis of diet composition, it was revealed that the preference for food components such as detritus, crustaceans, and foraminiferans varied with respect to sex, season, and size. *Heterocarpus chani* demonstrates detritivorous behaviour, with males exhibiting notably higher feeding activity and intensity than their female counterparts. Juvenile females exhibited the highest gastrosomatic index and the lowest vacuity index. Observed seasonal variations in feeding strategies are attributed to increased energy requirements associated with ontogenetic and reproductive developments. The results emphasising the prey elements of *H. chani* shed light on its crucial contribution to sustaining the equilibrium within the food web of the deep-sea ecosystem.

Acknowledgements

The authors express their gratitude to the Director, Indian Council of Agricultural Research-Central Marine Fisheries Research Institute (ICAR-CMFRI) for the facilities provided. We also thank the Head, Shellfish Fisheries Division (SFD) for the support extended to carry out this work.

Conflict of Interest

All authors of this manuscript declare no conflict of interest is present in this manuscript.

Ethical Statement

This article does not contain any experimental studies with live animals by any of the authors.

Author Contributions

RDC: Fund acquisition from DST-SERB, India, conceptualization, sample collection, methodology, draft editing, investigation, software, and supervision**;** APG: Sample collection, draft editing of manuscript, methodology, measurements, analysis, and original draft preparation**;** GK: Sample collection, draft editing of manuscript, methodology, and measurements; LS: Sample collection, measurements**,** dissection of specimens, and data recording; NR: Sample collection, measurements**,** and dissection of specimens; and APD: conceptualization and supervision**.**

References

1 Mohamed K H & Suseelan C, Deep-sea prawn resources off the South-West Coast of India, In: *Proceedings of the symposium on living resources of the seas around India, 1968, Mandapam Camp*, Special Publication, (CMFRI, Cochin), 1973, pp. 614–633.

2 Suseelan C, Observations on the deep-sea prawn fishery off the south-west coast of India with special reference to pandalids, *J Mar Biol Assoc India*, 16 (2) (1974) 491–511. http://eprints.cmfri.org.in/id/eprint/1433

3 Suseelan C, Nandakumar G & Rajan K N, Results of bottom trawling by FORV Sagar Sampada with special reference to catch and abundance of edible crustaceans, In: *Proceedings of First Workshop, Scientific Results of*

FORV Sagar Sampada, Special Publication, edited by Mathew K J, (CMFRI, Cochin), 1989, pp. 337–346. http://eprints.cmfri.org.in/id/eprint/5200

4 Suseelan C, Muthu M S, Rajan K N, Nandakumar G, Kathiravel M, *et al*., Results of an exclusive survey for the deep-sea crustaceans off southwest coast of India, In: *Proceeding of First Workshop, Scientific Results of FORV Sagar Sampada*, Special Publication, edited by Mathew K J, (CMFRI, Cochin), 1989, pp. 337–359. http://eprints.cmfri.org.in/id/eprint/5206

5 Radhika R, Biodiversity of deep sea prawns in the upper continental slope of Arabian Sea, off Kerala (South West India): A comparison between depths and years, *Turkish J Fish Aquat Sci*, 11 (2) (2011) 291–302. https://doi.org/10.4194/trjfas.2011.0214

6 Kuberan G, Chakraborty R D, Sarada P T & Maheswarudu G, Reproductive biology of the deep-sea shrimp *Heterocarpus chani* Li, 2006 (Decapoda: Caridea: Pandalidae) from southern India, *J Crustac Biol*, 41 (4) (2021) ruab055, 1-7. https://doi.org/10.1093/jcbiol/ruab055

7 Chakraborty R D, Sarada P T, Josileen J, Kuriakose S, Sreesanth L, *et al*., Saga of deep sea prawn fishery of Kerala, *Mar Fish Infor Serv T&E Ser*, 253 (2022) 15–20. http://eprints.cmfri.org.in/16617/

8 Kurup B M, Rajasree R & Venu S, Distribution of deep sea prawns off Kerala, *J Mar Biol Assoc India*, 50 (2) (2008) 122–126.

9 Radhika R, *Systematics, Fishery, Resource Characteristics and Bionomics of Deep Sea Prawns off Kerala*, Ph.D. Thesis, Cochin University of Science and Technology, Cochin, 2004, pp. 358.

10 Rajool Shanis C P, Radhakrishnan E V, Ganga U & Pillai N G K, Misidentification in fishery: The case of deep-sea pandalid shrimp *Plesionika spinipes* (Spence Bate, 1888) from Indian waters, *Int J Mar Sci*, 4 (50) (2014) 1–4. http://eprints.cmfri.org.in/id/eprint/10216

11 Kuberan G, Chakraborty R D, Purushothaman P & Maheswarudu G, A new record of deep-sea caridean shrimp *Heterocarpus chani* (Decapoda: Pandalidae) from the southern coast of India, *Mar Fish Infor Serv T&E Ser*, 226 (2015) 27–27. http://eprints.cmfri.org.in/id/eprint/10980

12 Yang C H, Kumar A B & Chan T Y, Further records of the deep-sea pandalid shrimp *Heterocarpus chani* Li, 2006 (Crustacea, Decapoda, Caridea) from Southern India, *ZooKeys*, 685 (2017) 151–159. https://doi.org/10.3897/zookeys.685.13398

13 Chakraborty R D, Purushothaman P, Kuberan G, Sebastian J & Maheswarudu G, Morphological analysis and molecular phylogeny of *Aristeus alcocki* Ramadan, 1938 from south-west coast of India, *Indian J Geo-Mar Sci*, 44 (2015) 1716–1725.

14 Kuberan G, Chakraborty R D & Purushothaman P, Phenotypic variation using truss network system in the deep-sea shrimp *Heterocarpus chani* Li, 2006 (Caridea: Pandalidae) off Arabian Sea and Bay of Bengal, *Indian J Geo-Mar Sci* 49 (12) (2020) 1839–1847. http://nopr.niscair.res.in/handle/123456789/55948

15 Radhika Rajasree S R & Kurup B M, Food and feeding habits of deep-sea pandalid prawns *Heterocarpus gibbosus*, Bate 1888 and *Heterocarpus woodmasoni*, Alcock off Kerala, south India, *Indian J Fish*, 58 (2011) 45–50.

16 Li X, Additional pandaloid shrimps from the South China Sea (Crustacea: Decapoda: Caridea), with description of one new species, *Raffles Bull Zool*, 54 (2006) 361–372.

17 Yang C H, Chan T Y & Chu K H, Two new species of the "*Heterocarpus gibbosus* Bate, 1888" species group (Crustacea: Decapoda: Pandalidae) from the western Pacific and north-western Australia, *Zootaxa*, 2372 (2010) 206–220. https://doi.org/10.11646/zootaxa.2372.1.19

18 Li X & Chan T Y, Pandalid shrimps (Crustacea, Decapoda, Caridea) collected from the Philippines PANGLAO 2005 deep-sea expedition 1993, In: *Tropical Deep-Sea Benthos*, Vol 27, edited by Ahyong S T, Chan T Y, Corbari L & Ng P K L, *Mémoires du Muséum National d'Histoire Naturelle*, 204 (2013) 129–154.

19 King M G & Moffitt R B, The sexuality of tropical deepwater shrimps (Decapoda: Pandalidae), *J Crustac Biol*, 4 (1984) 567–571. https://doi.org/10.2307/1548071

20 Pillay T V R, A critic of the methods of study of food of fishes, *J Zool Soc India*, 4 (1952) 185–200.

21 Mohammed Koya K, Vase V K, Abdul Azeez P, Sreenath K R, Dash G, *et al.*, Diet composition and feeding dynamics of *Trichiurus lepturus* Linnaeus, 1758 off Gujarat, north-west coast of India, *Indian J Fish*, 65 (2) (2018) 50–57. http://epubs.icar.org.in/ejournal/index.php/IJF/article/view/69184

22 Rao L M & Rao P S, Food and Feeding Habits of *Glossogobius giuris* from Gosthani Estuary, *Indian J Fish*, 49 (2002) 35–40. https://epubs.icar.org.in/index.php/IJF/article/view/8366

23 Hyslop E J, Stomach contents analysis - a review of methods and their application, *J Fish Biol*, 17 (1980) 411– 429. https://doi.org/10.1111/j.1095-8649.1980.tb02775.x

24 Bhatnagar G K & Karamchandani S J, Food and feeding habits of *Labeo fimbriatus* (Bloch) in river Narbada near Hoshangabad (MP), *J Inland Fish Soc India*, 2 (1970) 30–50.

25 Debenay J P, *A guide to 1,000 Foraminifera from Southwestern Pacific: New Caledonia*, IRD Éditions, (Publication Scientifiques du Muséum, Paris), 2012, pp. 386.

26 Natarajan A V & Jhingran V G, Index of preponderance – A method of grading the food elements in the stomach analysis of fishes, *Indian J Fish*, 8 (1) (1961) 54–59. https://epubs.icar.org.in/index.php/IJF/article/view/13580

27 Paramasivam P, Chakraborty R D, Ganesan K & Gidda M, Feeding ecology of deep-water Arabian red shrimp, *Aristeus alcocki* Ramadan, 1938 (Decapoda: Penaeoidea: Aristeidae) from southwestern India (Arabian Sea), *Reg Stud Mar Sci*, 40 (2020) p. 101500. https://doi.org/10.1016/j.rsma.2020.101500

28 Anderson M J, A new method for non-parametric multivariate analysis of variance*, Austral Ecolo*, 26 (2001) 32–46. https://doi.org/10.1111/j.1442-9993.2001.01070.pp.x

29 Anderson M J, Permutational multivariate analysis of variance (PERMANOVA), In: *Wiley StatsRef: Statistics Reference Online*, 1st Edn, edited by Balakrishnan N, Colton T, Everitt B, Piegorsch W, Ruggeri F, *et al.*, (Wiley, Hoboken), 2017, pp. 1–15. https://doi.org/10.1002/9781118445112.stat07841

30 Jolliffe I T, Principal component analysis for special types of data, In: *Principal Component Analysis*, 2nd Edn, Book Series - Springer Series in Statistics (SSS), (Springer New,

York), 2002, pp. 338–372. https://doi.org/10.1007/0-387-22440-8_13

31 Ambatt Padmanabhan G, Chakraborty R D & Lakshman S, Food and feeding strategies of the deep-sea shrimp *Heterocarpus woodmasoni*, Alcock 1901 (Decapoda: Pandalidae) from southwestern India, *J Crustac Biol*, 43 (1) (2023) p. ruad005. https://doi.org/10.1093/jcbiol/ruad005

32 Sreelakshmy S, Chakraborty R D & Sreesanth L, Feeding ecology of the pandalid shrimp, *Plesionika semilaevis* (Spence Bate 1888) in South Eastern Arabian Sea, *Reg Stud Mar Sci*, 6 (2023) p. 102866. https://doi.org/10.1016/j.rsma.2023.102866

33 Muralidharan A, Chakraborty R D, Chakraborty K & Dhara S, Trophic ecology and diet of the deep-sea penaeid shrimp *Metapenaeopsis andamanensis* (Wood-Mason in Wood-Mason and Alcock, 1891) by fatty acid signatures and stomach content analysis, *Deep-Sea Res I: Oceanogr Res Pap*, 200 (2023) p. 104135. https://doi.org/10.1016/j.dsr.2023.104135

34 Karuppasamy P K & Menon N G, Food and feeding habits of the pelagic shrimp, *Oplophorus typus* from the deep scattering layer along the west coast of India, *Indian J Fish*, 51 (2004) 17–20.

35 Liao Z, Li Y, Hui C & Lin L, Flow velocity determines detritus availability and microbial food web patterns in a river confluence, *J Hydrol*, 643 (2024) p. 131987. https://doi.org/10.1016/j.jhydrol.2024.131987

36 Dineshbabu A P & Manisseri J K, Food and feeding of the ridgeback shrimp, *Solenocera choprai*, Nataraj along Karnataka coast, *Indian J Fish*, 56 (2009) 21–26. http://eprints.cmfri.org.in/id/eprint/5883

37 Mukadam M, Gut content analysis and Feeding Habits of the Indian Mackerel, *Rastrelliger kanagurta* (Cuvier) at Ratnagiri, *Int J Sci Eng Res*, 11 (8) (2020) 104-109.

38 Patury R C G & Myla S C, Food and feeding habits of the deep-water mud shrimp (*Solenocera melantho*) of Visakhapatnam Coast, India, *Not Sci Biol*, 9 (2017) 161–168. https://doi.org/10.15835/nsb9210051

39 Kapiris K, Food quality, In: *Food quality*, edited by Kapiris K, (InTech, Rijeka, Croatia), 2012, pp. 111–134.

40 Papaconstantinou C & Kapiris K, Distribution and population structure of the red shrimp (*Aristeus antennatus*) on an unexploited fishing ground in the Greek Ionian Sea, *Aquat Living Resour*, 14 (2001) 303–312. https://doi.org/10.1016/S0990-7440(01)01128-7

41 Papaconstantinou C & Kapiris K, The biology of the giant red shrimp (*Aristaeomorpha foliacea*) at an unexploited fishing ground in the Greek Ionian Sea, *Fish Res*, 62 (2003) 37–51. https://doi.org/10.1016/S0165-7836(02)00254-0