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Feeding habits of the freshwater crab *Sodhiana iranica* from Southern Iran

Habito alimentar do caranguejo de água doce *Sodhiana iranica* do sul do Irã

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Abstract: Aim: Freshwater crab, *Sodhiana iranica*, is an endemic gecarcinucid crab that has been recently reported from Southern Iran. This research examined some feeding aspects of *S. iranica* from Eelood freshwater spring, Southern Iran. **Methods:** Crabs were randomly sampled from April 2012 to April 2013, on a bimonthly basis. The stomach contents were obtained from 120 exemplars with carapace width ranging from 15.0 to 35.2mm. **Results:** Results showed stomach contents consist of mainly large quantities of plant remains, insects, oligochaetes, crustaceans and also small quantities of unidentifiable matter and debris. Major food groups were observed in different season, with plant remains the most dominant in spring (39.8%), whereas in autumn, the insects and crustaceans were dominant with 38.6% and 23.1%, respectively. The other food items include oligochaetes and debris, were the most abundant in summer (19.0%) and winter (15.5%), respectively. There were no difference observed in the quantity of the food consumed in both sexes and also significant differences observed in the preference for food items in the different season. The CV index varied significantly in both sexes that were ranged between 1.4 to 38.9% and 12.5 to 83.3%, for male and female, respectively. **Conclusions:** Despite the diversity in diets and feeding habits of *S. iranica*, it was shown an herbivore-biased omnivore mainly rely on plant sources.

Keywords: crab; Decapoda; CV index; feeding; freshwater.

Resumo: Objetivo: o caranguejo de água doce, *Sodhiana iranica*, é uma espécie endêmica da família Gecarcinucidae que recentemente foi registrado no sul do Irã. Esta pesquisa examinou alguns aspectos de alimentação de *S. iranica* de uma nascente de água doce da região de Eelood, no sul do Irã. **Métodos:** os caranguejos foram amostrados aleatoriamente de abril de 2012 a abril de 2013, em intervalos de dois meses. O conteúdo estomacal foi obtido a partir de 120 exemplares com largura de carapaça variando de 15,0 a 35,2 mm. **Resultados:** os resultados mostraram que os conteúdos estomacais consistiram principalmente de grandes quantidades de restos vegetais, insetos, oligoquetas, crustáceos e também pequena quantidade de materiais não identificados e detritos. Os principais itens alimentares foram observados em diferentes épocas, sendo restos vegetais os dominantes na primavera (39,8%), enquanto que no outono, os insetos e os crustáceos foram dominantes com 38,6% e 23,1%, respectivamente. Os oligoquetas e detritos foram mais abundantes no verão (19,0%) e no inverno (15,5%), respectivamente. Não se observou diferenças na quantidade de alimentos consumidos entre os sexos, mas diferenças significativas dos itens alimentares nas diferentes estações do ano. O índice CV variou significativamente para ambos os sexos, entre 1,4 a 38,9% e 12,5 a 83,3%, para machos e fêmeas, respectivamente. **Conclusões:** a despeito da diversidade das dietas e dos hábitos alimentares de *S. iranica*, esta espécie apresentou uma dieta onívora com tendência à herbivoria dependente principalmente de recursos vegetais.

Palavras-chave: caranguejo; Decapoda; índice CV; alimentação; água doce.

1. Introduction

Freshwater crabs as one important component of freshwater ecosystem are one of the most ecologically important macro-invertebrate groups (Yeo et al., 2008) and the most species-rich of all decapod crustacean groups in inland waters worldwide (Ng et al., 2008). Despite the importance of freshwater crabs, only a few aspects of their biology and ecology are known. Species of this habitat are rarely represented in food webs and their role in these ecosystems has been largely ignored. The lack of sufficient information from the food web may be the reason that freshwater crabs are not included in these ecosystems, and subsequently, it leads researchers to ignore their environmental role and the capacity to interact with other members of freshwater community (Carvalho et al., 2013).

Freshwater crab *Sodhiana iranica* Sharifian, Kamrani & Sharifian 2014, is a gecarcinucid crab that has been recently reported only from Bastak, in southern Iran as a new species (Sharifian et al., 2014). The species inhabits a freshwater spring located in a semi-mountainous area in Iran (Eellod Area), covered by dense stands of common reeds and salt cedar trees in the periphery, with mats of algae on the bottom (Sharifian et al., 2014). The crab *S. iranica* is fourth species of *Sodhiana* Yeo and Ng 2012, and is the second one known from Iran. Up to now, some information about oogenesis and ovarian development (Sharifian et al., 2015), the morphometric variations (Sharifian & Kamrani, 2015), structure population (Sharifian et al., 2017a), and reproductive biology (Sharifian et al., 2017b) of *S. iranica* have been discussed.

To understand the nutritional requirements of the species and how interacting with the environment and other organisms is essential the knowledge about trophic ecology aspects. In inland water systems, the characterization of trophic links is essential for the identification of the 'trophic species' and can be leads to understand the dynamics of energy in these environments (Woodward, 2009). Trophic ecology is of central interest in the study of intra lacustrine sympatric speciation, since trophic niche differentiation is a common phenomenon during adaptive radiations (Horstkotte & Strecker, 2005; Gavrilets & Losos, 2009). Moreover, the community organization patterns during time can be achieved through the knowledge of the feeding ecology of animal species (Lampert et al., 1992). In details, the availability of preferred prey organisms can largely affect the distribution, growth, reproduction, behavior and migration rate of crabs (Vinagre et al., 2007).

The trophic ecology of brachyuran crabs has been widely studied in marine crabs probably because of their ecological and economic importance (Balasubramanian & Suseelan, 1998; Frick et al., 2001; Mantelatto & Christofoletti, 2001; Chande & Mgaya, 2004; Josileen, 2011). However, almost confined studies are performed among freshwater crabs (Collins et al. 2007; Carvalho et al., 2013; Williner & Collins, 2013; Kobayashi, 2012; Williner et al., 2014; Bahuguna et al., 2016). Regarding to the large number of freshwater crabs in tropical and subtropical freshwater ecosystems (Yeo et al., 2008), the analysis of freshwater crabs diet can provide particular information about the crab in the ecosystem.

In the present study, we examined the natural diet and the composition of feeding of *S. iranica* in the freshwater spring located at the southern of Iran. The aim of this study was to gain a better understanding of the feeding biology of the crab *S. iranica*. Despite the ecological significance of gecarcinucid crabs, there are little information about the biology and ecology of some species such as *S. iranica* (Sharifian et al., 2017a, b). Moreover, the feeding habits of this species and its exact ecological niche (position in the food web) are unclear. This endemic distribution and the progressive modification of the habit where they occur make this research so important.

2. Material and Methods

The Eelood freshwater spring is located in Eelood Area of Hormozgan Province, south of Iran (27°13' N- 54°40' E) (Figure 1). The region has a subtropical climate, with distinct spring and summer seasons. On annual average, the spring has pH 7.99, salinity 4, temperature ranging from 25 to 30°C, sediment TOM (total organic matter) 4.6% and granulometry composed by 50% sand, 34% silt and 16% clay. The crabs are usually found under algal mats, stones and among the reeds, only occasionally in burrows. The streams pass through Eelood's village groves and often used to irrigate palm. The sampling was done from April 2012 to April 2013. Crabs of *S. iranica* were haphazardly collected by hand bimonthly (in order to minimize impact on the population). Samples were placed on ice inside plastic buckets and transported to the laboratory of Hormozgan University. In the laboratory, crabs were identified and sexed. Carapace width (CW) was measured using precision

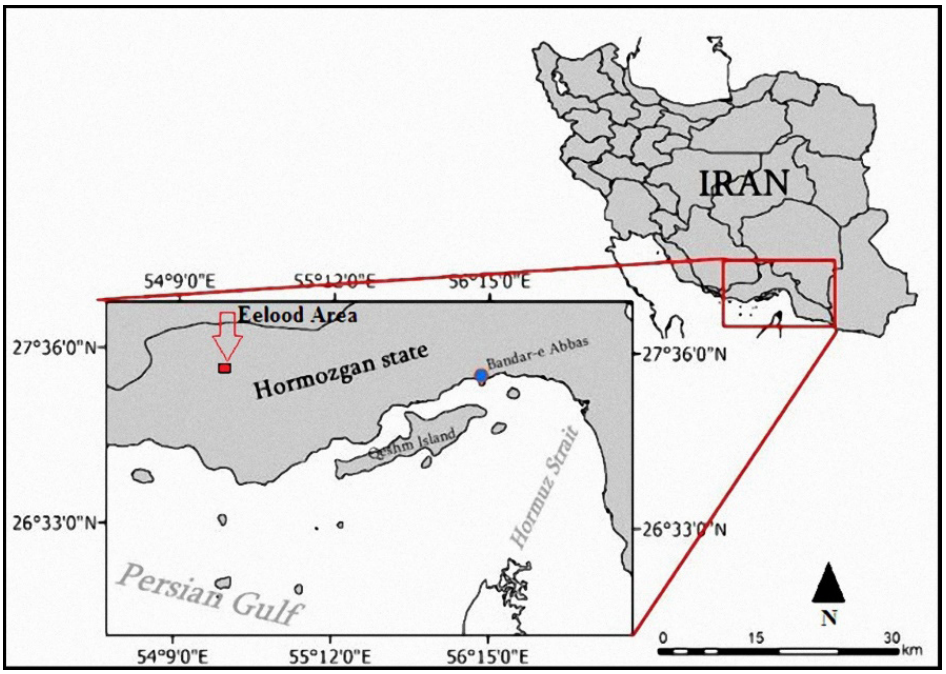

Figure 1. Sampling locations in Eelood Area, Hormozgan Province, Southern Iran.

calipers (0.01mm). Total weight is taken in grams by electronic digital balance (0.0001g). After recording of data, the carapace was submitted to dissection and the foregut carefully removed and weighted.

The Gastro-Somatic Index (GSI) was calculated according to the percentage ratio between weight of gastric stomach (GW) and the total weight (TW), according Biswass (1993) by the Formula 1:

$$GSI = \frac{GW}{TW} \times 100 \quad (1)$$

The vacuity index (CV) was represented by the percentage ratio between the numbers of empty stomachs (ES) and the total number of stomachs analyzed (TS), as considered by Biswass (1993) with Formula 2:

$$CV = \frac{ES}{TS} \times 100 \quad (2)$$

The data were normally distributed, thus the data were kept untransformed. The differences in CV index between different sex and months were determined by two-way ANOVA.

The repletion of the stomach was visually examined and assessed as 0, 25, 50, 75 or 100%. The foreguts were preserved in 10% formalin for a week, prior to being cut open and their contents transferred into Petri dishes with distilled water. The food components of the gut contents were separated and identified under a stereomicroscope. Gut contents were broadly classified into five categories, as follows: Crustaceans, Oligochaetes, Insects, Plant remains and Debris.

For each specimen, the whole stomach content was segregated according to food-groups, and contribution of each ones was visually determined. Dominance of food groups was evaluated by ranking them according their percentage frequency of occurrence (FO%) and so-called percentage points (see further below), as follow by Formula 3:

$$FO\% = \frac{\text{Nº of stomachs with particular food group}}{\text{Total Nº of stomachs with food}} \times 100 \quad (3)$$

To estimate the volume of the food by food-group, points were assigned to each group as suggested by Stehlik (1993), and percentage points (PP) were estimated by Formula 4:

$$PP = \frac{\text{Point of particular food group}}{\text{Total points of all food groups}} \times 100 \quad (4)$$

For the percentage point method, after the stomach has been removed it was scored from 1–5, according to the following fullness degrees (i.e., 100%, 75%, 50%, 25% and 0%, respectively). Food categories were given a value ranging from 0–100 according to the percentage of the stomach contents of a given individual represented to each category. The number of points that each category received was weighted according to the actual

fullness of the stomach in which it was found. For example, in a stomach that was half full and contained 25% insects and 75% crustaceans, the insects received a score of 12.5 points, the crustaceans a score of 37.5 points.

3. Results

In total, 120 individuals (58 male and 62 female) of *S. iranica* were analyzed, with 49 male crabs (84.5%) presenting trace-full stomachs and 9 (15.5%) with empty stomachs, while 35 females (56.5%) had trace-full and 27 (43.5%) with empty stomachs. The Gastro-Somatic Index (GSI) had minimum value in December 2012 and an increase until maximum value in April 2013 (Figure 2). The CV index (for both sexes) had a minimum and maximum in June 2012 and October 2012, respectively. Moreover, the highest and lowest values for males were observed in August 2012 and April 2013 (33.3%) and October 2012 (1.4%). While, in female crabs the order mentioned were observed in October 2012 (83.3%), June 2012 and February 2013 (12.5%) respectively (Figure 3). There were no significant differences between means of vacuity stomachs for both sex in different months ($F=2.10$, $P>0.05$), but there was a significant difference ($F=9.53$, $P<0.05$) between means of vacuity stomachs of female and male during survey.

The stomach contents of *S. iranica* appeared to consist of mainly large quantities Plant remains, Insects, Oligochaeta, Crustacean, also small quantities of debris. Out of total stomachs examined of males, 50% were full (35.5%) or empty (14.5%), with the intermediate categories ranging from 14.9 to 18.1%; for females 62.3% were represented by full (26.2%) or empty (36.1%) stomachs, and the others in a range of 3 to 18.1%, with inferior limit represented by stomachs with 50% of fullness. Details by month and the size class by sex are given in Tables 1 and 2.

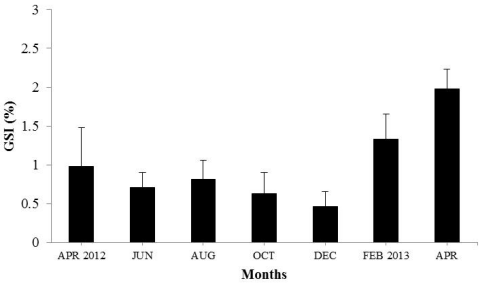

Figure 2. *Sodhiana iranica* Sharifian, Kamrani & Sharifian, 2014. Bimonthly Temporal trend of the gastric index during April 2012 to April 2013 at Eelood Area, Hormozgan Province, Southern Iran. Where: bars, average; lines, standard error.

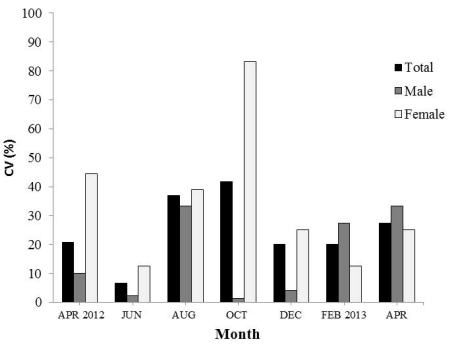

Figure 3. *Sodhiana iranica* Sharifian, Kamrani & Sharifian, 2014. Bimonthly fluctuation of CV index of *S. iranica* in the study area, during April 2012 to April 2013 at Eelood Area, Hormozgan Province, Southern Iran. Where: bars, average; lines, standard error.

Table 1. Stomach fullness during various months in *Sodhiana iranica.*

Sex	Month	Percentage (%)				
		Empty	25%	50%	75%	full
Females	April 2012	44.4	22.2	0	11.2	22.2
	June	12.5	25.0	12.5	12.5	37.5
	August	38.9	11.1	5.6	22.2	22.2
	October	83.3	16.7	0	0	0
	December	25.0	25.0	0	25.0	25.0
	February	12.5	0	0	37.5	50.0
	April 2013	25.0	12.5	25.0	0	37.5
Males	April 2012	10.0	40.0	10.0	15.0	25.0
	June	0.0	28.6	0.0	14.3	57.1
	August	33.4	0	44.4	22.2	0.0
	October	0	33.3	16.7	16.7	33.3
	December	0	0.0	0.0	0	100.0
	February	25.0	25.0	0.0	16.7	33.3
	April 2013	33.4	0.0	33.3	33.3	0

Table 2. Stomach fullness in different size groups (CW, carapace width in mm) of *Sodhiana iranica.*

Sex	CW class	Percentage (%)				
		0 (empty)	25	50	75	100 (full)
Females	10-19	0	0	0	50.0	50.0
	20-29	16.7	16.7	0	16.7	49.9
	30-39	46.1	15.4	7.7	7.7	23.1
Males	10-19	40.0	20.0	0	20.0	20.0
	20-29	8.3	25.0	0	16.7	50.0
	30-39	0	37.5	12.5	12.5	37.5

Whenever food was found in any stomach, it always consisted of a mixture of various food groups. Upon analysis (Table 3) it was found that the percentage frequency of occurrence obtained to each food item was represented in the follow hierarchical sequence: plant remains (34.8%) > insects (22.5%) > crustaceans (15.9%) = oligochaetes (15.9%) > debris (11.0%).

The points of the major food groups can be consulted in Table 3 and Figure 4. In the percentage of points, plant remains were the most dominant food group, and was found in 29.2% of the stomachs 'with food'. Plant remains were the most dominant in spring, and were found in 39.8% of the stomachs with food. Insects were the second dominant food item (20.1% of the stomachs), mainly in autumn (38.6%), the same occurring with the crustaceans in this same season (23.1%). Oligochaetes and crustaceans formed the third and fourth more important food items with 14.2 and 14.2%, respectively. Oligochaetes ranged between 5.2 and 19.1% in various seasons, with a maximum percentage registered in summer. Crustaceans ranged between 5.2 to 23.1% in winter and autumn, respectively. Debris was present in 8.9% of the stomachs, with a higher abundance in winter (15.5%). There were no significant differences in the preference for food items in the different season of the crab ($F=1.9$, $P>0.05$).

Table 3. Percentage of points and frequency of occurrence of major food groups in *Sodhiana iranica.*

Items	Points (%)	Frequency of occurrence (%)
Crustacea	14.2	15.9
Oligochaeta	14.2	15.9
Insects	20.1	22.5
Plant remains	29.2	34.8
Debris	8.9	11.0

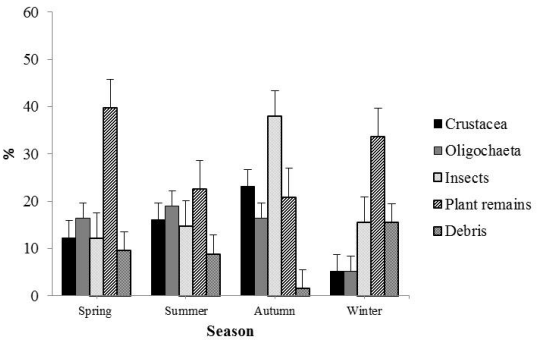

Figure 4. *Sodhiana iranica* Sharifian, Kamrani & Sharifian, 2014. Points of major food groups of the *S. iranica*in each season, during April 2012 to April 2013, at Eelood Area, Hormozgan Province, Southern Iran. Where: bars, average; lines, standard error.

4. Discussion

The wide spectrum of food items found in the stomach of *S. iranica* indicates herbivore-biased omnivore, which is in accordance with previous assessments (Williner & Collins, 2002; Collins et al., 2006; Kobayashi, 2012; Williner & Collins, 2013; Bahuguna et al., 2016). The presence of omnivorous organisms can contribute to understand the dynamics of aquatic systems (Long et al., 2011; Kratina et al., 2012). The supply of energy mainly from allochthonous sources can be showed the importance of *S. iranica* as grazer in subtropical spring and its effective nutrient assimilation of plant matter. In tropical and subtropical zones, the paucity of grazers can be compensated by alternative decomposition pathways, which are favored by higher temperatures (Irons et al., 1994). However, decapod crustaceans bear a strong impact as macro consumers of vegetarian items (Cheshire et al., 2005; Mancinelli et al., 2013). The land crabs are unusual as the largest organisms to rely on plant matter as their main food source (Linton & Greenaway, 2007). In this way, *S. iranica* can play a significant role at multiple trophic levels from subtropical spring of southern Iran.

On the other hand, the significant amount of vegetal items in the gut content of *S. iranica* can show metabolic ways for the digestion of

cellulose, either by an endogenous capacity or endosymbiotic organisms as reported for other crustaceans (Zimmer et al., 2001). Because of low nutritional quality of plant matter, a high amount of vegetal items had been ingested by *S. iranica* that actually implied a way to enhance the energy supply derived from a poor nutritional food in this crab. Moreover, this crab acts as an opportunistic predator. The analysis of items found in the stomach of *S. iranica* showed both sexes prey mainly upon animals that move slowly, such as oligochaetes, and insect larvae. Indeed, one of optimum way for minimizing the energy expended in capturing food can be preying on evasive, slow-moving prey (Collins & Paggi, 1998). The oligochaetes and insect larvae due to their high proportion of protein relative to biomass have an important role in the diet of crabs (Hepher, 1989; Ciancio et al., 2007). In addition, high frequency of these organisms in streams (Cushing & Allan, 2001), can be suggested the opportunistic trophic behavior of *S. iranica*. The elongated form and slow moving behavior of oligochaetes can be made positive balance between the gain and loss of energy during foraging behavior of species (Carvalho et al., 2013). Therefore, oligochaetes were susceptible and advantageous prey for predation by many aquatic organisms (Bouguenec & Giani, 1989; Carvalho et al., 2013). The results is in conform with the finding of Williner & Collins (2013) who reported the diet of freshwater crab with a high relatively percentage of oligochaetes and insect larvae. The usage of animal resources, and hunting them by freshwater crab is evident in previous studies (Williner & Collins, 2002; Collins et al., 2006; Carvalho et al., 2013; Pirela & Rincón, 2013; Williner & Collins 2013). However, it is quite indubitable the prominence of vegetal component in the diet of freshwater crabs. Plant remains were more relevant than other items in the gut content of *S. iranica.* In floodplains of springs and rivers, the macrophytic remains are an important item because of their nutritional value. The energy of plant matter would be more readily available than from animal matter (Mattson Junior, 1980).

Item such as crustacean was found in diet of *S. iranica* frequently in autumn. Because of limited frequency of molting in freshwater crabs (Yamaguchi & Takamatsu, 1980) it can be suggested the possibility of cannibalism in *S. iranica*. The occurrence of crustacean items in stomach increased in autumn that corresponds with when juvenile crabs are abundant in their habitat (Sharifian et al., 2017a). It was reported previously that crustaceans could be a nutritionally important item in the natural diet of decapods (Collins & Paggi, 1998; Collins & Williner, 2003). Moreover, because crustacean species have a lower proportion of protein in its biomass than oligochaetes, crabs must ingest a higher number of crustaceans than oligochaetes to receive the same amount of net energy (Carvalho et al., 2013). It is seem, *S. iranica* has the ability to consume crustaceans at certain times of the year when other, more preferred prey are not available.

The low frequency for debris in four season can be suggested the sorting of foods by the chelipeds to some extent, moreover, it is possible crabs do not directly bring debris to their mouth. A third possibility can be the preference of live animals in most cases.

It is clear, all trophic items, together with those of less relative importance are nutritionally essential for the crabs' growth and reproduction. However, endogenous and environmental factors can modulated the ingestion of different kinds of food (Aréchiga & Rodríguez-Sosa, 1997). Changes in the food type and the amount of ingested food have already been observed both in freshwater and marine decapods (Jayachandran, 2001; Collins et al., 2006). In this respect, it can be said crab of *S. iranica* had showed major trophic activity and used different kinds of trophic sources. It is known there was an efficient trituration process in brachyuran decapods because of their complex foregut armature with a robust gastric mill (Icely & Nott, 1992) which it will result difficult identification of gut content. Moreover, the surviving time can be greatly effected by the type of food (McGaw & Curtis, 2013). Therefore, prey with rapid digestion may be underestimated and those with slow digestion overestimated.

Briefly, it can be concluded the freshwater crab *S. iranica* is herbivore-biased omnivore, which mainly rely on plant sources. The ability of this species to digest and subsist on such low-grade plant material has a considerable physiological interest and precise information on this capacity is essential to understanding the ecology of this species.

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