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Dietary Diversity of Crayfish (*Procambarus clarkii* Girard 1852) (Crustacea, Decapoda) in Herbaceous Vegetation Dominated Swamps in Uasin Gishu, Kenya

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Abstract: ***The feeding ecology of red swamp crayfish (Procambarus clarkii Girard 1852) in terms of food and feeding habits was conducted in two sympatric East African wetlands (Uasin Gishu, Kenya) between February and November, 2012. Microscopic examination of the gut content of 320 P clerkii in the two swamps, showed distinct tendency towards herbivory with dominance of plant materials, algae and lower abundance of insects. There were no significant (p > 0.05) differences in the overall composition of food items between the two swamps. The electivity values for pooled data in the two sites showed a strong negative electivity for rotifers and, to a minor extent, for molluscs. Also P. clerkii showed significant (p < 0.05) ontogenetic variation in the diet. Plant materials, crustaceans and molluscs increased in proportion with respect to size class as they could not be digested by young P. clerkii while insects and algae reduced with increasing age classes. Overestimation of herbivory and detrivory in this omnivorous species may indicate diet complexity in the tropical swamps in an environment dominated with dense herbaceous plants species.***

Keywords: Crayfish, Feeding habits, Diet, Herbaceous plants, East African Wetland, Herbivory

1. Introduction

The red swamp crayfish (*Procambrus clarkii*) is an autochthonous species from the Northeast of Mexico and South Central US [1], which was introduced worldwide and has become the dominant freshwater crayfish in almost all areas it occupies [2]. There are no indigenous species of crayfish in mainland Africa, but expanding populations of introduced *P. clarkii* can be found in Kenya, Uganda and Zambia [3]. In Kenya, the *P. clarkii* was introduced into Lake Naivasha, in the 1970's, and has spread into many waterbodies [4]. Mechanisms of their spread to the wetlands in Kenya, including swamps of Uasin Gishu Districts is not clear. Nevertheless the *P. clerkii* now occupy an important ecological component of swamps in Kenya.

Trophic response of species is a key element in evaluating the ecological role of a population or species in the community of any ecosystem. Moreover, studies of food habits, are important in provision of information on the impact of predator on prey population dynamics, contribution of prey and other food items to predator nutrition and relative abundance of all potential prey and food preferences, which can result to proper managerial decision on fishery or biodiversity of local water bodies [5]. With respect to trophic response, studies of feeding habits of introduced species are vital. Studies of the food and feeding habits of many species including *P. clarkii* in several habitats are well described. Most studies on the dietary habits *P. clarkii* have been done under controlled conditions in laboratory experiments [6-9], in commercial ponds [10,11], in rivers [12,13] and lakes [14]. Information on the food and feeding habits of *P. clarkii* is therefore well-understood in its natural range and in the laboratory conditions. However, there is still paucity of knowledge on the feeding habits of the organism introduced in the tropical wetlands. This study examines the feeding ecology of *P. clarkii* in swamps of Uasin Gishu in Kenya.

2. Materials and Methods

Field study was carried out between February and November, 2012 in Leseru Swamp (0° 30' 24.25" N and 35° 24' 12.42" E) along River Sosiani and Marula Swamp (0° 39' 20.15" S and 36° 21' 9.55" E) situated along River Sergoit in Kenya. A total of 160 *P. clarkii* was sampled from each swamp using traps and handpicking. They were weighed immediately using a meter rule to determine their sizes. The samples were then preserved using 90% ethyl alcohol and finally transported to laboratory for further analyses. Water samples were also collected in triplicate at each site. Water was fetched using bucket and transferred to the 50 ml sampling bottles for analysis of food content in *P. clarkii* habitats.

In the laboratory, the crayfish were measured (total length, TL, in mm) and allocated into four class sizes: <40 mm; 40.1–80 mm; 80.1–120 mm; and >120 mm using a Vanier calipers to the nearest ± 0.01 mm according to the protocols in Pérez-Bote (2005). The guts were carefully removed, washed in running tap water to remove excess 90% ethanol solution and dissected in a Petri dish to remove the viscera. The gut contents were washed out with ethanol into a dish for later identification. The preserved ingesta were examined and quantified under a dissecting microscope, normally by determining the prey from remnants of exoskeleton and other undigested prey parts. For algae analyses, 1 ml of the sub-sample was pipetted to a WILDCO® Gridded Counting Chamber and placed in the mechanical stage of a compound microscope. Diet items were identified under a dissecting microscope (up to 50 × magnification) or a high power microscope (400 × magnification). Identification of food items was done to the lowest taxonomic unit using several identification guides. The amorphous material and sand were separated by centrifuging for 15 minutes, and weighed separately. All weights were measured to the nearest 0.1 mg. Food items that were not easily quantified were noted and recorded. Also all guts were analyzed for fullness and content.

Numerical abundance (%N), frequency of occurrence (%F) and contribution by biomass (%Bio) were used in quantitative description of the diet [5]. Numerical abundance was the number of each food item determined from the fish examined and was calculated as: Numerical abundance (%N) = (Ni/∑Ni)*100. Where Ni is the number of food items counted in the stomach, ∑Ni is the total number of items counted in all stomachs. Frequency of occurrence was calculated as Frequency of Occurrence (%F) = (Fi/∑Fi)*100. Where Fi is the number of stomach with food items and ∑Fi is the total number of stomach analyzed. Percentage contribution by biomass (%Bio) = (Bioi/∑Bioi)*100. Where Bioi is the biomass of individual food item in the stomach and ∑Bioi is the total biomass of food items analyzed in all the stomachs. Selectivity of food items by *P. clarkii* was estimated using the Ivlev's index of electivity (E) [15].

$$E = \frac{r_i - p_i}{r_i + p_i}$$

Where $\boldsymbol{r_i}$ = proportion of a food item in fish stomach; ***Pi***= proportion of the food item in the water sample

Electivity values determined using the index have a possible range of –1 to +1. Values closer to +1 indicate preference whereas values closer to –1 indicate avoidance of prey. Differences in diets per sampling site, and among different size classes were analyzed using Chi-square test.

3. Results

We analyzed a total of 320 *P. clarkii* stomachs from each swamp (160 from each swamp). All stomachs were full except 2 in Leseru Swamp. Table 1 provides information on the diet composition using three measures. A total of 6 different dietary groups were identified. These were: herbaceous plant materials, algae, crustacean, Mollusca, Insecta, Rotifera. The herbaceous plant materials belonged to fifteen classes dominated by acanthaceae, asteraceae, poaceae and cyperaceae. The algae classes were: Cholorophyceae, Cyanophyceae and diatoms. Insect classes identified included: Diptera, Ephemeroptera, Coleoptera and Hemiptera. In terms of numerical abundance, plants were the most important food item (35%), followed by algae (29%) and insecta (22%). Most of these plant species were deemed edible. Based on the frequency of occurrence; crustaceans, occurred more in the stomachs followed by plant materials and algae. Based on the percentage contribution by biomass; plant materials were the highest (58%) items in the guts of *P. clarkii*, followed by insecta (21% and 24% in the two swamps respectively). Algae contributed 10% by biomass to the diet of *P. clerkii*. There were no significant ($p > 0.05$) differences in the overall composition of food items in the two swamps.

Table 1: Diet composition expressed as percentage contribution by number (%N), frequency of occurrence and percentage contribution by biomass in guts of *P. clarkii* in Leseru and Marula Swamps from February to September 2012.

	Numerical abundance (%N)		Frequency of occurrence (% F)		Percentage contribution by biomass (%Bio)	
Food items	Leseru	Marula	Leseru	Marula	Leseru	Marula
Herbaceous plant materials	**35.63**	**35.00**	**61.53**	**61.85**	**51.88**	**50.85**
Algae						
Microcystis aeruginosa	0.21	0.00	96.88	98.75	0.07	0.00
Melosira spp	6.54	5.98	88.13	93.13	2.33	2.13
Botryococcus brauni	5.54	7.89	63.75	71.25	1.97	2.81
Chlamydomonas spp.	1.33	0.37	62.50	68.13	0.47	0.13
Chloromonas spp.	0.28	0.56	75.63	78.13	0.10	0.20
Sphaerellopsis	0.65	1.36	33.75	35.00	0.23	0.48
Chlorogonium fusiforme	1.44	2.56	15.63	16.25	0.51	0.91
Navicula spp	5.64	5.41	20.63	21.88	2.01	1.93
Chloroglea spp	0.30	1.33	22.50	30.63	0.11	0.47
Diatoma spp	5.17	3.35	97.50	96.25	1.84	1.19
Synedra	0.09	0.20	27.50	28.75	0.03	0.07
Euglena spp	0.39	0.41	90.00	83.13	0.14	0.15
Unidentified algae	2.35	0.21	96.25	97.50	0.84	0.07
Total	**29.93**	**29.63**	**60.82**	**62.98**	**10.66**	**10.55**
Crustacea						
Cladocera	1.46	2.63	90.00	87.50	1.64	2.95
Copedoda	3.44	2.45	87.50	94.38	3.86	2.75
Nauplius	1.22	0.78	85.63	65.63	0.15	0.10
Calanoida	3.38	1.74	78.75	76.25	3.79	1.95
P. clerkii shells	1.20	1.50	92.50	98.75	1.35	1.68
Total	**10.70**	**9.10**	**86.88**	**84.50**	**10.79**	**9.43**
Mollusca						
Gastropod shells	1.14	1.36	14.38	9.38	1.23	1.56
Total	**1.14**	**1.36**	**14.38**	**9.38**	**1.23**	**1.56**
Insecta						
Trichoptera spp.	0.49	0.66	78.13	82.50	0.48	0.65
Limnaea spp.	3.41	1.32	83.13	90.00	3.33	1.29
Heptogenia spp.	0.32	0.56	10.00	6.88	0.31	0.55
Chironomus spp.	9.89	10.36	90.00	83.13	9.67	10.13
Baetis spp.	0.18	2.31	90.63	91.88	0.18	2.26
Caenis spp.	4.07	4.54	83.13	68.75	3.98	4.44
Heptogenia spp.	0.56	0.00	63.75	61.88	0.55	0.00
Notonecta spp.	0.21	1.08	40.63	70.00	0.21	1.06
Phymata spp.	0.36	0.45	20.63	21.88	0.35	0.44
Gomphus spp.	0.79	0.88	35.00	29.38	0.77	0.86
Sphaerium spp.	0.24	1.17	57.50	35.00	0.23	1.14
Hydropsyche spp.	0.00	1.19	44.38	60.00	0.00	1.16
Diptera spp.	1.44	0.17	85.00	78.75	1.41	0.17
Total	**21.96**	**24.69**	**60.14**	**60.00**	**21.48**	**24.15**
Rotifera	0.64	0.22	35.00	40.63	0.78	0.54
Sand grains	NC	NC	98.75	98.75	1.56	1.12
Detritus	NC	NC	100.00	100.00	1.63	1.80

The Ivlev's electivity index for pooled data in the two sites shows a strong negative electivity for rotifers (-0.85) and, to a minor extent, for molluscs (-0.50). There was a positive electivity for herbaceous plants (0.97), algae (0.87-0.96) and insects (0.81-0.99) (Table 2).

Table 2: Ivlev's electivity index (d) of biomass consumed compared to availability for prey categories available at two swamps in Uasin Gishu between February and November 2012. Diversity index (H') values for the habitat and gut contents of the two wetlands

	Sites	
Food items	Site 1	Site 2
Herbaceous plant materials	0.97	0.98
Algae	0.87	0.96
Crustacea	0.66	0.57
Mollusca	-0.58	-0.48
Insecta	0.99	0.81
Rotifera	-0.90	-0.85

The diet of the *P. clerkii* showed significant ($p < 0.05$) variation according to the size class (Fig 1). Generally, plant materials, crustaceans and molluscs increased in proportion with respect to size class while algae and insects showed opposing trends. We also noted that cannibalism increased with size class, being highest at > 80.1 mm.

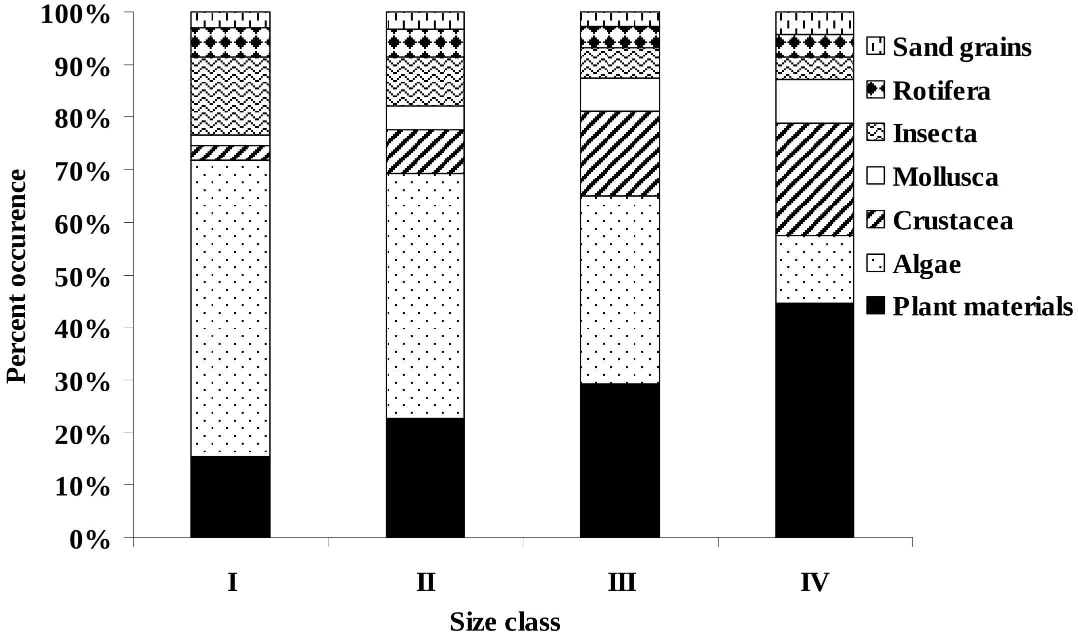

Figure 1: Diet of size classes of *Procambarus clarkii* (Girard) in the swamps, in % of total. The results are based on pooled data.

4. Discussion

Ecological plasticity of *P. clarkii* may be expressed in its feeding habits. Our results reflect the trophic plasticity of *P. clarkii* which is able to exploit a large variety of food sources in the two swamps studied. Currently, *P. clarkii* fed on a total of 17 categories of food items indicating strong tendency towards herbivory. The resources most frequently used by *P. clarkii* at both study sites were higher plants, crustacean, algae, and to less extent, detritus. Most of the stomachs contained crustacean but their contribution numerically and to biomass was less than 10% suggesting that the crayfish fed on lower quantities of these food items. From an energetic point of view, *P. clarkii* with its high energetic demands [16] is expected to consume macroinvertebrates when available, and be selective with respect to herbivorous plant food sources. It has been previously reported that based on stable isotopes analysis, crayfish food sources of animal origin are more important than detritus and plant material [17]. The observed differences in preference of plant and algae materials in wetlands could therefore be associated with food switching behaviour in environment with low animal food items since *P. clarkii* is biochemically equipped to assimilate material of plant origin [16,18].

Our findings highlight the importance of prey selection in the diet of *P. clerkii* based on the occurrence of food items in the environment. In this study, *P. clerkii* showed strong preference for edible herbaceous plants, algae and insects which were also available in high quantity in the environment but appeared not to feed on low abundance food items like rotifers and molluscs. Selection of plant proteins over animal protein in the swamps is surprising since protein of animal origin, especially of macro-invertebrates, is often better-digested [19] than the plant-based proteins. Additionally, secondary metabolites in plants adversely affect the digestive processes. Perhaps the absence of more profitable prey may lead to increased selection of plant materials that were more abundant in the environment, an indication that this species has to meet part of its energetic demands by ingesting food items that are available in the environment.

A shift in food habits has been found to accompany increase in length for several species of crayfish [20]. Greater consumption of animal matter by classes I and II may be related to the necessity for protein-rich food sources to support the rapid growth of young crayfish, which are more susceptible to fish predation than larger adult *P. clerkii* [21]. Adult *P. clekii* was more herbivorous-detritivorous, because their large size relative to prey may render them effective at capturing small invertebrates within the substrate. The omnivory nature of the *P. clarkii* may enhance food availability during important life history events such as moulting and reproduction, and with an increased diversity of prey items in the field. These results suggest that *P. clerkii* exhibit ontogenetic shifts in food habits.

5. Conclusion

In conclusion, *P. clarkii* plays an important role in the swamps of Uasin Gishu because as a shredder and predator, it obtains most of its energy from feeding on plants, animals and insects. By feeding on a variety of the food items in the wetlands, *P. clerkii* dominate the energy flow in this system and act as the keystone species. Thus, further evaluation of the impact of *P. clarkii* on the biomass and productivity in the tropical swamps is undoubtedly needed.

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