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Length-Weight Relationships of Some Important Forage Crustaceans from South Africa

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Abstract

The diet of marine animals is usually determined by stomach content analysis. Although partially digested prey fragments can often be identified to species level, it is difficult to estimate the original mass of the prey organism. This information, however, is essential for calculating both the total food intake as well as the relative contribution of each prey item. In this study we present regression equations that can be used to estimate the original mass of 18 common South African crustaceans from various indigestible fragments such as the carapace (length and width), chelae (length and width of left and right dactylus) and eye (length and width).

Introduction

Stomach content analysis is commonly used to determine the diet of marine teleosts, chondricthyans, cephalopods, crustaceans, seabirds and mammals. It is often possible to identify the prey remains to actual species, and this information can provide insight into foraging behavior. The results of stomach-content analyses can also be used to determine the trophic position of a species within the ecosystem. Prey fragments are usually separated into taxonomic groups, weighed and then used to calculate an index of relative importance for each prey item (Cortés 1997). Such “quantitative” interpretations of stomach contents, however, are biased by digestive breakdown (Berg 1979).

To quantify the relative contribution of the various dietary components, it is necessary to calculate the ingested mass of each food item from the fragments recovered in the stomach contents. The procedure of calculation relies on two pieces of information. First, it must be possible to assign individual prey fragments to individual prey species. Hard body parts of cephalopods (beaks), fish (otoliths) and most decapod crustaceans (carapaces, chelae and eyes) are relatively resistant to digestion and are sufficiently distinctive to allow identification to species or genus level. Second, there must be an established relationship between the size of the fragments and the mass of the prey item. There are some regression equations that can be used to convert otolith length to fish size, and beak length to cephalopod size (Smale 1983). However, few such relationships exist for crustaceans, even though their fragments are common in teleosts (Joubert and Hanekom 1980; Pulfrich and Griffiths 1988; Punt et al. 1992), chondrichthyans (Ebert et al. 1996; Smale and Compagno 1997), cephalopods (Nixon 1987; Sánchez and Obarti 1993; Quetglas et al. 1998), marine mammals (David 1987) and other crustaceans (Lawton and Lavalli 1995). In this study, we attempt to redress this gap in knowledge by providing regression equations that will allow the calculation of ingested prey mass from the size of conspicuous and characteristic fragments for a number of common South African crustaceans.

Materials and Methods

Crustaceans from intertidal, shallow and deepwater marine environments as well as estuaries were collected from a variety of localities along the west coast of South Africa. The crustaceans examined included crabs, hermit crabs, prawns and mantis shrimps. Some of the material was collected specifically for the purpose of this study, whereas other specimens (particularly the benthic and benthopelagic crustaceans that occupy the continental shelf) were examined from the collections at the South African Museum. All material was preserved in 70% ethanol.

The conspicuous crustacean fragments that were recovered from the stomach include carapaces, chelae and eyes. The following standardized measurements were recorded from each intact specimen of non-natantian decapod and stomatopod: wet weight; carapace width; carapace length; left dactylus length; left dactylus width; right dactylus length; right dactylus width; and eye width. Eye length was also measured when the eye was ovoid. In the case of natantian decapods (the true prawns and shrimps), only the carapace, eye and weight measurements were made.

The length and width of the dactylus of the left and right chelae were measured separately because these limbs can show marked asymmetry, with some species being either right or left-“handed”. For example, the hermit crab *Parapagurus bouvieri*

Table 1. Regression equations for 18 crustacean species from South Africa.

Group	Species	Wet weight Mean (range) (g)	Variable	a	b	r^2	n	Range (mm)
Crabs	*Cyclograpsus punctatus*	2.47 (0.12-9.96)	carapace length	0.9416	2.553	0.88^{***}	107	0.4-2.2
			carapace width	0.5260	2.753	0.82^{***}	107	0.6-2.8
			left chela length	1.4674	1.988	0.72^{***}	105	0.4-2.5
			left chela width	5.3479	1.486	0.52^{***}	105	0.2-1.6
			right chela length	1.4984	1.884	0.65^{***}	104	0.4-2.4
			right chela width	4.4221	1.306	0.36^{***}	105	0.2-1.9
			eye width	6.4741	2.199	0.43^{***}	107	0.2-0.8
	Geryon chuni	91.58 (39.69-220.07)	carapace length	0.0002	3.239	0.90^{***}	14	47-77
			carapace width	0.0001	3.308	0.87^{***}	14	55-90
			left chela length	0.0054	2.551	0.90^{***}	14	31-61
			left chela width	0.2585	2.179	0.61^{***}	14	10-20
			right chela length	0.0037	2.620	0.85^{***}	14	34-65
			right chela width	2.6030	1.262	0.27^{+}	14	9-22
			eye width	16.9443	0.797	0.22^{+}	14	3.75-11.25
	Goneplax angulata	8.81 (3.13-20.24)	carapace length	0.0359	1.829	0.61^{***}	62	14-33
			carapace width	0.0061	2.160	0.63^{***}	62	18-43
			left chela length	0.1016	1.225	0.70^{***}	62	21.0-59.1
			left chela width	0.5082	1.315	0.62^{***}	62	5-19
			right chela length	0.0643	1.348	0.78^{***}	50	21.3-61.0
			right chela width	0.1583	1.823	0.82^{***}	50	6-16
			eye width	5.1603	0.284	0.08^{*}	62	0.83-8.75
			eye length			$0.20^{n.s.}$	10	2.08-5.00
	Hymenosoma orbiculare	1.77 (0.06-4.35)	carapace length	0.0005	2.787	0.97^{***}	90	5.95-24.02
			carapace width	0.0007	2.757	0.96^{***}	90	5.67-23.34
			left chela length	0.0217	2.284	0.81^{***}	86	2.31-11.81
			left chela width	0.3594	1.497	0.64^{***}	86	0.66-6.20
			right chela length	0.0296	2.120	0.76^{***}	82	2.26-11.97
			right chela width	0.3546	1.495	0.65^{***}	82	0.69-6.33
			eye width	2.3543	2.780	0.70^{***}	90	0.35-1.40
			eye length	0.9469	3.693	0.76^{***}	90	0.55-1.70
	Mursia cristimanus	13.34 (0.75-37.93)	carapace length	0.0009	2.843	0.85^{***}	101	9-50
			carapace width	0.0010	2.730	0.92^{***}	101	8.8-54
			left chela length	0.0079	2.296	0.84^{***}	101	7.5-50.0
			left chela width	0.0590	1.994	0.78^{***}	101	4.4-28
			right chela length	0.0087	2.279	0.88^{***}	97	5.6-40.0
			right chela width	0.0667	1.957	0.74^{***}	95	4-25
			eye width	2.2228	1.152	0.49^{***}	99	1-10
			eye length			$0.23^{n.s.}$	8	1.00-4.17
	Plagusia chabrus	22.96 (0.55-82.20)	carapace length	0.0015	2.759	0.99^{***}	38	7.0-49.1
			carapace width	0.0014	2.718	0.98^{***}	37	9-58.4
			left chela length	0.0024	3.082	0.95^{***}	36	6-34
			left chela width	0.1018	2.755	0.90^{***}	36	2-15
			right chela length	0.0033	2.971	0.90^{***}	35	5-35
			right chela width	0.1198	2.658	0.89^{***}	37	2-15
			eye width	5.7447	2.014	0.75^{***}	38	0.4-3.33
	Thelxiope barbata	9.61 (2.06-17.79)	carapace length	0.0064	2.131	0.54^{**}	16	21-42
			carapace width	0.1218	1.437	0.64^{***}	16	10-36
			left chela length			$0.10^{n.s.}$	14	15-29
			left chela width			$0.09^{n.s.}$	14	5-9
			right chela length			$0.19^{n.s.}$	12	12-31
			right chela width	0.8759	1.245	0.37^{*}	12	4-11
			eye width	2.0795	1.548	0.21^{+}	16	1.88-3.75
Hermit crabs	*Diogenes brevirostris*	0.74 (0.11-1.81)	carapace length	0.0010	3.668	0.93^{***}	119	3.69-7.50
			carapace width	0.0047	3.267	0.92^{***}	119	2.79-6.05
			left chela length	0.0025	2.952	0.88^{***}	115	4.02-9.09
			left chela width	0.0046	2.997	0.93^{***}	115	3.02-7.24
			right chela length	0.0112	3.051	0.87^{***}	119	2.39-5.30
			right chela width	0.1027	2.691	0.87^{***}	119	1.15-3.07
			eye width	2.1560	4.450	0.76^{***}	119	0.55-0.95
			eye length	0.8363	4.467	0.75^{***}	119	0.65-1.20

Table continued....

	Parapagurus bouvieri	6.85 (1.97-15.62)	carapace length	0.1993	1.136	0.25*	22	10-27
			carapace width	0.4601	1.055	0.22*	21	6-15
			left chela length	0.5013	1.039	0.22*	22	6-16
			left chela width	1.9719	0.847	0.30**	22	2-6
			right chela length	0.2151	1.099	0.32**	22	11-36
			right chela width	0.4735	1.174	0.23*	22	5-13
			eye width	1.2008	1.479	0.34**	22	1.88-4.38
	Parapagurus dimorphus (with sponge shelter)	6.89 (2.08-15.70)	right chela length	0.4575	0.895	0.43***	22	7.4-42.3
			right chela width	0.7854	1.003	0.43***	22	3.1-12.0
			eye width	4.6952	0.919	0.68***	23	0.5-2.5
	Parapagurus dimorphus (without sponge shelter)	4.59 (1.96-12.61)	carapace length	0.1647	1.196	0.50***	70	10-24
			carapace width	0.8792	0.778	0.40***	70	3-13
			left chela length	0.9083	0.739	0.18***	69	4-12
			left chela width	2.5906	0.406	0.08*	69	2-6
			right chela length	0.3753	0.892	0.28***	70	9-26
			right chela width	1.1432	0.683	0.44***	70	3-19
			eye width	1.8037	0.726	0.43***	68	0.63-5.13
Mantis shrimps	*Pterygosquilla armata capensis*	5.30 (0.51-36.41)	carapace length	0.0051	2.322	0.81***	54	8.3-37
			carapace width	0.0545	1.730	0.70***	54	4-28.6
			left chela length	0.0023	2.428	0.82***	53	11-42.7
			left chela width	0.4126	1.709	0.71***	52	1.3-10
			right chela length	0.0038	2.266	0.75***	54	10-43.8
			right chela width	0.5008	1.528	0.65***	54	1-10.4
			eye width	0.6434	1.085	0.16**	54	2.5-8.75
Mud prawns	*Upogebia africana*	4.83 (0.59-9.18)	carapace length	0.0005	2.988	0.97***	50	10.86-25.49
			left chela length	0.0806	1.873	0.80***	50	4.03-12.45
			left chela width	1.2769	0.898	0.47***	50	1.94-7.61
			right chela length	0.0697	1.951	0.81***	49	4.06-12.09
			right chela width	1.2056	0.937	0.47***	49	2.02-7.63
			eye width	5.1263	2.854	0.69***	51	0.6-1.3
Prawns	*Funchalia woodwardi*	12.45 (7.40-17.07)	carapace length	0.0011	2.343	0.46**	19	45.1-58.8
			carapace width	0.0718	1.957	0.82***	19	10.6-16.6
			eye width			0.02$^{n.s.}$	19	2.50-4.33
	Paraeus sp.	0.21 (0.02-0.54)	carapace length	0.0005	3.005	0.88***	29	3.7-10.0
			eye width	0.1156	2.146	0.45***	29	0.83-1.67
			eye length	0.0242	2.683	0.72***	29	1.17-3.17
	Parapenaeopsis acclivirostris	1.24 (0.17-4.94)	carapace length	0.0016	2.025	0.76***	83	12.2-36.0
			carapace width	0.0414	1.922	0.70***	83	3-10
			left chela length	0.0028	1.736	0.26***	51	22-49
			left chela width	0.1277	1.304	0.32***	51	3-9
			eye width	0.5232	0.685	0.27***	83	0.83-6.25
			eye length	0.0272	3.432	0.83***	32	1.83-4.00
	Sergia potens	5.19 (2.53-13.27)	carapace length	0.0063	2.034	0.85***	30	22.1-45.8
			carapace width	0.2667	1.436	0.69***	30	5.7-14.2
			eye width	2.6792	0.748	0.24**	30	1.5-4.17
Sand prawns	*Callianassa kraussi*	1.96 (0.097-7.69)	carapace length	0.0017	3.276	0.97***	166	2.92-12.73
			max chela length	0.0035	2.718	0.92***	142	0.59-1.30
			max chela width	0.0210	2.476	0.91***	142	0.36-1.10
			min chela length	0.0057	3.123	0.96***	142	0.37-1.03
			min chela width	0.0767	2.843	0.94***	142	0.06-0.70
			eye length	214.7207	4.986	0.71***	166	0.20-0.50
		berry weight	weight	0.2090	0.820	0.25*	22	2.03-4.10

Significance levels are:

n.s. = not significant.

$^{+}$ p < 0.1. ** p < 0.01.

* p < 0.05. *** p < 0.001.

is right-handed (see Table 1), while the sand prawn *Callianassa kraussi* can be either right or left-handed. As the large and small chelae of this species are easily distinguished morphologically, we have grouped all the large chelae together and all the small chelae together. Crustacean eyes were measured, although they cannot generally be identified to species. However, other fragments in the stomach may provide a positive identification, in which case the length-weight regression using eyes becomes useful.

The wet weight (±0.01 g) of all material was determined on a Sartorius balance, after the specimens had been dried on blotting paper. All length measurements were in mm. Eye dimensions were measured at x20 magnification under a dissecting microscope. All other measurements were made using electronic vernier calipers.

Relationships between wet weight and the linear dimensions of the different fragments were calculated using least squares regression ($\mathbf{Y = aX^b}$), after log transformation of both **X** and **Y** variables. Males and females were not analyzed separately because of the difficulty of assigning a sex to fragments.

Results and Discussion

The regression equations for the 18 crustacean species are summarized in Table 1. In all instances, wet weight is the dependent variable and the dimensions of various characteristic fragments are the independent variables. The proportion of variance explained by each relationship is also shown, as is the sample size and the significance level. Nonsignificant equations have been identified to show which relationships were assessed. The mean mass of each species is also included, because it provides an estimate of the mass of a specimen when a fragment can be identified to species level, but the regression equation is nonsignificant. The range of the various independent variables is also shown (Table 1), as regression relationships should be applied with caution beyond the limits of the range of the original data (Zar 1984). Two sets of equations are given for *Parapagurus dimorphus*, one set with and one without its sponge shelter, because the sponge could also provide nutrition for a predator. The relationship between berry weight and wet weight for *Callianassa kraussi* is also given. This relationship can be used to calculate the mass of berry ingested by an animal if it can be seen that some berry is present.

Overall, wet weight was strongly correlated with carapace, chelae and eye dimensions, and 92% (103 out of the 112) of the relationships were significant at the 5% level. Wet weight was more strongly correlated with carapace dimensions and chelae length than with chelae width or eye dimensions. This could reflect the difficulty of measuring small body parts accurately. Some of the scatter of points in the relationships relating wet weight to chelae dimensions could have arisen because individuals lose limbs and then regenerate a new one that is smaller than the original.

We have shown that the original mass of many crustacean species can be predicted from the size of their indigestible fragments. This will enable the relative contribution by mass of some decapods and stomatopods to the diet of many marine animals to be estimated, rather than just the relative contribution of their prey fragments. This information is essential for quantifying trophic flows in marine food webs.

A knowledge of trophic flows is needed in order to understand ecosystems, so as to manage them sustainably. The traditional approach of managing fisheries using single-species models has had limited success (Bakun 1996). It has been argued that to manage fisheries resources sustainably, it is necessary to use a multispecies approach (Pauly et al. 1998). Trophic models such as Ecopath have been developed for this purpose (Christensen and Pauly 1992). These tools not only require information on the different prey items of a fish, but information on the relative importance by mass of each prey item. It is hoped that the relationships provided in this paper will contribute toward this end.

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