Korean J. Zool. 34:338-351, 1991

The Growth Analysis of the Crayfish (*Cambaroides similis* Koelbel) (Crustacea) I. Absolute Growth

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The analysis of the absolute growth in seven body parts of crayfish (*Cambaroides similis* Koelbel), such as carapace length, carapace width, abdominal length, abdominal width, cheliped length, second pereiopod length and third pereiopod length (the growth formula, $y = a + bt + ct^2$ applied) was performed. The results obtained are as follows:

1. The analyses of changing growth quantity for the seven body parts in both sexes showed concave shaped increase.

2. The largest ratios of the growth quantity in both sexes were revealed in abdominal width (18.3677 times in male and 18.9253 times in female).

3. The growth rates of the seven body parts in both sexes showed a smooth increasing pattern.

4. All the specific growth rates revealed a decreasing pattern, moreover steep descendent patterns of it appeared in abdominal length of both sexes and abdominal width in male.

KEY WORDS: Growth analysis, Growth formula, Absolute growth, Carapace length.

The development and growth of an organism undergo having relation to its biological inherited differences, internal factors such as inorganic substances, organic compounds, hormones, vitamins and physiological functions and external factors such as weather, season, nutrition and geographical circumstances. In human being, specially, whose occupation, living circumstances, deseases, periods and even sychological factors influence to them.

In our country, the researches of the development and the growth of human being had already been performed by Paik (1961), Lee (1969) and Kwon *et al* (1981). Park (1974), Kim (1974) and Rhee and Kim (1976) studied and analyzed on the development of the several organs of chick embryo. In Arthropoda, the growth analyses for several kinds of insect with relation to their metamorphosis were studied by many researchers (Park and Lee, 1971; Park, 1976, 1977; Park and Son, 1984; Noh and Yeun, 1986) and the crayfish of crustacea was studied on the growth analysis to the partial period by Yeun (1985). In 1934, Zimmerman *et al.* and Ishikawa (1938) applied the growth formula, a quadrate equation $y = a + bt + ct^2$, to the growth of an organism on account of similarity with the law of physiological movement.

In this study, the crayfish (*Cambaroides similis* Koelbel), known as Korean unique species growing by ecdysis without larva stage after hatching from egg to an adult, were surveyed on the seven body parts and analyzed to the absolute growth.

Materials and Methods

Material and Measurement

Three hundred and fifty-six crayfish, *Cambaroides similis* Koelbel (190 males and 166 females), were used in this study which were collected from the valley in San-Nai Myon Jyong-Up Gun in Chyon-Buk province from April in 1983 to April in 1988. The carapace length of the collected

specimens ranged from 2.76 mm (just hatched from egg) to 34.67 mm in fully grown adult. The parts of the body taken in this study were carapace length, carapace width, adbominal length, abdominal width, cheliped length, second pereiopod length and third pereiopod length, and the valiables of the forth and fifth pereiopod were selected because of showing almost similar dimensions with that of the second pereiopod. The measurements were performed by dissecting microscope in μm by the use of micrometer. The dimensions of which fully grownup's were measured with the ruler (1/600 mm) made by Takeda Co. Japan. To aboid errors as possible, the measurement of all aspects of the materials was carried out by one person. The dimensions of carapace width and abdominal width measured to the broadest part of them, of carapace length was the range from the tip of the rostrum to the hind margin of carapace, of abdominal length was the range from the margin of the first abdominal segment to the hind margin of the anus plate, and of the three legs were the range from the apex (tip or basal part) of the protopodite to the tip of the dactylopodite.

Statistical calculation and Growth analysis

For the analysis of the data, we transfered and followed the general formula $y = a + bt + ct^2$, outlined by Zimmerman *et al.* (1934). In this quadratic equation, y as a growth quantity (GQ) is a function of time in each growing period, that is the value of y depends upon the time t in each growing period. We substituted the seven periods from zero to six for the initial period to the fully grownup adult. Finally the three constants a, b and c and be calculated by applying the least square method. The derivatives obtained from the formula are as follows.

1) Growth rate (GR), $dy/dt = b + 2c$

2) Specific growth rate (SGR), $100/y \times dt/dy$

3) Growth power (GP), $d^2y/dt^2 = 2c$

4) Initial quantity of growth (IQ) is gained from the first constant a of the formula $y = a + bt + ct^2$, and initial velocity of growth (IV) is represented as b.

5) Ratio of growth quantity (QR), the mathematical rate of y at the particular instant can be obtained by the expression qi/ql, in which the qi is the growth quantity of each grwoth period and the ql is the grwoth quantity of the initial growth period.

Results

For the study of certifying the growth state of *Cambaroides similis*, the basic data for the measurement in each period of all the aspects were showed in Table 1.

The results analysing the data applying the growth formula are in Table 2 to 15 and Figures 1 to 5. The total mean of the growth quantity (in observed value) in both sexes from the ones in the first growth period to the fully grown adult (6th growth period) appeared 12.02 times, and there were no significant differences between the same body parts of the both sexes at the level of $p > 0.05$.

Carapace length in male

The results are shown in Table 2. The growth formula is the equation $y = 2.5644 + 3.0705\ t + 0.2350\ t^2$, shows the concave curve. The maximum relative error of the formula is 0.3762 percent, that means the formula indicates the completion of the growth within the limits of the error of 0.3762 percent. The maximum range of the relative error was 0.6129 percent. The growth quantity is increased in length by 11.4939 times from 2.5644 mm of the initial growth period nymph to 29.4744 mm of the adult (the 6th growth period). In the ratio of growth quantity by developmental period, the first growth period nymph was the largest (2.2908 times) whereas that of the adult (1.2377 times) was the smallest. The growth rate was increased from 3.0750 mm/t of the first growth period nymph to 5.8950 mm/t of the adult. The specific growth rate decreased steeply from 119.9111 percent of the initial growth period nymph to 60.3466 percent of the first, and smoothly to the adult (20.0004 percent). The growth power was 0.4700 mm/t^2. The initial quantity of the growth was 2.5644 mm and the initial velocity of the growth was 3.0705 mm.

Carapace width in male

The results are shown in Table 3. The growth

Table 1. The lengths of seven body parts for each growth period in mm (Mean ± SD).

	P	CL	CW	AL	AW	Ch	Sp	Tp
Male	0	3.5290±0.2289	2.3920±0.2555	3.8000±0.2596	1.1500±0.1025	4.8611±0.4324	3.3160±0.2945	3.7880±0.3140
	1	4.4840±0.3490	2.1587±0.2326	4.0407±0.4924	1.6787±0.1744	6.4043±0.5384	4.0387±0.4473	4.9080±0.3804
	2	9.1822±0.8344	4.3311±0.3385	9.9433±0.8250	4.1133±0.5905	11.7878±4.3837	7.3511±2.7882	10.2644±0.9004
	3	14.4054±1.2422	7.0017±1.0592	16.6552±1.9118	6.5339±0.7397	18.7017±1.7065	12.7287±1.4927	15.7251±1.8526
	4	19.2477±2.7513	9.9877±1.9636	21.1045±1.7904	8.7081±1.7233	25.1312±5.7725	17.2871±2.0377	21.0665±3.2601
	5	23.9800±0.9341	12.5257±0.4447	24.4800±1.0543	10.8029±0.6255	32.6026±1.9626	21.5029±1.4155	26.4057±2.7503
	6	29.0367±1.6128	15.4100±1.2679	29.1267±2.6454	13.2133±1.1401	41.8308±4.3696	26.1400±1.9116	31.2533±1.7877
Female	0	3.5290±0.2289	2.3920±0.2555	3.8080±0.2596	1.1500±0.0125	4.8611±0.4324	3.3160±0.2945	3.7880±0.3140
	1	4.4840±0.3490	2.1587±0.2326	4.0407±0.4924	1.6787±0.1744	6.4043±0.5384	4.0387±0.4473	4.9080±0.3804
	2	9.1200±0.7075	4.4545±0.4208	10.4373±1.1291	4.0473±0.3600	13.7055±0.8509	8.1960±0.4735	10.3120±0.6271
	3	14.2650±1.3015	7.1682±0.9121	16.2132±1.9854	6.5788±0.7986	18.5635±3.6367	12.4241±1.4351	15.5106±1.8182
	4	19.0767±3.0602	9.6538±2.1979	21.1630±4.5604	9.2367±1.2440	23.3685±4.0039	17.0584±1.9804	20.6975±3.7010
	5	23.8000±0.8548	12.6600±0.7933	25.7790±1.3984	12.4467±0.8770	29.2193±2.1461	21.2333±1.0913	25.9093±1.4632
	6	29.0222±1.9767	15.7867±1.4938	30.5778±1.9358	16.2133±1.4790	37.0156±3.7600	25.4889±2.0828	31.2000±2.7936

SD: Standard deviation P: Growth period (0-6) CL: Carapace length CW: Carapace width AL: Abdominal length AW: Abdominal width Ch: Cheliped length Sp: Second pereiopod length Tp: Third pereiopod length

Table 2. Analysis of carapace length in male.

P	GQ mm	QR times	QRP	E mm	ER %	GR mm/t	SGR %	GP mm/t^2
0	2.5644	1.0000	1.0000	0.9646	0.3762	3.0756	119.9111	0.4700
1	5.8744	2.2908	2.2908	−1.3904	−0.2363	3.5450	60.3466	
2	9.6544	3.7648	1.6435	−0.4722	−0.0489	4.0150	41.5873	
3	13.9044	5.4221	1.4402	0.5460	0.0393	4.4850	32.2560	
4	18.6244	7.2627	1.3395	0.6233	0.0335	4.9550	26.6049	
5	23.8144	9.2865	1.2787	0.1656	0.0070	5.4250	22.7803	
6	29.4744	11.4937	1.2377	−0.4377	−0.0149	5.8950	20.0004	

P: Growth period {0; initial g.p., 1-6; the first growth growth period- the sixth growth period} GQ: Growth quantity QR: Ratio of growth quantity·QRP: QR for each growth period E: Error ER: Error rate GR: Growth rate SGR: specific growth rate GP: Growth power

Table 3. Analysis of carapace width in male.

P	GQ mm	QR times	QRP	E mm	ER %	GR mm/t	SGR %	GP mm/t^2
0	1.7486	1.0000	1.0000	0.3464	0.1981	1.0485	59.9623	0.4296
1	3.0119	1.7225	1.7225	−0.8532	−0.2833	1.4781	49.0753	
2	4.7048	2.6906	1.5621	−0.3737	−0.0794	1.9077	40.5480	
3	6.8273	3.9044	1.4511	0.1744	0.0255	2.3373	34.2346	
4	9.3794	5.3639	1.3738	0.6053	0.0645	2.7669	29.4998	
5	12.3611	7.0691	1.3179	0.1646	0.0133	3.1965	25.8593	
6	15.7724	9.0200	1.2760	−0.3624	−0.0230	3.6261	22.9902	

(Abbreviations are the same as in Table 2.)

formula ($y = 1.7486 + 1.0485\ t + 0.2148\ t^2$) shows the concave curve. The maximum relative error of the formula is 0.1981 percent. The maximum range of the relative error was 0.4814 percent. The growth quantity is increased by 9.0200 times from 1.7486 mm of the initial growth period nymph to 15.7724 mm of the adult. The ratio of growth quantity of the first growth period nymph was the largest (1.7225 times) whereas that of the adult (1.2760 times) was the smallest. The growth rate was increased from 1.0485 mm/t of the initial growth period nymph to 3.6261 mm/t of the adult. The specific growth rate decreased smoothly from 59.9623 percent of the initial growth period nymph to the adult (22.9902 percent). The growth power was 0.4296 mm/t^2. The initial quantity of the growth was 1.7486 mm and the initial velocity of the growth was 1.0485 mm.

Abdominal length in male

The results are shown in Table 4. The growth formula ($y = 2.2951 + 4.1813\ t + 0.0580\ t^2$) shows the concave curve. The maximum relative error of the formula is 0.6557 percent. The maximum range of the relative error was 1.0373 percent. The growth quantity is increased by 12.8408 times from 2.2951 mm of the initial growth period nymph to 29.4709 mm of the adult. The ratio of growth quantity of the first growth period nymph was the largest (2.8471 times) conspicuously, and followed smooth decreasing tendency to the adult. The growth rate was increased from 4.1813 mm/t of the initial growth period nymph to 4.8773 mm/t of the adult. The specific growth rate decreased steeply from 182.1838 percent of the initial growth period nymph to 65.7643 percent of the first, and then smoothly to the adult (16.5495 percent). The growth power was 0.1160 mm/t^2. The

Table 4. Analysis of abdominal length in male.

P	GQ mm	QR times	QRP	E mm	ER %	GR mm/t	SGR %	GP mm/t^2
0	2.2951	1.0000	1.0000	1.5049	0.6557	4.1813	182.1838	0.1160
1	6.5344	2.8471	2.8471	−2.4937	−0.3816	4.2973	65.7643	
2	10.8897	4.7448	1.6665	−0.9464	−0.0869	4.4133	40.5273	
3	15.3610	6.6930	1.4106	1.2942	0.0843	4.5293	29.4857	
4	19.9483	8.6917	1.2986	1.1562	0.0580	4.6453	23.2867	
5	24.6516	10.7410	1.2358	−0.1716	−0.0070	4.7613	19.3144	
6	29.4709	12.8408	1.1955	−0.3442	−0.0117	4.8773	16.5495	

(Abbreviations are the same as in Table 2.)

Table 5. Analysis of abdominal width in male.

P	GQ mm	QR times	QRP	E mm	ER %	GR mm/t	SGR %	GP mm/t^2
0	0.7259	1.0000	1.0000	0.4241	0.5842	1.5858	218.4598	0.1718
1	2.3976	3.3028	3.3028	−0.7189	−0.2998	1.7596	73.3901	
2	4.2411	5.8425	1.7689	−0.1278	−0.0301	1.9294	45.4929	
3	6.2564	8.6188	1.4752	0.2775	0.0444	2.1012	33.5848	
4	8.4435	11.6318	1.3496	0.2646	0.0313	2.2730	26.9201	
5	10.8024	14.8814	1.2794	0.0005	0.0000	2.4448	22.6320	
6	13.3331	18.3677	1.2343	−0.1198	−0.0090	2.6166	19.6248	

(Abbreviations are the same as in Table 2.)

initial quantity of the growth was 2.2951 mm and the initial velocity of the growth was 1.0485 mm.

Abdominal width in male

The results are shown in Table 5. The growth formula ($y = 0.7259 + 1.5858\ t + 0.0859\ t^2$) shows the concave curve. The maximum relative error of the formula is 0.5842 percent. The maximum range of the relative error was 0.8840 percent. The growth quantity is increased by 18.3677 times from 0.7259 mm of the initial growth period nymph to 13.3331 mm of the adult. The ratio of growth quantity revealed succesive decrease from the first growth period nymph to the adult (1.2343 times). The growth rate was increased from 1.5858 mm/t of the initial growth period nymph to 2.6166 mm/t of the adult. The specific growth rate decreased steeply from 218.4598 percent of the initial growth period nymph to 73.3901 percent of the first, and smoothly to the adult (19.6248 percent). The growth power was 0.1718 mm/t^2. The initial quantity of the growth was 0.7259 mm and the initial velocity of the growth was 1.5858 mm.

Cheliped length in male

The results are shown in Table 6. The growth formula ($y = 4.0916 + 2.8948\ t + 0.5702\ t^2$) shows the concave curve. The maximum relative error of the formula is 0.1881 percent. The maximum range of the relative error was 0.3406 percent. The growth quantity is increased by 10.2619 times from 4.0916 mm of the initial growth period nymph to 41.9876 mm of the adult. The ratio of growth quantity of the first growth period nymph was the largest (1.8469 times) whereas that of the adult (1.2793 times) was the smallest. The growth rate was increased from 2.8948 mm/t of the initial growth period nmyph to 9.7372 mm/t of the adult. The specific growth rate decreased smoothly from 70.7498 percent of the initial growth period nymph to 23.1907 percent of the adult. The growth power was 1.1404 mm/t^2. The initial quantity of the growht was 4.0916 mm and the initial velocity of the growth was 2.8948 mm.

Table 6. Analysis of cheliped length in male.

P	GQ mm	QR times	QRP	E mm	ER %	GR mm/t	SGR %	GP mm/t^2
0	4.0916	1.0000	1.0000	0.7695	0.1881	2.8948	70.7498	1.1404
1	7.5566	1.8469	1.8469	−1.1523	−1.1525	4.0352	53.3997	
2	12.1620	2.9724	1.6095	−0.3742	−0.0308	5.1756	42.5555	
3	17.9078	4.3767	1.4724	0.7939	0.0443	6.3160	35.2695	
4	24.7940	6.0597	1.3845	0.3372	0.0136	7.4564	30.0734	
5	32.8206	8.0215	1.3237	−0.2180	−0.0066	8.5968	26.1933	
6	41.9876	10.2619	1.2793	−0.1568	−0.0037	9.7372	23.1907	

(Abbreviations are the same as in Table 2.)

Table 7. Analysis of second pereiopod length in male.

P	GQ mm	QR times	QRP	E mm	ER %	GR mm/t	SGR %	GP mm/t^2
0	2.3885	1.0000	1.0000	0.9275	0.3883	2.4453	102.3781	0.3998
1	5.0997	2.1351	2.1351	−1.0610	−0.2081	2.9785	58.4054	
2	8.3455	3.4940	1.6365	−0.9944	−0.1192	3.5117	42.0790	
3	12.1259	5.0768	1.4530	0.6028	0.0497	4.0449	33.3575	
4	16.4409	6.8834	1.3558	0.8462	0.0515	4.5781	27.8458	
5	21.2905	8.9138	1.2950	0.2124	0.0100	5.1113	24.0074	
6	26.6747	11.1680	1.2529	−0.5347	−0.0200	5.6445	21.1605	

(Abbreviations are the same as in Table 2.)

Second pereiopod length in male

The results are shown in Table 7. The growth formula ($y = 2.3885 + 2.4453\ t + 0.2666\ t^2$) shows the concave curve. The maximum relative error of the formula is 0.3883 percent. The maximum range of the relative error was 0.5964 percent. The growth quantity is increased by 11.1680 times from 2.3885 mm of the initial growth period nymph to 26.6747 mm of the adult. In the ratio of growth quantity according to developmental period, the first growth period nymph was the largest (2.1351 times) whereas that of the adult (1.2793 times) was the smallest. The growth rate was increased from 2.4453 mm/t of the initial growth period nymph to the adult (5.6445 mm/t) smoothly. The specific growth rate decreased steeply from 102.3781 percent of the initial growth period nymph to the first (58.4054 percent), and then smoothly to the adult (21.1605 percent). The growth power was 0.3998 mm/t^2. The initial quantity of the growth was 2.3885 mm and the initial velocity of the growth was 2.4453 mm.

Third pereiopod length in male

The results are shown in Table 8. The growth formula ($y = 2.6992 + 3.5562\ t + 0.2180\ t^2$) shows the concave curve. The maximum relative error of the formula is 0.4034 percent. The maximum range of the relative error was 0.6452 percent. The growth quantity is increased by 11.8123 times from 2.6992 mm of the initial growth period nymph to 31.8838 mm of the adult. The ratio of growth quantity of the first growth period nymph was the largest (2.3982 times) whereas that of the adult was the smallest (1.2296 times). The growth rate was increased from 3.5562 mm/t of the initial growth period nymph to 6.1722 mm/t of the adult. The specific growth rate decreased steeply from 131.7501 percent of the initial growth period nymph to the first (61.6718 percent), and then smoothly to the adult (19.3584 percent). The growth power was 1.1404 mm/t^2. The initial quantity of the growth was 2.6992 mm and the initial velocity of the growth was 3.5562 mm.

Table 8. Analysis of third pereiopod length in male.

P	GQ mm	QR times	QRP	E mm	ER %	GR mm/t	SGR %	GP mm/t^2
0	2.6992	1.0000	1.0000	1.0888	0.4034	3.5562	131.7501	0.4360
1	6.4733	2.3982	2.3982	−1.5653	−0.2418	3.9922	61.6718	
2	10.6834	3.9580	1.6504	−0.4190	−0.0392	4.4282	41.4494	
3	15.3295	5.6793	1.4349	0.3956	0.0258	4.8642	31.7310	
4	20.4116	7.5621	1.3315	0.5649	0.0321	5.3002	25.9666	
5	25.9297	9.6064	1.2703	0.4760	0.0184	5.7362	22.1221	
6	31.8838	11.8123	1.2296	−0.6305	−0.0198	6.1722	19.3584	

(Abbreviations are the same as in Table 2.)

Table 9. Analysis of carapace length in female.

P	GQ mm	QR times	QRP	E mm	ER %	GR mm/t	SGR %	GP mm/t^2
0	2.6131	1.0000	1.0000	0.9159	0.3505	2.9589	113.2333	0.5026
1	5.8233	2.2285	2.2285	−1.3393	−0.2300	3.4615	59.4422	
2	9.5361	3.6493	1.6376	−0.4161	−0.0436	3.6941	41.5694	
3	13.7515	5.2625	1.4420	0.5135	0.0373	4.4667	32.4815	
4	18.4695	7.0680	1.3431	0.6072	0.0329	4.9693	26.9054	
5	23.6901	9.0659	1.2827	0.1099	0.0046	5.4719	23.0978	
6	29.4133	11.2561	1.2416	−0.3911	−0.0330	5.9745	20.3122	

(Abbreviations are the same as in Table 2.)

Carapace length in female

The results are shown in Table 9. The growth formula is the equation $y = 2.6131 + 2.9589\ t + 0.2513\ t^2$, shows the concave curve. The maximum relative error of the formula is 0.3505 percent, that means the formula indicates the completion of the growth within the limits of the error of 0.3505 percent. The maximum range of the relative error was 0.5805 percent. The growth quantity is increased in length by 11.2561 times from 2.6131 mm of the initial growth period nymph to 29.4133 mm of the adult. The ratio of growth quantity, by developmental period, of the first growth period nymph was the largest (2.2285 times) whereas that of the adult was the smallest (1.2416 times). The growth rate was increased from 2.9589 mm/t of the initial growth period nymph to the adult (5.9745 mm/t) smoothly. The spesific growth rate showing the growth ratio per unit body length, decreased steeply from 113.2333 percent of the initial growth period nymph to 59.4422 percent of the first, and smoothly to the adult (20.3122 percent). The growth power was 0.5026 mm/t^2. The initial quantity of the growth was 2.6131 mm and the initial velocity of the growth was 2.9589 mm.

Carapace width in female

The results are shown in Table 10. The growth formula ($y = 1.8252 + 0.9495\ t + 0.2369\ t^2$) shows the concave curve. The maximum relative error of the formula is 0.3105 percent. The maximum range of the relative error was 0.5937 percent. The growth quantity is increased by 8.7939 times from 1.8252 mm of the initial growth period nymph to 16.0506 mm of the adult. The ratio of growth quantity of the first growth period nymph was the largest (1.6500 times) whereas that of the adult (1.2845 times) was the smallest. The growth rate was increased from 0.9495 mm/t of the initial growth period nymph to 3.7923 mm/t of the adult. The specific growth rate decreased smoothly from 57.0217 percent of the initial growth period nymph to the adult (23.6272 percent). The growth power was 1.1378 mm/t^2. The initial quantity of the growth was 1.8252 mm and the initial velocity

Table 10. Analysis of carapace width in female.

P	GQ mm	QR times	QRP	E mm	ER %	GR mm/t	SGR %	GP mm/t^2
0	1.8252	1.0000	1.0000	0.5668	0.3105	0.9495	52.0217	0.4738
1	3.0116	1.6500	1.6500	−0.8529	−0.2832	1.4235	47.2606	
2	4.6718	2.5596	1.5512	−0.2173	−0.0465	1.8971	40.2606	
3	6.8058	3.7288	1.4568	0.3624	0.0532	2.3709	34.8365	
4	9.4136	5.1576	1.3832	0.2402	0.0255	2.8447	30.2190	
5	12.4952	6.8459	1.3274	0.1648	0.0310	3.3185	26.5582	
6	16.0506	8.7939	1.2845	−0.2639	−0.0164	3.7923	23.6272	

(Abbreviations are the same as in Table 2.)

Table 11. Analysis of abdominal length in female.

P	GQ mm	QR times	QRP	E mm	ER %	GR mm/t	SGR %	GP mm/t^2
0	2.3148	1.0000	1.0000	1.4932	0.6451	3.9114	168.9736	0.2986
1	6.3755	2.7542	2.7542	−2.3348	−0.3662	4.2100	66.0340	
2	10.7348	4.6375	1.6838	−0.3875	−0.0361	4.4086	41.9999	
3	15.3927	6.6496	1.4339	0.8205	0.0533	4.8072	31.2303	
4	20.3492	8.7909	1.3220	0.8138	0.0400	5.1058	25.0909	
5	25.6043	11.0611	1.2582	0.1747	0.0068	5.4044	21.1074	
6	31.1580	13.4603	1.2169	−0.5802	−0.0186	5.7030	18.3035	

(Abbreviations are the same as in Table 2.)

of the growth was 0.9495 mm.

Abdominal length in female

The results are shown in Table 11. The growth formula ($y = 2.3148 + 3.9114\ t + 0.1493\ t^2$) shows the concave curve. The maximum relative error of the formula is 0.6451 percent. The maximum range of the relative error was 1.0113 percent. The growth quantity is increased by 13.4603 times from 2.3148 mm of the initial growth period nymph to 31.1580 mm of the adult. The ratio of growth quantity of the first growth period nymph was the largest (2.7542 times) conspicuously, and decreased smoothly from the second growth period nymph (1.6838 times) to the adult (1.2169 times). The growth rate was increased from 3.9114 mm/t of the initial growth period nymph to 5.7030 mm/t of the adult smoothly. the specific growth rate decreased most steeply from 168.9736 percent of the initial growth period nymph to 66.0340 percent of the first, and then smoothly to the adult (18.3035 percent). The growth power was 0.2986 mm/t^2. The initial quantity of the growth was 2.3148 mm and the initial velocity of the growth was 3.9114 mm.

Abdominal width in female

The results are shown in Table 12. The growth formula ($y = 0.8597 + 1.0936\ t + 0.2458\ t^2$) shows the concave curve. The maximum relative error of the formula is 0.3377 percent. The maximum range of the relative error was 0.5743 percent. The growth quantity is increased by 18.9253 times from 0.8597 mm of the initial growth period nymph to 31.1580 mm of the adult. In the ratio of growth quantity according to developmental period, the first growth period nymph was the largest (2.5580 times) whereas that of the adult (1.3045 times) was the smallest. The growth rate was increased from 1.0936 mm/t of the initial growth period nymph to the adult (4.0432 mm/t) smoothly. The specific growth rate decreased most steeply from 127.2072 percent of the initial growth period nymph to the first (72.0840 percent), and then smoothly to the adult (24.8505 percent). The growth power was 0.4916 mm/t^2.

Table 12. Analysis of abdominal width in female.

P	GQ	QR	QRP	E	ER	GR	SGR	GP
	mm	times		mm	%	mm/t	%	mm/t^2
0	0.8597	1.0000	1.0000	0.2904	0.3377	1.0936	127.2072	0.4916
1	2.1991	2.5580	2.5580	−0.5204	−0.2366	1.5852	72.0940	
2	4.0301	4.6878	1.8326	0.0172	0.0043	2.0768	51.5322	
3	6.3527	7.3894	1.5763	0.2261	0.0356	2.5684	40.4301	
4	9.1669	10.6629	1.4430	0.0698	0.0076	3.0600	33.3810	
5	12.4727	14.5082	1.3606	−0.0260	−0.0021	3.5516	28.4750	
6	16.2701	18.9253	1.3045	−0.0568	−0.0035	4.0432	24.8505	

(Abbreviations are the same as in Table 2.)

Table 13. Analysis of cheliped length in female.

P	GQ	QR	QRP	E	ER	GR	SGR	GP
	mm	times		mm	%	mm/t	%	mm/t^2
0	4.1979	1.0000	1.0000	0.6632	0.1580	3.6871	87.8020	0.5764
1	8.1732	1.9470	1.9470	−1.7689	−0.2164	4.2635	52.1644	
2	12.7249	3.0313	1.5570	0.9806	0.0771	4.8399	38.0349	
3	17.8530	4.2528	1.4030	0.7105	0.0398	5.4163	30.3383	
4	23.5575	5.6117	1.3195	−0.2890	−0.0123	5.9927	25.4386	
5	29.8384	7.1097	1.2666	−0.6191	−0.0207	6.5691	22.0156	
6	36.6957	8.7414	1.2298	0.3199	0.0087	7.1455	19.4723	

(Abbreviations are the same as in Table 2.)

The initial quantity of the growth was 0.8597 mm and the initial velocity of the growth was 1.0936 mm.

Cheliped length in female

The results are shown in Table 13. The growth formula ($y = 4.1979 + 3.6871\ t + 0.2882\ t^2$) shows the concave curve. The maximum relative error of the formula is 0.1580 percent. The maximum range of the relative error was 0.3744 percent. The growth quantity is increased by 8.7414 times from 4.1979 mm of the initial growth period nymph to 36.6957 mm of the adult. The ratio of growth quantity of the first growth period nymph was the largest (1.9470 times) whereas that of the adult was the smallest (1.2298 times). The growth rate was increased from 3.6871 mm/t of of the initial growth period nymph to 7.1455 mm/t of the adult. The specific growth rate decreased smoothly from 87.8020 percent of the initial growth nymph to the adult (19.4723 percent). The growth power was 0.5764 mm/t^2. The initial quantity of the growth was 4.1979 mm and the initial velocity of the growth was 3.6871 mm.

Second pereiopod length in female

The results are shown in Table 14. The growth formula ($y = 2.4518 + 2.5944\ t + 0.2210\ t^2$) shows the concave curve. The maximum relative error of the formula is 0.3525 percent. The maximum range of the relative error was 0.5857 percent. The growth quantity is increased by 10.5939 times from 2.4518 mm of the initial growth period nymph to 25.9742 mm of the adult. The ratio of growth quantity of the first growth period nymph was the largest (2.1483 times) whereas that of the adult was the smallest (1.2399 times). The growth rate was increased from 2.5944 mm/t of the initial growth period nymph to 5.2464 mm/t of the adult smoothly. The specific growth rate decreased steeply from 105.8161 percent of the initial growth period nymph to the first (57.6473 percent), and smoothly to the adult (20.1985 percent). The growth power was 0.4420 mm/t^2. The initial quantity of the growth was 2.4518 mm and

Table 14. Analysis of second pereiopod length in female.

P	GQ	QR	QRP	E	ER	GR	SGR	GP
	mm	times		mm	%	mm/t	%	mm/t²
0	2.4518	1.0000	1.0000	0.8642	0.3525	2.5944	105.8161	0.4420
1	5.2672	2.1483	2.1483	−1.2285	−0.2332	3.0364	57.6473	
2	8.5246	3.4769	1.6184	−0.3286	−0.0385	3.4784	40.8043	
3	12.2240	4.8957	1.4340	0.2001	0.0164	3.9204	32.0713	
4	16.3654	6.6749	1.3388	0.6930	0.0423	4.3624	26.6562	
5	20.9488	8.5443	1.2801	0.2845	0.0136	4.8044	22.9340	
6	25.9742	10.5939	1.2399	−0.4853	−0.0187	5.2464	20.1985	

(Abbreviations are the same as in Table 2.)

Table 15. Analysis of third pereiopod length in female.

P	GQ	QR	QRP	E	ER	GR	SGR	GP
	mm	times		mm	%	mm/t	%	mm/t²
0	2.8050	1.0000	1.0000	0.9830	0.3504	3.3890	120.8000	0.4730
1	6.4305	2.2925	2.2925	−1.5225	−0.2368	3.8620	60.0575	
2	10.5290	3.7537	1.6374	0.2170	0.0206	4.3350	41.1720	
3	15.1005	5.3834	1.4342	0.4101	0.0272	4.8080	31.8400	
4	20.1450	7.1818	1.3341	0.5525	0.0274	5.2810	26.2150	
5	25.6625	9.1488	1.2739	0.2468	0.0096	5.7540	22.4218	
6	31.6530	11.2845	1.2334	−0.4530	−0.0143	6.2270	19.6727	

(Abbreviations are the same as in Table 2.)

the initial velocity of the growth was 2.5944 mm.

Third pereiopod length in female

The results are shown in Table 15. The growth formula ($y = 2.8050 + 3.3890\ t + 0.2365\ t^2$) shows the concave curve. The maximum relative error of the formula is 0.3504 percent. The maximum range of the relative error was 0.5872 percent. The growth quantity is increased by 11.2845 times from 2.8050 mm of the initial growth period nymph to 31.6530 mm of the adult. The ratio of growth quantity of the first growth period nymph was the largest (2.2925 times) whereas that of the adult was the smallest (1.2334 times). The growth rate was increased from 3.3890 mm/t of the initial growth period nymph to 6.2270 mm/t of the adult smoothly. The specific growth rate decreased steeply from 120.8200 percent of the initial growth period nymph to the first (60.0575 percent), and smoothly to the adult (19.6727 percent). The growth power was 0.4730 mm/t^2. The initial quantity of the growth was 2.8508 mm, and the initial velocity of the growth was 3.890 mm.

Discussion

As the first performance of the growth analysis of *Cambaroides similis* throughout the full range of growing period, we have to discuss with the result by Yeun (1985) and the studies of growth of larvae of insect growing in same pattern with the crayfish, carried out by many authors. Growth phenomena of all the body parts of both sexes were showed with concave shaped pattern (Fig. 1). The ratio of growth quantity (GQ) was the largest in the abdominal width of both sexes (18.9257 times in female, 18.3677 times in male) and the abdominal length, the third pereiopod length, the carapace length and the second pereiopod length of both sexes were followed in that order. Thereafter, the carapace width and the cheliped length in female and the cheliped length and the carapace width in male were followed in that order (Fig. 2). But there were no significant differences between the ratio of growth quantity of the largest one (18.3577 time of the abdominal

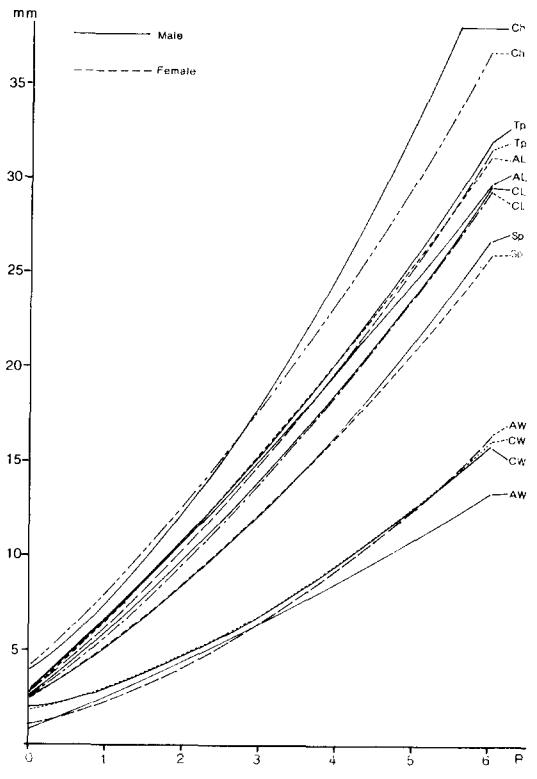

Fig. 1. The growth quantities of each body parts in both sexes.

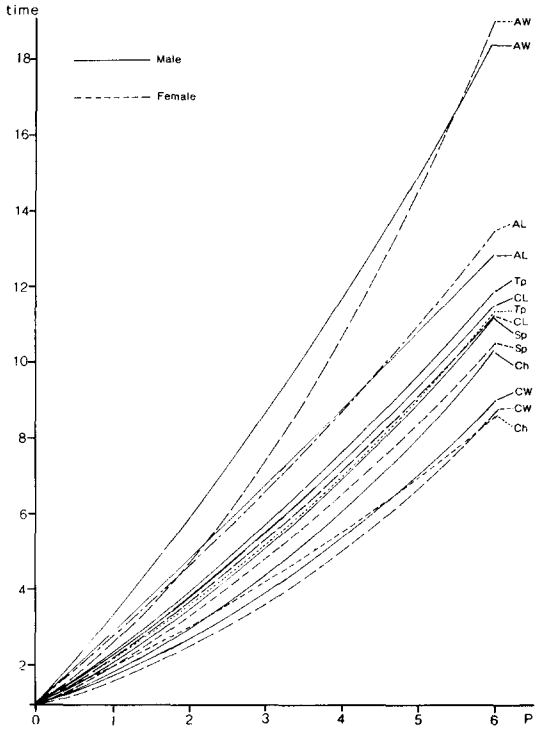

Fig. 2. The ratios of growth quantity of seven body parts in both sexes.

width in female) and the second (12.8408 time of the abdominal length in female) ($X^2 = 1.0068$, $P > 0.05$), and also between the ratio of growth quantity of the cheliped length of male and female which showed the largest difference among the body parts ($X^2 = 0.1276$, $P > 0.05$). The ratio of growth quantity by each growth period of each aspect decreased along with growing period. Park and Lee (1971), Park (1977) and Park and Son (1984) described that those of the body parts of most insects showed increase by 2 nd or 3rd instar period and decrease thereafter in developing stages. In contrast, the ratio of growth quantity in a dismorphing animal showed a decrease pattern in all aspects but a few exceptions (Park, 1974; Kim, 1974). The growth rate of all the body parts of both sexes showed gradual increase. The largest increase of growth rate was appeared in the cheliped length of male, from 2.8948 mm/t of the initial growth period (0) to 9.7372 mm/t of the final growth period (6), and the smallest was showed in the abdominal length of male, from 4.1813 mm/t of the initial growth period to 4.8773 mm/t of the final growth period. The rest showed similar increasing pattern (Fig. 3). Park and Lee (1971) described the increase of growth ratio in all the body parts including the rostrum of *Anoplocnemis dallasi*, while Park and Son (1984) reported the decrease of the growth ratio of only the rostrum of *Piesma maculata*. In the study on the infant growth (Kim and Lee, 1980), authors reported that the growth ratio of many aspects, body weight, stature, kidney and liver, showed the decreasing pattern. The specific growth rate of the abdominal length and the abdominal width of both sexes showed the steep decrease from the initial growth period, (0) to the first growth period, (1) and thereafter decreased smoothly like the other body parts. The specific growth rate of the carapace width of female showed almost smooth decrease only (Fig. 4, 5). In insect larvae, the specific growth rates of all aspects decreased steeply

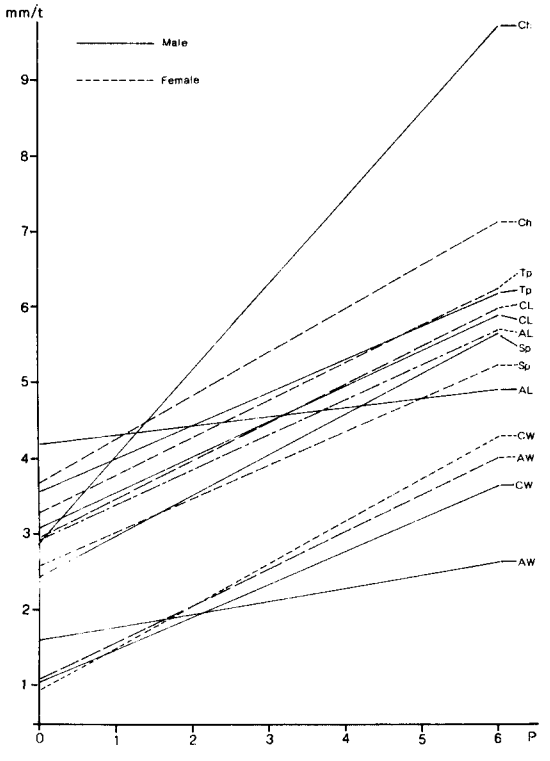

Fig. 3. The growth rates of seven body parts in both sexes.

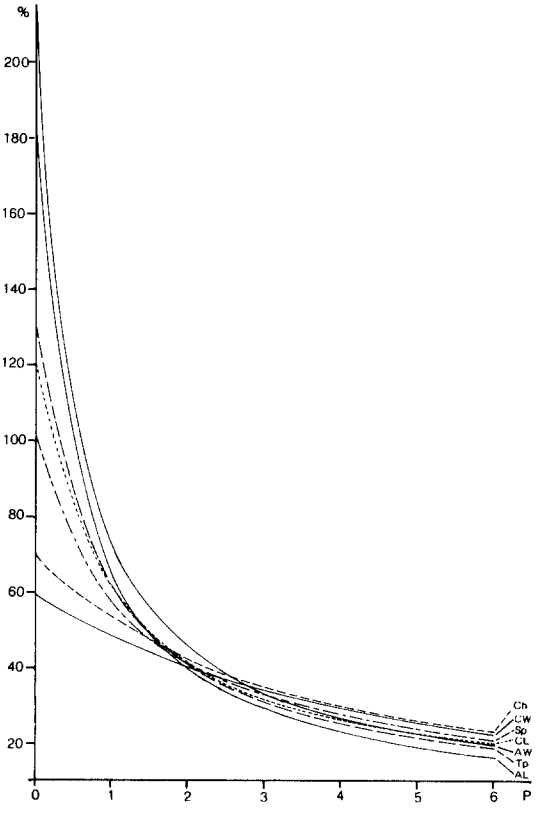

Fig. 4. The specific growth rates of seven body parts in male.

Table 16. The analysing data of seven body parts in both sexes.

	P	GQ mm		QR time	GR mm/t		SGR %		GP mm/t^2
	sex	0	6		0	6	0	6	
CL	M	2.5644	29.4744	11.4937	3.0750	5.8950	119.9111	20.0004	0.4700
	F	2.6131	29.4133	11.2561	2.9589	5.9745	113.2333	20.3122	0.5026
CW	M	1.7486	15.7724	9.0200	1.0485	3.1955	59.9623	22.9902	0.4296
	F	1.8252	16.0506	8.7939	0.9495	3.7923	52.0217	23.6272	0.4738
AL	M	2.2951	29.4709	12.8408	4.1813	4.8773	182.1838	16.5495	0.1160
	F	2.3148	31.1580	13.4603	3.9114	5.7030	168.9736	18.3035	0.2986
AW	M	0.2759	13.3331	18.3677	1.5858	2.6166	218.4598	19.6248	0.1718
	F	0.8597	16.2701	18.9253	1.0936	4.0432	127.2072	24.8505	0.4916
Ch	M	4.0916	41.9876	10.2619	2.8948	9.7372	70.7498	23.1907	1.1404
	F	4.1979	36.6957	8.7414	3.6871	7.1455	87.8020	19.4723	0.5764
Sp	M	2.3885	26.6747	11.1680	2.4453	5.6445	102.3781	21.1605	0.3998
	F	2.4518	25.9739	10.5939	2.5944	5.2464	105.8161	20.1985	0.4220
Tp	M	2.6992	31.8838	11.8123	3.5562	6.1722	131.7501	19.3584	0.4360
	F	2.8050	31.6530	11.2845	3.3890	6.2270	120.8200	19.6727	0.4730

(Abbreviations are the same as in Table 1 and Table 2.)

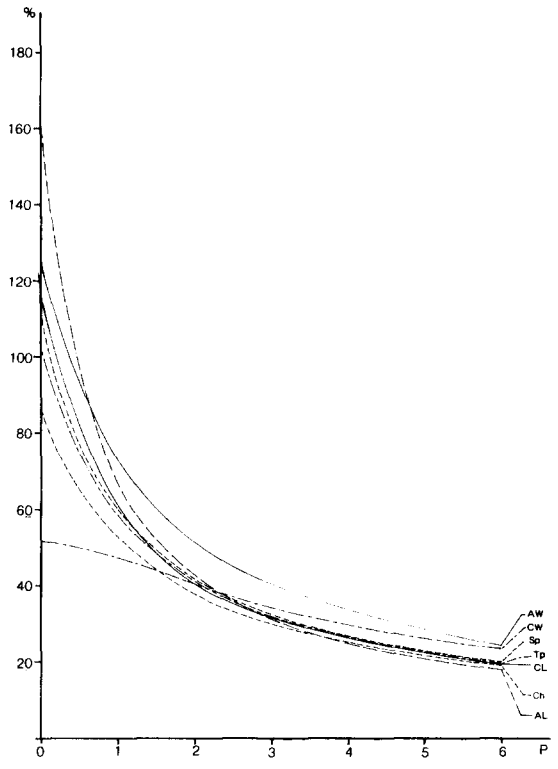

Fig. 5. The specific growth rates of seven body parts in female.

to the second or the fourth instar larva period and thereafter decreased smoothly (Park and Lee, 1971; Park and Son, 1984). Kim (1974) and Park (1974) reported in the studies of the growth of chick embryo that the specific growth ratio of all aspects except the lung decreased according to time. The growth power of the cheliped length (1.1404 mm/t^2) of male was the largest and that of the cheliped length, the the carapace length, the abdominal width, the carapace width of female and the carapace length, the third pereiopod length, the carapace width of male were followed respecitvely (Table 16).

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(Accepted May 20, 1991)

가재(*Cambaroides similis* Koelbel)의 성장 분석

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전북 정주시 일원에서 채집한 가재를 암수별(암컷 195, 수컷 170)로 일곱 가지 체량 즉, 두흉갑각장, 두흉갑각폭, 복절장, 복절폭, 제일각장, 제이각장 및 제삼각장에 대한 절대성장(성장식 $y = a + bt + ct^2$)을 분석한 결과는 다음과 같다. 1. 성장량은 암수 모두 전 체량에서 아래로 오목한 증가를 보였다. 2. 최대 성장량비는 암수 모두 복절폭에서 나타났다(암컷 18.9253배, 수컷 18.3677배). 3. 성장률은 암수 모두 완만한 증가형태를 보였다. 4. 비성장률은 모두 감소형태를 보였는데 암수의 복절장과 수컷의 복절폭에서는 매우 급격한 감소추세를 나타냈다.