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RESEARCH ARTICLE

Length-weight relationship, relative condition factor and growth of the *Harpiosquilla harpax* (de Haan, 1844) (Crustacea: Stomatopoda) off Visakhapatnam, east coast of India.

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Abstract

The length-weight relationship of males and females of *Harpiosquilla harpax* collected at Visakhapatnam were $W = 0.00007985\ L^{2.5650}$ and $W = 0.00004792\ L^{2.6622}$ respectively. A single length-weight relationship is given for both the sexes as $W = 0.00006554\ L^{2.6015}$. Analysis of covariance conducted to test the difference between the regression slopes of males and females of *H. harpax* showed significant differences ($P < 0.05$). Relative condition factor for males and females was given for this study. The age and growth were estimated by applying ELEFAN 1method; it confirmed the longevity of the stomatopod to be 86 months. The growth rate was high during the first year and then it declines during subsequent years. The Von Bertalanffy's growth parameters were $L_\infty = 220.50$, K = 1.5 /yr, $t_0 = 0.06$ and Ø = 4.8629/Yr. respectively.

Introduction:-

Stomatopods belonging to order stomatopoda, class crustacea are referred as 'Squilla' or mantis shrimp. Stomatopod crustaceans are common member of benthic ecosystems in tropical and subtropical marine and brackish waters throughout the world. Few species are known from temperate seas. There are 412 species of known to inhabit the world oceans (Hans-George Muller, 1994), 54 species of stomatopods inhabiting in the sea around India (Manning, 1968a and 1969b).

In the fishery point of view stomatopods are important resources in global fishery especially in Asia (Lui *et al.*, 2007). In these communities, many species of mantis shrimps are commercially valuable species, such as *Oratosquilla oratoria* (Kodama *et al*., 2004), *Squilla* species (Musa and Wei, 2008) and *H .raphidea* (Wardiatno and Mashar, 2011). As fisheries product, mantis shrimp can be found regularly in fish markets of several countries, such as Spain, Italy, Egypt and Morocco (Abello and Martin, 1993). In many Asian countries, mantis shrimps are considered as delicacy and commonly eaten by middle and upper class people. Basically, mantis shrimps are an important commercial species, especially in Hong Kong (Lai and Leung, 2003). In India, especially in Andhra Pradesh, stomatopods are non-target species incidentally or accidentally caught by benthic trawl operations. They are treated as by-catch and not used for human consumption.

Stomatopods landed in considerable quantities in almost all maritime states of India. 26 species of stomatopods occurring at Visakhapatnam fishing harbour. Among the 26 species *H. harpax* an important component of by-catch of the shrimp trawl at Visakhapatnam fishing harbour (YedukondalaRao *et al*., 2013). The present study focused on length–weight relation, relative condition factor and growth of *H. harpax* represented in the trawl net by-catches at Visakhapatnam.

Materials and Methods:-

The present study is based on 895 specimens of *H. harpax* (344 males in size range76-211 mm TL and weight 6-76 g; 551 females length in size range of 75-195 mm TL and weight 4-63 g) were collected from commercial trawl catches off Visakhapatnam fishing harbour (Lat: 17º 41' N Long: 83º 18 ' E) trice in a month during January 2008 to December 2009. The samples were not available in the month of May due to fishing holidays from April 15th to May 31st, which were implemented for conservational purpose.

The random samples of *H. harpax* collected in fresh condition from trawl catches at Visakhapatnam fishing harbour. The collected samples were stored in crushed ice and immediately brought to the laboratory, where they were washed with tap water and sorted into sex and length-wise. The mantis shrimps were measured to obtain the Kubo's body length (from base of the rostrum to the anterior edge of the median natch of the telson). Length measurement was made to the nearest 1mm and weight was measured nearest 1g for each specimen was measured. The three samples in a month were pooled and treated as a single sample of the month.

The length–weight relationship was derived using the exponential hypothetical formula $W = aL^b$ given by Le Cren (1951). Where W is body weight (g), L is total length (mm), 'a' is coefficient related to body form and 'b' is an exponent indicating isometric growth when equal to 3 (Spiegel, 1991). The equation can be expressed in the logarithmic form as log W = log a + b. log L. For testing the difference between regression slopes of males and females, analysis of covariance employed (Snedecor and Cochran, 1967). The relative condition factor, $Kn = W/ \hat{W}$ was calculated following Le Cren (1951) and Lyla *et al*., (1998). Where W= observed weight, $\hat{W}$ = calculated weight according to the regression equation.

Age and growth was estimated by applying the ELEFAN I (Electronic Length Frequency Analysis) method; FiSAT II Software package, version 1.2.2 to get the estimate of asymptotic length ($L\infty$) and growth coefficient (K) (Pauly and David, 1981). By using the value t_o was calculated by Pauly's equation (Pauly, 1979). The Von Bertalanffy's growth model was used to fit growth curve to the length frequency data (Von Bertalanffy's, 1938). The equation was expressed as:

$$L_t = L\infty \left(l - e^{-k\,(t-to)}\right)$$

Where, L_t = length at age t, $L\infty$ = asymptotic size, K = growth coefficient and t_o = age of the individual mantis shrimp at '0' size.

The growth performance index ($Ø'$) was estimated according to Pauly and Munro (1984) as:

$$Ø' = \log K + 2 \log L\infty$$

Where, K = Growth constant/yr, $L\infty$ = Asymptotic length

Results:-

Length-weight relationship:-

The regression equation for the length-weight relationship of males and females were calculated as:

Males : $\log W = 0.00007985\, L^{2.5650}$ ($r = 0.6645$)

Females : $\log W = 0.00004792\, L^{2.6622}$($r = 0.8519$)

The length-weight relation of males and females can be pooled to obtained common regression equation for both the sexes as $W = 0.00006554\, L^{2.6015}$($r = 0.8077$). The comparison lines in Table 1 showed significant difference ($p < 0.05$) between the slopes of two sexes at 5% level and showed negative allow metric growth for individual sexes. The scattered diagram of observed weight against to length of the stomatopods reveals curvi-linear relation between the two variables for both the sexes in Fig 1 and 2.

Relative condition factor (Kn values):-

Variations in the relative condition factor in the different months and in different size groups were studied for *H. harpax* (Fig 3, 4 and 5). The higher values were recorded during Jan to Apr in both the sexes due to indicating the spawning seasons. Lowest values were observed during Nov in *H. harpax* due to accumulation of fat in these species at Visakhapatnam. Study of relative condition factor corresponds to different length groups showed that peak value was observed at 161-180 mm in both the sexes and a steep fall observed at 81-100 mm length group in male's and121-140 mm length groups in females of *H. harpax* at Visakhapatnam.

Age and growth studies:-

The best fit estimate of asymptotic length ($L\infty$) and growth constant (K) were estimated by ELEFAN I. $L\infty$ was 220.50 mm and K was $1.5 yr^{-1}$ with highest Rn value 0.135 in Fig 6. Calculated growth performance index (($Ø'$) was 4.8629 and t_0 was 0.06. The length of the mantis shrimp at specific time in *H. harpax* was expressed as:

$$L_t = 220.50 \left(1-e^{-1.5(t-0.06)}\right)$$

On the basis of this formula, growth curves were drawn in Figure 6 according to Von Bertalanffy growth equation. The length attained in mm at ages of 3, 6, 9 and 12 months were 41.6743, 83.3490, 125.1735 and 166.6980 respectively.

Basing on the ELEFAN I method *H. harpax* attained a total length of 116.6980 mm, 208.505 mm, 217.832 mm, 219.902 mm and 220.367 mm during 1st, 2nd , 3rd, 4th and 5th year respectively. The longevity of *H. harpax* was 86 months was show in Fig 7 and Table 2.

A separated equation for on length-weight relationship is given as log W = 0.00007985 $L^{2.5650}$(r = 0.6645) for males; log W = 0.00004792 $L^{2.6622}$ (r = 0.8519) for females and W = 0.00006554 $L^{2.6015}$ (r = 0.8077) for combined sexes in the present study. From these equations it is clear that the "b" values of males and females were less than 3, indicated that negative allow metric growth in this mantis shrimp.

Rocket *et al*., (1984) estimated that the length-weight relationship for *S. empusa* shown as isometric growth pattern as the 'b' value (2.9574) for males and (2.9362) for females. James and Thirumilu (1993) reported the length-weight relationship has been given as log W = - 2.226907 + 1.623622 log L for males, log W = - 2.023819 + 1.50877 log L for females and log W = - 4.8665 + 2.9661 log L for combined sexes of *O. nepa*. Lyla *et al*., (1998) reported that length-weight relationship as log W = - 3.18 + 2.21 log L for males and log W = - 2.98 + 2.12 log L for females of *H. melanoura*. Abdurahiman *et al*., (2004) reported that length-weight relationship parameters, i.e intercept (a) and slope (b) and correlation coefficient (r) for the stomatopod *O. nepa* are 0.017, 2.786 and 0.97 respectively. Antony *et al*., (2004) given a length-weight relationship as log W = - 3.6479 + 2.3758 log x for males, log W = - 3.4826 + 2.3024 log x for females and log W = - 3.5589 + 2.336 log x for combined sexes of *H. harpax*. Yedukondala Rao and Rajendra Prasad (2008) reported the length-weight relationship for four stomatopod species from fish landing centre of Visakhapatnam. The length weight relationship has been given as log W = - 3.3317 + 2.2126 log L for males, log W = - 4.1143 + 2.5784 log L for females and log W = - 3.9807 + 2.5171 log L for combined sexes of *H. harpax*; log W = - 6.1218 + 3.5447 log L for males, log W = - 4.2094 + 2.5892 log L for females and log W = - 4.8488 + 2.9100 log L for combined sexes of *H. annandalei*; log W = -3.1388 + 2.1031 log L for males, log W = - 3.3935 + 2.2337 log L for females and log W = - 3.3401 + 2.2074 log L for combined sexes of *O. anomala* and log W = -2.1987 + 1.6715 log L for males, log W = - 2.3474 + 1.7422 log L females and log W= - 2.3474 + 1.7422 log L for combined sexes of *O. holoschista*. Wardiatno and Mashar (2011) reported the length-weight relationship of *H. raphidea*. The length-weight relationship has been given as W = 3E-05$L^{2.743}$ and 'b' value 2.686-2.800 (r = 0.936) for males and W = 4E-05$L^{2.678}$ and 'b' value 2.643-2.731 (r = 0.941) for females in the intertidal area; W = 0.0003$L^{2.356}$ and 'b' value 2.322-2.390 (r = 0.947) for males and W = 0.0002$L^{2.413}$ and 'b' value 2.366-2.460 (r = 0.883) for females in the sub-tidal area.

James and Thirumilu (1993) reported that analysis of covariance showed not significant at 5% level between slopes of two sexes. Lyla *et al*., (1998) reported that the regression co-efficient varied from 1.43 to 3.03. Males and females showed significant differences in length–weight relationship of *H. melanoura*. Antony *et al*., (2004) reported that analysis of covariance showed not significant difference between the regression lines in males and females of *H. harpax* at 5% level. Yedukondala Rao and Rajendra Prasad (2008) reported that covariance showed significant difference between the slopes of two sexes in *H. harpax, H. annandalei, O. anomala* but in *O. holoschista* comparison of regression between males and females was not significant. Rajendra Prasad and Yedukondala Rao (2015) reported that comparison of regression lines showed a significant difference (P ‹ 0.05) between slopes of two sexes in *O. anomala.* The Comparison of regression lines showed a significant difference (P ‹ 0.05) between slopes of two sexes in the present study.

According Tanuja (1998) reported that the Kn values were found high during Jul to Apr and again Nov to Dec in *O. nepa*. This agree with present study Kn values were high during Jan to Apr. Reddy and Shanbhogue (1994) reported Kn values against size class indicated that the stomatopod mature at 95-96 mm size. Rajendra Prasad and Yedukondala Rao (2015) reported Kn values against size class indicated that *O. anomala* mature at 71-80 mm size. In the present study Kn value were high during 161-810 mm length groups.

James and Thirumilu (1993) estimated the growth using Von Bertalanffy parameters of growth for males and female of *O. nepa*. Growth coefficient was (K) 3.9871 for males and 2.7173 for females; while $L\infty$ was 96 mm for males and 114 mm for females. Males and females of *O. nepa* such a length of 92.23 mm and 95.81 mm; 95.99 mm and 107.82 mm; 113.59 mm and 113.97mm at the end of 1,2 and 3 years respectively. Hamano and Morissy (1990) estimated growth using Von Bertalanffy's growth models were Lt = 57.2 (1 - exp (0.0190 (t + 8.25))) for males and Lt = 55.8 (1-exp (0.0191 (t + 8.45))) for females of *O. oratoria*. Wardiatno and Mashar (2011) estimate the growth parameters (K and L∞) and t_o for both sexes, using Ford-walford plot analysis from Von Bertalanffy's equation; K = 0.14 for males and 0.11 for females; L∞ = 381.68 for both sexes. Then the values of growth parameters are used as basis to get the *H. raphidea* Von Bertalanffy equation, i.e. Lt = 381.68* (1-e $^{[-0.11(t + 0.5533]]}$)]) for males and Lt = 381.68* (1-e $^{[-0.11(t + 0.3802]]}$)]) for females. Rajendra Prasad and Yedukondala Rao (2015) estimated the growth parameters were L∞ = 124.95, K = 1.0/yr, t_0 = 0.11 and Ø = 4.1935/yr in *O. anomala*. In the present study age and growth of *H. harpax* has been estimated by using ELEFAN-1 programme of FISAT software.

The parameters of the Von Bertalanffy growth models were L_∞ = 124.95, K = 1.0 /yr, t_0 = 0.11 and Ø = 4.1935/Yr. The estimated length of the *H. harpax* was 166.698 mm, 208.505 mm, 217.832 mm, 219.902 mm and 220.367 mm at 1st, 2nd, 3rd, 4th and 5th yrs respectively. The rate of growth was high during initial months and then it slows down with advancement of age.

Life span of *H. harpax* was 86 months. Life span *H. harpax* was higher than that of some other types of mantis shrimps: such as *S. mantis* was 1.5 yrs (Abello & Martin, 1993); *O. oratoria* from 3-3.5yrs (Dell & Sumpton, 1999) and *O. stephensoni* 2.5-3 yrs. *H. raphidea* was 6.7-8.5yrs (Wardiatno & Mashar, 2011). *O. anomala* was 13.33 yrs (Rajendra Prasad and Yedukondala Rao). The asymptotic size (L∞) in *S. mantis* reported was 200 mm (Abello & Martin, 1993); *O. stephensoni* 163 mm (Dell & Sumpton, 1999); *H. raphidea* 381.68 mm (Wardiatno & Mashar, 2011) and in *O. anomala* 124.95 mm (Rajendra Prasad and Yedukondala Rao, 2015).

Fig 1: Scattered diagram showing relationship between length and weight in males of *H. harpax*

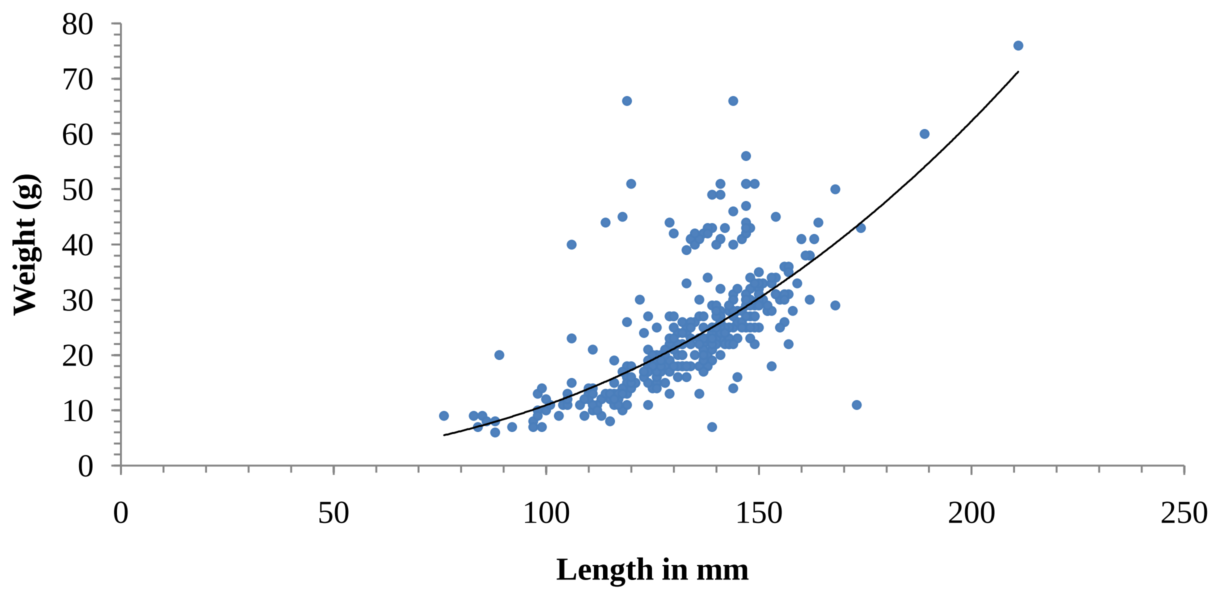


Fig 2: Scattered diagram showing relationship between length and weight in females of *H. harpax*

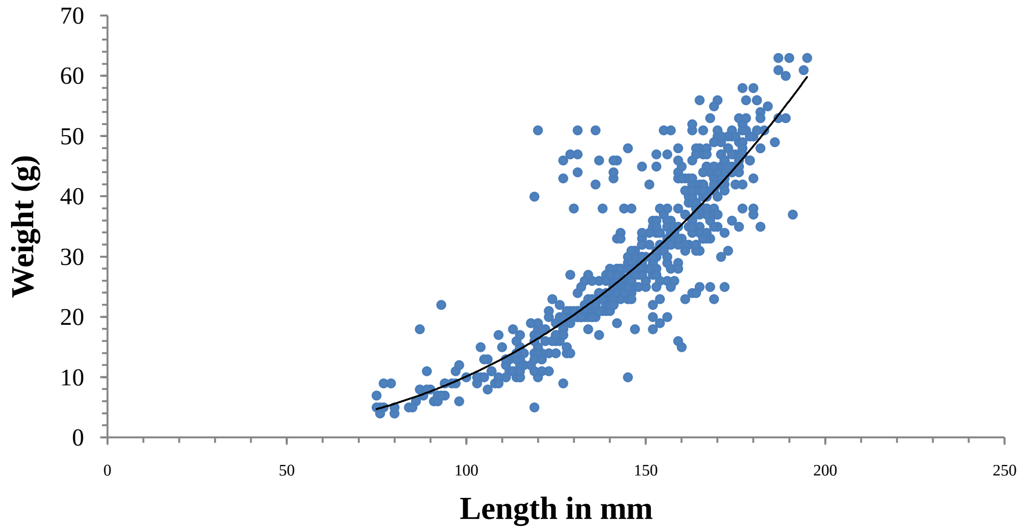


Fig 3: Comparison of relative condition factor of *H. harpax* in relation to months during January – December 2008

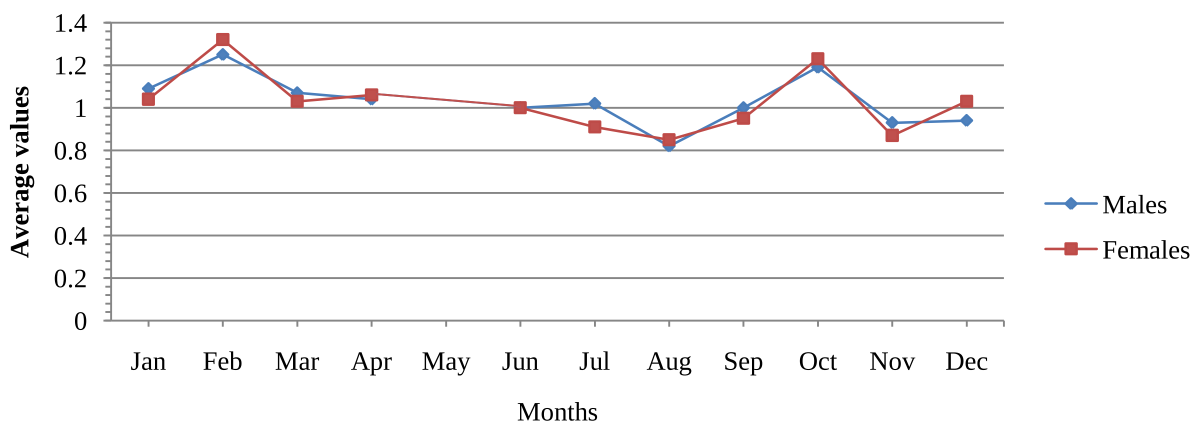


Fig 4: Comparison of relative condition factor of *H. harpax* in relation to months during January – December 2009

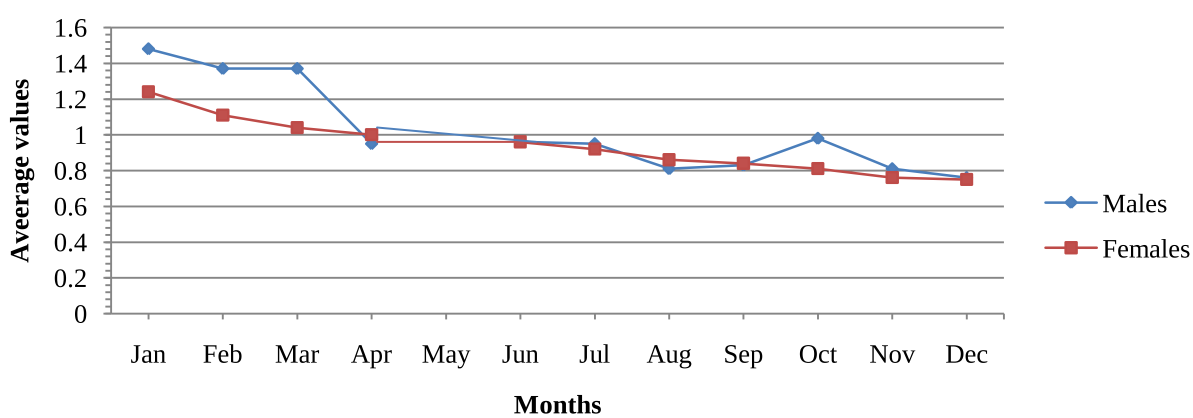


Fig 5: Comparison of relative condition factor of *H. harpax*in relation to lengths during January 2008 – December 2009

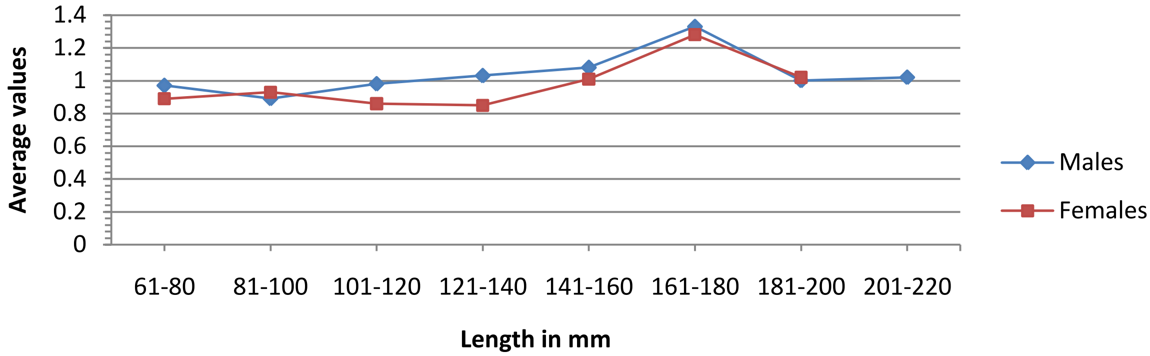
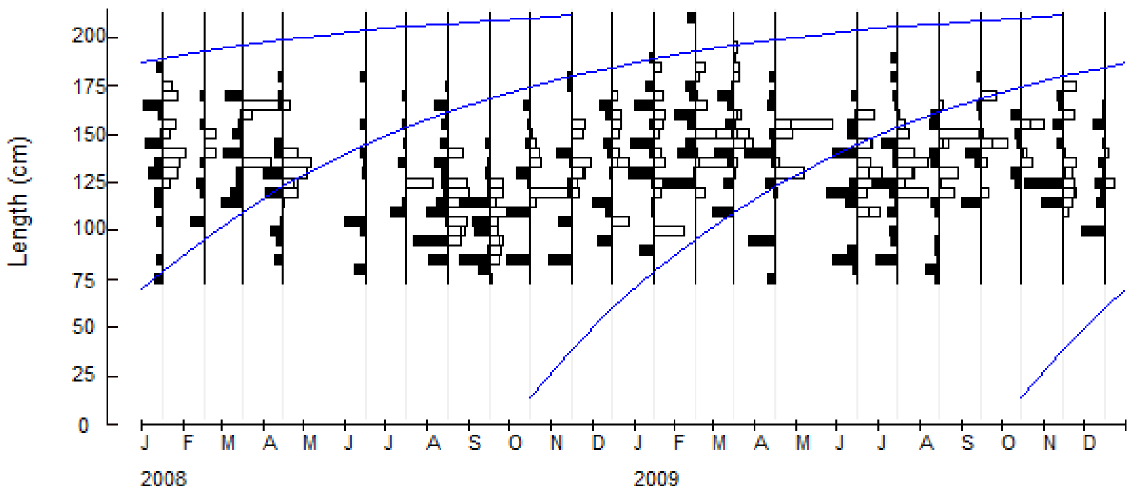


Fig 6: Estimate of L∞ in *H. harpax* using ELEFAN I method



L∞ (Asymptotic length) [220.50]

K (Growth constant) [1.5]

SS (Starting sample) [22.00]

SL (Starting length) [212.50]

Fig 7.Von Bertalanffy growth curves of *H. harpax*

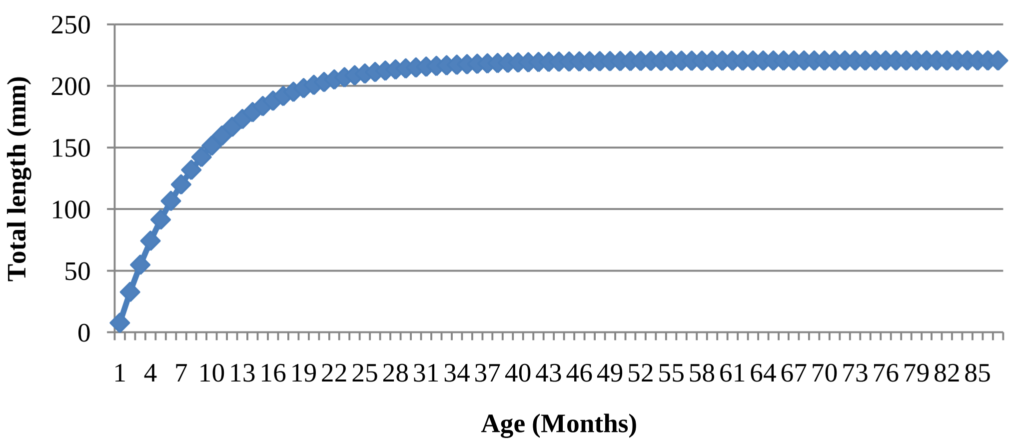


Table 1: Comparison of regression lines of length-weight relationship in males and females of *H. harpax*

	DF	X^2	Y^2	XY	Regression coefficient Intercept (log a)	Slope (b)	DF	SS	MSS
Within males	344	4.5046	1.8476	2.8609	0.0000798546	2.5097	343	0.0175	
Females	551	4.6528	2.0698	3.0756	0.0000479181	2.6631	550	0.0113	
							893	0.0288	0.0000322
Pooled	895	9.1574	3.9174	5.9365	0.000065539	2.6015	894	0.0291	0.0000325
Difference between slope							1	0.0003	0.0003
Slope F= 9.3167702			**D.F.1, 893.**				**Significant at 5% level**		

Table 2.Von Bertalanffy equation to the growth data of *H. harpax*

$L\infty$ = 220.50 mm K = 1.5 t_0 = 0.06 years

t (years)	t-t0	K(t-t0)	e-k(t-to)	1- e-k(t-to)	Lt = L∞(1- e-k(t-to))
0.17	0.11	0.16	0.8521	0.1479	32.612
0.33	0.27	0.41	0.6636	0.3364	74.1762
0.5	0.44	0.66	0.5168	0.4832	106.546
0.66	0.6	0.9	0.4065	0.5935	130.867
0.83	0.77	1.16	0.3134	0.6866	151.395
1	0.94	1.41	0.244	0.756	166.698
1.16	1.1	1.65	0.192	0.808	178.164
1.33	1.27	1.91	0.148	0.852	187.866
1.5	1.44	2.16	0.1153	0.8847	195.076
1.66	1.6	2.4	0.009	0.991	218.516
1.83	1.77	2.66	0.0699	0.9301	205.087
2	1.94	2.91	0.0544	0.9456	208.505
2.16	2.1	3.15	0.0428	0.9572	211.063
2.33	2.27	3.41	0.033	0.967	213.224
2.5	2.44	3.66	0.0257	0.9743	214.833
2.66	2.6	3.9	0.0202	0.9798	216.046
2.83	2.77	4.16	0.0156	0.9844	217.06
3	2.94	4.41	0.0121	0.9879	217.832
3.16	3.1	4.65	0.00956	0.9904	218.392
3.33	3.27	4.91	0.00737	0.9926	218.875
3.5	3.44	5.16	0.00574	0.9943	219.234
3.66	3.6	5.4	0.00451	0.9955	219.506
3.83	3.77	5.66	0.00348	0.9965	219.733
4	3.94	5.91	0.00271	0.9973	219.902
4.16	4.1	6.15	0.002133	0.9979	220.03
4.33	4.27	6.41	0.00164	0.9984	220.138
4.5	4.44	6.66	0.00128	0.9987	220.218
4.66	4.6	6.9	0.001007	0.999	220.278
4.83	4.77	7.16	0.00077	0.9992	220.33

5	4.94	7.41	0.000605	0.9994	220.367
5.17	5.11	7.66	0.000471	0.9995	220.396
5.25	5.19	7.79	0.000413	0.9996	220.409
5.33	5.27	7.91	0.000367	0.9996	220.419
5.42	5.36	8.04	0.000322	0.9997	220.429
5.5	5.44	8.16	0.000285	0.9997	220.437
5.58	5.52	8.29	0.000251	0.9997	220.445
5.67	5.61	8.41	0.000222	0.9998	220.451
5.75	5.69	8.54	0.000195	0.9998	220.457
5.83	5.77	8.66	0.000173	0.9998	220.462
5.92	5.86	8.79	0.0001522	0.9998	220.466
6	5.94	8.91	0.000135	0.9999	220.47
6.08	6.02	9.04	0.0001185	0.9999	220.474
6.17	6.11	9.16	0.000105	0.9999	220.477
6.25	6.19	9.29	0.0000923	0.9999	220.48
6.33	6.27	9.41	0.0000819	0.9999	220.482
6.42	6.36	9.54	0.0000719	0.9999	220.484
6.5	6.44	9.66	0.0000637	0.9999	220.486
6.58	6.52	9.79	0.000056	0.9999	220.488
6.67	6.61	9.91	0.00004967	1	220.489
6.75	6.69	10	0.00004539	1	220.49
6.83	6.77	10.2	0.00003717	1	220.492
6.92	6.86	10.3	0.00003363	1	220.493
7	6.94	10.4	0.00003043	1	220.493
7.08	7.02	10.5	0.00002753	1	220.494
7.17	7.11	10.7	0.00002254	1	220.495
7.25	7.19	10.8	0.00002039	1	220.496

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