

2.1. Introduction

The information on environmental variables that affect the living organisms is vital. Hydrographical studies play an important role in understanding the various biological processes (growth, physiology, reproduction, etc.) and the general productivity of aquatic ecosystem. The physico-chemical parameters such as temperature, salinity, dissolved oxygen and nutrients are of profound biological significance and are used as population indicators (Head, 1985). Temperature and light play an important role in the gonadal gametogenesis, spawning and initiation of gonadal development (Pandey and Shukla, 2005). It is believed that the morphology of fish is determined by genetic and environmental factors, with these being particularly important during the early developmental stages when individuals are influenced by the environment (Ihssen *et al.*, 1981).

Estuaries may have the highest economic values per hectare of many aquatic environments (Costanza *et al.*, 1997). Estuarine ecosystem is characterized by a variable salinity and temperature range of greater than Sea. In tropical estuaries seasonal changes in salinity is obviously greater than in temperature (Blaber, 2000). Tropical and subtropical estuaries

represent one of the most exploited ecosystems in the world. In India the estuaries vary from near 30 - 37 psu in salinity of the dry season (Qasim, 2004).The Mandovi - Zuari estuarine systems are tropical estuarine systems and play major role in the economy of Goa.

Some of the early hydrographical and ecobiological work carried out on Goa estuaries are those of Dehadrai (1970); Cherian *et al.* (1975); Gangadhara Rao *et al.* (1976); Rao (1977); De Souza (1977); Qasim and Sen Gupta (1981); De Souza and Sen Gupta (1986); Ansari (1988); Padmavati and Goswami (1996); Ingole and Parulekar (1998). In the view of the importance of environmental condition and hydrographic parameters in fishery biology, it was felt necessary to study the environmental parameters such as temperature, salinity, dissolved oxygen and pH of the study area (Dona Paula in Zuari estuary).

2.2. Study area

Goa is located between 14° 54' -15° 48' N latitudes and 73° 41' - 74° 21' E longitudes. The two rivers Mandovi and Zuari are joined by Cumbarjua canal, forming major estuarine system in Goa. Mandovi - Zuari estuarine systems are called the lifeline due to their major importance among the seven rivers flowing through the hills and plains of Goa. Geographically, the Mandovi - Zuari River estuaries could be classified as drowned river valley estuaries formed due to the Holocene rise in the sea level (Anon, 1978) .They are rich in living resources such as finfish and shellfish and

are used for fishing activity round the year particularly during the monsoon season when the marine fishing is suspended. The minimum wave action in the estuary during monsoon makes it ideal for fishing during this season.

River Zuari originates in the Dighi Ghat in Karnataka. It joins Arabian Sea at its eastern end forming a bay called Mormugao - Dona Paula point after flowing about 67 km (Qasim, 2004). The mouth region of the estuary is rocky and subjected to heavy wave's action while the upstream region is quite narrow (Untawale *et al.*, 1982). Its width at the mouth of the estuary is about 5.9 km while at the upper reaches the width is less than 1 km (Ansari, 1988). The study site was selected at Dona Paula Bay, which is less than two km upstream of the opening of Zuari River in the Arabian Sea (Fig. 2.1.).

2.3. Material and Methods

Water samples were collected from a fixed station at monthly intervals and analyzed for temperature, salinity, dissolved oxygen and pH. The study was carried out during January 2004 - April 2005.

Surface water temperature was measured on the site with a mercury thermometer and the values are expressed as degree centigrade (°C).

Fig. 2.1. Map showing location of the study area.

Salinity was estimated using Guildline “Autosal” model 8400A salinometer (measurement range: 0.005-42 psu), which measure the electrical conductivity ratio of the samples. The readings of the instrument, then converted from conductivity ratio to salinity, which its values are expressed in practical salinity unit (psu).

Dissolved oxygen (DO) was estimated following standard Winkler’s method and the values are expressed in mg/ l.

pH was measured immediately in the field using a portable pH meter.

The rainfall and atmospheric temperature data for the period of the study was obtained from the meteorological station, located at NIO.

2.4. Results

Seasonal variability of different environmental features in the estuarine system is chiefly controlled by the regime of the rainfall dividing the year into three distinct seasons: Pre-monsoon (February - May), Monsoon (June - September) and Post-monsoon (October - January). Monthly variations in hydrographical parameters of Zuari estuary (off Dona Paula) are given in Table (2.1.).

Table 2.1. Seasonal variation of different hydrographical and climate parameters during January 2004 – April 2005.

Month/parameter	Water				Rainfall (mm)	Air Temperature.(°C)
	Temperature.(°C)	Salinity(PSU)	D.O(mg/l)	pH		
Jan	28.2	32.9	3.21	8.34	0	26.1
Feb	29	33	3.52	8.39	0	26.8
Mar	30	34.21	3.91	8.22	0	29.1
Apr	30	34.67	3.98	8.26	0	29.5
May	32.7	34.72	3.91	8.13	164.7	29.5
Jun	26	23.5	4	7.86	601.9	27.8
Jul	24.5	19.01	4.8	7.66	617.3	26.9
Aug	28	26.02	4.54	7.78	476.1	26.8
Sep	29	32.61	3.74	7.8	149.8	26.9
Oct	29	33.1	3.71	8.09	86.2	28.4
Nov	30.5	34.54	3.7	8.09	60	26.7
Dec	26.5	34.64	3.74	8.13	0	26.6
Jan	27	34.63	3.62	7.97	0	25.7
Feb	28	34.76	3.53	7.96	2	26.1
Mar	29.5	35.57	3.45	7.92	0	27.1
Apr	32	35.68	3.92	8.06	45	29.2

2.4.1 Temperature

The surface water temperature fluctuated between 24.5 and 32.7 °C, with an average of $28.8 \pm 2.20^{\circ}\text{C}$ for the whole period. There was a progressive increase in the water temperature from January to May with peak value of 32.7°C in May (Fig. 2.2.). With the onset of monsoon, a sudden fall in temperature (26°C) was observed in June. The temperature remained low during monsoon with minimum value of 24.5 °C in July. A gradual increase in the water temperature noticed at the end of monsoon. The temperature remained high during the rest of the period.

2.4.2 Salinity

Seasonal variation in the salinity of the estuary was very large (Fig. 2.3.). It ranged from 19.01 to 35.7 psu with an average value of 32.09 ± 5.02 psu during the period of observation. In general salinity was high during Pre-monsoon (February - May) reaching 34.7 psu in May. With the onset of monsoon in June the salinity dropped sharply and remained low until August with minimum value of 19.01 psu in July. Salinity began to increase from September onwards.

2.4.3 DO

Seasonal variation in dissolved oxygen concentration during the study period ranged from 3.21 to 4.8 mg/l with an average of 3.83 ± 0.39 mg/l.

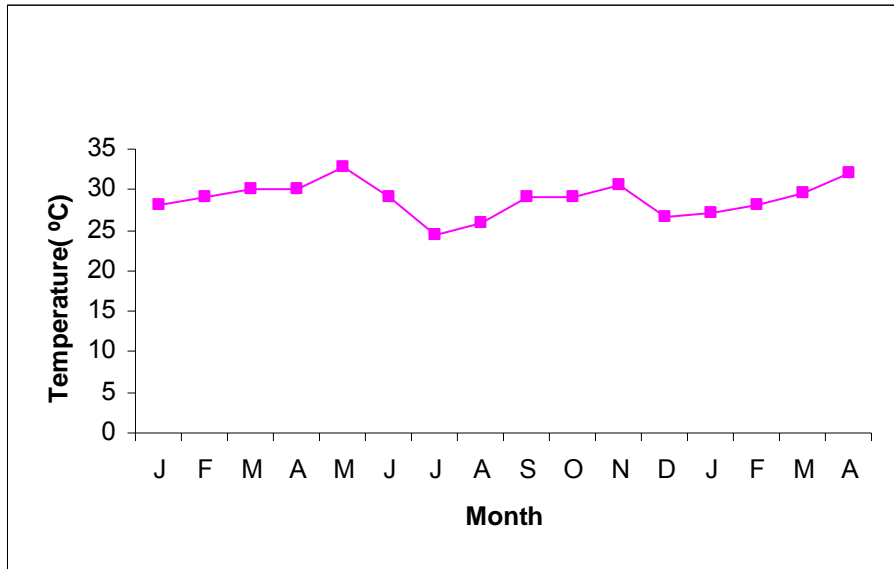


Fig. 2.2. Monthly variation of water Temperature of Zuari Estuary during January 2004 – April 2005.

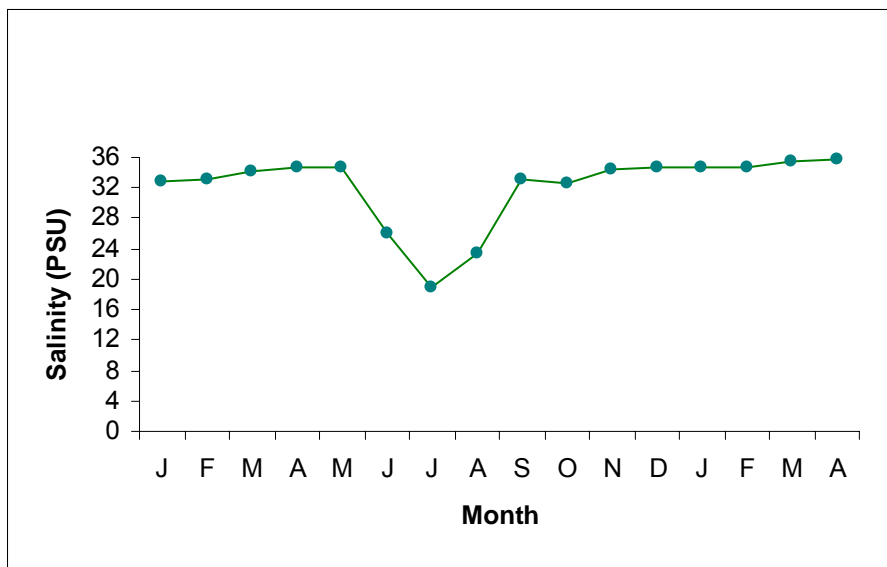


Fig. 2.3. Monthly variation in water dissolved oxygen of Zuari Estuary during January 2004 – April 2005.

The dissolved oxygen values were almost stable (3.21 mg/l - 3.91 mg/l) from January to May (Fig. 2.4.). The values increased during June - August with a maximum value of 4.80 mg/l in July. After September the dissolved oxygen value dropped sharply, reaching to a minimum of 3.74 mg/l. It remained almost stable until December. It is interesting to mention that the annual variation of dissolved oxygen was in contrast with the variation in salinity.

2.4.4 pH

The value varied within a narrow range of 7.66 in July to 8.39 in February with an average value of 8.04 ± 0.21 . Comparatively higher pH values were recorded during pre-monsoon (8.13 - 8.39) when the water salinity was high (Fig. 2.5.). During monsoon pH decreased to 7.66 in July coinciding with heaviest rainfall and lowest salinity value. pH began to increase from October onward.

An attempt was made to determine a correlation matrix of the environmental parameters. Positive correlation was observed between temperature and salinity ($r = 0.69$, $P < 0.05$) and between pH and salinity ($r = 0.62$, $P < 0.05$), while negative correlation was found between dissolved oxygen and salinity ($r = - 0.75$, $P < 0.05$) and pH and dissolved oxygen ($r = - 0.60$, $P < 0.05$).

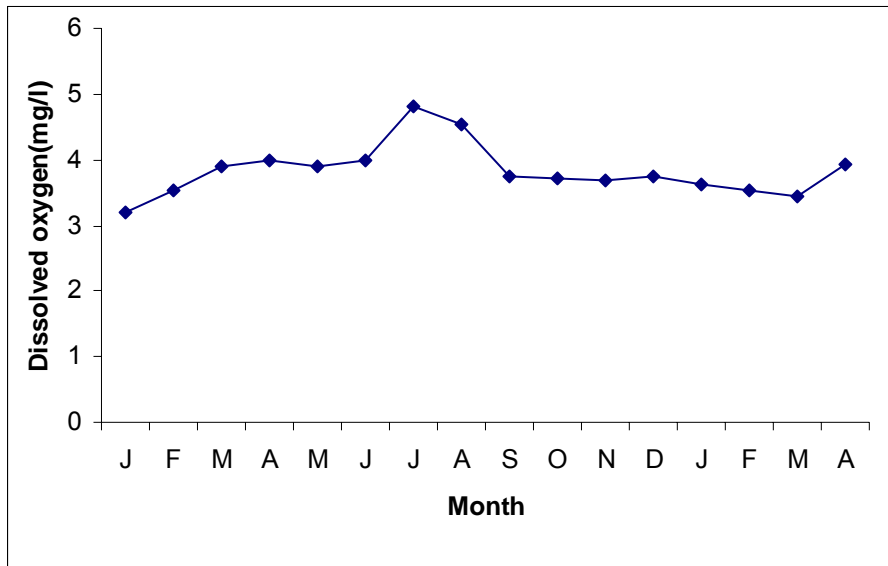


Fig. 2.4. Monthly variation in water dissolved oxygen of Zuari Estuary during January 2004 – April 2005.

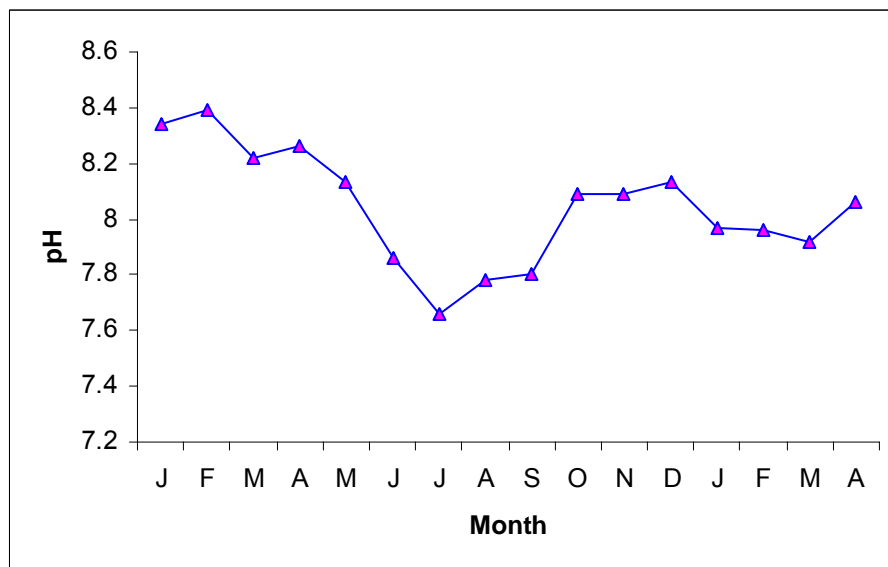


Fig. 2.5. Monthly variation of water pH of Zuari Estuary during January 2004 – April 2005.

Annual variation in atmospheric temperature during the study period is given in Fig. 2.6. The minimum and maximum atmospheric temperature observed during the study period was 25.8 °C and 29.5 °C, in January and April - May, respectively. Goa has an annual rainfall of about 3453 mm, out of which the maximum is recorded during south - west monsoon (June - September). During the present study, the maximum rainfall was received in June - July (Fig. 2.7.). However, some rain showers were observed in May and October - November during the study period. The total average rainfall during January - December 2004 was 2156 mm with an average of 165.85 mm/month, which is below the average. This happened because Goa received less rain in the year 2004 (2156 mm). Effect of rainfall on the water temperature and salinity is shown in Fig. 2.8. The low values of temperature and salinity recorded during monsoon months coincided with heaviest rainfall. This indicates the direct effect of rainfall on the temperature and salinity.

2.5. Discussion

An extensive work on hydrographical parameters of Mandovi - Zuari estuarine system revealed that the physical, chemical and biological features are adapted to a seasonal rhythm, and the changes are dependent upon the monsoon cycle and the amount of freshwater received in this season. Precipitation and land runoff during monsoon

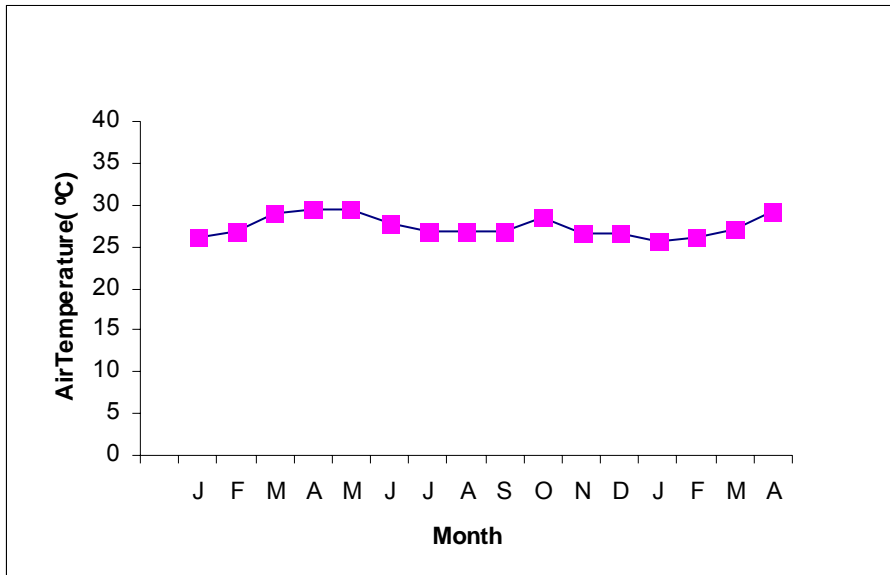


Fig. 2.6. Seasonal changes of Air temperature during January 2004 – April 2005.

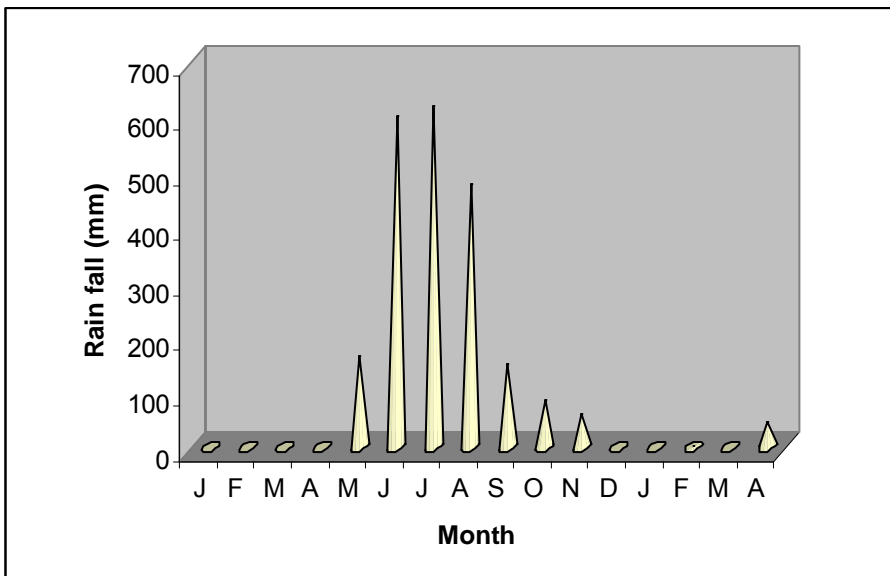


Fig. 2.7. Seasonal changes of rainfall during January 2004 – April 2005 in Goa.

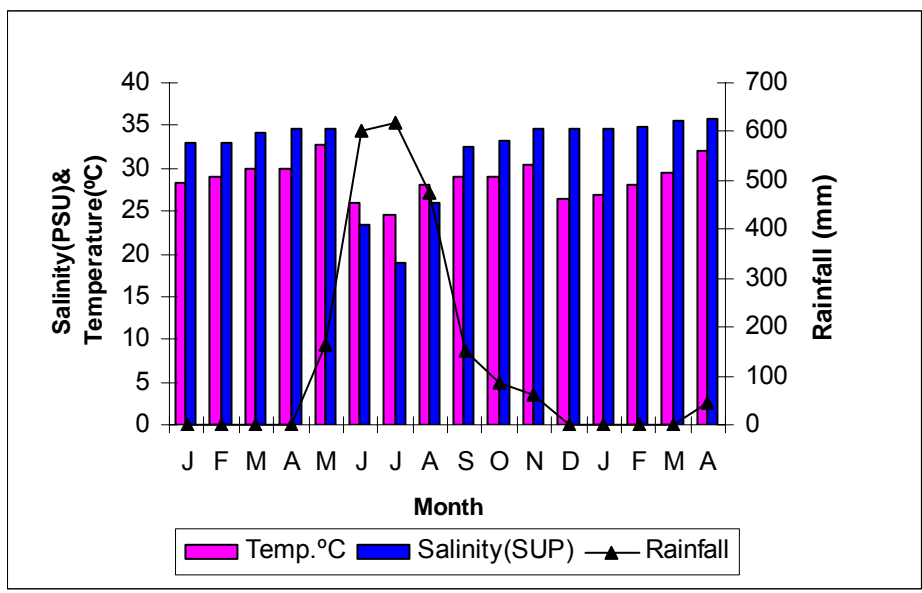


Fig. 2.8. Effect of Rainfall on temperature and salinity of water in Zuari Estuary.

bring about dynamic changes from typically marine to typically brackish water condition in the estuaries (Qasim and Sen Gupta, 1981). That leads to large changes in temperature, salinity, flow pattern, dissolved oxygen and nutrients. The variation in these parameters is known to be lesser in Zuari compared to Mandovi (Padmavati and Goswami, 1996). The changes are however, not significant except in monsoon. Diurnal variations in the physio - chemical conditions in both the Mandovi and Zuari estuaries (Singbal, 1973; 1976) are reported to be controlled by the tides. The water remains well mixed during the pre-monsoon season and gets stratified during monsoon (Qasim and Sen Gupta, 1981). The lighter and less saline water floats at the surface while heavier water remains at the bottom.

In the present study, there was a gradual increase in temperature from January to May and the temperature declined during the monsoon followed by increase in the later months. Similar observations were reported by Dehadrai (1970); Qasim and Sen Gupta (1981) and Rivonker (1991). Temperature was higher during pre-monsoon with peak value in the month of May. This can be attributed to higher atmospheric temperature prevailing at that time. During monsoon the high precipitation and freshwater influx brings cooler water from the upper reaches of the river due to which the water temperature was low at that time.

Salinity is the only factor, which undergoes spectacular change during the year (Qasim, 2004). During the study period, salinity was high and uniform with minute variations except in monsoon. Higher salinity values during major period of study can be attributed to higher temperature. High atmospheric temperature particularly during March - May leads to increasing the rate of evaporation, which in turn increase the salinity values. Heavy clouds reduce the solar radiation decreasing the temperature and rate of evaporation during monsoon. The decrease in salinity can be attributed to heavy precipitation and influx of freshwater from upper reaches of Zuari River during monsoon. Dehadrai and Bhargava (1972) reported similar observations. With the cessation of monsoon, the fresh water flow decreased and the salinity started increasing gradually in the post-monsoon. However, fall in salinity in this estuary during monsoon was not significant. This could be attributed to the thorough mixing of water resulting from intense tidal action and negligible influx of fresh water from the river, which contributes to more saline nature of this area (Cherian *et al.*, 1975). The direct effect of the onset of monsoon can be observed in the rapid decline in salinity of the estuary (Padmavati and Goswami, 1996; Ingole and Parulekar, 1998). Similar trend was reported from Kali estuary in Karwar (Reddy, 1991).

The dissolved oxygen content in the water showed a high level with maximum values in monsoon months. Inverse relationship between dissolved oxygen and salinity was observed from the variation pattern of

dissolved oxygen during the study period. Decrease salinity increases the solubility of oxygen in the water, which probably appears to be the main cause for the increase in the concentration of dissolved oxygen during monsoon. This corroborates the earlier findings by Singbal (1976) Qasim and Sen Gupta (1981) and De souza and Sen Gupta (1986). The high values during monsoon are mainly due to precipitation and influx of oxygen rich fresh water from the river runoff.

The pH of the river water is strongly influenced by the terrain through which it flows. The pH of water was slightly alkaline during pre-monsoon and post-monsoon coincided with high values of salinity. Decrease of pH during monsoon can be attributed to decrease in the level of salinity. A positive correlation between the two parameters ($r = 0.62$, $P < 0.05$) indicates that pH in brackish water is influenced by the tidal salinity. Low pH values during monsoon have been reported by various workers (Srinivasan and Pillai, 1973; Singbal, 1985; James and Najmuddin, 1986). Low values of pH coincided with high values of dissolved oxygen indicating inverse relationship between pH and dissolved oxygen ($r = -0.060$, $P < 0.05$). Such relationship has been observed by Ingole and Parulekar (1998). Nagarajaiah and Gupta (1983) reported similar trend in brackish water pond along Nethravati estuary, Mangalore. pH regulation by soil water interaction besides biological processes in rivers and estuaries was suggested by Sarma *et al.* (2001).

From the above environmental features, the Mandovi-Zuari estuarine system can be classified as a tide-dominated coastal plain estuary (Qasim and Sen Gupta, 1981). During the southwest monsoon the river Zuari gets less diluted than that in Mandovi although the distance of penetration of the salt front during the summer months is almost similar in both rivers. The water is well aerated. The high temperature leads to evaporation and high salinity in summer season.

3.1. Introduction

Morphological characters that can be seen externally are the ones used to separate the species. Two types of characters e.g.; morphometrics and meristics have been frequently used to delineate stock of fish species (Haddon and Willis, 1995; Murta, 2000; Silva, 2003). Knowledge of fish stock structure is essential for effective fishery management (Grimes *et al.*, 1987; Carvalho and Hauser, 1994; Begg *et al.*, 1999). Despite the advent of biochemical and molecular genetics techniques, studies of morphological variations among populations continue to play an important role in stock identification (Swain and Foote, 1999).

Different populations of the same species living in different geographical areas are known to differ morphologically. Furthermore, the morphometric and meristic characters are highly variables even in the same population depending upon their macro and micro geographical distribution. Morphometric characters have been used to distinguish between stocks of various marine fish population and differentiate intra-specific variations (Ihssen *et al.*, 1981; Winans, 1984).

In early studies (Heincke, 1898), the variation in morphometric characters was assumed to be entirely controlled by genetic factors. However, in recent

years the morphology of fish is believed to be determined by genetic and environmental factors (Clayton, 1981; Foote *et al.*, 1989; Robinson and Wilson, 1996; Cabral *et al.*, 2003). Morphometric studies are also commonly used in fishery biology in determining discreteness and relationship among various taxonomic categories.

Some of the earlier studies on the biometrics, morphometrics and racial analyses of the populations of commercially important fishes from Indian waters are those of Pillay (1952; 1957); Radhakrishnan (1957); Rao (1965; 1966) and Vijaya Gupta (1970); Das (1978); Srivastava and Seth (1981) among others.

In spite of the wide distribution of *S. sihama* in Indian waters, the Published work on its morphometry particularly from Goa waters is scanty. Thus, the present investigation on *S. sihama* was made to study the inter relationships of various morphometric characters, their growth rates in relation to total length.

3.2. Material and methods

Sample for the present study were collected during January - April 2005 from Zuari estuary (Dona Paula Bay). Three hundred and fifty specimens of *S. sihama* in the size range 98 - 212 mm total length were examined for body measurements. Specimens with damaged dimension and body parts were left out. Body measurements were recorded carefully in millimeter using

a pair of fine dividers. Fifteen morphometric characters have been selected for the study and are shown in Fig. 3.1. They are:

Total length (T.L): The distance from tip of the snout to the tip of longest ray of caudal fin.

Standard length (Std.L): The distance from the tip of the snout to the end of hypural plate.

Head length (H.L): The distance from tip of the snout to the posterior point of opercular membrane.

Snout length (S.L): The distance from the tip of upper jaw to the front margin of the orbit.

Post-orbital length (P.O.L): The distance from hind margin of orbit to the tip of opercular membrane.

Inter-orbital length (I.O.L): The distance between the dorsal margins of the eyes.

Eye diameter (E.D): The greatest horizontal distance between the free orbital rims.

Pre-first dorsal fin (P.ID): The distance from the tip of the snout to the anterior end of the first dorsal fin base.

Insert Figure 3.1. from power point

Pre-second dorsal fin (P.IID): The distance from the tip of the snout to the anterior end of the second dorsal fin base.

Pre-pectoral length (P.Pc.L): The distance from the tip of the snout to the insertion of the pectoral fin.

Pre-pelvic length (P.Pv.L): The distance from the tip of the snout to the insertion of the pelvic fin.

Pre-anal length (P.A.L): The distance from the tip of the snout to the insertion of the anal fin.

Body depth (B.Dep): The distance from the anterior end of first dorsal fin to the ventral surface of the fish at deepest part.

Depth through anal fin (Dep.A): The distance from the anterior end of second dorsal fin to the anterior end of the anal fin.

Caudal peduncle depth (Cd.Dep): The minimum distance between the dorsal and ventral edges of the caudal peduncle.

In order to determine the degree of association between various variables (measurements) correlation coefficient (r) between these morphometric measurements were calculated. Since there was a significant correlation between total length and the other measurements, all the measurements were taken into consideration to analyze their relationships with total length.

These relationships were estimated on the basis of that “the relationship between two variables may be one of functional dependence of one variable on the other” (Zar, 2006). That is the magnitude of the dependent variable is assumed to be determined by the magnitude of the independent variable. For this purpose, linear regression analysis was applied in case of male and female separately. The statistical relationships between total length and various body characters were derived through the regression equation

$$Y = a + b X$$

Where ‘X’ denotes total length as independent variable and ‘Y’ the other dependent variables ‘a’ and ‘b’ are constants.

Differences between slopes of various regression lines of male and female were tested using student’s t test. The test statistic is:

$$t = \frac{b_1 - b_2}{S_{b_1 - b_2}}$$

Where ‘b’ is the slope of the regression line, and ‘Sb’ is the standard error of ‘b’.

3.3. Results

The mean with standard error, minimum and maximum values of each measurement were calculated against each character as presented in Table

3.1. The correlation matrix between various measurements is presented in Table 3.2. for male and Table 3.3. for female. Established correlation coefficients (r) showed high positive significant correlation ($P < 0.001$) in both the sexes. The highest correlation coefficient was observed between total length and standard length ($r = 0.998$) in male and ($r = 0.999$) in female. The lowest was between postorbital length and eye diameter ($r = 0.889$) in male and ($r = 0.836$) in female.

The results of statistical analysis on morphometric characters are summarized in Table 3.4. Scatter plots of various regression lines are illustrated in Fig. 3.2a-d for male and Fig. 3.3a-d for female. It was found that all the body measurements showed a linear relationship against total length.

Standard length on Total length

The equation derived for standard length and total length was $Y = -6.3971 + 0.9067 X$ for male and $Y = -5.3507 + 0.8974 X$ for female. The regression coefficient 'b' was significant ($P < 0.001$) with an average rate of 0.91 mm increase standard length in male and 0.90 mm in female per 1 mm of total length. There is a high degree of positive correlation between standard length and total length with 'r' value being 0.998 in male and 0.999 in female.

Table 3.1. Various examined measurements in male and female of *S. sihama*.

Morphometric Measurements	Male			Female		
	Mean \pm SE	Minimum	Maximum	Mean \pm SE	Minimum	Maximum
T.L	132.75 \pm 2.28	98	187	133.45 \pm 2.105	101	212
Std.L	113.96 \pm 2.07	83	165	114.41 \pm 1.89	85	188
H.L	31.39 \pm 0.48	24	45	32.22 \pm 0.48	25	50
S.L	14.25 \pm 0.23	10	21	14.74 \pm 0.256	11	24
P.O.L	13.04 \pm 0.22	9	18.5	13.46 \pm 0.23	10	20
I.O.L	7.21 \pm 0.15	5	12	7.26 \pm 0.13	5.5	11
E.D	7.50 \pm 0.11	6	10	7.63 \pm 0.097	6.5	11
P.ID.L	40.30 \pm 0.65	28	59	41.31 \pm 0.70	29	69
P.IID.L	64.28 \pm 1.19	46	92	65.02 \pm 1.12	49	107
P.Pc.L	35.84 \pm 0.64	26	56	36.59 \pm 0.58	27	57
P.Pv.L	37.43 \pm 0.62	27	53	38.44 \pm 0.62	28	61
P.A.L	63.69 \pm 1.17	45	95	64.68 \pm 1.16	47	110
Dep.ID	20.30 \pm 0.44	13	33	20.61 \pm 0.397	16	34
Dep.IID	18.96 \pm 0.46	11.5	33	19.20 \pm 0.44	13	35
C.PdDep	8.71 \pm 0.15	6	13	8.82 \pm 0.14	7	13

Table 3.2. Correlation matrix between various morphometric measurements in male of *S. sihama*.

	<i>T.L</i>	<i>Std.L</i>	<i>H.L</i>	<i>S.L</i>	<i>P.O.L</i>	<i>I.O.L</i>	<i>E.D</i>	<i>P.ID.I</i>	<i>P.IID. L</i>	<i>P. Pc.L</i>	<i>P. Pv.L</i>	<i>P.A.L</i>	<i>Dep.ID</i>	<i>Dep.IID</i>	<i>C.PdDep</i>	
<i>T.L</i>	1															
<i>Std.L</i>	0.9984	1														
<i>H.L</i>	0.9571	0.9492	1													
<i>S.L</i>	0.9377	0.9277	0.9636	1												
<i>P.O.L</i>	0.9370	0.9275	0.9708	0.9740	1											
<i>I.O.L</i>	0.9589	0.9585	0.9425	0.9296	0.9326	1										
<i>E.D</i>	0.9250	0.9176	0.8999	0.8962	0.8890	0.9140	1									
<i>P.ID.I</i>	0.9562	0.9482	0.9481	0.9431	0.9400	0.9240	0.9131	1								
<i>P.IID. L</i>	0.9940	0.9927	0.9604	0.9489	0.9486	0.9583	0.9274	0.9631	1							
<i>P. Pc.L</i>	0.9629	0.9593	0.9650	0.9552	0.9531	0.9522	0.9049	0.9172	0.9643	1						
<i>P. Pv.L</i>	0.9783	0.9722	0.9734	0.9710	0.9626	0.9521	0.9262	0.9667	0.9809	0.9770	1					
<i>P.A.L</i>	0.9903	0.9892	0.9591	0.9401	0.9423	0.9527	0.9194	0.9526	0.9880	0.9665	0.9765	1				
<i>Dep.ID</i>	0.9583	0.9532	0.9320	0.9366	0.9218	0.9324	0.9236	0.9477	0.9644	0.9242	0.9546	0.9515	1			
<i>Dep.IID</i>	0.9482	0.9406	0.9127	0.9244	0.9139	0.9040	0.9280	0.9370	0.9525	0.9063	0.9453	0.9383	0.9650	1		
<i>C.PdDep</i>	0.9502	0.9462	0.8968	0.9006	0.8953	0.9006	0.9083	0.9059	0.9468	0.9130	0.9308	0.9353	0.9259	0.9380	1	

$r = 0.314$, 105 DF, $P < 0.001$

Table 3.3. Correlation matrix between various morphometric measurements in female of *S. sihama*.

	<i>T.L</i>	<i>Std.L</i>	<i>H.L</i>	<i>S.L</i>	<i>P.O.L</i>	<i>I.O.L</i>	<i>E.D</i>	<i>P.ID.I</i>	<i>P.IID. L</i>	<i>P. Pc.L</i>	<i>P. Pv.L</i>	<i>P.A.L</i>	<i>Dep.ID</i>	<i>Dep.IID</i>	<i>C.PdDep</i>
<i>T.L</i>	1														
<i>Std.L</i>	0.9988	1													
<i>H.L</i>	0.9651	0.9600	1												
<i>S.L</i>	0.9555	0.9492	0.9679	1											
<i>P.O.L</i>	0.9338	0.9265	0.9624	0.9666	1										
<i>I.O.L</i>	0.9435	0.9452	0.9233	0.9143	0.9155	1									
<i>E.D</i>	0.9198	0.9229	0.8708	0.8735	0.8358	0.8895	1								
<i>P.ID.I</i>	0.9815	0.9793	0.9703	0.9735	0.9521	0.9439	0.9053	1							
<i>P.IID. L</i>	0.9933	0.9921	0.9672	0.9653	0.9486	0.9481	0.9233	0.9878	1						
<i>P. Pc.L</i>	0.9663	0.9604	0.9798	0.9750	0.9673	0.9373	0.8840	0.9777	0.9718	1					
<i>P. Pv.L</i>	0.9730	0.9694	0.9782	0.9719	0.9652	0.9310	0.8907	0.9742	0.9759	0.9890	1				
<i>P.A.L</i>	0.9888	0.9893	0.9570	0.9558	0.9323	0.9426	0.9234	0.9799	0.9869	0.9685	0.9741	1			
<i>Dep.ID</i>	0.9605	0.9576	0.9154	0.9233	0.8974	0.9276	0.9247	0.9514	0.9620	0.9400	0.9406	0.9531	1		
<i>Dep.IID</i>	0.9601	0.9571	0.9180	0.9266	0.8903	0.8916	0.9167	0.9492	0.9591	0.9360	0.9415	0.9530	0.9697	1	
<i>C.PdDep</i>	0.9270	0.9250	0.8816	0.8749	0.8666	0.8552	0.8799	0.8954	0.9202	0.8851	0.9068	0.9040	0.8963	0.9098	1

$r = 0.324$, 96 DF, $P < 0.001$

Table 3.4. Summery of statistical analysis of male and female of *S. sihama*.

Morphometric measurements (mm)	Male No= 107			Female No= 98		
	a	b	r	a	b	r
Std.L	-6.3971	0.9067	0.9984	-5.3507	0.8974	0.9988
H.L	4.6721	0.2013	0.9571	2.9188	0.2196	0.9651
S.L	1.6364	0.095	0.9377	-0.7322	0.1160	0.9555
P.O.L	1.272	0.0887	0.937	0.1737	0.0996	0.9338
I.O.L	-1.3067	0.0642	0.9589	-0.4908	0.0581	0.9435
E.D	1.6411	0.0441	0.925	1.9332	0.0427	0.9198
P.ID.L	3.8917	0.2743	0.9562	-2.1307	0.3255	0.9815
P.IID.L	-4.5639	0.5186	0.994	-5.4519	0.5281	0.9933
P.Pc.L	-5.4735	0.2741	0.9629	0.8617	0.2677	0.9663
P.Pv.L	1.8355	0.2681	0.9783	0.0166	0.2879	0.9730
P.A.L	-3.8179	0.5086	0.9903	-7.7459	0.5428	0.9888
Dep.ID	-4.4198	0.1862	0.9583	-3.6020	0.1815	0.9605
Dep.IID	-6.4499	0.1915	0.9482	-7.6755	0.2014	0.9601
C.PdDep	0.5395	0.0616	0.9502	0.6470	0.0612	0.9270

Head length on Total length

The estimated equation derived was $Y = 4.6721 + 0.2013 X$ for male and $Y = 2.9188 + 0.2196 X$ for female. The regression coefficient 'b' was significant ($P < 0.001$) in both the sexes with an average rate of 0.20 mm increase head length in male and 0.22 mm in female per 1 mm of total length. The degree of association between the two is high and positive with 'r' value being 0.957 in male and 0.965 in female.

Snout length on Total length

The relationship between snout length and total length can be expressed by the equation $Y = 1.6364 + 0.095 X$ and $Y = -0.7322 + 0.1160 X$ for male and female, respectively. From the equation, it is clear that for each 1 mm increase in total length there will be an increase of 0.10 mm and 0.12 mm in snout length in male and female, respectively. The regression coefficient 'b' was significant ($P < 0.001$). There was a high positive correlation between the two variables with 'r' value being 0.938 and 0.956 for male and female, respectively.

Post-orbital length on Total length

The estimated equation was $Y = 1.272 + 0.0887 X$ for male and $Y = 0.1737 + 0.0996 X$ for female. The regression coefficient 'b' was significant ($P < 0.001$) in both the sexes with an average rate of 0.09 mm

increase in postorbital length per 1mm of total length in male and 0.10 mm in female. The degree of association between the two is high and positive with 'r' value being 0.937 in male and 0.934 in female.

Inter-orbital length on Total length

The relationship was found to be linear as is clear from the regression equation

$Y = -1.3067 + 0.0642 X$ for male and $Y = -0.4908 + 0.0851 X$ for female, with significant 'b' value ($P < 0.001$) with an average rate of 0.06 mm increase in interorbital length for every 1 mm increase in total length and 0.09 mm in female. Correlation coefficients 'r' was calculated to be 0.959 and 0.944 in male and female, respectively.

Eye diameter on Total length

The linear relationship between the eye diameter and total length may be expressed as $Y = 1.6411 + 0.0441 X$ and $Y = 1.9332 + 0.0427 X$ for male and female, respectively. The 'b' values were found to be significant ($P < 0.001$) in both the male and female with an average rate of 0.04 mm and 0.04 mm increase in eye diameter with 1 mm increase in total length for male and female respectively. High positive correlation was calculated with 'r' values of 0.925 and 0.920 in male and female, respectively.

Pre-first dorsal length on Total length

The estimated equations were $Y = 3.8917 + 0.2743 X$ for male and $Y = -2.1307 + 0.3255 X$ for female. The 'b' values were found to be significant ($P < 0.001$) in both the male and female with an average rate of 0.27 mm and 0.33 mm increase in pre-first dorsal length with 1 mm increase in total length for male and female respectively. The degree of association between the two is high and positive with 'r' value being 0.956 in male and 0.982 in female.

Pre-second dorsal length on Total length

The regression of pre-second dorsal fin on Total length can be written as $Y = -4.5639 + 0.5186 X$ and $Y = -5.4519 + 0.5281 X$ with 'r' values of 0.994 and 0.993 for male and female respectively. Significant 'b' values ($P < 0.001$) were found in both the sexes with an average rate of 0.52 mm and increase in pre-second dorsal fin length for every 1 mm increase in total length in male and 0.53 mm in female.

Pre-pectoral length on Total length

The relationship between pre-pectoral fin length and total length was linear with correlation coefficients 'r' 0.963 in male and 0.966 in female. The regression equation can be written as $Y = -5.4735 + 0.2741 X$ and $Y = 0.8617 + 0.2677 X$ in male and female respectively. The regression

coefficient 'b' values were found to be significant ($P < 0.001$) with an average rate in both sexes of 0.27 mm increase in pre-pectoral length with 1 mm increase in total length.

Pre-pelvic length on Total length

The estimated equations were $Y = 1.8355 + 0.2681 X$ for male and $Y = 0.0166 + 0.2879 X$ for female. The 'b' values were found to be significant ($P < 0.001$) in both the male and female with an average rate of 0.27 mm and 0.29 mm increase in pre-pelvic length with 1 mm increase in total length for male and female respectively. The degree of association between the two is high and positive with 'r' value being 0.978 in male and 0.973 in female.

Pre-anal length on Total length

The relationship between pre-anal fin length and total length was linear with correlation coefficients 'r' 0.990 in male and 0.989 in female. The regression equation can be written as $Y = -3.8179 + 0.5086 X$ and $Y = -7.7459 + 0.5428 X$ in male and female, respectively. The regression coefficient 'b' values were found to be significant ($P < 0.001$) with an average rate of 0.51 mm and 0.54 mm increase in pre-anal fin length with 1 mm increase in total length.

Depth through first dorsal length on Total length

Depth through first dorsal fin showed a linear relationship with total length, and the estimated equation derived was $Y = -4.4198 + 0.1862 X$ in male and $Y = -3.6020 + 0.1815 X$ in female. The estimated 'b' value was significant ($P < 0.001$) in both the sexes. The average rate of the increment of depth through first dorsal length was 0.19 mm and 0.18 mm for every 1 mm increase in total length in male and female respectively. The degree of association between the two is high and positive with 'r' value being 0.958 in male and 0.961 in female.

Depth through second dorsal length on Total length

The linear relationship of depth through second dorsal length with total length is derived by regression equation $Y = -6.4499 + 0.1915 X$ and $Y = -7.6755 + 0.2014 X$ for male and female, respectively. The equation infers that the depth through second dorsal length increases by 0.19 mm in male and 0.20 mm in female for every 1 mm increase in total length. This character showed high positive correlation with total length, with 'r' value 0.948 in male and 0.960 in female.

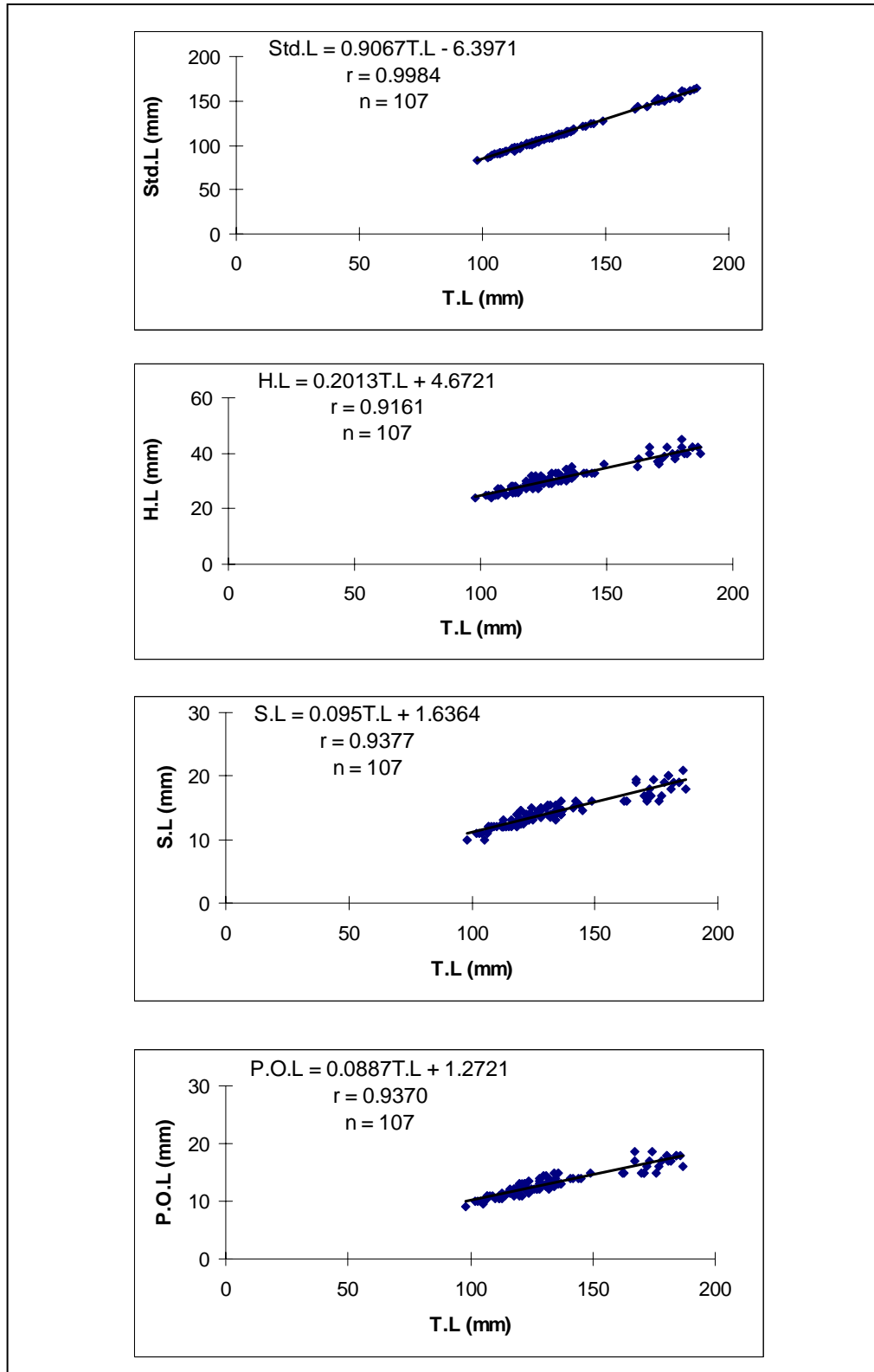


Fig. 3.1a. Relationship between various morphometric measurements and total length in male of *S. sihana*.

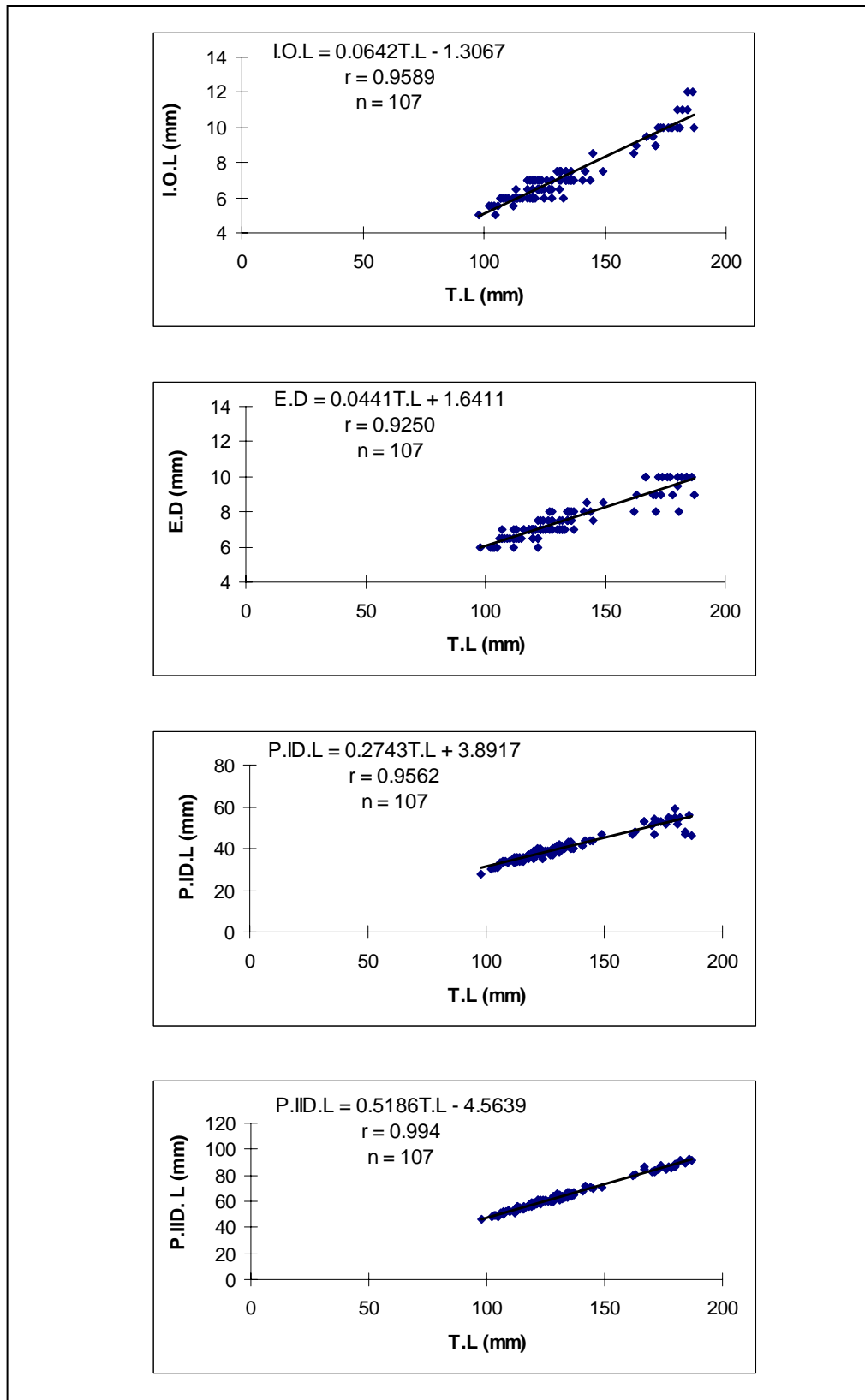


Fig. 3.1b. Relationship between various morphometric measurements and total length in male of *S. sihama*.

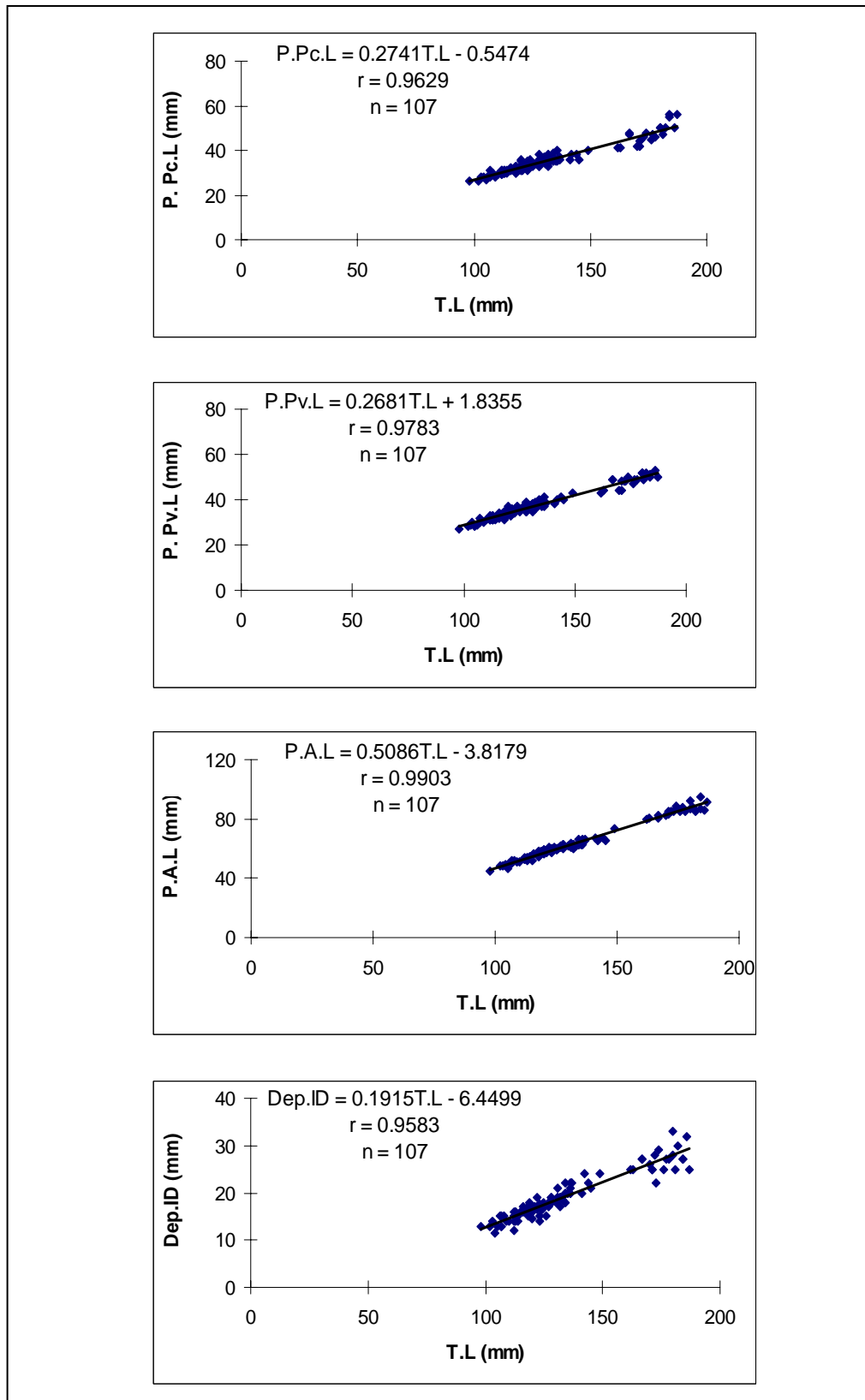


Fig. 3.1c. Relationship between various morphometric measurements and total length in male of *S. sihama*.

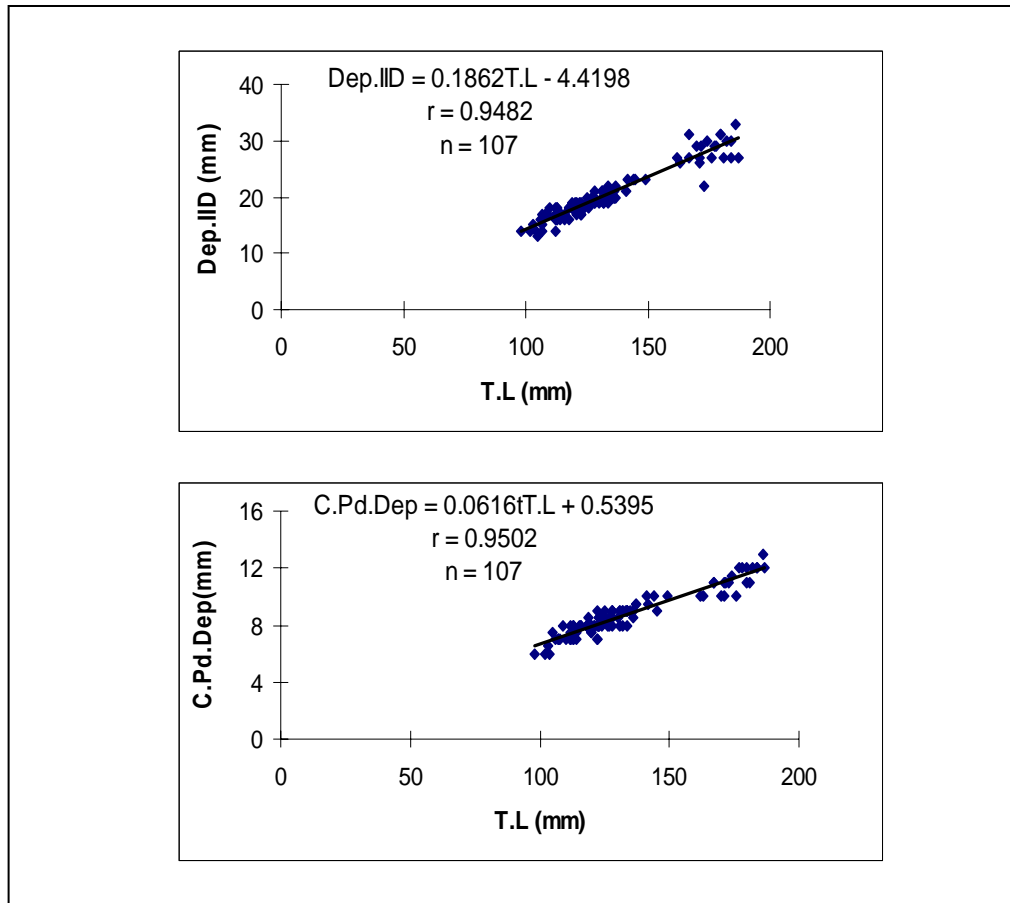


Fig. 3.1d. Relationship between various morphometric measurements and total length in male of *S. sihama*.

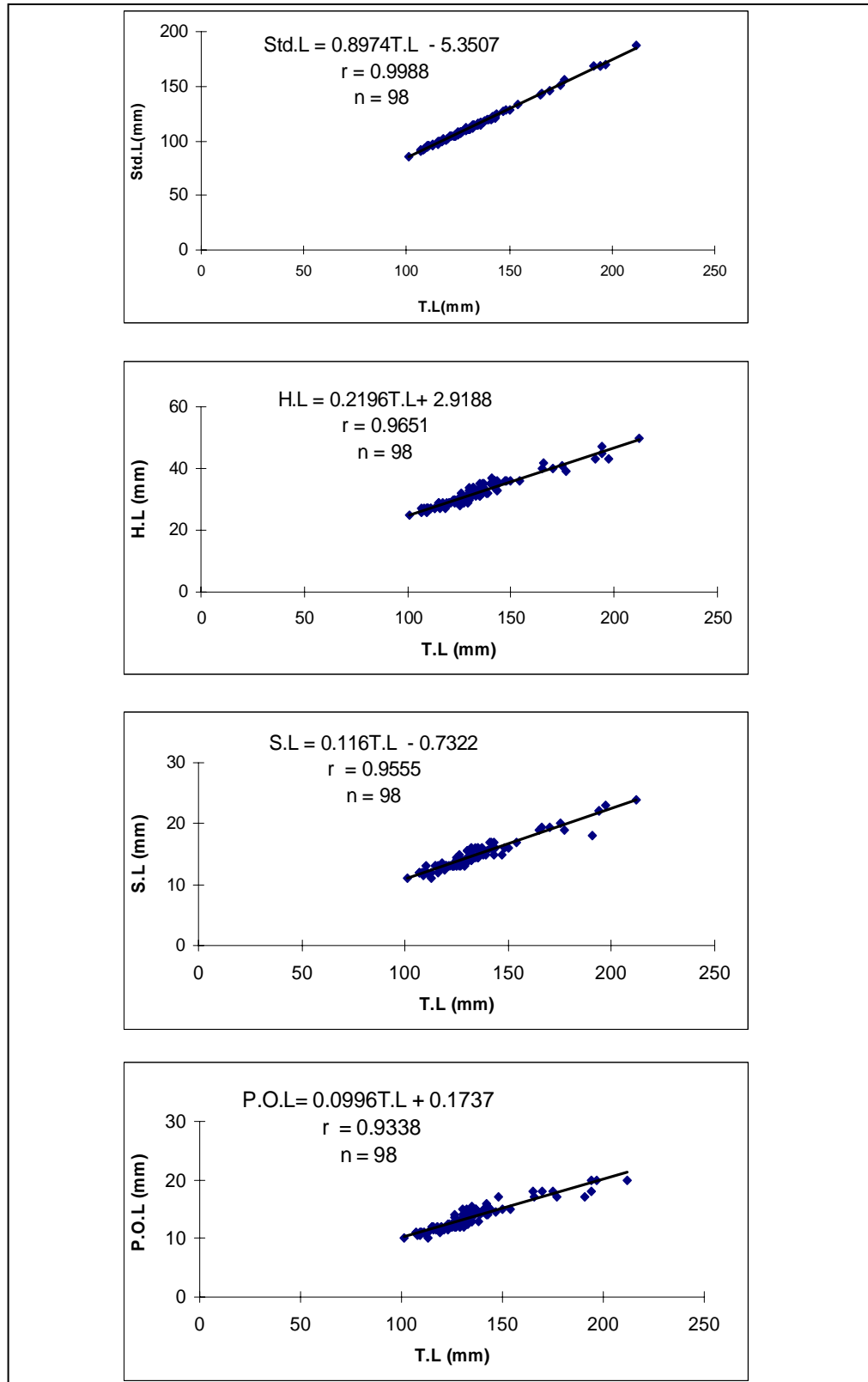


Fig. 3.2a. Relationship between various morphometric measurements and total length in female of *S. sihama*.

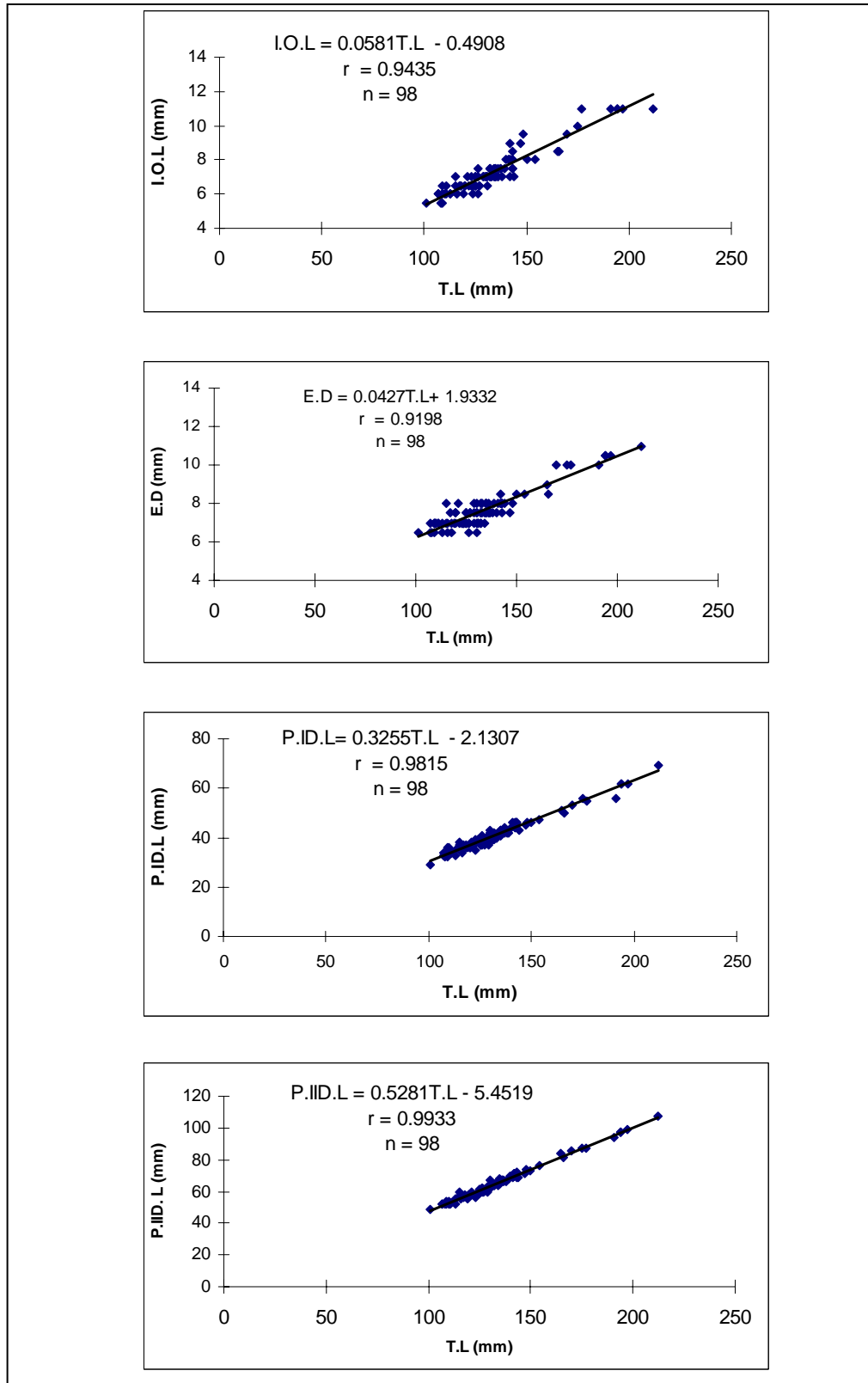


Fig. 3.2b. Relationship between various morphometric measurements and total length in female of *S. sihama*.

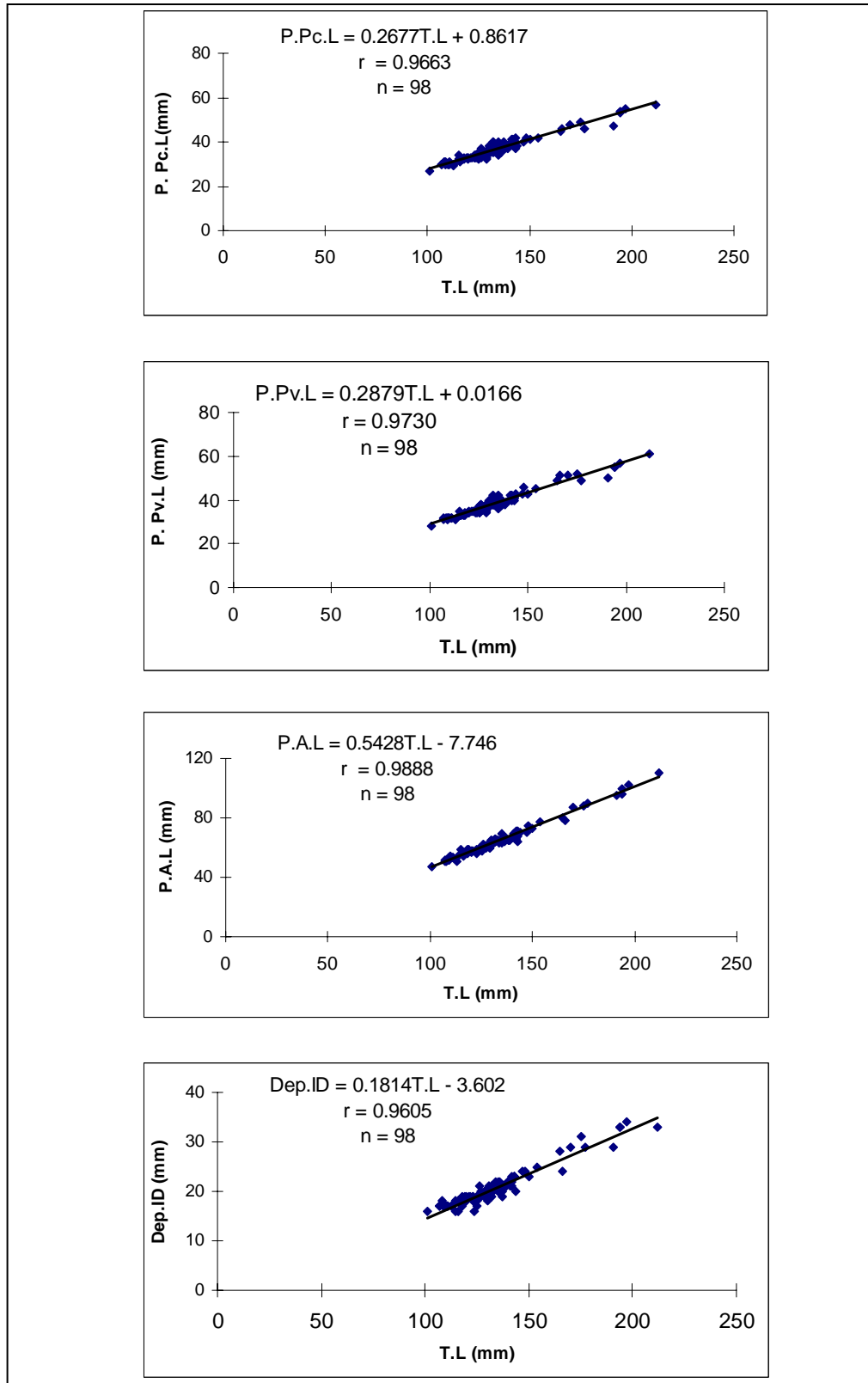


Fig. 3.2c. Relationship between various morphometric measurements and total length in female of *S. sihama*.

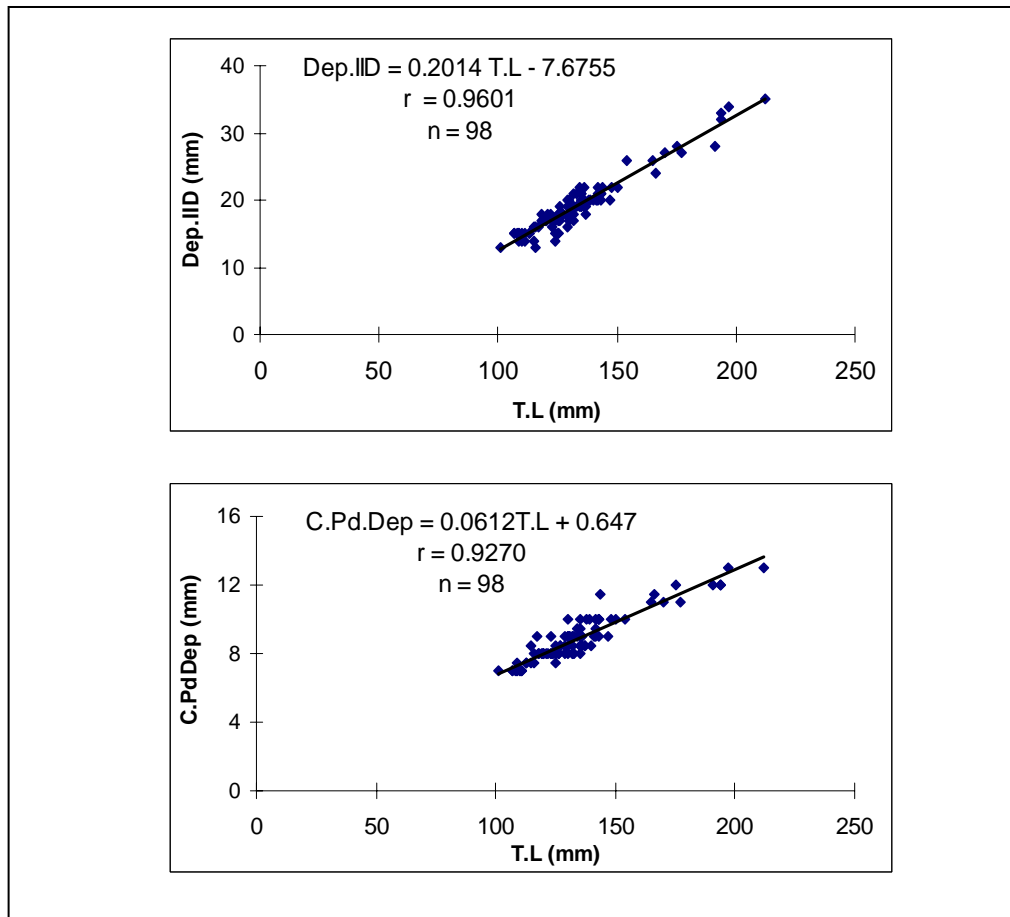


Fig. 3.2d. Relationship between various morphometric measurements and total length in female of *S. sihama*.

Caudal peduncle length on Total length

The regression equation of Caudal peduncle length on total length can be written as $Y = 0.5395 + 0.0616 X$ and $Y = 0.6470 + 0.0612 X$, for male and female, respectively. The equation suggests linear relationship between the two variables. The significant 'b' value ($P < 0.001$) infers that this character increases by 0.06 mm and 0.06 mm per 1 mm increase in total length in male and female, respectively. Like other characters, caudal peduncle length showed high positive correlation with 'r' value 0.950 in male and 0.927 in female.

Difference between slopes of various regression lines of male and female is shown in Table 3.5. Comparisons of slopes estimated in above relationships showed a significant difference between male and female ($P < 0.001$) except for the relationship between caudal peduncle depth and total length, which did not show a significant difference between male and female ($P > 0.05$).

3.4. Discussion

Analysis of morphometric characters of *S. sihama* in the present study revealed that all the fourteen measure of the external parts of the fish have a linear association with total length. This finding was drawn from the value of correlation coefficient 'r' which was highly significant ($P < 0.001$) in all the

Table 3.5. Comparison between regression coefficient in male and female of *S. sihama*.

Morphometric measurements (mm)	Male		Female		t	Significance
	b1	Sb1	b2	Sb2		
Std.L	0.9067	0.0051	0.8974	0.0046	18.574	***
H.L	0.2013	0.0059	0.2196	0.0061	91.509	***
S.L	0.095	0.0034	0.1160	0.0036	104.887	***
P.O.L	0.0887	0.0032	0.0996	0.0039	15.561	***
I.O.L	0.0642	0.0019	0.0581	0.0021	-30.589	***
E.D	0.0441	0.0018	0.0427	0.0019	-14.000	***
P.ID.L	0.2743	0.0082	0.3255	0.0065	-30.118	***
P.IID.L	0.5186	0.0056	0.5281	0.0063	13.571	***
P.Pc.L	0.2741	0.0075	0.2677	0.0073	32.000	***
P.Pv.L	0.2681	0.0056	0.2879	0.0069	15.231	***
P.A.L	0.5086	0.0069	0.5428	0.0084	22.800	***
Dep.ID	0.1862	0.0054	0.1815	0.0053	47.000	***
Dep.IID	0.1915	0.0063	0.2014	0.006	-33.000	***
C.PdDep	0.0616	0.002	0.0612	0.0025	-0.800	NS

(t, 2, 201 DF) = 3.340 *** P<0.001

relationships in male as well as in female. Although the measure related to eye diameter followed by caudal peduncle showed the lower values of correlation coefficient with all the other characters, still their correlation were significant at the same significance level in both the sexes.

Pillay (1952; 1957) has referred to the usefulness of regression analysis and analysis of covariance as employed by Godsil (1948) in racial studied of fishes. The regression analysis in the present study revealed that the growth is taking very similar pattern in both the male and female with slight but significant differences in the values of growth rate of different characters in relation to total length. The highest growth rate is that of standard length 0.9067 mm and 0.8974 mm for male and female respectively, indicating that this character is the fastest growing part of the body. The next faster growing parts are pre-second dorsal length (0.5186 mm), and pre-anal fin length (0.5086 mm). In female the pre-anal fin length is the next most important character (0.5428 mm) followed by pre-second dorsal length (0.5281 mm). Eye diameter was the slowest growing character with growth rate of 0.0441 and 0.0427 in male and female, respectively.

The results of the present study corroborate the findings by Radhakrishnan (1957). He found maximum rate of growth in standard length followed by the body length. The depth of the body through pectoral fin base has the minimum rate of growth in *S. sihama* from Gulf of Mannar and Palk Bay. Similarly, Reddy (1991) studied the relationship between total length and

fourteen morphometric characters in *S. sihama* from Karwar waters. He reported that all the morphometric measurement showed a significant association with total length. Moreover, of the fourteen selected characters the maximum rate of growth was noticed in standard length, followed by pre-anal length and snout to second (pre-second dorsal length). The slowest growth was seen in eye diameter followed by, interorbital and postorbital length. These findings are in agreement with the results of the present study.

The most variables ratios are those connected with the eye, and the least variable was the value of body length on total length in five common species of *Cynoglossus* (Seshappa, 1970). Ramanathan *et al.* (1977) studied the relationship between various body measurements using standard length as a basic character against which regression curves of other variables were drawn. They reported that the total length was the fastest growing character, next to it is the head length and the lowest rate of growth was of the eye diameter comparing to all others. Sharp *et al.* (1978) reported that eye diameter and snout length were the two most important variables, and body length contributed the fourth most important variable. Misra and Carscadden (1978) found that body depth and snout length were the most important variables.

In the present study, linear relationships observed among various parts of body measurements suggest that the growth in length of the fish was isometric. This agrees with findings of Radhakrishnan (1957); Misra and

Choudary (1982); Reddy (1991) and Bumb (1992). On the other hand, Marr (1955) reported non-linear relationship between various body measurements in teleost fishes. Such differences in ratio or proportional growth of body parts may be due to environmental conditions or due to genetic differences (Krumholz and Cavanah, 1968; Das Gupta, 1991).

The simple method for testing hypotheses about equality of two population's regression coefficient 'b' involves the use of student's t test. This test was applied for finding the differences between growth rate of various morphometric characters of male and female. The test showed significant differences between male and female in all the characters except in caudal peduncle depth (Table 3.5).

This study suggests that male and female of *S. sihama* have similar values of growth rate of the examined measurements. Nevertheless, they followed different pattern of growth.