Indian J. Fish., **53**(1) : 1-12, Jan.-Mar., 2006

Fishery resource characteristics and stock assessment of ribbonfish, *Trichiurus lepturus* (Linnaeus)

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ABSTRACT

Ribbonfish, *Trichiurus lepturus* (Linnaeus) has become one of the most important exploited resources in the northwest coast of India. It was landed as bycatch of shrimp trawler earlier but on account of emerging export demand it is now increasingly targeted. The resource has been monitored for more than ten years. The landings of ribbonfishes varied between 16,000 t (1995) and 63,000 t (2000) with an average catch of 33,000 t. The trawl contributed about 93 % of the total landing. Peak catch rates were observed in September and November-December. *T. lepturus* is a carnivorous predator feeding on crustaceans, fishes and cephalopods. Spawning season is prolonged from October-May. Individual fish spawns once in a year and the minimum size at maturity is 75 cm. The fecundity varied between 4,900 and 81,000 with a relative fecundity of 65 ova/gm of body weight.

It grows at faster rate and attains 65.1 cm, 98.0 and 114.7 cm. at the end of first, second and third year respectively. The estimated L" is 127.3 cm. and K 0.67 (annual). The average total mortality coefficient (Z) for the period 1992-'97 was 3.3 whereas it was 3.64 during 1998-2001. The estimated fishing mortality (F) was 2.49 with exploitation ratio (F/Z) 0.756 and F 2.96 with F/Z 0.815 during the same quiniqual periods respectively. During the last two years of 2000-2001, the rate of exploitation was very high and the average Z was 3.97 with F/Z 0.814. The average F was 3.232, the yield was about 60,000 t and the biomass was 46,391 t. The yield can be optimized at 70 % of the current fishing effort.

Introduction

Ribbonfish, *Trichiurus lepturus* (Linnaeus) is one of the most important pelagic fish resources of the Indian Exclusive Economic Zone, particularly off the northwest coast of India. It formed about 28 % of the resources between Lat 15^0 and 23^0 N during the exploratory fishing conducted by M.T. *Murena*(Bapat *et al.*, 1982). The total resource was estimated to the extent of 156 thousand tonnes (Somvansi and Antony Joseph, 1989). On the southwest biomass estimated was 67 thousand tonnes (Rao *et al.*, 1977). Inspite of being an important resource no biological study has been conducted from the northwest coast. However, some information is available form the east coast, notable among them are by James (1967), James *et al.* (1983) and Narshimham (1978 and 1983). The species is widely distributed in the Indo-Pacific and Atlantic and it is known to form commercial fishery in

China, Japan and Mexico. The landings are very heavy in China seas where 5,20100 tonnes were recorded in 1974 (Hu and Zu, 1986) 4, 00100 (Yimin and Rosenberg, 1991).

Of late, ribbonfish has been increasingly targeted in India on account of its demand for export to China and other Southeast Asian countries. It has now assumed foremost place and ranked second in the year 2000 among the exploited marine fishery resources of India. The export varied between 62, 942 t and 1, 21017 t during 1997–1998 and 1999-2000 valued at Rs.961 to 3308 million. About 83 % of the export was to China during 1999-2000.

Attempts have been made to study its population dynamics by Chakraborty (1990) and Chakraborty *et al.* (1997) and Thiagrajan *et al.* (1992). The present work is a comprehensive study based on the data collected for a decade from 1992 to 2001.

Material and methods

The basic data on catch and effort was taken from New Ferry Wharf, Mumbai where chief gear employed is trawl net. These are operated from shrimp trawlers of 12.5-15 m in overall (OAL) fitted with 95-120 BHP engine. The trawlers operated 20-25 m trawl net with 15-20 mm cod-end mesh size and 55-60 kg otter board.

Along with catch and effort data anal length measurement of ribbonfish was taken in the field and the same was converted to total length. The length-based data were raised to the days catch and subsequently to monthly estimated catch in number in the size groups of 2 cm following the methods described by Sekharan (1965).

The gut contents were identified to species level. Occurrence method was utilized for the study of food and feeding habits. The standard maturity scale adopted by the International Council for Exploration of the Sea was followed, however for presentation the same was classified into four stages viz. resting, developing, gravid and spent stages. The procedure of Hickling and Rutenberg (1936) was used for determining the periodicity of spawning. To determine the minimum size at maturity the method of cumulative percentage plot of fishes above the resting stages was used.

The initial value of $L\infty$ was estimated by Powell and Wetherall (1986) exercise and modes were resolved by subjecting the monthly length frequency distribution to Bhattacharya (1967) analysis. K was estimated by Gulland and Holt plot (1959); total mortality coefficient (Z) was estimated by Pauly's catch curve (1981 a) and VPA (Jones 1984); biomass and yield at different level of exploitation estimated by Thompson and Bell (1934) analysis and Emax was estimated by relative yield per recruit (Beverton and Holt, 1957). All these methods are incorporated in FAO-ICLARM Stock assessment tools (FiSAT), a computer based programme developed by Gayanilo *et al.*(1996).

Results

Relationship between the snout–vent length and total length

As the tip of the tail of *T. lepturus* is very fragile and liable to break easily, a large number of specimens were encountered with regenerated tail. Hence, snout-vent length should be more reliable than total length. Therefore, a relationship was worked out between the two parameters i.e. snout-vent and total length based on 120 fishes ranging

between 200 to 560 mm anal length without regenerated tails as was followed by James (1967). The regression equation was estimated by the method of linear regression equation. The relationship is as follows:

$Y= 147.0064 + 2.1518 X \ (r^2 = 0.88)$

Where, X is snout-vent length and Y is total length of fish.

All the biological and population parameters are given as total length.

Fishing season and area: The trawling operations commence in late August or early September and continue till end of May. The fishing is conducted in depth range of 25-90 m along the shoreline between $17^0 – 20^0$ N. Trawlers at New Ferry Wharf undertake 6-8 days of actual fishing but prior to 1990 they used to undertake 3-4 days of fishing.

Fishery: The all India landings of ribbonfishes are only next to oil sardine in term of production. Its production varied between 74, 000 t (1995) and 1,82,000 t (2000) during last ten years period with an average landings of 1,29,000 t. During 1992 to 2001 the landings of ribbonfish in Maharashtra ranged from 16, 000 t in 1995 to 63, 000 t in 2000 with an average catch of 33, 000 t. The average catch during the five-year period of 1992-96 was 23, 800 t, which increased to 42, 800t during 1997-2001. Gear-wise catch during the last decade indicated that trawl contributed about 93 %, *dol* net 6 % and gill net 1 %.

T. lepturus is the most dominant species in the trawl. The other two resources viz. *Lepturacanthus savala* and *Eupleurogrammus muticus* constitute a minor fishery. The basic data on effort, catch and size composition of the *T. lepturus* landed were collected from New Ferry Wharf, where more than 1200 trawlers operate on regular basis.

TABLE 1. *Average estimated total landings, catch of Ribbonfish, catch rate and percentage composition at New Ferry wharf during 1997-98 to 2000-2001.*

Month	Effort No. of Unit	Fish Catch in total (Kg)	Catch/Unit in total fish	*T.lepturus*	C/U inKg	% In total Catch
April	3151	5643212	1790.70	222254	70.53	3.94
May	1966	3693815	1879.23	167817	85.38	4.54
June	372	498204	1340.70	13437	36.16	2.70
July	533	901093	0.00	16761	0.00	0.00
August	1025	1797068	1753.92	66206	64.62	3.68
September	3118	7730708	2479.22	1409697	452.09	18.24
October	2812	5919267	2105.00	619914	220.45	10.47
November	3038	7555831	2486.94	1423643	468.58	18.84
December	3203	7659199	2391.11	1315202	410.59	17.17
January	3103	6723958	2166.92	882303	284.34	13.12
February	2695	5502345	2041.69	275900	102.37	5.01
March	3084	6355341	2060.48	261070	84.64	4.11
Total	28100	59980042	2134.51	6674204	237.51	11.13

The percentage contribution of the species in the total fish catch by trawlers at this centre varied between 6.9 % (1997-98) and 20 % (2000-2001) (Table 1.). The peak catch rates were observed in September and November-December. The year 2000 was the best year, when an estimated 14, 000 t was landed at the catch rate of 507 kg per unit forming about 20 % of the catch.

Food and feeding habits: More than 1000 specimens were examined in the size range of 30-1140 mm during 1997-98 to 2000-2001 for biological studies. The species is carnivorous predator feeding on crustaceans, fish and cephalopods. Large percentage (67.2) fishes were encountered with empty stomach. The basic food consisted of crustaceans, fishes and cephalopods.

Among prawns sergestid, *Acetes* spp was most frequently encountered followed by *Nematopalaemon tenuipes* and *Exhippolysmata ensirostris*. The penaeid prawns found in the guts were *Solenocera crassicornis, Parapeneopsis stylifera, and Metapenaeopsis stridulans.* Stomatopods were also observed.

The fish component consisted of *Myctophum* sp. *H. nehereus, Megalaspis cordyla, Polynemus heptadactylus, Upeneus* spp., *Apogon* spp., *Fistularia* sp., *Stolephorous* spp., *Decapterus* sp., young ones of *Congresox talabonoides, Arius* spp *and* flat fishes. Its own youngones have been observed frequently indicating that the species resorts to cannibalism. Among cephalopods mainly *Loligo* sp. was also recorded. The most important food item with highest occurrence was *Acetes* spp.

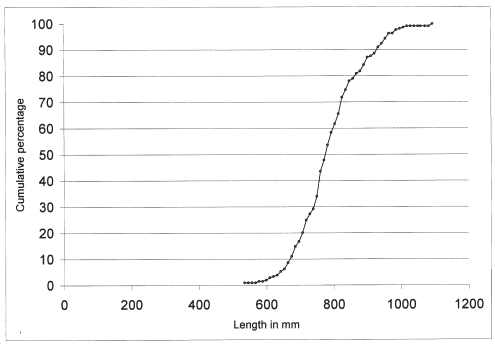

Fig. 1. Cummulative percentage mature fish verses length for determining minimum size of maturity of *T. lepturus*

Maturity and spawning: The sex ratio was 1:1. This is in contrast to earlier observation based on the data collected during 1979-80 and 1991-92 (unpublished data), when the sex ratio was 1:0.93 and the males were dominant over females due to the movement of females to deeper waters. However, with the extension of fishing to 90m the sex ratio is found to be 1:1.

Most of the females were with resting or developing gonads. However 8.1 % of gravid specimens were recorded during October–May indicating prolonged spawning season. This is in contrast to the earlier work when only in April-May high percentage of running specimens were observed.

The ova diameter studies indicated the presence of two batches of ova measuring 0.05-0.65 mm of immature ova and 1.15-1.75 mm of ripe ova in the gravid female. As the two batches of ova are widely separated, it is unlikely that the individual fish would spawn more than once in a year.

The smallest size fish in the gravid condition measured was 61.1cm. However, size at first maturity has been estimated at 75 cm (Fig. 1.).

The fecundity studies were conducted for 40 fishes ranging from 71.5 to 120.9 cm weighing between 340 and 741 gm respectively. The fecundity varied from 4, 900 to 81, 000. The

following relationship between length of fish and number of ova has been observed:

$Y = -63767 + 1104X \quad (r^2 = 0.494)$

The average fecundity was 65 ova per gm of fish.

Age and growth studies

The maximum length that the species can attain was estimated through FiSAT exercise of prediction of the maximum length from the extreme values (Gumble, 1954). The predicted extreme length was 131.3 cm with 95% probability of occurrence 117.7-144.8cm. Powell–Wetherall (1986) plot estimated L∞ at 122.8 cm with Z/K 3.919.

The age and growth studies were conducted by using ELEFAN I programme. The growth parameters L∞ and K have been estimated, which are as follows:(Fig. 2).

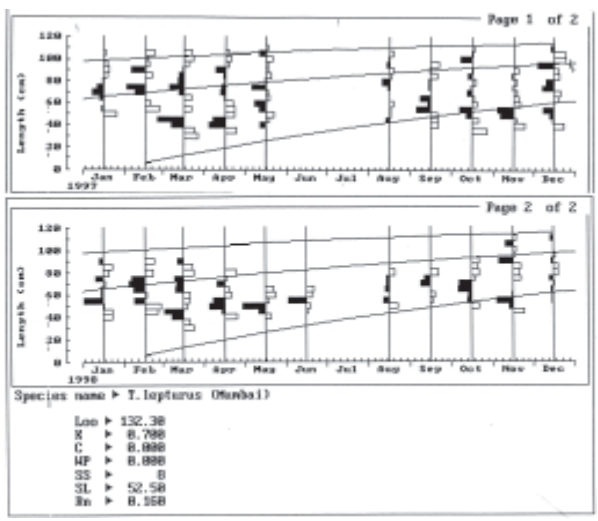

Fig. 2. Estimation of growth parameter through ELEFAN I programme of *T. lepturus*.

L∞ = 132.3 cm and K = 0.7 (annual)

The various cohorts segregated through Bhattacharya analysis and subsequently by linking the means of the cohorts, growth parameters were estimated and by Gulland and Holt plot which produced the following parameters:

L∞ = 127.3 cm and K = 0.68 with r^2 = 0.943

The seasonal growth oscillation is not significant (Fig. 3.).

Fabens' (1965) Method gave Standard error for L∞ at 5.0 cm and K 0.06.

All these methods produced estimated growth parameters, which varied in a narrow range. Hence, for estimation of L ∞ and growth coefficient obtained by Gulland Holt Plot was utilized as inputs of von Bertalanffy growth formula (VBGF). Most of these computer-based models consider t_0 to be equal to zero. Hence, VBGF equation can be written for *T. lepturus* as follows:

$$Lt = 127.3(1-e^{-0.68(t-0)})$$

Accordingly the first year growth has been estimated as 65.1 cm. The fish attains the length of 98.0 and 114.7 cm at the end of second and third years respectively.

Length-Weight relationship: The length-weight relationship based on 1,021 specimens ranging from 46.5 to 124.4 cm and weighing 50 to 1500 gm is expressed as:

Log W = Log –3.8448 +3.352 * log L (r^2 = 0.924)

Mortality: The total mortality coefficient Z has been estimated for a ten year period by catch curve method and it varied from 2.44 (1993) to 4.1 (2000).

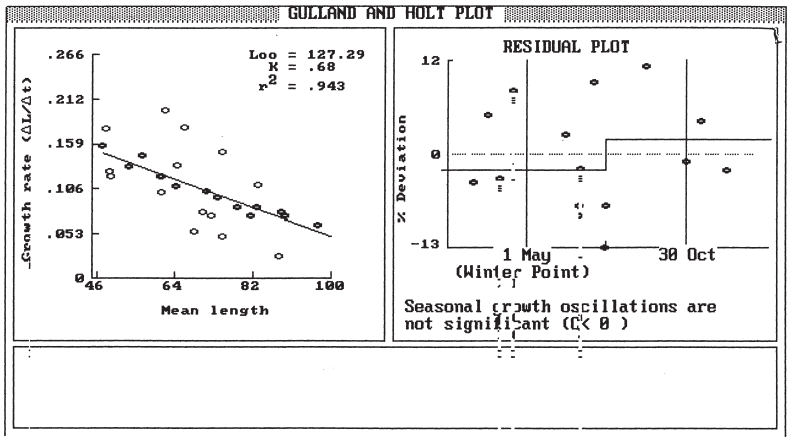

Fig. Gulland and Holt plot of *T. lepturus*

The natural mortality (M) has been estimated at 0.93 by Pauly's empirical equation (1980 b).

The fishing mortality (F) estimated by Virtual population analysis (VPA) varied between 1.56 (1993) and 3.17 (2001) while the biomass fluctuated between 8,154 t and 37, 528t (Table 2.).

Stock assessment: The size at first capture (Lc) has been at 68.3 cm. The size at recruitment is 65.4 cm and size at 75 % retention is 74.3.cm . Relative Yield per recruit studies with input of L^{∞} 132 and M/K ratio of 1.37 produced Emax at 0.604 and E0.1= 0.56 (Fig. 4.) whereas the present average exploitation is 0.775 indicating that the present level of exploitation is higher than the optimum and needs to be reduced.

Virtual Population Analysis (VPA) for the years 2000-2001 indicated the biomass of about 46, 000 t and the present yield of 60, 000 t (Fig.5). Thompson and Bell studies also indicates that the fishing effort needs to be

TABLE2. *Total mortality coefficient (Z), yield (Y) and biomass of* T. lepturus

Year	Yield (Y) (t)	Z	F Catch curve	F VPA	F/Z	Biomass (t)
1992	29258	2.86	1.93	1.967	0.688	20722
1993	21608	2.55	1.62	1.56	0.612	17539
1994	26259	2.84	1.91	2.05	0.722	20261
1995	15606	4.06	3.13	3.76	0.926	8154
1996	26154	4.18	3.25	3.13	0.749	14001
Av.	23777	3.30	2.37	2.49	0.756	16135
1997	41691	3.08	2.15	2.39	0.776	25878
1998	27067	4.1	3.17	3.4	0.829	11880
1999	27821	3.07	2.14	2.57	0.837	16626
2000	60205	4	3.07	3.294	0.824	35535
2001	57144	3.94	3.01	3.168	0.804	3756
Av.	42786	3.64	2.71	2.96	0.815	25489

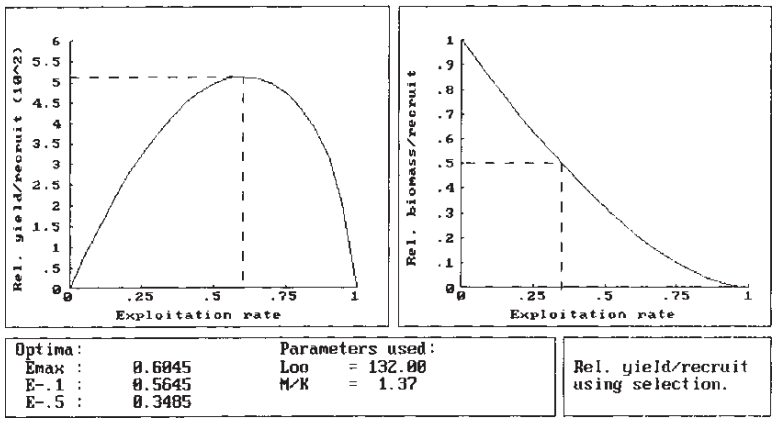

Fig. 4. Estimation of relative yield per recruit (Yw/R) of *T. lepturus.*

reduced by 30 % of the present level for optimizing the yield.

Discussion

Of late ribbonfish has emerged as a leading fishery of Maharashtra, occupying the first place among various fish resources. It was achieved by the expansion of the fishery in the deeper waters. The nineties was the developing phase of the fishery of ribbonfishes and by the end of the nineties the catch has peaked (Keeping in view of biomass estimates of Antony and Somavanshi) contributing about 15 % of the total fish landings in the state in 2001. Prior to ninetees the fishery was incidental.

It accounted for about 28 % of the total catch during the exploratory fishing conducted by M.T. *Murena* from the depth range of 55-360 m. The highest catch rate of 1, 300 kg/hr was recorded during February-April from 19^0 N while 638-783 kg/hr came around 20^0 N in the depth range of 90-125 m. during April-May in bottom trawling (Bapat *et al.*, 1982). The present exploitation is mainly restricted to depths < 90m, but in view of biomass estimates (Somvansi and Joseph, 1989) and its migratory nature, the stock appears to be within the range of full exploitation. Peak landings of ribbonfish have been recorded in Gujarat during October-November and May in *dol* nets (Khan, 1986), September-November and March-April in gill nets (Kasim and Khan, 1985) and January-May in trawl (Rao and Kasim, 1985). High catch of ribbonfish in April-May in Gujarat and low in Maharashtra may be attributed to movement of fish from Maharashtra to Gujarat. Very heavy landing 13, 000 t of *T. lepturus* in the size range of 20-105 cm was recorded during April-May 1986 in Veraval (Gujarat) (Raje, S.G. personal communication). The peak landings are during September and November – December may be attributed to high abundance of its prey species in the region during post monsoon period.

Ribbonfishes undertake regular diurnal vertical migration to some extent. Generally, during daytime they are found close to bottom and at night ascend in the water column and disperse (Rao *et al.*, 1977). *T. lepturus* is a carnivorous predator feeding on crustaceans, fish and cephalopods. *Acetes spp* among prawns, like most of the fishes in the region is the preferred food item.

Variation in the diet appears as per the availability of prey species, the size of fish and the ecological condition. In the present observations lucifer, mysids, copepods and amphipods and other micro planktonic organisms were not encountered as observed by

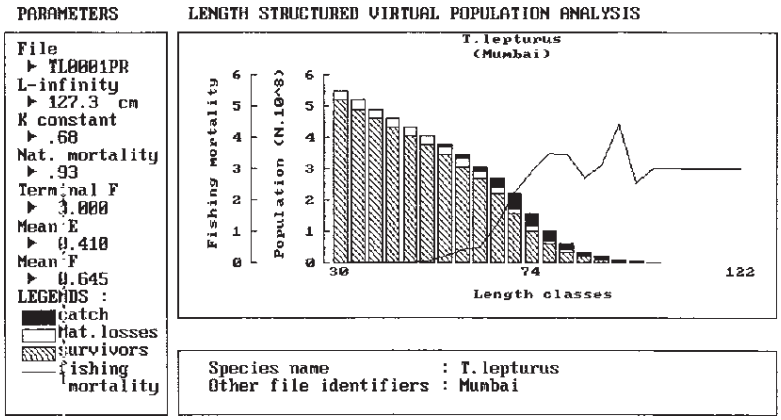

Fig. 5. VPA analysis, *T. lepturus* for the year 2000 and 2001

Viajayraghvan (1951). It was probably due to the fact that present study is based on the specimens ranging from 30 to 100 cm. James *et al.* (1983) were of the opinion that in spite of record of 50 different species of fish caught in trawl, the stomach content included a few of them indicating that the species exercise certain amount of selectivity in feeding. Though *Acetes* spp. do not contribute much to the trawl catches it is abundant in the area and it forms an important food item in its diet and obviously it is a preferred food item. Despite of having powerful jaw and long stomach it prefers to feed on smaller items of food. It is supported by the fact that the gorged stomachs are rarely encountered.

Earlier, studies show that April-May was the peak-spawning season but now the species exhibits a prolonged spawning season, and seems to have lost its seasonality during the last few years. Bapat *et al.* (1982) recorded running specimens in good percentage from the depth zone of 91-125 m during April-May.

The species appears to spawn once in a year. This is in conformity with observations made by Bapat *et al.* (1982). The size at first maturity has been estimated at 75 cm, which is in contrast to 52.5 cm estimated by Narshimam (1983).

A critical review of the growth studies carried out by the various authors indicates that the estimates of L^{∞} varied from 56 cm by Prabhu (1955) to 152.4 cm (Dawson1967).

Any estimate less than 1m may in all probability be a mistaken identity or the data were restricted to only juvenile phase. From Maharashtra two estimates of L^{∞} are available 129 cm (Chakraborty, 1990) and 148 cm (Chakraborty *et al.*, 1997) with respective K of 0.5 and 0.4.During the present investigations the maximum size recorded was 118 cm. Therefore, an estimate of $L\infty$ 127.3 cm appears to be reasonable. The present K of 0.68 is an indication that the fish grows at a faster rate than estimated earlier. The length attained at the end of first, second and third year were estimated as 65.1, 98.0 and 114.7cm respectively.

The average total mortality coefficient (Z) was 3.3 during the period of 1992-97 and fishing mortality coefficient (F) was 2.37 with F/Z 0.71 while during 1997-2001 the Z was 3.64 and F 2.71 with F/Z 0.74 indicating increasing fishing pressure. During the year 2000-2001, when the exploitation was very heavy, the average Z was 3.91. Z estimated by various workers from Mahrashtra are not comparable on account of difference in the input of $L\infty$

and K but according to Mohite and Birader (2001) the estimated F/Z was well beyond 0.5, and suggested reduction of the fishing effort in the state.

On an average 33, 000 t was landed annually in the last 10 years period of 1992-2001. In fact the nineties was the developing phase for the fishery of ribbonfishes and by the end of nineties the exploitation has peaked due to targeting. Prior to nineties the fishery was bycatch/incidental in nature. Somavanshi and Joseph (1989) estimated the biomass of 1, 56, 530 t from the 55 to 320 m northwest zone of India between15 to 23 ^{o}N and MSY of about 70, 000 t. The average yield during the years 2000 and 20001 is about 60,000 t from Maharashtra alone. About equal quantity is landed from Gujarat during the same period. Therefore the MSY of northwest sea may be much higher than estimated by Somvansi and Joseph (1989).

The present study indicates overfishing and the yield in Maharashtra can be optimized (66, 000 t) by reducing the effort to 70 % of the present effort.

Acknowledgements

I am grateful to the Director, CMFR Institute and Head, PF Division for their encouragement during the period of investigations. I am also thankful to J.D. Sarang for sincere assistance during the entire period of studies.

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Date of Receipt : 15-1-2005
Date of Acceptance : 3-10-2005