Trends In Goa Fisheries With Reference To Indian Mackerel (*Rastrelliger kanagurta*) And Solar Shrimp (*Metapenaeus dobsoni*)

Ph.D. Thesis

By

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Trends In Goa Fisheries With Reference To Indian Mackerel (*Rastrelliger kanagurta*) And Solar Shrimp (*Metapenaeus dobsoni*)

Thesis

Submitted to the Goa University
For the Degree of Doctor of Philosophy
In
Marine Science

By

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Under the Guidance of

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December, 2006

Dedicated

to my

Father

who taught me to aim high in life

&

to my

Husband

who shows me the ways to achieve that

Trends In Goa Fisheries With Reference To Indian Mackerel (*Rastrelliger kanagurta*) And Solar Shrimp (*Metapenaeus dobsoni*)

CERTIFICATE

This is to certify that the thesis entitled, 'Trends In Goa Fisheries With Reference To Indian Mackerel (*Rastrelliger kanagurta*) And Solar Shrimp (*Metapenaeus dobsoni*)', submitted by Ms. Shamila Dos Milagres Monteiro for the award of the degree of Doctor of Philosophy in Marine Science is based on her original studies carried out by her under my supervision. The thesis or any part there of has not been previously submitted for any other degree or diploma in any University or institutions.

Place: Goa, India

Date: 18. 5. 2007

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STATEMENT

As required under the University Ordinance 0.19.8 (vi), I state that the present thesis entitled '**Trends In Goa Fisheries With Reference To Indian Mackerel (*Rastrelliger kanagurta*) And Solar Shrimp (*Metapenaeus dobsoni*)**' is my original contribution and the same has not been submitted on any previous occasion. For the best of my knowledge, the present work is the first comprehensive work of its kind from the area mentioned.

The literature related to the problems analyzed and investigated has been appropriately cited. Due acknowledgements have been made wherever facilities and suggestions have been availed of.

Place: Goa, India

Date: 18/5/07

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PREFACE

The state of Goa with a coastline of 104 km is blessed with a multi-species fishery. This tiny state has seen a big leap in the growth of marine fishing industry by over 800% in the last 40 years. From a catch of 12 thousand metric tons (mt) in 1967, the year 2005 recorded a landing of over 100 thousand mt. The present study was conducted with an aim to understand the fluctuating trends in the marine fishery resources of Goa and to assess the present management strategies to arrive at logical conclusions so as to formulate suitable guidelines for its sustainable management. The biology of two species that form the mainstay of marine fishery in the state, one a pelagic and the other a demersal representative, viz. the Indian mackerel (*Rastrelliger kanagurta*) and the Flowertail prawn or Solar shrimp (*Metapenaeus dobsoni*), were studied .

The thesis, 'Trends in Goa Fisheries with Reference to Indian Mackerel (*Rastrelliger kanagurta*) and Solar Shrimp (*Metapenaeus dobsoni*)', has been divided into 6 broad chapters, each dealing with a different aspect of the study.

Chapter I: General Introduction

This chapter deals with the objectives of the study, review of literature on the biological aspects of the Indian mackerel, *R. kanagurta* and the Flowertail prawn, *M. dobsoni*.

Chapter II: Biology of the Indian mackerel, *R. kanagurta (Cuvier)*

This chapter has four sub-sections; Introduction, Materials and Methods, Results and Discussion. It deals with the length-weight relationship,

condition factor, reproductive biology, age and growth and fishery of Indian mackerel along the Goa coast.

Chapter III: Biology of the Solar Shrimp, *M. dobsoni* (Meirs)

This chapter also has four sub-sections; Introduction, Materials and Methods, Results and Discussion. It deals with the length-weight relationship, condition factor, reproductive biology, age and growth studies, fishery of shrimps and Solar shrimp along Goa coast.

Chapter IV: Trends in the Marine Fishery Resources of Goa

This chapter deals with the trends in the fishery resources of Goa, catch per unit effort, maximum sustainable yield and the mechanised and traditional sector. It has four sub sections; Introduction, Materials and Methods, Results and Discussion.

Chapter V: Management of the Marine Fishery Resources of Goa

This chapter covers the salient features of the existing Fisheries Acts and Rules pertaining to the state of Goa and that of neighboring states of Karnataka and Maharastra. It also deals with the management of the fisheries resources and the recommendations for a sustainable fishery in Goa, based on the findings of the present research work.

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I. General Introduction

1.1 Introduction

The marine fishery sector plays a very important role in the Indian economy. Not only does it generate employment and foreign exchange, but also plays an important role in the augmentation of protein resource. However, with the population of India crossing 1.0 billion, making available the much-needed protein to its people is a great challenge. The fishing industry in India has evolved substantially after independence with the concerted efforts of the Government (Bensam, 1999), leading to the recent production level of 6.18 million metric tons (mmt) in 2002 - 2003 (Das and Mishra, 2006). The focus of the fisheries sector is to increase per capita availability of fish for the people from the present level of around 5 kg to around 11 kg (Morgan, 2006). India contributes about 4.5% of total world fish production and occupies a prominent position as the fourth largest fish producing nation. It ranks seventh in the total marine fish production and second in total inland fish production among the fish-producing nations of the world (Bensam, 1999).

India is located between latitudes 8° 4' and 37° 6' N and Longitudes 68° 7' and 97° 25' E. To its west lies the Arabian Sea and to its east is the Bay of Bengal. It is one of the largest countries in the world comprising of 28 states and 7 union territories, covering a total land area of about 3.3 million km^2 (Arora and Grover, 1996) (Fig. 1.1). Nine states and four union territories make up its vast coastline of 8,118 km. It has an Exclusive Economic Zone (EEZ) of 2.02 million km^2 with a continental shelf covering 0.5 million km^2 (Vivekanandan *et al*, 2003). The EEZ has a harvestable marine resource potential of 3.9 mmt (Sudarsan *et al*, 1990; Anon, 2000a) out of which 2.2 mmt is from the coastal waters and 1.7 mmt from the off-shore waters and deep seas (Pillai *et al*, 2000).

The west coast of India, comprises of 5 states and 2 union territories and the east coast, consists of 4 states and 2 union territories. The west coast has a broader continental shelf (Anon, 1994) and is by far the most productive zone, contributing to over 70% of the total marine fish landings (Morgan, 2006). The marine fish production of the different maritime states and union territories of India for the last 5 years is given in Table 1.1.

Goa, which lies on the west coast, is the smallest maritime state of India. It is situated on the slopes of the Western Ghat and is bounded on the north by Sindhudurg district of Maharashtra. On the east and the south it is bordered by Belgaum and Uttara Kanara districts of Karnataka. To its west is the Arabian Sea. It has an area of 3,702 km^2, comprising of two districts (North Goa and South Goa) and 11 talukas (Fig. 1.2). The total population of Goa as per 2005 census is 13,47,668. With a coastline of 104 km, continental shelf of 10,000 km^2 and six major rivers viz. Terekol, Chapora, Mandovi, Zuari, Sal and Talpona, fishery forms an important sector in the state's economy (Table 1.2).

Fishing has traditionally been one of the chief occupations and the source of livelihood of the people living in the coastal areas in Goa. Prior to liberation (in 1961), the fishing activity in Goa was primarily a traditional one and was based on the availability of different varieties of fish in different seasons at different areas in the sea and rivers (Padki *et al,* 1967). However, after mechanisation the scenario has completely changed. The evolution of fishing gears from manual tools to mechanical hardware has led to a huge positive impact on the catch both in terms of quantity and variety. Most of the species are available throughout the year in varied proportions as fishing is carried out at far away fishing grounds. Among the marine fisheries resources, the pelagic fisheries dominate the catch. Indian mackerel and oil sardine, the two pelagic species, contribute the major share of the total marine fish catch in Goa (Monteiro, 2006).

Although the marine fishery sector has made considerable growth over the years, it has also generated a number of socio-political issues. The catch levels in many other maritime states in India have also shown an increase, but presently either stagnating or declining. Therefore, the time has come to deal with the issues that are responsible for making this sector uneconomic and effective steps must be taken without delay for the sustainable management and conservation of the resources for posterity.

It is widely recognized that catch statistics and effort data are crucial to fisheries management as they provide most important information about a fishery over a period of time (Pauly and Zeller, 2003). The studies on reproductive behavior, environmental factors, biology, etc., are important factors that help in devising management policies and design conservation strategies. However, the knowledge on biology and breeding habits of majority of the species of fish and shrimps in Goa is sparse. Since it is not practical to study these aspects on all the commercially important species it is imperative to study some representative species that form the main stay of pelagic and demersal fisheries. The Indian mackerel, *Rastrelliger kanagurta* forms an important pelagic fishery in Goa, while the Flowertail prawn, *Metapenaeus dobsoni* contributes the major share of the demersal resources. These two species play a very significant role for the sustainability of the fishing industry in Goa.

Besides *R. kanagurta, Sardinella longiceps* is among the most important pelagic fish caught in Goa. The former is commonly known as **Indian Mackerel** and the latter as **Indian Oil Sardine**. Although Indian oil sardine is being caught in abundance in the recent years, the Indian mackerel is the one; which is the most important in the context of national food security. It also is commercially very important commanding a very good price in the domestic and international market. The Indian mackerel is locally known as ***Bangada***.

R. kanagurta belongs to the family Scombridae and can be easily identified by its elongated and sub-cylindrical body (Day, 1878). A black blotch is present behind pectoral fin. Body is moderately deep, its depth at margin of gill-cover is 4.3 to 5.2 times in fork length; head is longer than body depth. Maxilla is partly concealed, covered by the lacrimal bone, but extending to about hind margin of eye; gill-rakers are very long, visible when mouth is opened, 30 to 46 on lower limb of first arch; a moderate number of bristles are present on longest gill-raker. Intestine is 1.4 to 1.8 times the fork length. Narrow dusky longitudinal strips are present on upper part of body (golden yellow in fresh specimens) and a black spot on body near lower margin of pectoral fin; dorsal fins are yellowish with black tips, caudal and pectoral fins are yellowish; other fins are dusky; dorsal region is bluish green and lower region silvery.

In the last 40 years, the catch for Indian mackerel in Goa fluctuated between 1,224 metric tons (mt) in 1983 and 44,254 mt in 1996 (GOG, 2000a). However, the catches in the recent years are not good (Monteiro, 2006). Though a great deal of information is available on the biology of the Indian mackerel along the west coast of India (George *et al*, 1959; George and Banarji, 1964; Radhakrishnan, 1962; Venkataraman, 1970; Yohannan, 1977, 1979; Azad and Udupa, 1989; Devaraj *et al*, 1994; Pratibha *et al*, 1998) not much work has been done on this species from Goa coast (Doiphode, 1974). Hence, Indian mackerel was chosen as the representative pelagic species of interest for the present study.

Among the demersal species, the shrimps constitute the most important group and are the major foreign exchange earners for the nation. The demand for shrimps, the 'pinkish gold of the sea' (Anon, 1992) has been increasing in the world market. This has led to the increasing pressure on these resources as it has been the target group among the demersal fisheries

resources. Among the shrimps the most sought after group is penaeid species.

The penaeids are classified under the suborder Dendrobranchia, under the order Decopoda. The commercially important species available on the Indian coasts are *Penaeus indicus, P. merguiences, P. monodon, P. semisulcatus, Metapenaeus dobsoni, M. monocerous, M. affinis* and *Parapenaeopis stylifera*. The penaeids contribute 7% of the total fish landings in the country (Anon, 2000b).

Among the penaeid shrimps, *M. dobsoni* is caught off the Goa coast in large quantities. It is commonly known as the **Flowertail prawn** and in Goa it is popularly known as the **Solar shrimp**. Identification of *M. dobsoni* is based on morphological characteristics and chromatophore patterns (Fisher and Bianchi, 1984). The post-larvae are relatively short, generally coloured mottled grey or brown compared to *Penaeus* sp. Rostrum is usually without ventral teeth and the telson with 7 + 7 spines on lateral and distal margins. Chromatophores are present on outer and inner rami of uropods. A prominent chromatophore is located in the middle of each uropod ramus. Rostrum is with 2 spines but there are no setae on disto-lateral aspect of 6th abdominal segment.

The adult has a doubly curved rostrum slightly armed with 7 - 9 dorsal teeth but toothless on its distal half. The last pair of thoracic legs falls considerably short of the middle of the antennalar scale. Usually almost entire body is pubescent, but pubescence can be restricted to a few patches. Rostrum is long, extending beyond the antennular pendecule. Colour is pale yellow to brownish with reddish tone.

The Solar shrimp is so important in the state that on its own it supports the fishing industry during the start of the fishing season of July - August. The species is central to the debate on the duration of the monsoon-fishing ban

in the state. However, its fishery is facing challenging problems of sustainable exploitation and management. Hence the Solar shrimp was selected for the present study as the species is commercially important among the demersal resources.

Inspite of the fact that the state of Goa was one of the first among the maritime states in India to have enacted the Marine Fisheries Act and the Fisheries Rules and Regulations, the state is still facing the threat of depletion of the fish resources. Besides, conflicts within the various stakeholders of the industry are also growing.

For the tiny state of Goa with a coast line of 104 km and a population of 1.34 million, fish provides a staple and affordable food. Besides, it provides employment, recreation, trade and economic well being for the people, both for the present and the future generation. Hence, it must be conducted in a responsible manner. Proper strategies for sustainable development of fishery need to be adopted so as to make the state a model state in maritime fisheries sector. A review of the state's fishery policies in context with the present scenario will also enable us to understand and frame action plans for the sustainable fisheries management in the state.

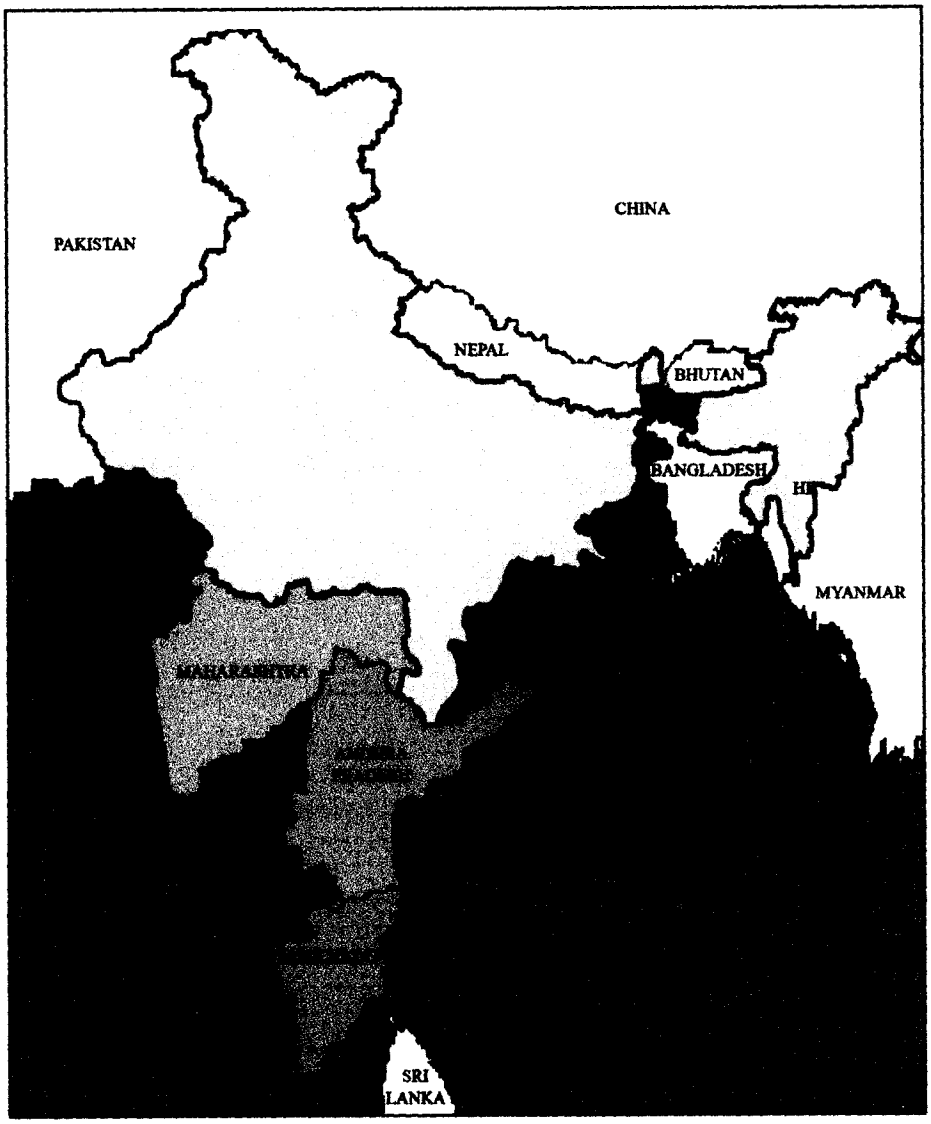


Fig. 1.1: Coastal map of India

Table 1.1: Marine fish landings (mt) for the last five years of the different maritime states and union territories of India

Maritime States	2000	2001	2002	2003	2004
Gujarat	6,32,119	6,20,660	7,28,916	6,41,138	6,00,605
Daman & Diu	17,050	17,081	15,672	12,278	12,531
Maharashtra	3,98,078	4,03,515	4,12,543	4,14,103	3,61,963
Goa	64,563	69,386	67,533	8,3756	84,394
Karnataka	1,15,244	1,16,436	1,72,933	1,95,156	1,70,329
Kerala	6,14,453	5,44,835	5,34,018	6,19,428	5,99,169
Lakshadweep	10,082	12,801	9,150	10,030	10,513
Tamil Nadu	3,72,402	3,73,861	3,79,214	3,81,148	5,53,352
Andaman & Nicobar	30,339	27,173	25,561	30,639	26,921
Pondicherry	39,266	38,405	40,034	42,096	44,033
Andhra Pradesh	1,67,466	2,02,120	1,35,714	2,63,926	2,10,732
Orissa	1,08,754	1,23,176	1,22,695	1,02,167	1,26,665
West Bengal	1,86,680	1,81,807	1,74,900	1,82,100	1,79,500

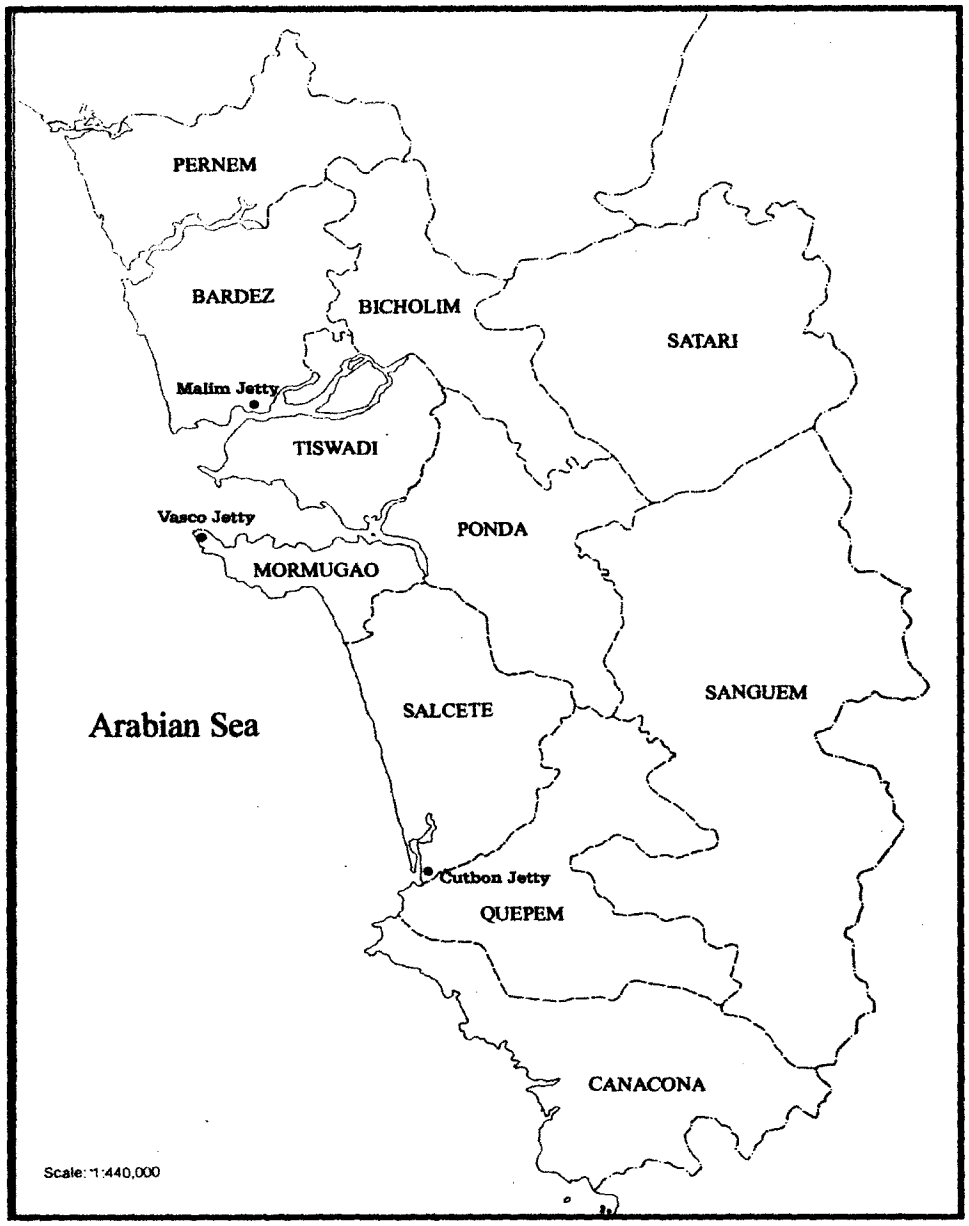


Fig. 1.2: Coastal map of Goa showing the sampling locations (Jetties)

Table 1.2: *Goa fisheries at a glance*

Area (km^2)	37,026
Total Population (2005 Census)	13,47,668
Coastal length (km)	104
Continental Shelf (km^2)	10,000
Major Rivers	6
Inland Waterways (km)	250
Inland Water Tanks (ha)	100
Fishing Villages (Marine)	42
Fishing Villages (Inland)	47
Fishermen Population	10,668
Active Fishermen	2515
Mechanised Boats	1,278
Motorised Canoes	631
Non-motorised Country-Crafts	859

1.2 Objectives of the Study

To study, analyse and understand the important issues concerning the marine fishing industry in Goa, the present research was undertaken with the following objectives:

i. To gather biological information on *Rastrelliger kanagurta* (Indian mackerel) and *Metapenaeus dobsoni* (Solar shrimp) from the Goa waters.

ii. To study the trends in the capture fisheries in the state with respect to the fishing effort.

iii. To review the fisheries management polices of the state.

iv. To recommend and frame action plans for sustainable development and management of fisheries in Goa.

Plate 1: The Indian mackerel, *Rastrelliger kanagurta*

Plate 2: Freshly landed *R. kanagurta*

Plate 3: Solar shrimp, *Metapenaeus dobsoni*; female and male

Plate 4: Freshly caught Solar shrimps, *Metapenaeus dobsoni*

1.3 Review of Literature

1.3.1 *Rastrelliger kanagurta*

1.3.1.1 Length-Weight Relationship

The Length-Weight relationship of Indian mackerel from Karwar coast in Karnataka was studied by Pradhan (1956). Jones and Silas (1962) studied the variability of Length-Weight relationship among the various species of Indian mackerels of the genus *Rastrelliger* from the Andaman waters in Andaman and Nicobar. The Length-Weight relationship of Log W = - 6.2161 + 3.390 Log L for Indian mackerel landed during the day and Log W = - 6.5662 + 3.1571 Log L for the fish in night landing from the Mandapam coast in Tamil Nadu was estimated by Sekharan (1962). Rao (1964) studied the Length-Weight relationship of Indian mackerel caught in the Lawson Bay near Waltair (Andhra Pradesh). According to Luther (1973) the Length-Weight relationship of the Indian mackerel was $W = 0.000002164\ L^{3.2874}$. The Length-Weight relationship of the Indian mackerel from the purse-seine catches of Goa coast was studied by Doiphode (1974).

Yohannan (1977) made observations on the Length-Weight relationship of Indian mackerel caught at two landing centers, Ullal and Baikampadi, near Mangalore, Karnataka. Udupa and Bhat (1983) studied the Length-Weight relationship of Indian mackerel off Mangalore, Gangolli and Karwar waters in Karnataka and compared their homogeneity using Analysis of Co-Variance. Azad (1983) and Azad and Udupa (1989) studied the Length-Weight relationship of Indian mackerel and the relative condition factor for female and male of this species. The Length-Weight relation of $W = 0.0000013848\ L^{3.3805}$ for Indian mackerel along Dakshina Kanara coast in Karnataka was arrived at by Prathibha *et al* (1998).

A report on the Length-Weight relationship on the Indian mackerel is also available from the East African waters (Kumanyi, 1975). Djamali (1977) studied the Length-Weight relationship of the Indian mackerel from Panggang island waters of Indonesia.

1.3.1.2 **Food and Feeding Habits**

Studies on the food habits of the Indian mackerel along the west coast of India indicate that the fish feeds on both zooplankton and phytoplankton depending on their availability in the area (Devanesan and John, 1940; John and Menon, 1942; Chidambaram, 1944; Bhimachar and George, 1952 and Pradhan, 1956).

Devanesan and Chidambaram (1948) observed fish scales in the gut of Indian mackerel suggesting that the fish occasionally supplements planktonic organisms by feeding at the bottom on dead and decaying fishes. According to Chacko (1949), Kuthalingam (1956) and Rao (1962) the Indian mackerel is a regular plankton feeder, feeding on both phytoplankton and zooplankton. A study on the feeding habits of juvenile and adult Indian mackerel by Bhimachar and George (1952) showed no difference in the feeding habits of juvenile and adult Indian mackerel at Calicut (Kerala); both groups being phyto and zooplankton feeders. Similar observations were made by Pradhan (1956). Rao (1964) observed that the stomach content of juvenile Indian mackerel of the size range of 3.2 - 8.9 cm from Waltair was found to consist mostly of fish larvae and *Lucifer* sp., indicating that they have preference for this diet. In contrast, the food of the adults of size 9.0 cm and above comprise mostly of copepods, diatoms, dinophysids, larval decapods and stomatopods.

Study conducted by Noble (1965) showed that the Indian mackerel is a plankton feeder, feeding on phyto and zooplankton. Doiphode (1974) observed the predominance of Dinophyceace in the food of Indian mackerel. The other groups were diatoms, copepods bivalves and miscellaneous items. Yohannan and Sivadas (2003) based on their study on Indian mackerel suggested that being a planktivore, it enjoyed a very important status in the marine food chain playing a major role in converting the abundant primary and secondary production in the coastal waters.

1.3.1.3 **Reproduction**

Devanesan and John (1940) studied the size at first maturity of Indian mackerel along Madras (Tamil Nadu) coast. They estimated it at 190 mm. It was estimated at 200 mm by Chidambaram and Venkataraman (1946). Radhakrishnan (1962) stated that the Indian mackerel matures for the first time when it measured 210 - 220 mm. According to Pradhan (1956) and Sekharan (1958), the Indian mackerel spawns in succession.

The study on the fecundity of Indian mackerel was carried out by Devanesan and John (1940), Rao V R (1967) and Varghese (1974). Devanesan and John (1940) estimated the fecundity of the Indian mackerel to be 94,000 eggs.

Rao V R (1967) worked on the maturity and the spawning season of the Indian mackerel. He observed that the Indian mackerel spawned in succession and the size at first maturity of the fish, derived from the maturity curve, was 21.7 cm. Noble (1979) made some observations on the sex composition, maturity and spawning. Bhatia and Chullasorn (1984) studied the spawning season, maturation and fecundity of Indian mackerel in the west coast of Thailand. Sousa and Gislason (1985) observed that the

Indian mackerel from Sofala Bank, Mozambique exhibits a long spawning season, extending from August to March or April, with peak in December or January.

Indian mackerel in spawning condition between June and September and immature ones between September and January was observed by Mwebaza-Ndawula (1990) along the Zanzibar coast. He further observed that maturity of the fish vary in relation to seasonal changes. Isa *et al* (1996) studied the spawning patterns of Indian mackerel along the Malaysian coast. The study showed that the *R. kanagurta* exhibited two pronounced spawning peaks in a year, one during post-monsoon and another during pre-monsoon. Prathibha *et al* (1996) observed that the Indian mackerel commenced spawning during June and progressed to reach a peak in August. Yohannan and Abdurahiman (1998a and b) noticed that the Indian mackerel along the Malabar coast in India spawned in succession. Further, they observed successful spawning and recruitment during the monsoon period. Yohannan and Abdurahiman (1998c) reported that body length and mature ovary maintained a curvilinear relation, whereas a straight-line relation existed between the weight of fish and the weight of ovary.

1.3.1.4 Age and Growth

Growth pattern in Indian mackerel has been studied by Seshappa (1958) using the scales. Yohannan (1979) documented the age and growth in Indian mackerel and observed the size of about 21 cm by the end of 8 months and 22 cm by the completion of first year. According to him once gonadal growth sets in, there is a reduction in linear growth. He reported a decreased growth rate after 8 months of age. Udupa and Bhat (1983 and 1984) studied the age and growth using Bhattacharya Method of age determination on monthly samples of Indian mackerel, *R. kanagurta* from

the purse-seine catches of 1980 - 81 fishing season at Mangalore, Gangolli and Karwar landing centers in Karnataka. They observed three broods whose respective mean total lengths were 19.45, 23.45 and 25.29 cm for 1st, 2nd and 3rd year, respectively. Of these, the two-year-old ones were found to dominate the purse-seine fishery.

Sousa and Gislason (1985) estimated the growth curves based on both otolith readings and Length-Frequency distribution of Indian mackerel in Sofala Bank (Mozambique). Guanco (1991) also studied the growth pattern of the Indian mackerel along Visayas Sea in central Philippines. Mansor and Abdullah (1994) estimated the growth parameters for Indian mackerel off the east coast of peninsular Malaysia using Electronic Length Frequency Analysis (ELEFAN) Module in the FiSAT program. Devaraj *et al* (1994) observed that the $L_{t\infty}$ = 23.83 cm, K = 2.48 and t_o = 0.0003 for Indian mackerel along the south-west coast of India. Isa *et al* (1996) studied the growth of Indian mackerel of east coast of peninsular Malaysia. The $L_{t\infty}$ and K were estimated by Yohannan and Abdurahiman (1998a) as 265 mm and 2.4 respectively for Indian mackerel from the landing centers around Calicut, Kerala. Prathibha *et al* (1998) studied the growth parameters of Indian mackerel along Dakshina Kanara (Karnataka) coast and the growth parameters estimated were $L_{t\infty}$ = 281.67 mm and K = 1.233 while the size range was 145 - 275 mm.

1.3.1.5 **Fishery**

Fair amount of documentation on mackerel fishery in India is available. Rao *et al* (1962) studied mackerel fishery of Mangalore area during late 1950s and beginning 1960s. According to Seshappa (1970), mackerel forms an important fishery in the seas around India. Menon and Radhakrishnan (1974) made some observations on mackerel fishery. Noble (1976) noted

that the Indian mackerel fishery was a highly fluctuating seasonal fishery. Bhatia and Chullasorn (1984) assessed the state of Indian mackerel stocks and noticed that its fishery fluctuated along the west coast of Thailand. Seasonal variations in the abundance of Indian mackerel fishery along the Zanzibar coast of East Africa was observed by Mwebaza-Ndawula (1990). Radhakrishnan *et al* (1991) observed that the Indian mackerel fishery was unusually high at Chennai (Tamil Nadu) in 1986 compared to earlier years. Nobel (1991) noticed fluctuating trend in Indian mackerel fishery. Dhulkhed and Annigeri (1994) made some observation on the Indian mackerel fishery along the north coast of Karnataka. Madhupratap *et al* (1994) studied the Indian mackerel fishery along the west coast of India in relation to coastal oceanography.

Mansor and Abdullah (1994) studied the fishery along the east cost of peninsular Malaysia. Indian mackerel contributed to 30% of the total catch by indigenous gears during the monsoon fishery along the Dakshina Kanara coast (Prathibha *et al,* 1996). Prathibha *et al* (1998) noticed that the Indian mackerel formed 5 - 40% of the marine fish landings along the Dakshina Kanara coast in Karnataka. Yohannan (2002) studied the Indian mackerel fishery along the Maharastra coast. Srinath *et al* (2003) studied the trends in the landings of Indian mackerel in Indian waters. Yohannan and Sivadas (2003) studied the status of Indian mackerel in India. They reported that the Indian mackerel resources contributed on an average 8.6% to the total marine fish production in the country during 1985 - 2000. During the last decade (1990 - 1999) the average annual catch of this species amounted to 0.19 mmt. Though distributed all along the Indian coast, the resource supported a fishery of high magnitude all along the west coast where it contributed 10.2% to the total marine fish catch during 1985 - 2000, whereas the contribution from the east coast was only 4.9%.

1.3.2 *Metapenaeus dobsoni*

1.3.2.1 **Length-Weight Relationship**

Observation on the Length-Weight relationship of *M. brevicornis* along the Hoogly estuary (West Bengal) was made by Rajalakshmi (1961). Rao A V P (1967) gave the Length-Weight relationship of *P. monodon* and *P. indicus* from Chilka Lake in Orissa. The Length-Weight relationship of *P. semisulcatus* from Mandapam, Tamil Nadu was estimated by Thomas (1975). Relationship between the total length and carapace length of three commercially important species of penaeids from Mangalore coast, Karnataka was given by Ramamurthy and Maniekraj (1978). Sukumaran and Rajan (1981) observed the Length-Weight relationship of *P. hardwickii* from Bombay area in Maharastra.

Sreekumaran *et al* (1982) estimated the Length-Weight relationship and condition factor of *P. indicus* and *M. dobsoni*. The Length-Weight relationship and Condition Factor of *P. indicus* and *M. dobsoni* from Cochin backwaters in Kerala were studied by Devi *et al* (1983). Achuthankutty and Parulekar (1986c) studied the growth of four commercially important species of penaeid prawns in Goa waters. They gave the Length-Weight relationship of *M. dobsoni* female as Log W = - 2.31 + 3.13 Log L and for male Log W = - 2.01 + 2.76 Log L. Antony and Soni (1986) worked on the Length-Weight relationship and Condition Factor of *M. kutchensis* from Okha in Gujarat. They found that the Length-Weight relationships were significantly different in both the sexes and the Relative Condition Factor (Kn) was the highest during the attainment of sexual maturity. Lalithadevi (1987) and Rao (1988) studied the Length-Weight relationship of *M. monoceros* from the Kakinada coast in Andhra Pradesh. They observed significant difference in both sexes. Ramamurthy

(1994) studied the Length-Weight relationship of penaeids of north-west coast of India.

Observations on the Length-Weight and Total Length-Carapace Length relationship of *M. dobsoni* and *M. barbata* from Visakhapatnam coast (Andhra Pradesh) were made by Murthy and Ramaseshaiah (1996) and Ramaseshaiah and Murthy (1997). Anantha and Shanbhogue (1997) investigated the Length-Weight relationship of *P. stylifera* and *M. monoceros* from Mangalore, west coast of India. They found significant difference in the Length-Weight relationship between males and females. Nandakumar (1997) studied the biology, population characteristics and fisheries aspects of the speckled shrimp, *M. monoceros* along the Kerala coast. The Length-Weight relationship and Condition Factor of *M. monoceros* along the Kerala coast was documented by Nandakumar (1998). He found significant difference among the sexes.

1.3.2.2 **Food and Feeding Habits**

Gopalkrishnan (1952) from his study on *P. indicus* inferred that in aquaria the shrimps consumed small ctenophores and medusae. Rao A V P (1967) observed large fractions of plant detritus in the foreguts of *P. monodon* from the Chilka Lake (Orissa). Subrahmanyan (1974) found crustaceans, molluscs (bivalves and gastropods), fish and foraminiferans to be the main dietary items of 7 species of penaeids from the Bay of Bengal. Balasubramanian *et al* (1979) reported that though *M. dobsoni* is a voracious feeder its preying efficiency decreased with increased quantity of mud in the substratum. Achuthankutty and Parulekar (1986b) observed that juveniles and adults of *M. dobsoni* were essentially detritivore.

Sudhakar (1988) analyzed the stomach content of *M. monoceros* from the inshore waters and the backwaters along the Kakinada coast in Andhra Pradesh. He found that the food comprised of polycheates, shrimps and other crustaceans. *M. monoceros* from inshore waters of Cochin (Kerala) preferred polycheates where as those in the backwaters preferred crustaceans as their major food items (Nandakumar and Damodaran 1998).

Hall (1962), based on the study on 31 species of penaeids, observed that the gut mainly contained small crustaceans (49%) followed by vegetable matter (39%), large crustaceans (29%), polycheates (26%) and molluscs (18%). Further, he found a wide difference between the genera of shrimps with respect to the most abundant food categories. Dall (1968) suggested that shrimp feed on the bacterial colonies and filamentous blue green algae together with an associated fauna of protozoans, harpacticoid copepods and nematodes. Tiews *et al* (1972), found that the most common food of *P. semisulcatus, P. canaliculatus, M. monoceros* and *P. merguiensis* caught in the offshore waters in the Philippines to be foraminiferans.

Luna-Marte (1980) reported that *P. monodon* feed on crustaceans and bivalves besides plants and detritus in the Philippine waters. Robertson (1988) noticed that the insects, especially dipteron larvae and ants that were common on mangrove sediments made upto 9% by volume of gut contents in small sized *P. merguiensis* from mangrove creeks in Australia.

1.3.2.3 Reproductive Biology

Studies pertaining to the reproduction of *M. dobsoni* are limited. Menon (1951) found that *M. dobsoni* breeds mainly in comparatively shallow inshore waters of the sea with an extended breeding period of 5 - 6 months. Menon (1955) also observed that *M. dobsoni* breeds throughout the year in

south-west coast of India. Sex ratio of 1:1 in *M. dobsoni* was observed by Menon (1957) from south-west Indian coast. George (1959) made some preliminary observations on the breeding habits of *M. monoceros*, based on the occurrence of juveniles in the Cochin backwaters of Kerala. George and Rao (1967) investigated the distribution of sex ratio of penaeid prawns from the Cochin backwaters. They found significant difference in the sex distribution associated with segregated movements of shrimps for the purpose of breeding.

Rao (1968) found that *M. dobsoni* breeds throughout the year with a peak spawning period from April to June and November to December. Further, he reported that the fecundity is between 34,500 to 1,60,000. Rao and Kathirvel (1973) studied the breeding habits of *M. dobsoni* from the backwaters of Kerala. Nalini (1976) observed the stages of maturity and spawning of *M. monoceros* in Cochin, and determined the size at first maturity at 180 mm with occurrence of breeding throughout the year. Goswami *et al* (1977) studied the larval distribution of commercially important penaeids in west coast of India. Achuthankutty *et al* (1977) observed the peak spawning season of *M. dobsoni, M. monoceros, P. merguiensis* and *P. stylifera* based on the larval abundance from the estuaries of Goa. Ramamurthy (1980) stated that the size at first maturity of *P. stylifera* was 71 mm in Mangalore coast of Karnataka. Sukumaran and Rajan (1981) recorded the size of first maturity of *P. hardwickii* as 73 mm.

Kurup (1985) found males in higher proportion than females in smaller size groups, whereas the proportion of females was higher in larger size groups in *M. dobsoni* from Allepy coast in Kerala. Sukumaran (1985) recorded that the sex ratio of *M. dobsoni* was almost equal in the trawl catches at Mangalore and Malpe in Karnataka. Achuthankutty and Parulekar (1986a) predicted the breeding season of commercially important shrimp species by studying the larval distribution in Goa coast. Achuthankutty and Parulekar

(1986b) observed that though the mature females of *M. dobsoni* were above 70 mm in length, the size group 95 - 105 mm formed the main stay of breeding population in Goa waters. They also reported a year round breeding activity for this species. Lalithadevi (1989) noticed that females of *M. dobsoni* from Godavari estuarine waters in Andhra Pradesh were dominant throughout the year except in August. The size at first maturity for *M. monoceros* from Kakinada coast was found to be 96 and 116 mm for males and females, respectively (Sudhakar, 1989). Suseelan *et al* (1989) documented the karikadi (*P. stylifera)* fishery in Kerala and reported the size at first maturity of female at 76 mm. Vasudevappa (1992) observed successful re-maturation and spawning of laboratory reared *M. dobsoni* in succession and bred many times in its life-time. Anantha (1993) from his study on *M. monoceros* and *P. stylifera* during 1990-1992 along Mangalore region, inferred that spawning season of both these species extended throughout the year with a peak from March to May.

1.3.2.4 Age and Growth

Studies on the age and growth of penaeids in India have been made mainly by employing the Length-Frequency method. According to Menon (1955) *M. dobsoni* from the west coast of India lived for about three years. Mohamed and Rao (1971) recorded a growth rate of 9.83 mm per month for *M. dobsoni* along the west coast of India. Rao (1973) observed the larval growth of *P. stylifera*, *M. monoceros*, *M. dobsoni* and *P. indicus*. He opined that the growth in different larval stages was almost constant for each species. Ramamurthy *et al* (1978) reported that males of *M. dobsoni* grew to a length of 85 and 95 mm during the first and second year of their life respectively, while the females grew to 105 and 120 mm during the same period.

Achuthankutty and Parulekar (1986c) reported that the females of *M. dobsoni* grew faster than males throughout the life and attained a maximum length of 121 mm in 31 months as against 32 months taken by males to attain the maximum length of 117 mm. Suseelan and Rajan (1989) estimated growth parameters for *P. stylifera* off Cochin and recorded an asymptotic length (L_∞) of 135 mm and growth co-efficient (K) equivalent to 1.19 per year. Dall *et al* (1990) studied the age and growth of penaeids and concluded that crustacean's growth is dependent on sex, population density, food quality, light, temperature and salinity.

Sukumaran *et al* (1993) observed that the asymptotic length (L_∞) and growth co-efficient (K) of *M. dobsoni* along the Indian coast to be 139 mm and 2.40 per year for males and 145 mm and 2.76 per year for females, respectively. Nandakumar (2000) studied the age and growth of *M. monoceros* along the Cochin coast and obtained L_∞ and K as 204 mm and 1.8 for females and 170 mm and 1.5 for males, respectively, whereas the estimated t_o (months) as 0.7235 and 0.3106 for females and males, respectively.

1.3.3 Marine Fisheries of Goa

The fisheries resources of Goa are considered to be rich in pelagic and demersal fish species (Ansari *et al,* 1995). Mohanta and Subramanian (2001) referred to the fishery of Goa as that of a multi-species one. Ansari *et al* (2006) have given an account of the fisheries resources of the state of Goa and have reported negative growth in the recent years, suggesting that the catches have crossed the maximum sustainable yield.

II. BIOLOGY OF RASTRELLIGER KANAGURTA

2.1 Introduction

The Indian mackerel, *R. kanagurta* is one of the most important pelagic fishery resources of India. It is locally known in Goa as *Bangada* and commands a good price. Of late, it has also gained a good export market and hence is commercially very important in the state. The fishery of this species is second only in size to that of oil sardines in the multi-species structure of Indian marine fishery (Yohannan and Sivadas, 2003). Together with oil sardines, it contributes to about 55% of the total pelagic fishery in Goa. The success of the Indian mackerel gives the overall wellbeing of the fishing industry in the state of Goa.

Indian mackerel is widely distributed in the inshore waters of India. A related species of Indian mackerel, *R. brachysoma* contributes to the fishery of the Andaman Islands and *R. faughni* to that of Tamil Nadu coast. The Indian mackerel is abundant in the tropical Indo-west pacific region (Pradhan and Rao, 1958). Balakrishnan (1970) observed that the Indian mackerel fishery is confined largely to coastal waters. He also reported that its fishery is dominant mainly between Quilon and Ratnagiri, although it occurs along both the coasts of India.

In Goa the fishing of Indian mackerel is carried out using a variety of gears, both in the mechanised sector as well as in the traditional sector. The purse-seine is the main gear followed by gillnet and the trawl net in the mechanised sector. Among the gears in the traditional sector, gillnet is the most important one, followed by the *Rampon* (a type of beach seine) and the mini purse-seine.

The studies on the biological aspects of Indian mackerel along the Goa coast are limited. Benergi (1970) analysed the population related issues of the Indian mackerel. Doiphode (1974) studied the length-weight

relationship and also made some observations on the food and feeding from the purse-seine catches.

Since this species forms a very important component of the pelagic fishery resources in Goa, it was felt appropriate to take up a detailed study on its fishery biology.

2.2 Materials and Methods

2.2.1 Biology

Weekly samples of *R. kanagurta* were collected from the three main fish landing centers of Goa, viz. Malim, Vasco and Cutbona from August 2003 to August 2005. Samples were collected weekly by random sampling. Samples could not be obtained for the month of July for both the years, due to the closed fishing season. A total of 1,092 specimens were examined during Aug '03 - Jun '04. Males constituted 41.02%, 46.88% were females and 12.10% were intermediate (treated as juveniles). During the period of Aug '04 - Aug '05 a total of 1,219 specimens were examined, of which 48.40% were females, 42.32% were males and 9.28% were juveniles.

The fresh specimens were brought to the laboratory and the weight (g) and total length (mm) of each specimen was recorded. Further, the maturity stages and other general features of interest were also recorded for further analysis of the data.

The data were analyzed following standard procedures for studying the length-weight relationship, condition factor, reproduction and age and growth.

2.2.1.1 Length-Weight Relationship

A total of 2,311 samples of *R. kanagurta* were analyzed for the study. It comprised of 47.4% females and 41.5% males. The Length-Weight relationship, $\mathbf{W = a\ L^b}$ (LeCren, 1951) was fitted as;

$$\mathbf{Log\ W = Log\ a + b\ Log\ L,}$$

by least square method, where W = weight of each specimen and 'a' and 'b' are the constants.

The data was divided into two sampling periods i.e. Aug '03 - Jun '04 and Aug '04 - Aug '05 to assess the trend during both these periods. Further, the two sexes were treated separately. The pattern of growth, (isometric or allometric) was tested by **t – test**, using the formula;

$$\mathbf{t = b - 3 / Sb,}$$

where b = Regression Coefficient; Sb = Standard Error of the estimate of Regression Coefficient.

Analysis of Co-variance (ANCOVA) (Snedecor and Cochran, 1967) was employed to test the significant difference in the fitted Length-Weight relationship between the two sexes.

2.2.1.2 Relative Condition Factor

The data analyzed for Length-Weight relationship were used for calculating the Relative Condition Factor, **Kn** (LeCren, 1951). The Kn was calculated for individual specimen by making use of the formula;

$$\mathbf{Kn = W/W\hat{}},$$

where W = observed weight, W^ = calculated weight. In order to find out the relation, if any between spawning season and the Relative Condition Factor, monthly mean values of Kn were calculated separately for males and females.

2.2.1.3 Reproduction and Maturity

For this study, the weekly samples collected from the three fish landing centers were used.

Classification of sexual maturity stages was done based on the external appearance of ovaries and testes. The works of Pradhan and Palekar (1956), James and Badrudeen (1981), Jayabalan (1986) were used as a reference for describing the maturity stages.

Size at first maturity, which is the average size at which 50% of the individuals are mature, was estimated by plotting the cumulative frequency of the mature specimens in the successive size groups (James and Badrudeen, 1981).

2.2.1.4 Sex Ratio

Sex ratio was studied with respect to the months. Data on sex ratio were analyzed by X^2 **(Chi-Square) test** to find out whether there was a dominance of either of the sexes during different months.

2.2.1.5 Age and Growth

2.2.1.5.1 Length-Frequency Analysis

Length frequency studies were based on samples collected from the three main landing centers during the periods, Aug '03 to Jun '04 and Aug '04 to Aug '05.

Total length (mm) of each specimen measured was used for the study. The growth study was carried out separately for each period of study. The monthly length measurements were grouped into 10 mm class intervals. The percentage frequencies were calculated and plotted against mid-points of each size group to get frequency polygons. Then by counting the number of discernable modes and relating them to the respective length, a rough estimate of mean length of each cohort was obtained. Age determination was done using **Peterson's Length-Frequency Analysis** (Peterson, 1891 and Devaraj, 1983).

2.2.1.5.2 Growth Equation

For obtaining the **von Bertalanffy** growth equation (von Bertalanffy, 1938 and 1957), the length at age data was used.

$$L_t = L_\infty (1-e^{-K(t-t_0)}),$$

was fitted, where, L_t = Length at age t

L_∞ = asymptotic length,

K = catabolic growth coefficient

t_o = age at zero length

The growth parameters L_∞, K and t_o were calculated by analytical method (Bagenal, 1955) and graphical method using **Ford-Walford Plot** (Walford, 1946 and Ford, 1933) and **Berveton and Holt Plot** (Berverton and Holt, 1957).

Ford-Walford Method

The method introduced by Ford (1933) and Walford (1946) has gained wide application because the plot can be obtained and L_∞ estimated quickly without many calculations. From the von Bertalanffy growth equation, a linear equation of the form was obtained as;

$$L_{t+1} = L_\infty (1 - K) + K L_t$$

where L_{t+1} is the length at time t+1, and L_t is the length at time t and K is the growth coefficient (e - K). The growth parameters K and L_∞ are derived by regression of L_{t+1} on L_t which gives the values of constants, a and b.

$$L_\infty = a / (1 - b) \text{ and}$$

$$K = - \ln (b).$$

Beverton & Holt Plot

The theoretical age, t_o at which the length of the fish would be zero, was estimated following the method of Beverton and Holt from the equation;

$$\ln (L_\infty - L_t) = K_{to} - K,$$

where the t_0 was estimated by regression of ln (L_∞ - L_t) on 't', which give the value of constant and slope 'b', t_0 was estimated by the relation;

$$t_0 = a - \ln L_\infty / K.$$

2.2.2 Fishery in Goa

The catch statistics of Indian mackerel from 1967 to 2005 collected from the Statistics Section, Department of Fisheries, Government of Goa, was utilized for the study. From the catch composition a trend graph was plotted to see the fluctuations in the landings of this species.

2.3 Results

2.3.1 Length-Weight Relationship

There are two main objectives in studying the Length-Weight relationship of fishes; firstly, to determine the type of mathematical relationship between the two variables, so that if one is known the other could be computed and secondly, to calculate the relative condition factor.

The data collected was divided into two periods Aug '03 - Jun '04 and Aug '04 - Aug '05. The Length-Weight relationships obtained from the data are as follows:

For the period of Aug '03 - Jun '04:

For Females:

$$\text{Log } W = -5.2943 + 3.1528 \text{ Log } L$$

or

$$W = 0.00000508\ L^{3.1528}$$

For Males:

$$\text{Log } W = -5.0452 + 3.0451 \text{ Log } L$$

or

$$W = 0.00000901\ L^{3.0451}$$

And for the period of Aug '04 - Aug '05:

For Females:

$$\text{Log } W = -5.9850 + 3.4490 \text{ Log } L$$

or

$$W = 0.00000104\ L^{3.4490}$$

For Males:

$$\text{Log } W = -5.7339 + 3.3414 \text{ Log } L$$

or

$$W = 0.00000185\ L^{3.3414},$$

where W = weight is in g and L = length in mm.

The results of the monthly Length-Weight relationship for females during Aug '03 - Jun '04 is presented in Table 2.1.1 and the corresponding Length-Weight relationship for males for the same period is presented in Table 2.1.2. Table 2.1.3 and Table 2.1.4 show the monthly Length-Weight relationship of females and males, respectively during the period Aug '04 to Aug '05.

The observed values of length and weight of the fishes were plotted in the form of a scatter diagram and the calculated Length-Weight curve was fitted to the data. These observed values were plotted separately for females and males for both the periods of study. Figures 2.1.1, 2.1.2, give the Length-Weight relationship of females and males, respectively for the period of Aug '03 - Jun '04 and Figures 2.1.3 and 2.1.4 give the corresponding relation of female and male for the period from Aug '04 - Aug '05, respectively. The two sets of data showed close relationship. The logarithmic values of lengths and weights were plotted (Figs. 2.1.5, 2.1.6, 2.1.7 and 2.1.8) separately for females and males for both the periods of the study. The regression line fitted to the data indicates a straight-line

relationship between the two variables for both sexes during both the periods of the study.

Tables 2.1.5 and 2.1.6 give the results of analysis of covariance carried out to see whether the Length-Weight relationships of males and females differ significantly for the period of Aug '03 - Jun '04 and for the period of Aug '04 - Aug '05, respectively. From the **F-Ratio**, it is evident that there is significant difference between the two regression equations for males and females during both the periods of study.

To test whether the species follows isometric or allometric growth pattern during the period from Aug '04 - Jun '04 and during Aug '04 - Aug '05 the t-test was employed. The analysis indicate isometric growth pattern for both the periods of study.

2.3.2 Relative Condition Factor

The Relative Condition Factor, Kn = W/W^ was calculated for female and male fishes separately by making use of the respective Length-Weight relationship. Tables 2.2.1 and 2.2.2 represent the monthly averages of the Relative Condition Factor calculated separately for females and males during the period of Aug '03 - Jun '04 and for the period of Aug '04 - Aug '05, respectively. In each case the weighted average for the whole period (Aug '03 - Jun '04 and Aug '04 - Aug '05) was also calculated.

It was observed that, for the period Aug '03 - Jun '04, the Relative Condition Factor of females was equal to or higher than the weighted average (1.0010) during the months of September '03, October '03 and February '04. The highest Kn value for female, 1.0022 was recorded during the month of September '03. In males, Kn was higher than the weighted

average (1.0007) during the months of August '03, September '03, October '03, and January '04. The highest Kn value of 1.0084 was observed in Jan '04.

For the period Aug '04 - Aug '05 the Relative Condition Factor for females was higher than the weighted average (1.0011) during the months of January '05 and August '05 (Table 2.2.2). The highest Kn value of 1.0045 was observed during August '05, whereas for males it was higher than the weighted average during the months of September '04, December '04 and August '05. The highest Kn of 1.0032 was observed in the month of September '04.

2.3.3 Reproduction

The results of the studies on maturity, spawning, size at first maturity and sex ratio are presented below:

2.3.3.1 Maturity Stages

The maturity stages of the Indian mackerel were recorded based on the external appearance of gonadal development. In the present study the following stages were identified.

Stage I: Immature: Ovaries and testes in immature state. The ovaries and testes occupy less than half of the body cavity.

Stage II: Maturing: Ovaries and testes are in maturing or intermediate state. The ovaries and testes occupy more than half but less than 2/3rd of the body cavity.

Stage III: Late Maturing: Ovaries and testes occupy more then 2/3rd of the length of the body cavity.

Stage IV: Mature: Ovaries and testes are swollen and extend the entire length of the body cavity.

Stage V: Spent: The ovaries and testes are blood shot with few visible eggs in case of females.

2.3.3.2 Spawning Seasons

The spawning seasons were determined on the basis of occurrence of individuals in the maturity stages III, IV and V during each month. A total of 960 specimens (512 females and 448 males) were examined during the period of Aug '03 - Jun '04 and 1,106 individuals (590 females and 516 males) during Aug '04 - Aug '05.

Figures 2.3.1 and 2.3.2 depict the percentage of females and males respectively, in various stage of maturity during the period of Aug '03 - Jun '04. Figures 2.3.3 and 2.3.4 give the percentage of females and males in different stages of maturity for the period of Aug '04 - Aug '05. From these figures it can be seen that during the month of June all females and males caught were in stage IV. Fish in stage I and II were recorded during months of September and October and January to April for both periods of study.

2.3.3.3 Size at First Maturity

For the determination of size at first maturity, during the period of Aug '03 - Jun '04 a total of 512 females and 448 males were examined and for the period of Aug '04 - Aug '05, 590 females and 516 males were examined.

Fishes were grouped in size intervals of 10 mm for this purpose. Only those in the III, IV and V stages were considered as matured ones. Both the sexes were treated separately during both the periods of study. The size at which 50% of the fish are mature was considered as the size at first maturity.

Figures 2.3.5 and 2.3.6 give the cumulative frequency percentage of females and males, respectively in the mature stages at various size groups. It was seen that during the period of Aug '03 - Jun '04, the size at first maturity for females was 215.5 mm and for males it was 211.6 mm.

The size at first maturity of the Indian mackerel for the period of Aug '04 - Aug '05 was found to be 217.5 mm in case of females and 213.6 mm in case of males. (Figs. 2.3.7 and 2.3.8)

2.3.3.4 Sex Ratio

The sex ratio of males and females calculated for the period Aug '03 - Jun '04 and Aug '04 - Aug '05, showed dominance of females during most of the months (Figs. 2.3.9 and 2.3.10). At probability level of 0.05, Chi-Square values did not indicate significant difference in the ratio of males and females in any particular month during both the periods of study. However, the overall difference in the sex ratio was significant ($p < 0.05$) for each period of study (Tables 2.3.1and 2.3.2).

2.3.4 Age and Growth

2.3.4.1 Length-Frequency Distribution

Data of the random samples collected from the three different landing centers of Goa were grouped into 10 mm size intervals. The percentage

frequency was calculated and plotted against the mid points of size groups in the form of frequency polygons for each month. Monthly Length-Frequency distribution for the period of Aug '03 - Jun '04 is plotted in Fig. 2.4.1. Figure 2.4.2 shows the monthly Length-Frequency distribution for the period of Aug '04 - Aug '05.

From the monthly Length-Frequency graphs it was observed that the Indian mackerel, landed in Goa during both the study periods, consisted of 5 age groups. Based on the Petersons method, it was observed that during the period of Aug '03 - Jun '04, the fish grew to a size of 201.36 mm, 225.00 mm, 245.00 mm and 261.67 mm at the end of 1st, 2nd, 3rd and 4th year, respectively. During the second period of the study, at the end of 1st, 2nd, 3rd and 4th year it grew to a size of 197.00 mm, 223.18 mm, 245.00 mm and 263.00 mm, respectively.

The mean lengths obtained by this method for each group during both the periods of study are documented in Tables 2.4.1 and 2.4.2.

2.3.4.2 Growth Equation

From the biological point of view, to understand any fish population, it is necessary to fit the growth equation with respect to the length or weight. The above mean length at age data obtained by Peterson's method was used to estimate the parameters of von Bertalanffy growth equation using the least square method.

Thus, the fitted growth equation for the period of

Aug '03 - Jun '04 is;

$$L_t = 286.3\,(1 - e^{-0.41\,(t + 2.10)}) \text{ and}$$

for the period Aug '04 - Aug '05 is;

$$L_t = 306.4\,(1 - e^{-0.31\,(t + 2.40)}).$$

The L_∞ obtained as per Ford-Walford method was found to be 290 mm for the period of Aug '03 - Jun '04 (Fig. 2.4.3). Figure 2.4.4 gives the value of t_0 as - 2.12 years obtained by Beverton and Holt method for the same period.

Whereas, for the period of Aug '04 - Aug '05, the L_∞ as obtained by Ford-Walford method was found to be 308 mm (Fig. 2.4.5). The t_0 for the corresponding period as obtained by Beverton and Holt method was - 2.38 years (Fig. 2.4.6).

The growth pattern for the period of Aug '03 - Jun '04 as per von Bertalanffy growth curve is given in Fig. 2.4.7. Similarly, Fig. 2.4.8 gives the growth pattern for the period of Aug '04 - Aug '05.

2.3.5 Fishery in Goa

The landings of Indian mackerel, *R. kanagurta* in Goa for the 5 decades (1967 to 2005), were plotted to study its landing trends (Fig. 2.5.1). The landing pattern show fluctuating trends. In 1967, the total Indian mackerel landing was 4,016 mt. This figure shot up to 35,258 mt in 1971. The landings dropped to the lowest ever in 1983 of 1,224 mt. The years 1994, 1995 and 1996 saw bumper catches of 38,230 mt, 42,712 mt and 44,254 mt, respectively contributing to approximately 40 to 50% of the total marine fish landings during the respective years. During the following years, the landings showed a downward trend again, reaching to a low of 5,779 mt in 2003. Thereafter, there has been a slow upward rise in landings. The year 2005 witnessed a landing of 12,006 mt. Figure 2.5.2 gives the Indian mackerel and oil sardines landings in Goa.

2.4 Discussion

2.4.1 Length-Weight Relationship

The Length-Weight relationship is indicative of the mathematical relationship between the length and weight of the fish. It also depicts the variation between the observed and the expected weight. This variation indicates the fatness, general wellbeing or gonadal development of the fish (LeCren, 1951). Growth is the change in body dimension or weight over time but can be more easily measured as the change in length. Length being a linear measure and weight a measure of volume, the Length-Weight relationship of a fish can be described by the hypothetical Cube Law;

$$\mathbf{W = a\,L^3},$$

where W = weight of the fish, L = length of the fish and a = constant.

The cube law represents a condition in an ideal fish wherein the fish maintains a constant shape (Allen, 1938). However, if there is a change in the density and form as a result of growth, there will be a change in the isometric growth pattern. Hence the Length-Weight relationship is expressed as $\mathbf{W = a\,L^b}$. The value of the exponent 'b' in the parabolic equation usually lies between 2.5 and 4.0 (Hile, 1936; Martin, 1949).

In the present study, the Length-Weight relationship of *R. kanagurta* showed that the weight of males and females increased as 3.0451 and 3.1528 times the power of length, respectively during the period Aug '03 - Jun '04 and as 3.3414 and as 3.4490 times the power of length for males and females, respectively during the period Aug '04 to Aug '05. The value of 'b' was found to be more than 3.0 in both males and females during both the periods of study.

The Length-Weight relationship obtained in the present study is in accordance with that observed by Luther (1973) who fitted the Length-Weight relationship for male and female of *R. kanagurta* from the Andaman waters as Log W = - 5.6647 + 3.2874 Log L and the parabolic equation, $W = 0.000002164\ L^{3.2874}$. The parabolic equation obtained in the present study is also in accordance with the findings of Prathibha *et al* (1998) who observed that $W = 0.00000138481\ L^{3.3805}$ for the Indian mackerel along the Dakshina Kanara coast in Karnataka. Azad and Udupa (1989) fitted similar Length-Weight relationship for *R. kanagurta* from the catches off Mangalore coast (Karnataka) with 'b' value above 3.

In the present study, a significant difference in the regression coefficient between the two sexes of Indian mackerel was observed during both the periods of study. It was also observed that the fish followed isometric growth pattern. These findings differed from that of Azad and Udupa (1989) who not only reported no significant difference in the regression coefficient between the two sexes but also that the Indian mackerel followed allometric growth. This may be attributed to the varying proportion of males and females in the samples, the sample size and the variation in the random sampling method used by individuals.

2.4.2 Relative Condition Factor

The coefficient of condition or Condition Factor is given by the formula;

$$K = 100\ W / L^3,$$

where W = weight of fish, L = length of fish and K = Ponderal Index, has been used to indicate the condition, fatness or general wellbeing of fish (Hile, 1936). The valve of 'K' is directly affected if fish does not follow the

cube law. To eliminate the effect of length and other factors, LeCren (1951) suggested the calculation of the relative condition (Kn) as, Kn = Wo / W^. It gives the general well being of the fish as well as the gonadal condition.

2.4.2.1 Seasonal Variation in Kn

It was observed that for the period of Aug '03 - Jun '04, the Kn of females was equal to or higher than the weighted average for the months of September, October and February. The highest Kn value for female was obtained in the month of September. In case of males, the relative condition factor was higher than the weighted average for the months of August, September, October and January. The highest Kn value for males was seen in January.

It was seen that for the period of Aug '04 - Aug '05, the Kn for females was higher than the weighted average in the months of January and August '05. The highest Kn value for females was observed during August '05, whereas, for males it was higher than the weighted average in the months of September '04, December '04 and August '05. The highest value of Kn was observed in the month of September, whereas, the months from March to June had the Kn values less than the weighted average for both the sexes.

The higher values of Kn observed for the months of August, September, and January may be due to the presence of mature gonads and the higher values in October and February may due to excess feeding. The lower Kn valves observed during March - June may be due to poor feeding or low occurrences of their favoured food.

During both the study periods the higher valves of Kn observed coincided with the breeding period of the fish, i.e. August - September and January, the latter being a second spawning season of the fish.

2.4.3 Reproduction

The results of the studies on maturity, spawning, size at first maturity, and sex ratio are discussed below.

The observation on the gonadal appearance of the Indian mackerel in both the periods of the present study showed that all the five maturity stages were present throughout the year except in June where only the stage IV was present. Juveniles were also seen during June to September. Further, the dominance of I and II stages of maturity were seen during October - December and February - March. The spent stage was observed during September and January. The peak period of maturity was recognized as June - August. Matured females in the IV stage of maturity were also observed from the month of November to January.

It can be inferred from the study that the Indian mackerel has two spawning periods along the Goa coast, the first being more prolonged. Juvenile fish made their appearance during the month of May. However, more number of juveniles was observed during September.

It is a known fact that in most fishes there is a marked seasonal periodicity in the breeding habits. Teleostean fishes have been found to exhibit different types of spawning behaviour with respect to periodicity, duration and quantum of release of eggs (Hickling and Rutenberg, 1936; De-jong, 1940; Prabhu, 1956; Qasim and Quayyum, 1961). A phenomenon wherein some fishes release batches of eggs over an extended area during a

protracted spawning period is prevalent in Indian waters. This behaviour is adaptive in situations where prey availability is unpredictable and the risk of total recruitment failure is avoided by many independent spawning bouts. Indian mackerel exhibits similar behaviour wherein it begins spawning by February and reaches a peak by May - July (Anon, 1999) and the spawning during May - July is very crucial for its recruitment. Successful recruitment of Indian mackerel was also observed in the present study during June - September.

The present study is also in agreement with the earlier work of Mwebaza-Ndawula (1990) and Prathibha *et al* (1996), who observed that Indian mackerel spawns between June and September, having immature ones between September and January. They also noticed that maturity of fish varied in relation to seasons. Further, they observed gravid and spent stages forming 95, 98 and 100% of population during June, July and August, respectively. The observations made in the present study during both the periods were closely similar. However, the present study differed from the findings of Isa *et al* (1996). According to them *R. kanagurta* exhibited two pronounced spawning peaks in a year, one during the post-monsoon and the other during the pre-monsoon along the east coast of Peninsular Malaysia. This may be due to the different environmental conditions prevailing along different coast.

In another study by Yohannan and Abdurahiman (1998a and b) it was reported that the Indian mackerel in the Malabar coast spawn in succession. Further, they also observed successful spawning and recruitment during the monsoon period. This is in agreement with the results of the present study wherein also successful spawning and recruitment were observed during the monsoon period.

The size at first maturity indicates when the fish attains sexual maturity for the first time. This can be used as a tool to know the optimum size at which the fish be permitted to be caught. According to Devanesan and John (1940), the size at first maturity of Indian mackerel was 190 mm. Chidambaram and Venkatraman (1946) reported that the minimum size at first maturity was at 200 mm. The present study is in agreement with the study of Radhakrishnan (1962) who observed that the Indian mackerel matured for the first time when it measured 210 - 220 mm. Rao (1967b) observed the size at first maturity derived from the maturity curve as 217 mm, which was also in close agreement with the present study.

The data on sex ratio of Indian mackerel in the present study showed dominance of females during most of the months for both the periods of study. At 0.05 probability levels, Chi-Square values did not indicate any significant monthly variations between the number of males and females during both the periods of study. However, significant difference was observed in the overall male and female population for each period of the study. A number of factors may be responsible for the difference in the proportion of male and female population, such as segregation of the sexes through various periods of the year including segregation resulting from sex differences in age and maturity. Other influencing factors may be the selectivity in relation to sex difference in morphology and physiological activity and differences in natural and fishing mortality between the sexes. Sex ratio may also depend on differential catch (Kesteven, 1942).

2.4.4 Age and Growth

2.4.4.1 Length-Frequency Distribution

The Length-Frequency method of age determination is based on the assumption that the size distribution of the individuals of any one group shows very little variation around the modal length. This indicates that it is possible to separate the successive age groups. However, estimation of age and growth on this principle is usually possible only for fishes having single restricted spawning season. Even in such condition the Peterson's method fails to separate the older age groups in a fish population due to the increasing overlap in length distribution.

It is evident from the results that the Indian mackerel off Goa coast is not constituted by a single age group. Such observations were reported by Udupa and Bhat (1984), for Indian mackerel caught off Mangalore coast. Based on earlier works of George and Banarji (1964) and Udupa and Bhat (1984), the age groups were assigned to different length frequency modes in the present study as obtained by Peterson's method.

Following the Peterson's method, it can be seen that during the period of Aug '03 - Jun '04 the Indian mackerel grew at the end of 1st, 2nd, 3rd and 4th year to a size of 201.36 mm, 225.00 mm, 245.00 mm and 261.67 mm, respectively. Similarly, during the second period of the study, Aug '04 - Aug '05, the respective sizes were 197.00 mm, 223.18 mm, 245.00 mm and 263.00 mm for 1, 2, 3 and 4 year olds.

The findings slightly differ with Yohannan (1979) who observed that the Indian mackerel grew to about 210 mm by the end of 8 months and 220 mm at completion of the 1st year. He also recorded that the growth rate in the fish decreases considerably after about 8 months. The present study is in conformation with Udapa and Bhat (1984) who documented the mean total

lengths of Indian mackerel at Mangalore, Gangolli and Karwar landing centers in Karnataka as 194.5, 234.5 and 252.0 mm for 1, 2 and 3 years old, respectively and Hulkoti (2005) who observed that the fish grew to 205.0, 223.3 and 245.0 mm at the end of 1st, 2nd and 3rd year, respectively.

In the present study, the Indian mackerel landings were found to be in five age groups with the 2-year-old group (215 to 235 mm) dominating the catches. Similar observations have been reported by Udupa and Bhat (1984) from the Indian mackerel landings in Mangalore, Gangolli and Karwar coasts in Karnataka.

2.4.4.2 Growth Equation

The growth equation of von Bertalanffy finds extensive usage in describing adequately the growth functions of many fish (Berveton and Holt, 1957). The expected lengths obtained by von Bertalanffy growth equation are in close agreement with the corresponding observed values. The growth parameters obtained by Least Ssquare method and Graphical method in the present study were also found to be in close agreement. The von Bertalanffy growth equation for Indian mackerel during the period of Aug ''03 - Jun '04 was;

$$L_t = 286.3\,(1 - e^{-0.41\,(t + 2.10)}) \text{ and}$$

for the period Aug '04 - Aug '05;

$$L_t = 306.4\,(1 - e^{-0.31\,(t + 2.40)}).$$

The expected lengths obtained by von Bertalanffy growth equation in the present study were in close agreement with the corresponding observed lengths. Similarly, the growth parameters obtained by Least Square method did not differ from those obtained by Graphical method and the respective

L_∞ values during the 1st and 2nd study periods were 286.3 and 306.4 mm. The results of this study are in close agreement with Prathibha *et al* (1998) and Prathibha and Gupta (2004), who estimated the growth parameters of Indian mackerel landed along Dakshina Kanara coast as L_∞ = 281.67 mm and K = 1.233 and L_∞ = 307 mm and K = 1.8, respectively. The growth parameters L_∞ and K were estimated as 265 mm and 2.4, respectively by Yohannan and Abdurahiman (1998a) for Indian mackerel from the landing centers in Calicut (Kerala). However, the values differed from the findings of Devaraj *et al* (1994) who estimated the L_∞ = 238.3 mm, K = 2.48 and t_0 = 0.0003 for the fish along the south-west coast of India.

The size range of Indian mackerel in this study was recorded as 132 - 280 mm. The Indian mackerel landed along Dakshina Kanara coast were in the size group of 145 - 275 mm (Prathibha *et al*, 1998). Kakati and Gowda (1999) recorded the maximum size of Indian mackerel as 421 mm weighing 859 g in Karwar (Karnataka). Abdurahiman *et al* (2004) recorded a maximum length of 280.2 mm along southern coast of Karnataka. This is in close agreement with the maximum size recorded in the study (280 mm).

2.4.5 Fishery in Goa

The Indian mackerel fishery along the Goa coast was highly fluctuating. This finding is in accordance with that reported by Noble (1976) who, based on his study during the period of 1965 - 1974, concluded that the mackerel fishery was a highly fluctuating seasonal fishery. Yohannan (2002) also observed similar trend along the Maharastra coast. Yohannan and Sivadas (2003) reported that the Indian mackerel contributed, on an average 8.6% to the total marine fish production in the country during 1985 - 2000. Further, they observed that although it is distributed all along the Indian coast, the Indian mackerel supported the marine fishery along the

west coast to a tune of 10.2% during 1985 - 2000, whereas its contribution from east coast was only 4.9%.

From the results of the present study it can be seen that the contribution of Indian mackerel varied from 3.5 to 88.2% of the total marine fish landings in the state during the last 4 decades (1967 - 2005). Prathibha *et al* (1998) recorded a contribution of 5 - 40% to the total marine fish catch along the Dakshina Kanara coast.

The year 1983 recorded the lowest landing of Indian mackerel in Goa (1,224 mt). The contribution of this fish during the same year was also the lowest (3.5%) to the total marine landings in the state. The highest landing (44,254 mt) was recorded in 1996, contributing to 47.7% of the total marine fish landings. Radhakrishnan *et al* (1991) observed that the fishery of Indian mackerel at Madras was unusually high in 1986 compared to earlier years. Sathianandan and Algaraja (1998) found 83.2% variation in mackerel landings from 1952 to 1992 based on spectral analysis. Many factors could be responsible for the abundance of this species during specific years. Besides the increased fishing intensity, environmental factors and abundance of the favoured food may also influence the catch.

Another important observation made in the present study was that the catch of Indian mackerel depended to a considerable extent on the landings of oil sardines. Upon comparison of landings since 1967 of these two commercially important pelagic fisheries, an inverse relationship was observed. When landings of Indian mackerel were found to be low, the oil sardine landings were high, and the vice-versa. It was observed that together they formed an average 55% of the total marine fish landings in Goa during the period 1967 - 2005 and the rise or fall in total marine fish production was directly dependent on the landings of these two fish species. These finding are in agreement with that of Morgan (2006) who reported

that there appears to be an inverse relationship between the abundance of Indian oil sardine and Indian mackerel. According to him though the basis of this relationship is not fully understood, the fishery appears to be driven more by oceanic conditions and the abundance of plankton blooms, which in turn are the result of the extent of upwelling on the south-west coast of India.

Sathianandan and Algaraja (1998) studied the landing patterns of some major fishery in India. They identified catch periodicity for both oil sardine and mackerel landing as 21 and 11 year cycles. Based on their spectral model studies they have projected the years 2010 - 2011 as peak landing for oil sardines and 2014 for mackerels.

Table 2.1.1: *R. kanagurta* female: Length-Weight Relationship for the period Aug '03 - Jun '04

Month	n	A	A	b	r	$W = a L^{b}$
Aug '03	19	-5.7306	0.00000186	3.3453	0.9942	$W = 0.00000186\ L^{3.3453}$
Sep '03	45	-4.8541	0.00001399	3.2444	0.9483	$W = 0.00001399\ L^{3.2444}$
Oct '03	39	-5.0117	0.00000973	3.0417	0.9762	$W = 0.00000973\ L^{3.0417}$
Nov '03	50	-4.9223	0.00001196	2.9933	0.9847	$W = 0.00001196\ L^{2.9933}$
Dec '03	58	-4.8807	0.00001316	2.9772	0.9787	$W = 0.00001316\ L^{2.9772}$
Jan '04	61	-4.7044	0.00001952	2.9034	0.9814	$W = 0.00001952\ L^{2.9034}$
Feb '04	53	-5.2049	0.00000623	3.1112	0.8874	$W = 0.00000623\ L^{3.1112}$
Mar '04	55	-4.8556	0.00001394	2.9614	0.9877	$W = 0.00001394\ L^{2.9614}$
Apr '04	57	-5.0301	0.00000933	3.0365	0.9917	$W = 0.00000933\ L^{3.0365}$
May '04	51	-4.9576	0.00001057	3.0108	0.9917	$W = 0.00001057\ L^{3.0108}$
Jun '04	24	-5.2152	0.00000609	3.1210	0.9924	$W = 0.00000609\ L^{3.1210}$
2003 - 2004	512	-5.2943	0.00000508	3.1528	0.9812	$W = 0.00000508\ L^{3.1528}$

Table 2.1.2: *R. kanagurta* male: Length-Weight Relationship for the period Aug '03 - Jun '04

Month	n	A	A	b	r	$W = a L^{b}$
Aug '03	12	-5.7886	0.00000163	3.3673	0.9859	$W = 0.00000163\ L^{3.3673}$
Sep '03	36	-5.5259	0.00000298	3.2444	0.9534	$W = 0.00000298\ L^{3.2444}$
Oct '03	29	-5.0387	0.00000915	3.0417	0.9568	$W = 0.00000915\ L^{3.0417}$
Nov '03	42	-4.7752	0.00001678	2.9293	0.9885	$W = 0.00001678\ L^{2.9293}$
Dec '03	54	-4.7602	0.00001737	2.9241	0.9903	$W = 0.00001737\ L^{2.9241}$
Jan '04	51	-4.7005	0.00001993	2.9024	0.9886	$W = 0.00001993\ L^{2.9024}$
Feb '04	50	-4.9569	0.00001104	3.0022	0.9847	$W = 0.00009569\ L^{3.0022}$
Mar '04	49	-4.7737	0.00001683	2.9265	0.9945	$W = 0.00007737\ L^{2.9265}$
Apr '04	55	-5.1999	0.00000631	3.1095	0.9932	$W = 0.00000631\ L^{3.1095}$
May '04	47	-4.9590	0.00001099	3.0096	0.9906	$W = 0.00001099\ L^{3.0096}$
Jun '04	23	-5.1622	0.00000688	3.0975	0.9851	$W = 0.00000688\ L^{3.0975}$
2003 - 2004	448	-5.0452	0.00000901	3.0451	0.9853	$W = 0.00000901\ L^{3.0451}$

Table 2.1.3: *R. kanagurta* female: Length-Weight Relationship for the period Aug '04 - Aug '05

Month	n	A	A	b	r	$W = a L^{b}$
Aug '04	56	-5.6790	0.00000209	3.3302	0.9906	$W = 0.00000209\ L^{3.3302}$
Sep '04	41	-5.9201	0.00000120	3.4293	0.9955	$W = 0.00000120\ L^{3.4293}$
Oct '04	47	-4.9719	0.00001067	3.0105	0.9944	$W = 0.00001067\ L^{3.0105}$
Nov '04	49	-5.2122	0.00000613	3.1135	0.9909	$W = 0.00000613\ L^{3.1135}$
Dec '04	47	-5.8826	0.00000131	3.4052	0.9893	$W = 0.00000131\ L^{3.4052}$
Jan '05	48	-5.5453	0.00000285	3.2602	0.9779	$W = 0.00000285\ L^{3.2602}$
Feb '05	52	-5.0734	0.00000904	3.0519	0.9777	$W = 0.00000904\ L^{3.0519}$
Mar '05	60	-4.8982	0.00001264	2.9800	0.9939	$W = 0.00001264\ L^{2.9800}$
Apr '05	62	-4.8614	0.00001376	2.9664	0.9932	$W = 0.00001376\ L^{2.9664}$
May '05	51	-5.0972	0.00000799	3.0670	0.9897	$W = 0.00000799\ L^{3.0670}$
Jun '05	26	-4.9530	0.00001114	3.0115	0.9884	$W = 0.00001114\ L^{3.0115}$
Aug '05	51	-6.2679	0.00000054	3.5694	0.9584	$W = 0.00000054\ L^{3.5694}$
2004 – 2005	590	-5.9850	0.00000104	3.4490	0.9867	$W = 0.00000104\ L^{3.4490}$

Table 2.1.4: *R. kanagurta* male: Length-Weight Relationship for the period Aug '04 - Aug '05

Month	n	A	a	b	r	$W = a L^b$
Aug '04	42	-5.8031	0.00000157	3.3836	0.9960	$W = 0.00000157 L^{3.3836}$
Sep '04	40	-5.9211	0.00000120	3.4115	0.9136	$W = 0.00000120 L^{3.4115}$
Oct '04	42	-4.9601	0.00001096	3.0048	0.9935	$W = 0.00001096 L^{3.0048}$
Nov '04	46	-4.8084	0.00001555	2.9411	0.9948	$W = 0.00001555 L^{2.9411}$
Dec '04	54	-5.7024	0.00000198	3.3269	0.9860	$W = 0.00000198 L^{3.3269}$
Jan '05	44	-4.9480	0.00001038	3.0052	0.9869	$W = 0.00001038 L^{3.0052}$
Feb '05	43	-4.9889	0.00001026	3.0170	0.9843	$W = 0.00001026 L^{3.0170}$
Mar '05	44	-4.9927	0.00001017	3.0208	0.9948	$W = 0.00001017 L^{3.0208}$
Apr '05	53	-4.8062	0.00001562	2.9422	0.9944	$W = 0.00001562 L^{2.9422}$
May '05	45	-4.8994	0.00001261	2.9845	0.9923	$W = 0.00001261 L^{2.9845}$
Jun '05	21	-4.9982	0.00001004	3.0291	0.9893	$W = 0.00001004 L^{3.0291}$
Aug '05	42	-6.3074	0.00000049	3.5925	0.9740	$W = 0.00000049 L^{3.5925}$
2004 - 2005	516	-5.7339	0.00000185	3.3414	0.9789	$W = 0.00000185 L^{3.3414}$

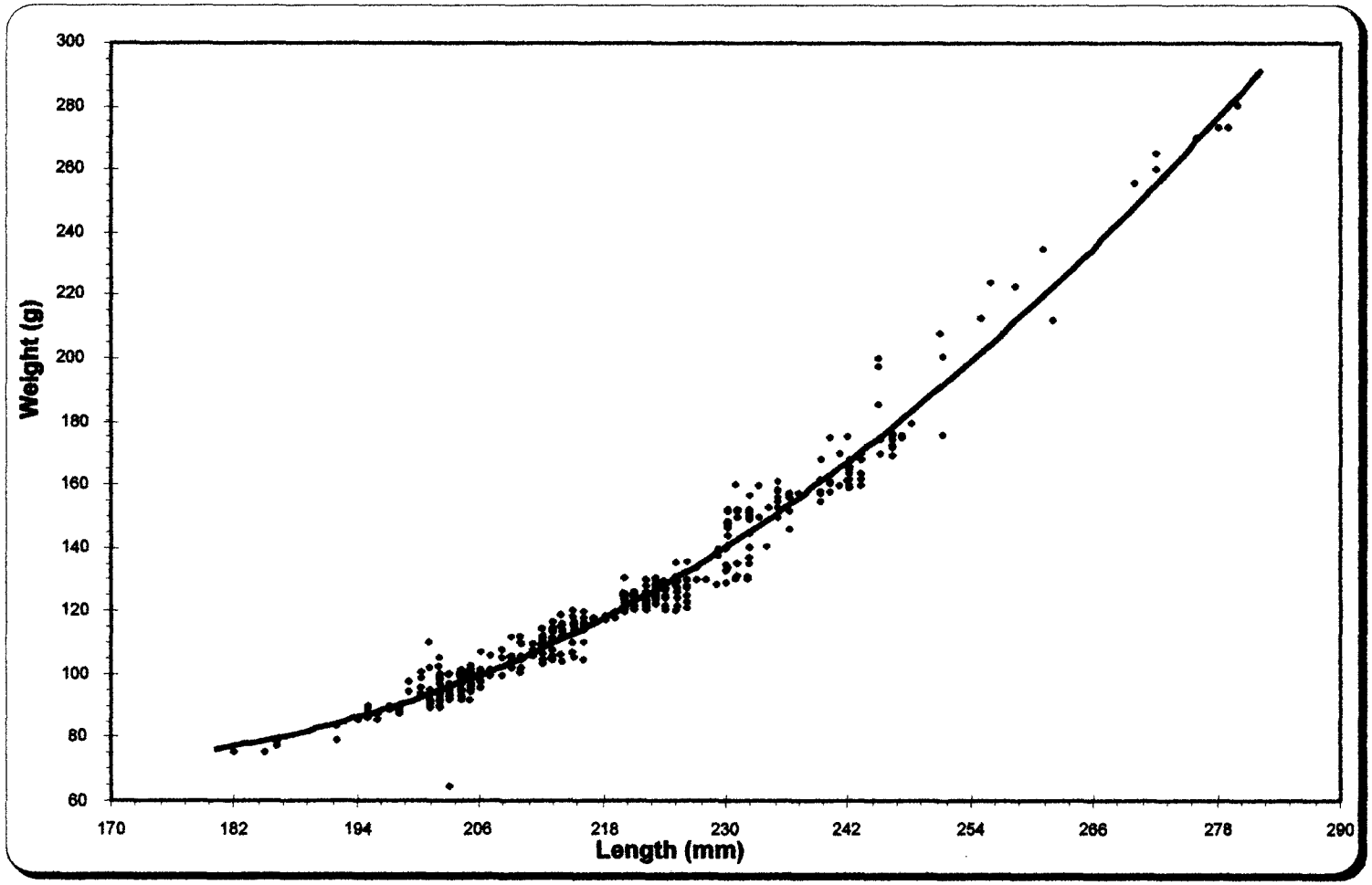


Fig. 2.1.1: *R. kanagurta* female: L-W Relationship for the period Aug '03 - Jun '04

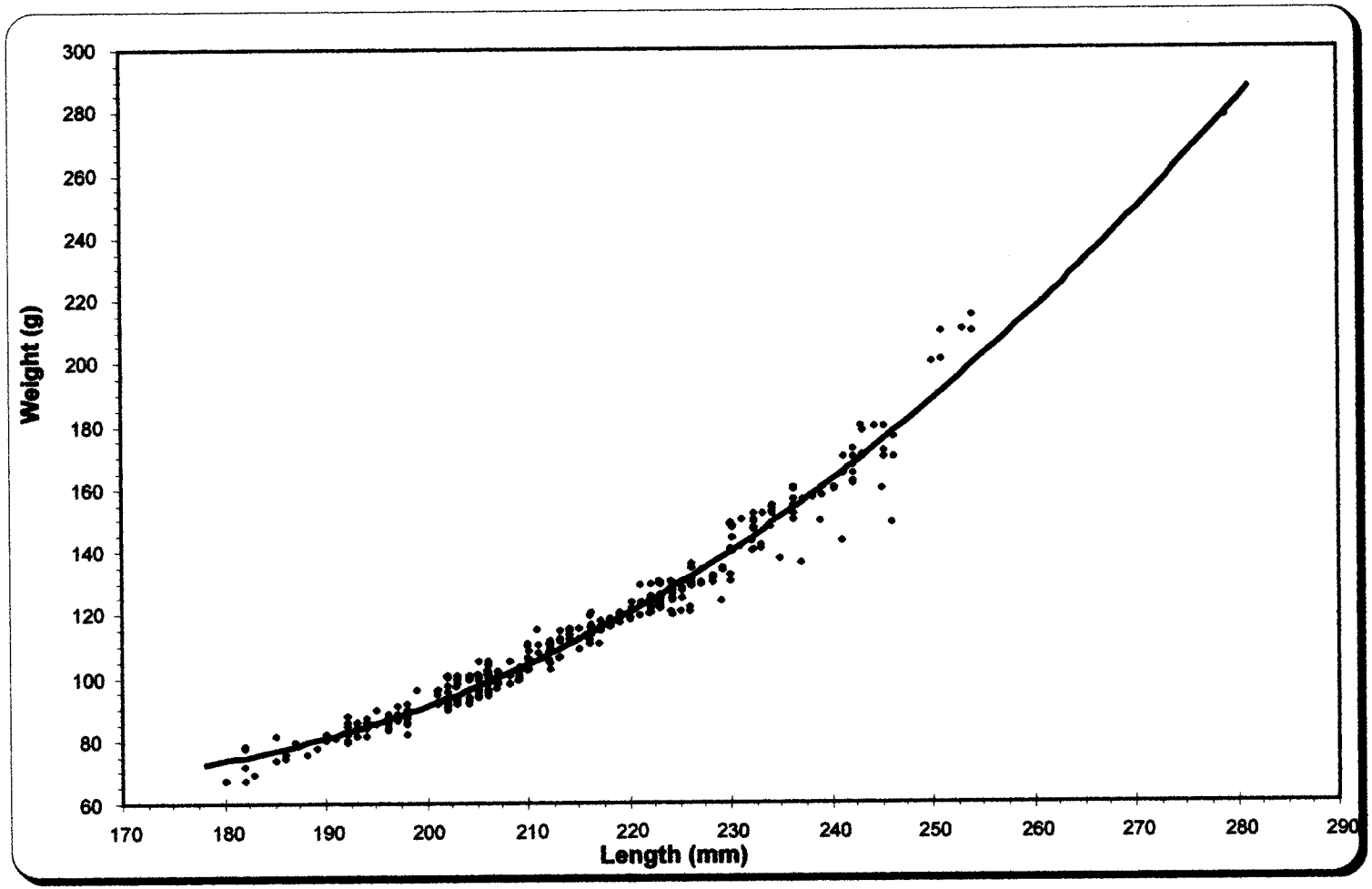


Fig. 2.1.2: *R. kanagurta* male: L-W Relationship for the period Aug '03 - Jun '04

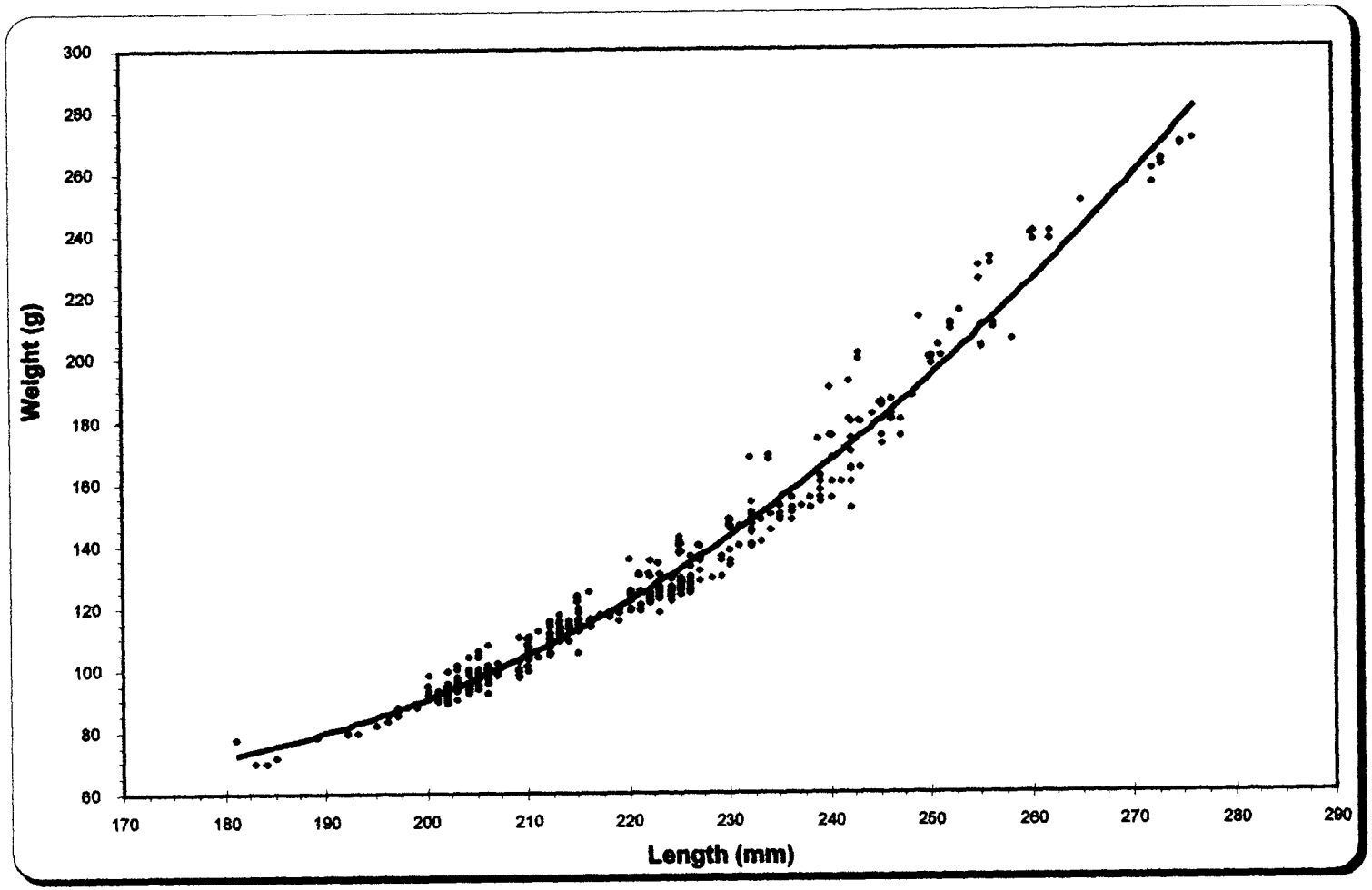


Fig. 2.1.3: *R. kanagurta* female: L-W Relationship for the period Aug '04 - Aug '05

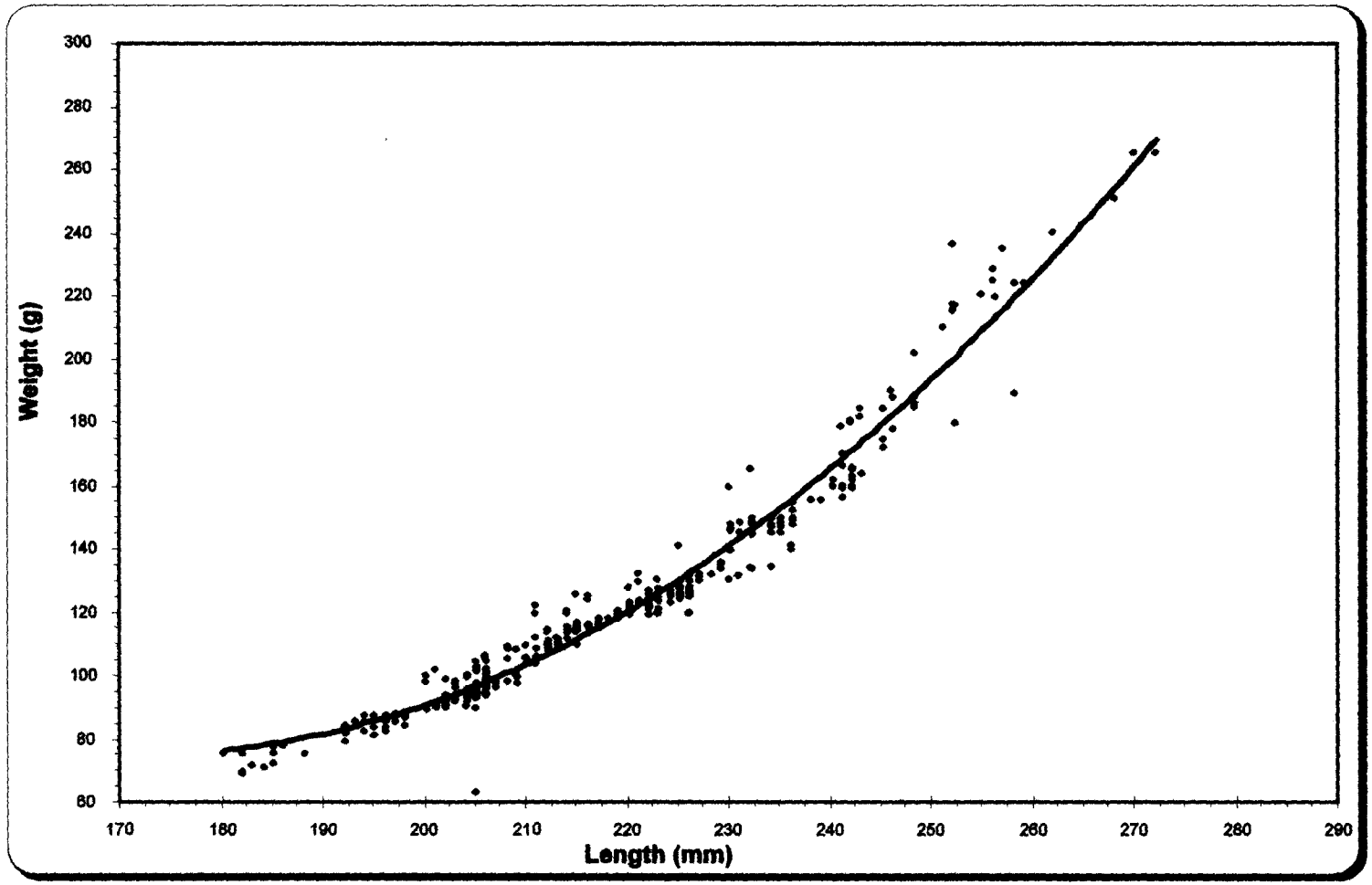


Fig. 2.1.4: *R. kanagurta* male: L-W Relationship for the period Aug '04 - Aug '05

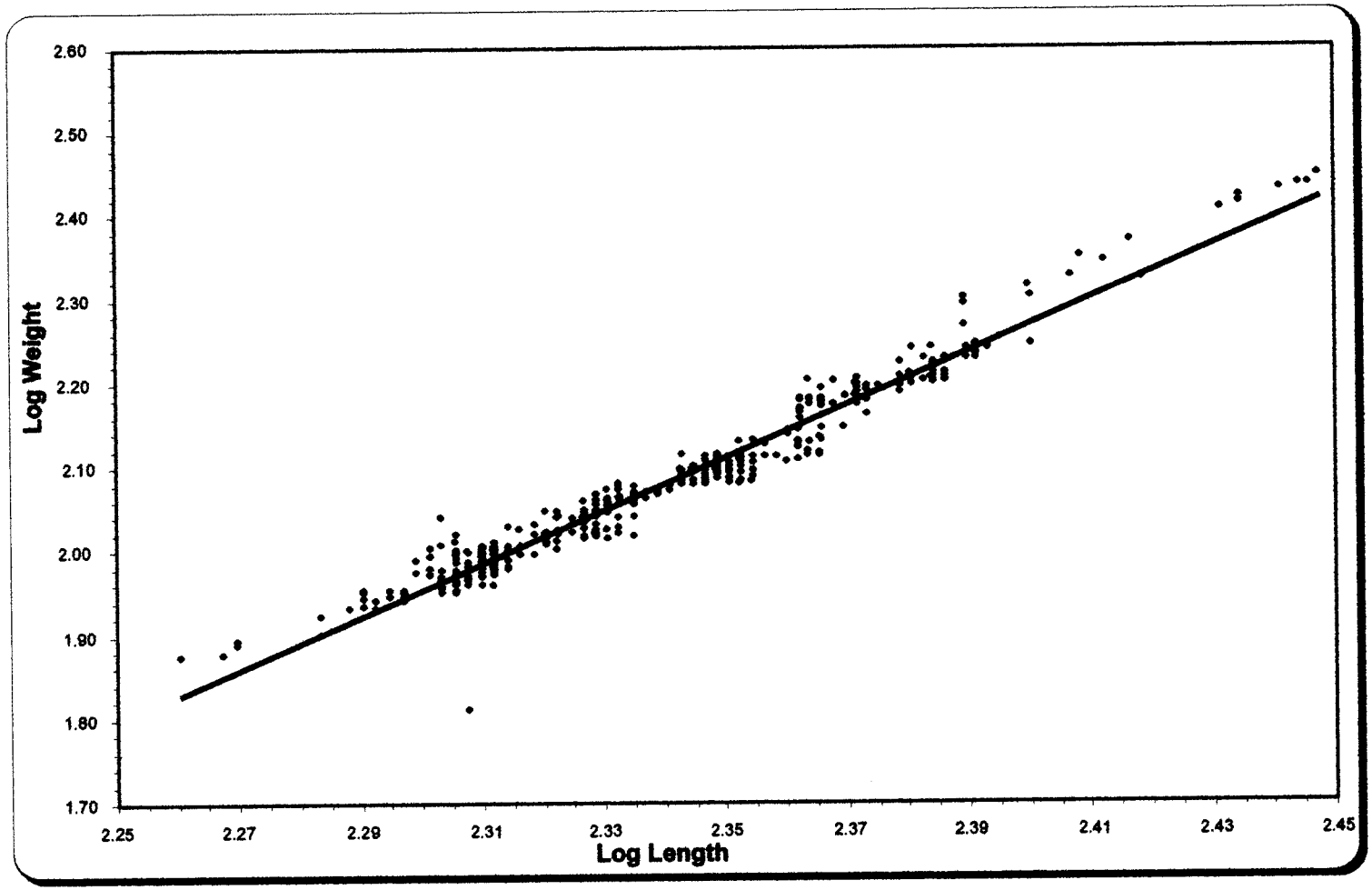


Fig. 2.1.5: *R. kanagurta* female: Logarithmic L-W Relationship for the period Aug '03 - Jun '04

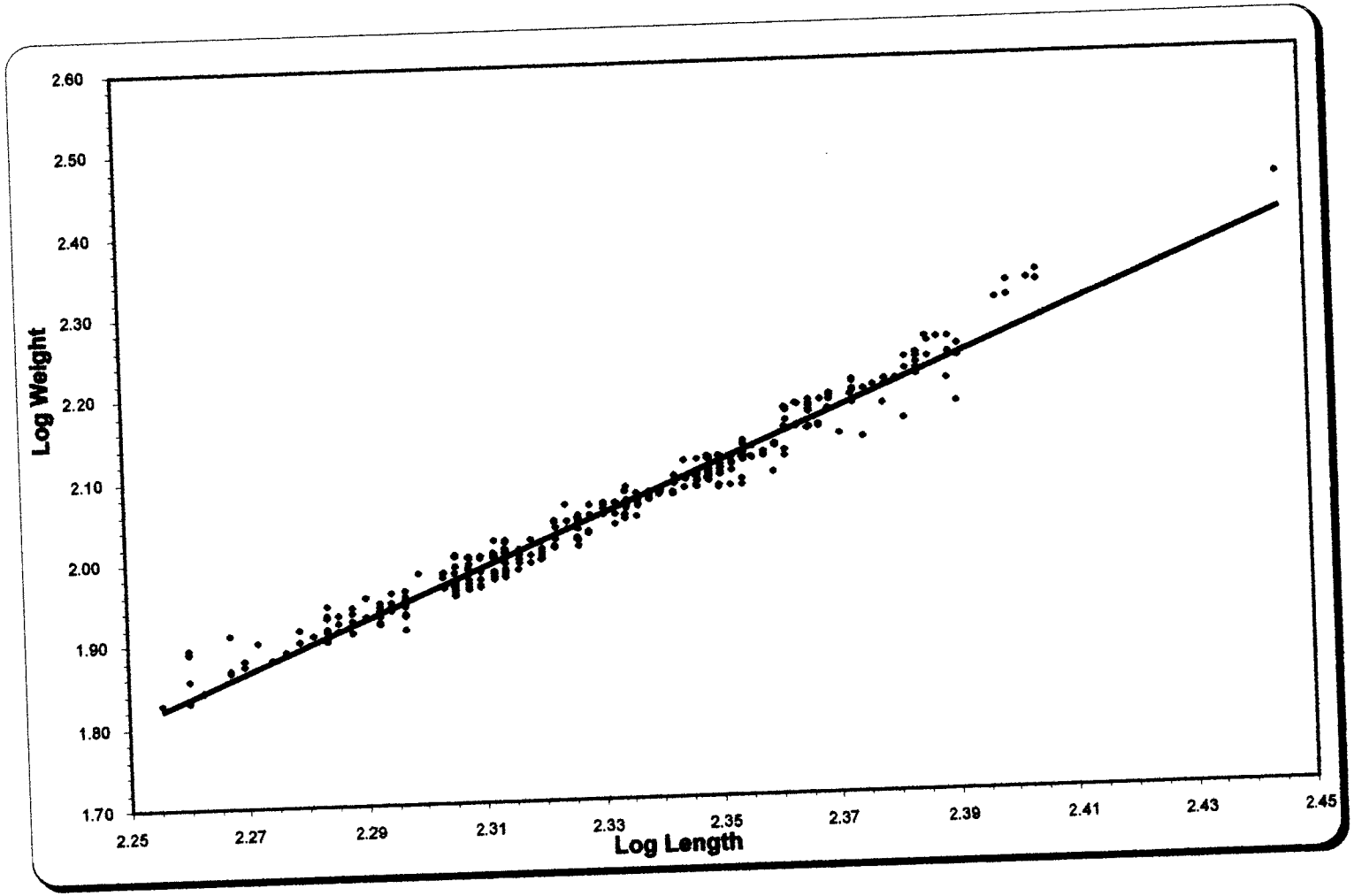


Fig. 2.1.6: *R. kanagurta* male: Logarithmic L-W Relationship for the period Aug '03 - Jun '04

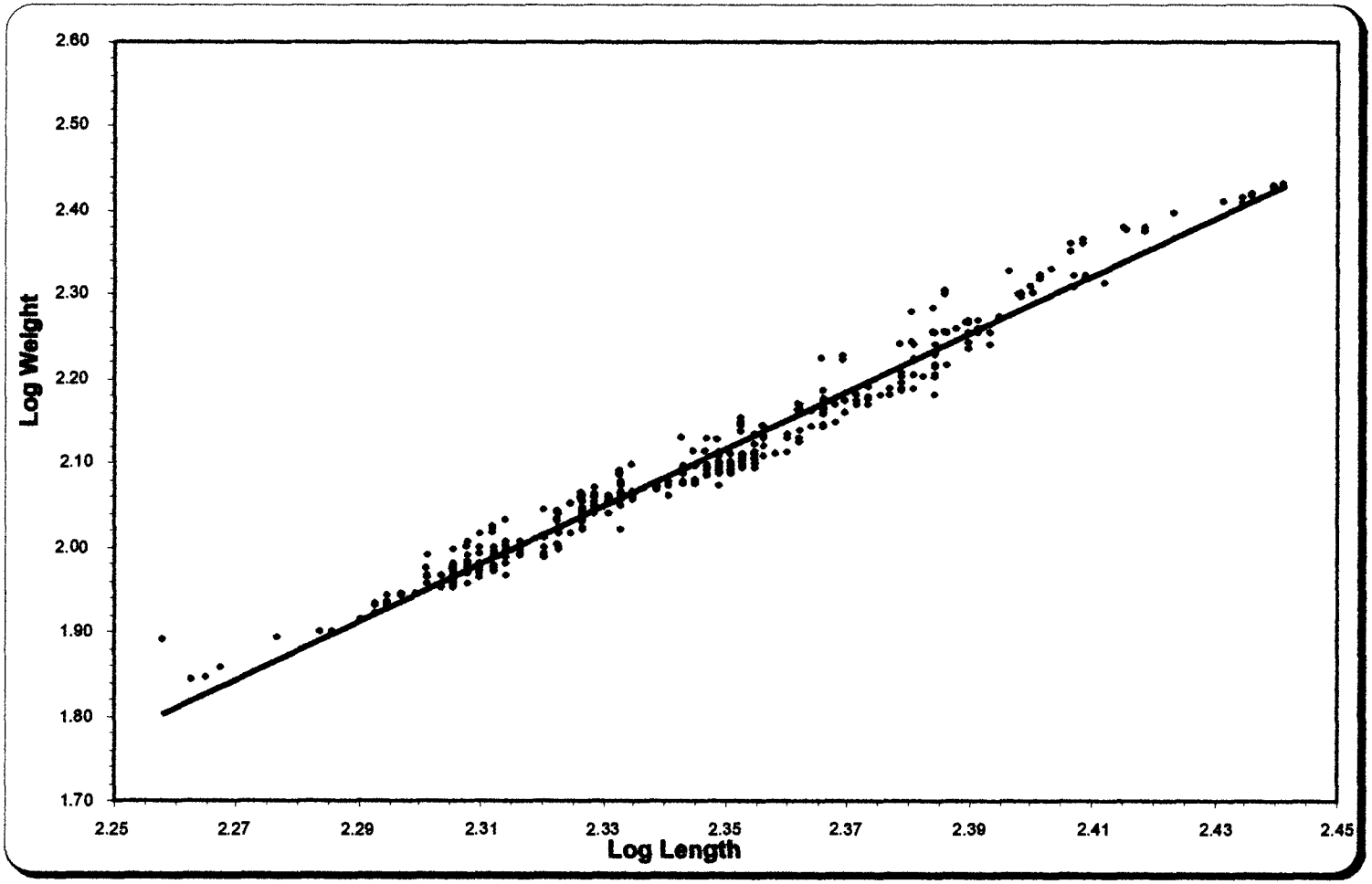


Fig. 2.1.7: *R. kanagurta* female: Logarithmic L-W Relationship for the period Aug '04 - Aug '05

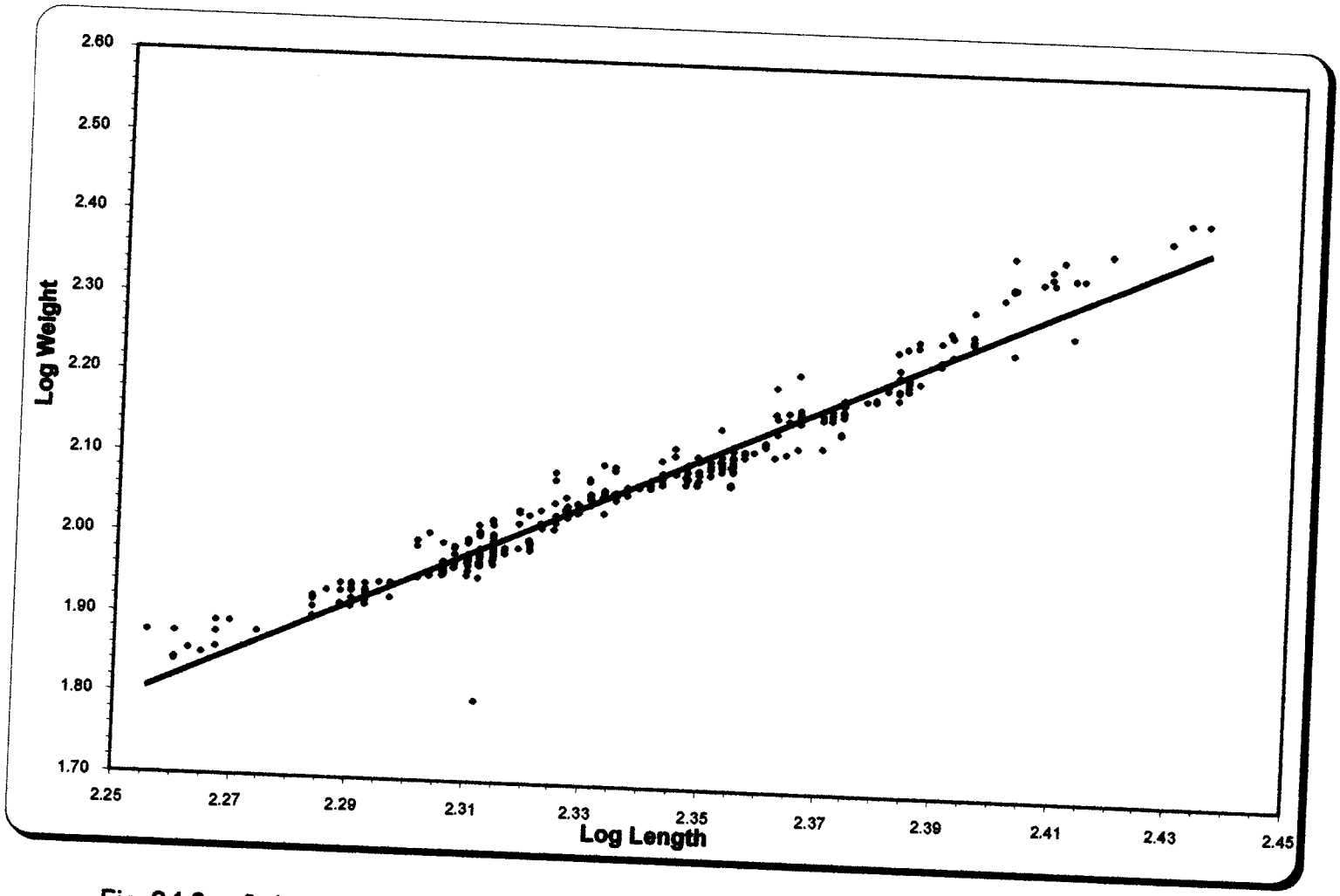


Fig. 2.1.8: *R. kanagurta* male: Logarithmic L-W Relationship for the period Aug '04 - Aug '05

Table 2.1.5: Analysis of Co-variance of Length-Weight Relationship of *R. kanagurta* during Aug '03 - Jun '04

Source of Variation	Degree Of Freedom (df) (n - 1)	$\sum x^2$	$\sum xy$	$\sum y^2$	b	Deviation From Regression			
						df (n - 2)	Sum of Squares	Mean Sum of Squares	F Ratio
Females	511	0.49	1.54	5.0002	3.1528	510	0.1322	0.000259	9.93*
Males	447	0.43	1.30	4.0742	3.0451	446	0.1190	0.000267	
Deviation from the Individual Regression Within Sexes						956	0.2512	0.000263	
Pooled	958	0.9163	2.843	9.0744	3.0990	957	0.2538	0.000265	
Difference Between Slopes							0.0026		

'* Significant at 5% Level

Table 2.1.6: Analysis of Co-variance of Length-Weight Relationship of *R. kanagurta* during Aug '04 - Aug '05

Source of Variation	Degree Of Freedom (df) (n - 1)	$\sum x^2$	$\sum xy$	$\sum y^2$	b	Deviation From Regression			
						df (n - 2)	Sum of Squares	Mean Sum of Squares	F Ratio
Females	589	0.78	2.68	9.4988	3.4490	588	0.2508	0.000427	7.93*
Males	515	0.61	2.03	7.0875	3.3414	514	0.2955	0.000575	
Deviation from the Individual Regression Within Sexes						1102	0.5463	0.000496	
Pooled	1104	1.3858	4.7141	16.5863	3.3952	1103	0.5503	0.000499	
Difference Between Slopes							0.0040		

* Significant at 5% Level

Table 2.2.1: Monthly mean Kn of *R. kanagurta* for the period Aug '03 - Jun '04

Month	Female		Male	
	No.	Mean Kn	No.	Mean Kn
Aug '03	19	1.0008	12	1.0013
Sep '03	45	1.0022	36	1.0020
Oct '03	39	1.0010	29	1.0008
Nov '03	50	1.0007	42	1.0003
Dec '03	58	1.0008	54	1.0003
Jan '04	61	1.0007	51	1.0046
Feb '04	53	1.0015	50	1.0002
Mar '04	55	1.0003	49	1.0002
Apr '04	57	1.0002	55	1.0002
May '04	51	1.0003	47	1.0004
Jun '04	24	1.0001	23	1.0003
Total	**512**	**1.0010**	**448**	**1.0007**

Table 2.2.2: Monthly mean Kn of *R. kanagurta* for the period Aug '04 - Aug '05

Month	Female		Male	
	No.	Kn	No.	Kn
Aug '04	56	1.0008	42	1.0004
Sep '04	41	1.0003	40	1.0032
Oct '04	47	1.0002	42	1.0002
Nov '04	49	1.0003	46	1.0003
Dec '04	47	1.0006	54	1.0011
Jan '05	48	1.0012	44	1.0007
Feb '05	52	1.0003	43	1.0003
Mar '05	60	1.0001	44	1.0001
Apr '05	62	1.0001	53	1.0002
May '05	51	1.0003	45	1.0003
Jun '05	26	1.0004	21	1.0004
Aug '05	51	1.0036	42	1.0029
Total	**590**	**1.0011**	**516**	**1.0015**

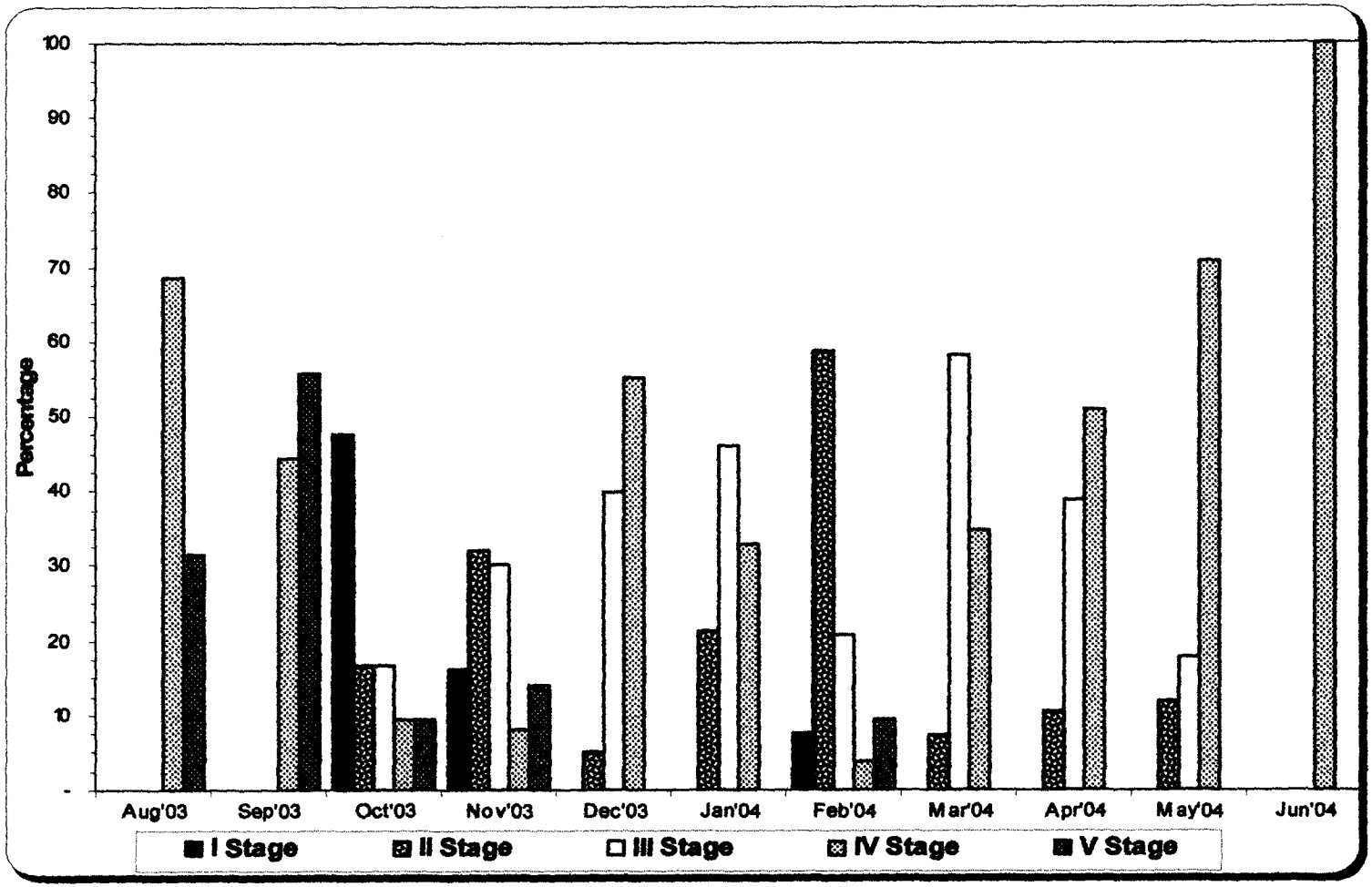


Fig. 2.3.1: *R. kanagurta* female: Percentage maturity stages for the period Aug '03 - Jun '04

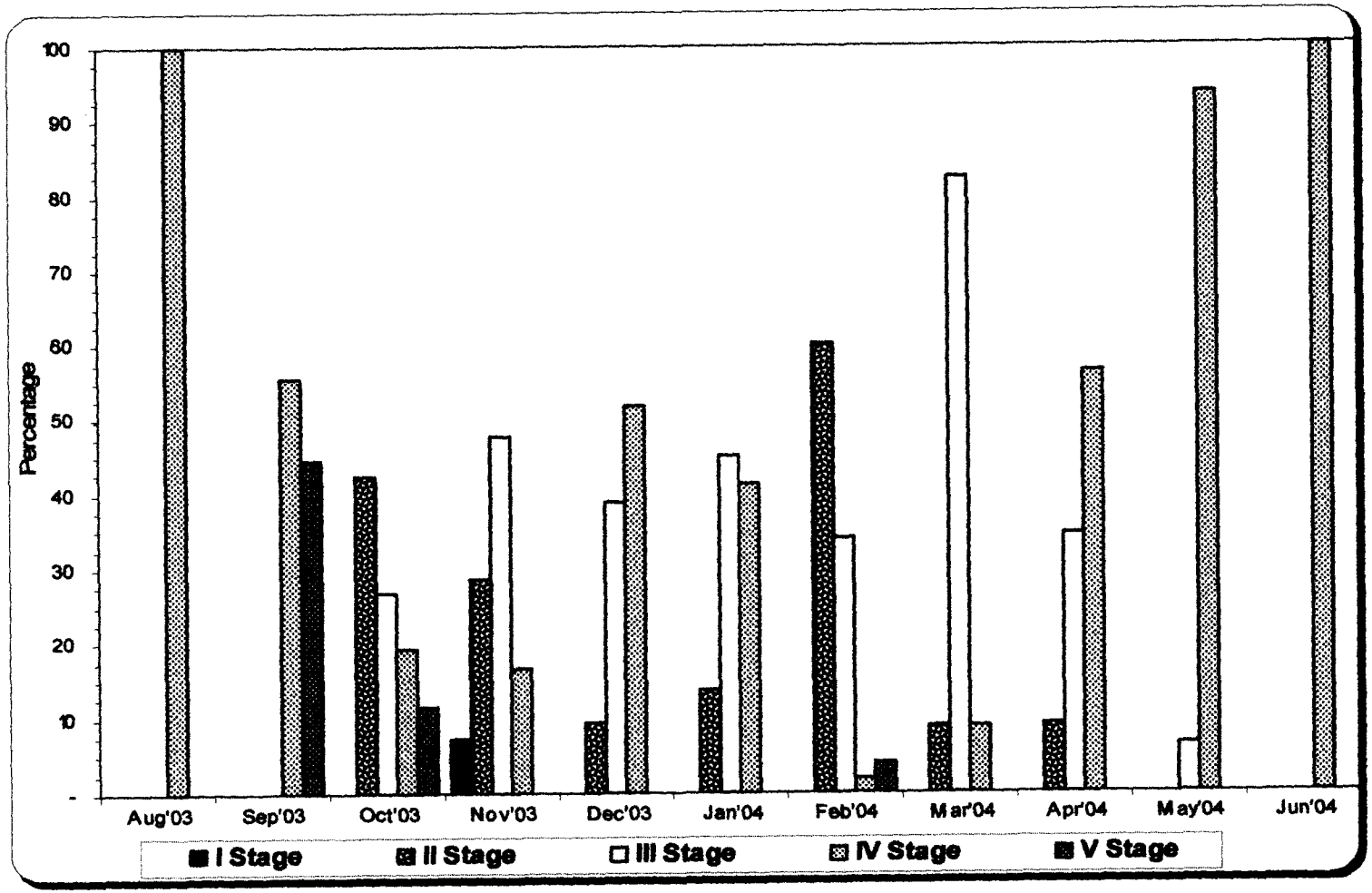


Fig. 2.3.2: *R. kanagurta* male: Percentage maturity stages for the period Aug '03 - Jun '04

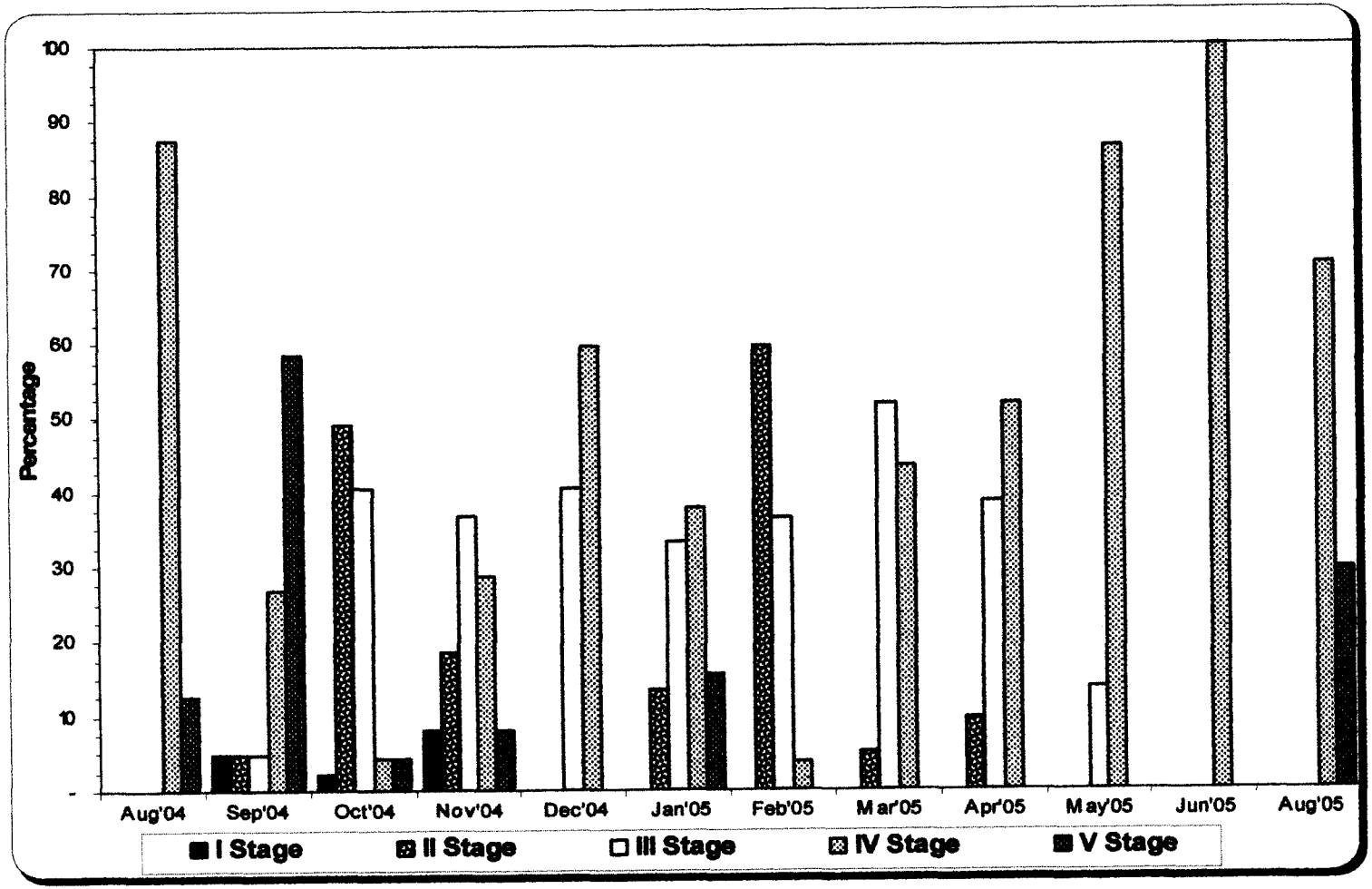


Fig. 2.3.3: *R. kanagurta* female: Percentage maturity stages for the period Aug '04 - Aug '05

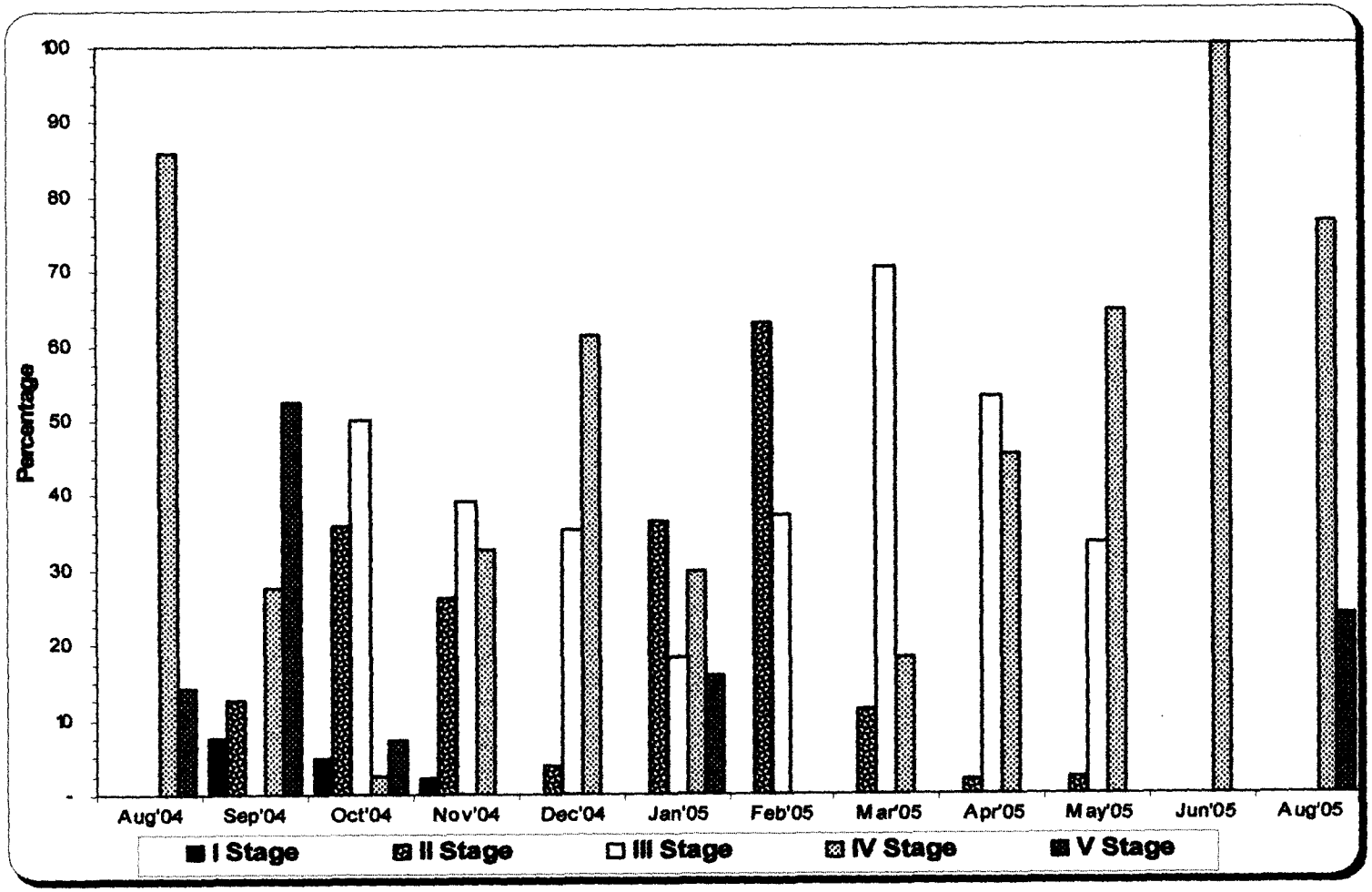


Fig. 2.3.4: *R. kanagurta* male: Percentage maturity stages for the period Aug '04 - Aug '05

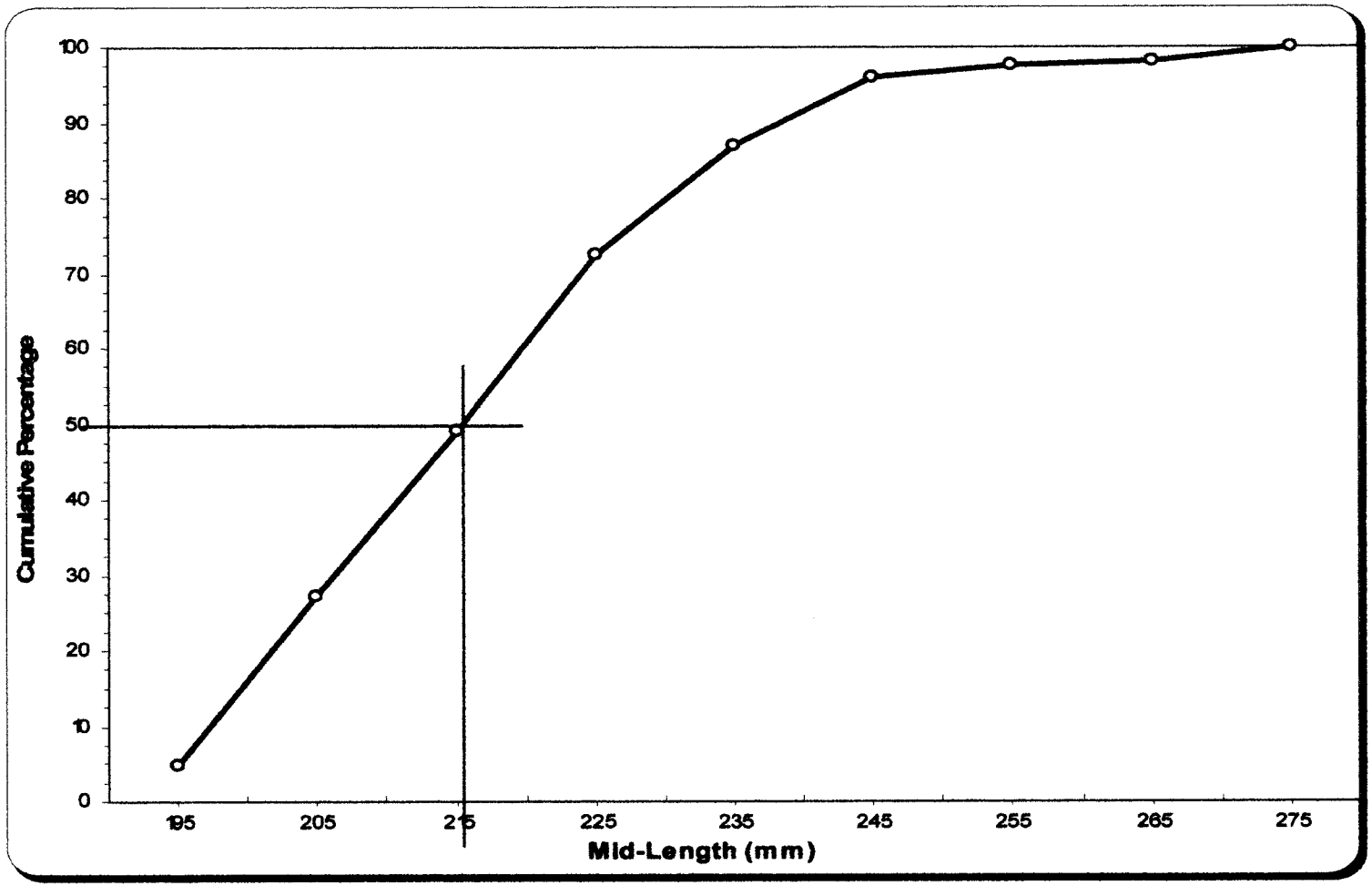


Fig. 2.3.5: *R. kanagurta* female: Size at 1st maturity for the period Aug '03 - Jun '04

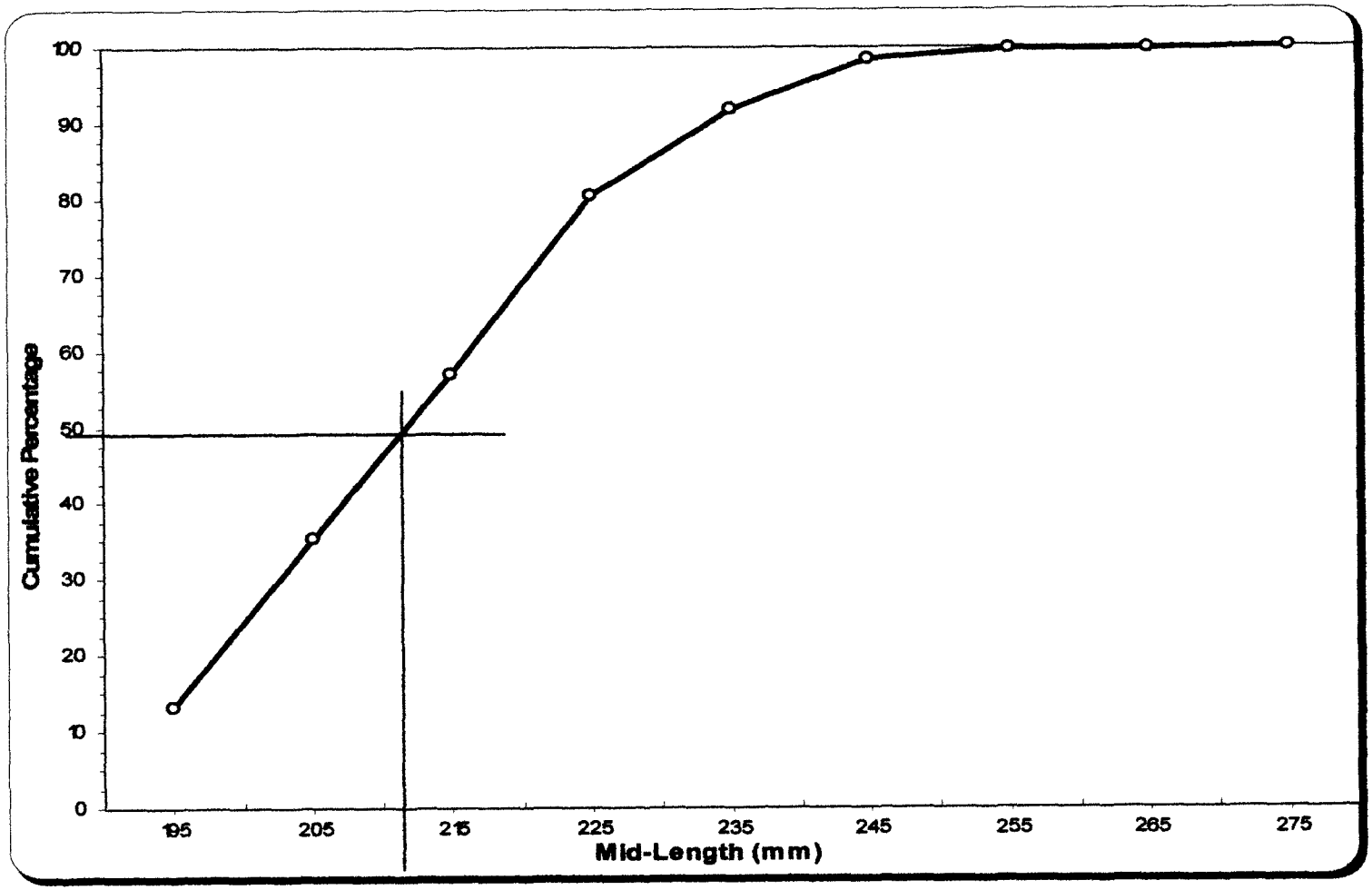


Fig. 2.3.6: *R. kanagurta* male: Size at 1st maturity for the period Aug '03 - Jun '04

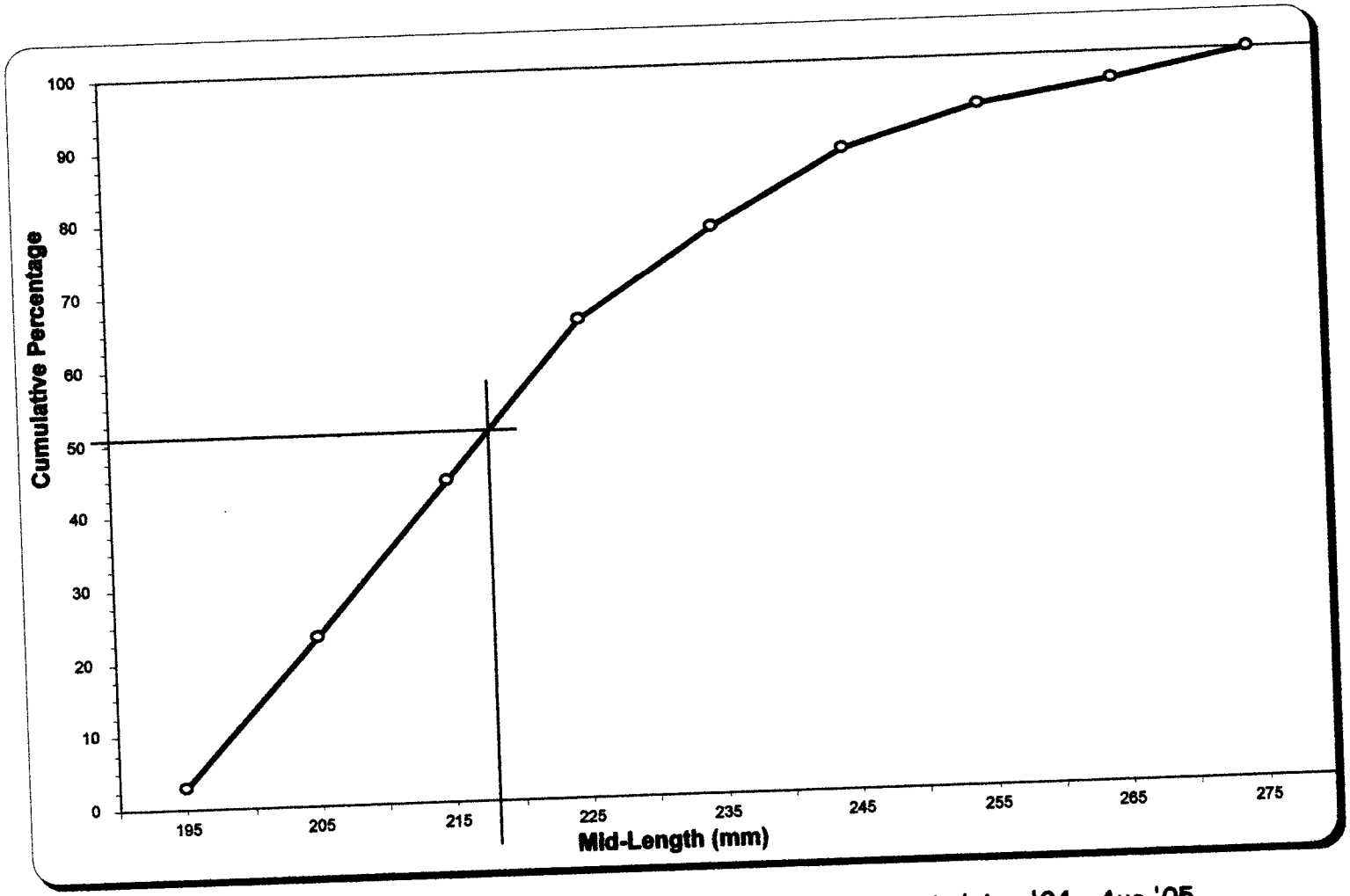


Fig. 2.3.7: *R. kanagurta* female: Size at 1st maturity for the period Aug '04 - Aug '05

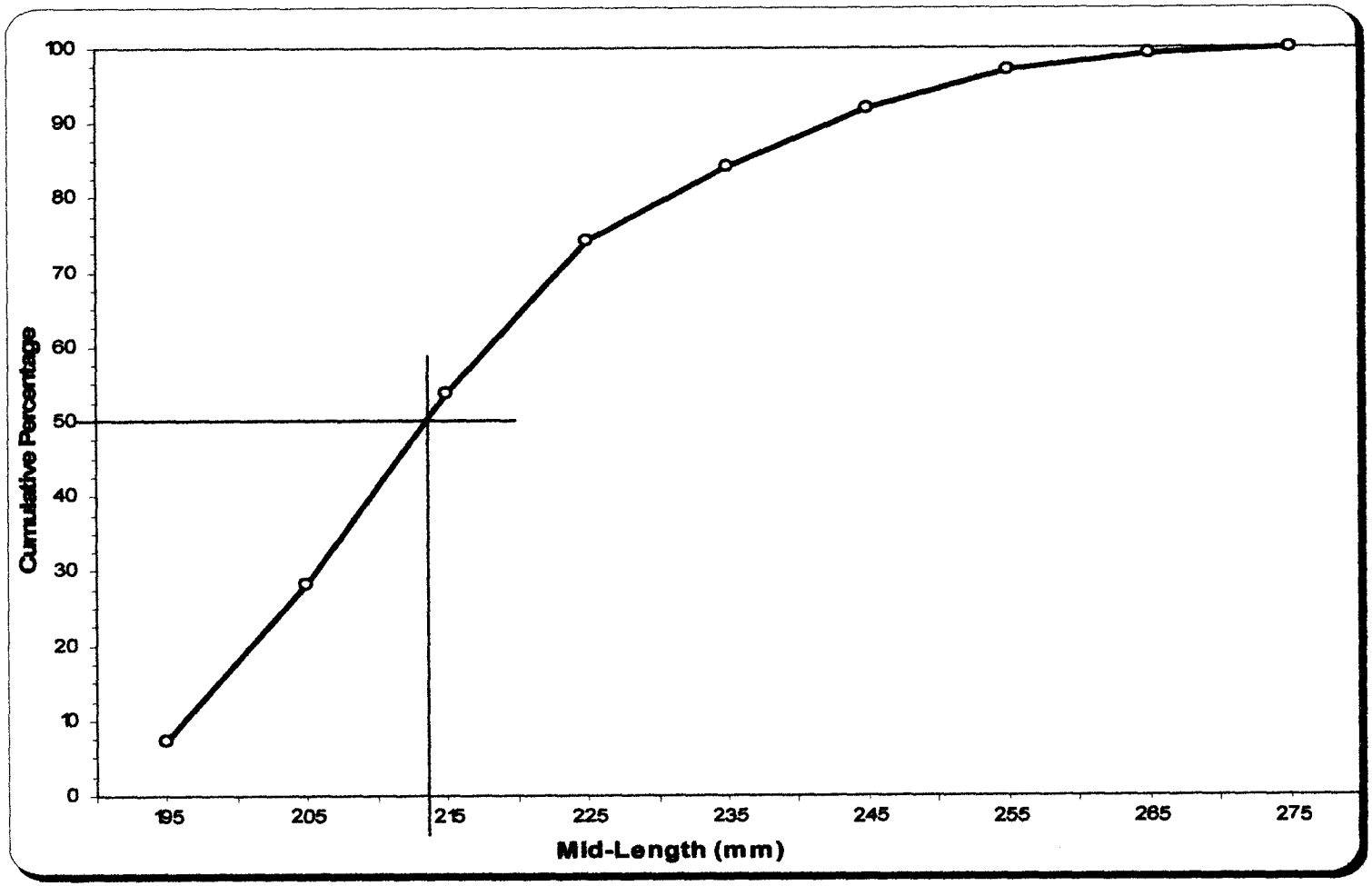


Fig. 2.3.8: *R. kanagurta* male: Size at 1st maturity for the period Aug '04 - Aug '05

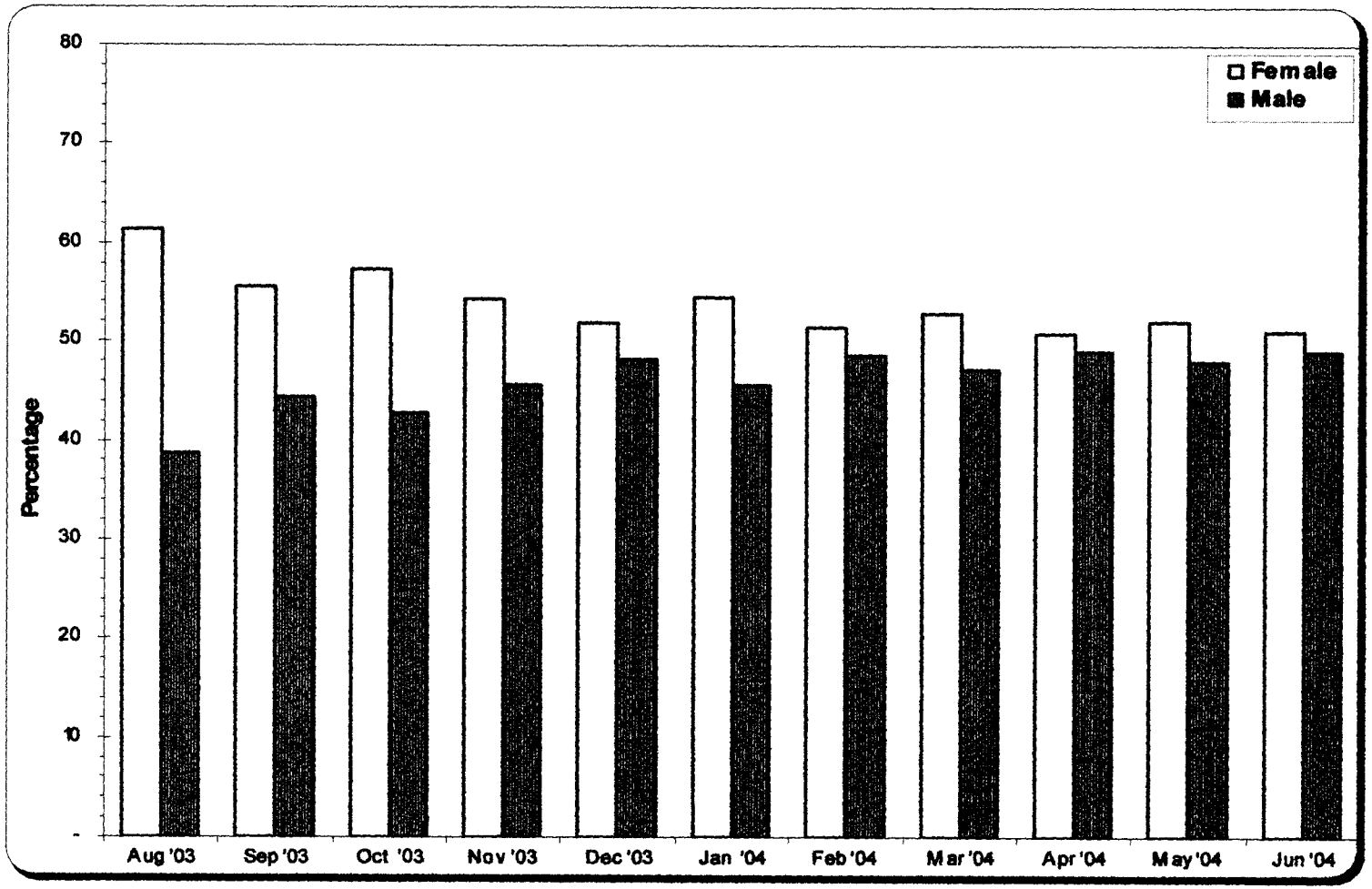


Fig. 2.3.9: *R. kanagurta*. Percentage occurrence of females and males during Aug '03 - Jun '04

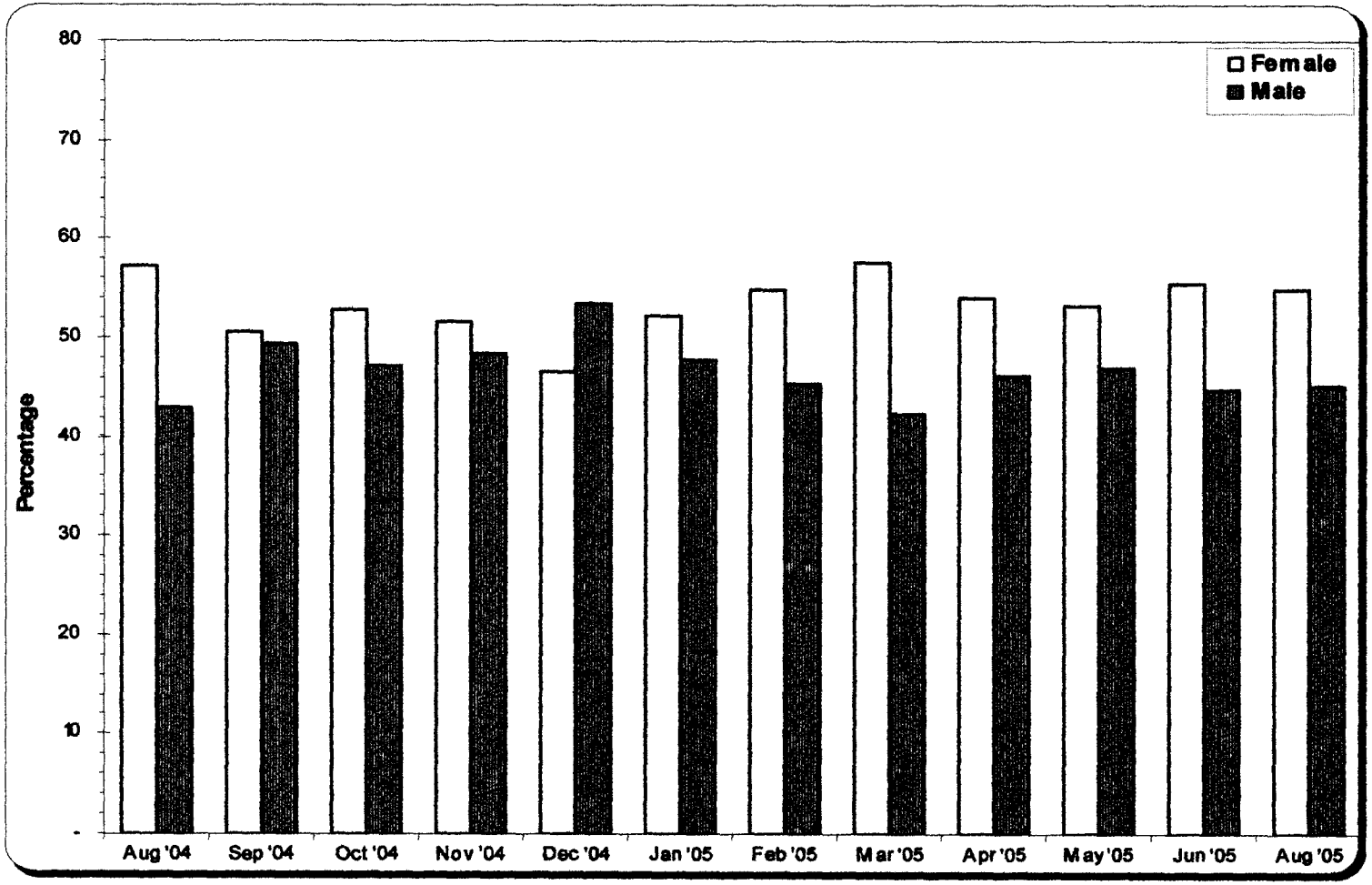


Fig. 2.3.10: *R. kanagurta*: Percentage occurrence of females and males during Aug '04 - Aug '05

Table 2.3.1: Sex Ratio of *R. kanagurta* in monthly samples during the period Aug '03 - Jun '04

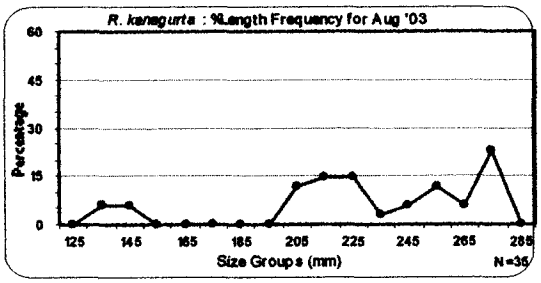
Month	Female	Male	Total	Female χ^2	Male χ^2	χ^2	F:M Ratio
Aug '03	19	12	31	0.7903	0.7903	1.5806	1.5833
Sep '03	45	36	81	0.5000	0.5000	1.0000	1.2500
Oct '03	39	29	68	0.7353	0.7353	1.4706	1.3448
Nov '03	50	42	92	0.3478	0.3478	0.6957	1.1905
Dec '03	58	54	112	0.0714	0.0714	0.1429	1.0741
Jan '04	61	51	112	0.4464	0.4464	0.8929	1.1961
Feb '04	53	50	103	0.0437	0.0437	0.0874	1.0600
Mar '04	55	49	104	0.1731	0.1731	0.3462	1.1224
Apr '04	57	55	112	0.0179	0.0179	0.0357	1.0364
May '04	51	47	98	0.0816	0.0816	0.1633	1.0851
Jun '04	24	23	47	0.0106	0.0106	0.0213	1.0435
2003 - 2004	**512**	**448**	**960**	**2.1333**	**2.1333**	**4.2667 ***	**1.1429**

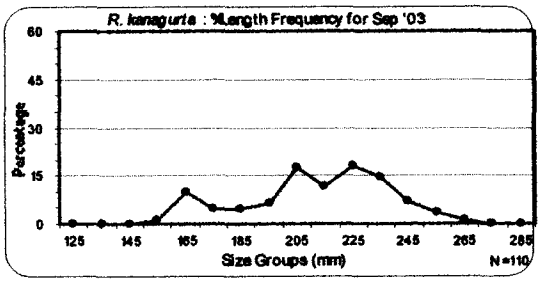
* Significant at 5% Level

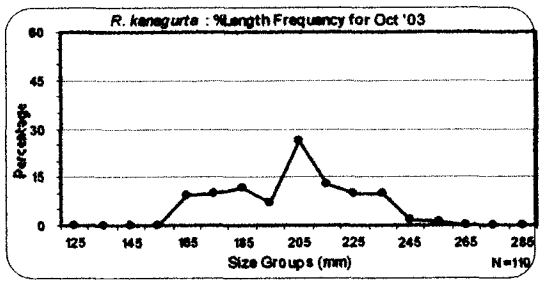
Table 2.3.2: Sex Ratio of *R. kanagurta* in Monthly Samples during the period Aug '04 - Aug '05

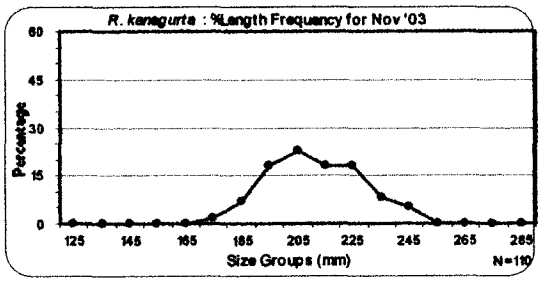
Month	Female	Male	Total	Female χ^2	Male χ^2	χ^2	F:M Ratio
Aug '04	56	42	98	1.0000	1.0000	2.0000	1.3333
Sep '04	41	40	81	0.0062	0.0062	0.0123	1.0250
Oct '04	47	42	89	0.1404	0.1404	0.2809	1.1190
Nov '04	49	46	95	0.0474	0.0474	0.0947	1.0652
Dec '04	47	54	101	0.2426	0.2426	0.4851	0.8704
Jan '05	48	44	92	0.0870	0.0870	0.1739	1.0909
Feb '05	52	43	95	0.4263	0.4263	0.8526	1.2093
Mar '05	60	44	104	1.2308	1.2308	2.4615	1.3636
Apr '05	62	53	115	0.3522	0.3522	0.7043	1.1698
May '05	51	45	96	0.1875	0.1875	0.3750	1.1333
Jun '05	26	21	47	0.2660	0.2660	0.5319	1.2381
Aug '05	51	42	93	0.4355	0.4355	0.8710	1.2143
2004 - 2005	**590**	**516**	**1106**	**2.4756**	**2.4756**	**4.9512 ***	**1.1434**

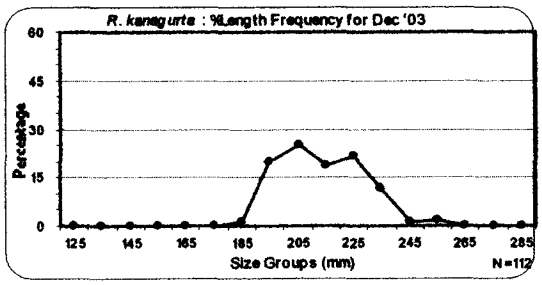
* Significant at 5% Level

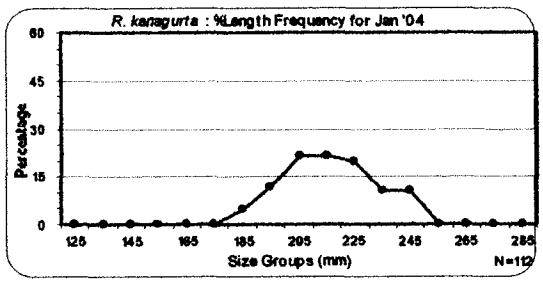


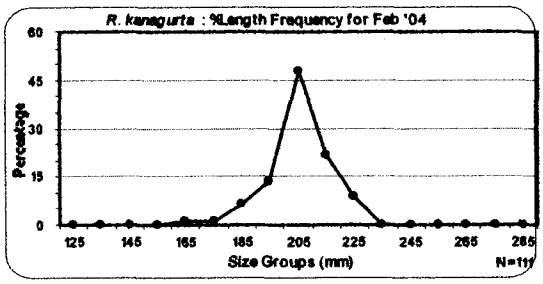


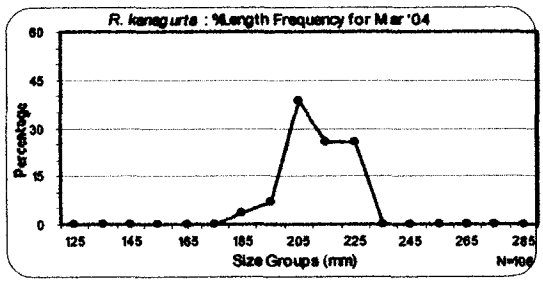


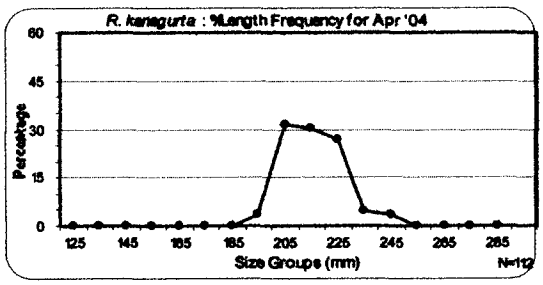


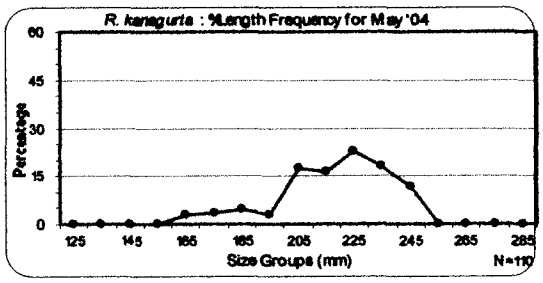












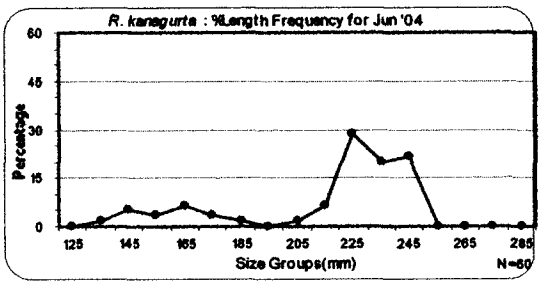


Fig. 2.4.1: Graphs depicting the percentage Length-Frequency of different size groups of *R. kanagurta* during Aug '03 - Jun '04.

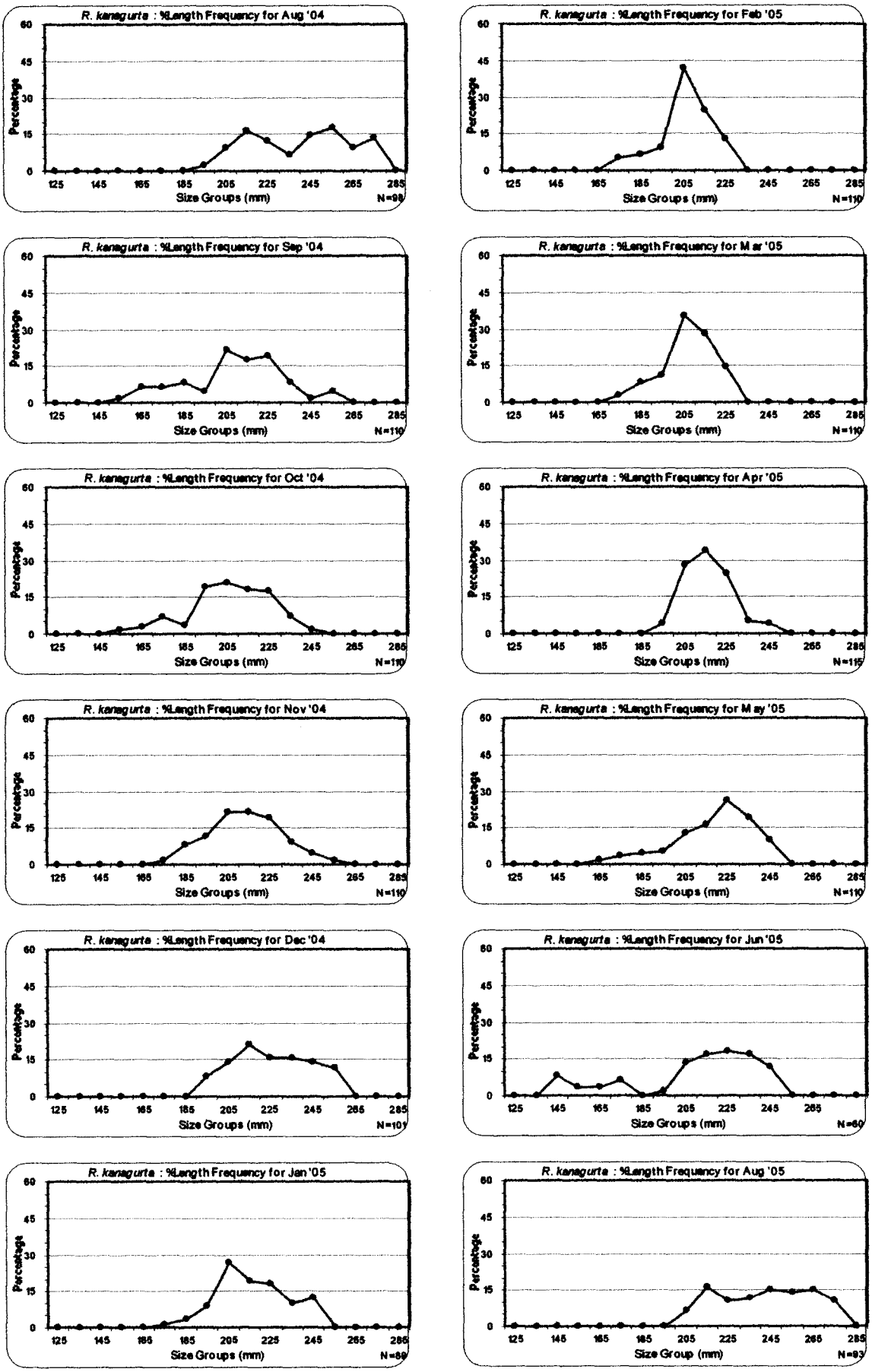


Fig. 2.4.2: Graphs depicting the percentage Length - Frequency of different size groups of *R. kanagurta* during Aug '04 - Aug '05.

Table 2.4.1: *R. kanagurta* Mean Length (mm) at yearly intervals derived from Length-Frequency method during Aug '03 - Jun '04

Years (t)	Mean Length	Growth Rate
0	155.00	-
I	201.36	46.36
II	225.00	23.64
III	245.00	20.00
IV	261.67	16.67

Table 2.4.2: *R. kanagurta* Mean Length (mm) at yearly intervals derived from Length-Frequency method during Aug '04 - Aug '05

Years (t)	Mean Length	Growth Rate
0	155.00	-
I	197.00	42.00
II	223.18	26.18
III	245.00	21.82
IV	263.00	18.00

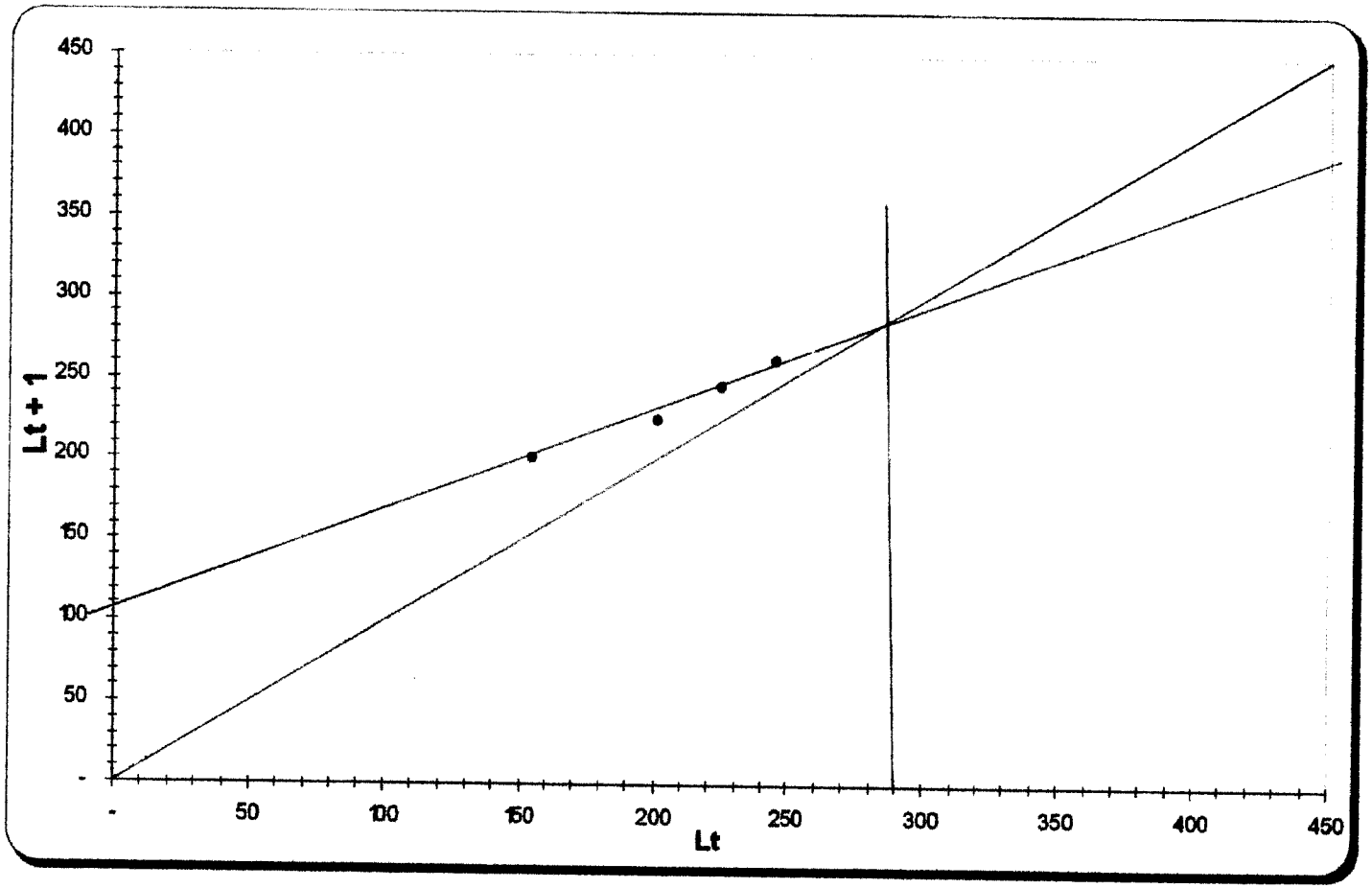


Fig. 2.4.3: *R. kanagurta*: Ford Wolford Plot for estimating L_∞ during Aug '03 - Jun '04

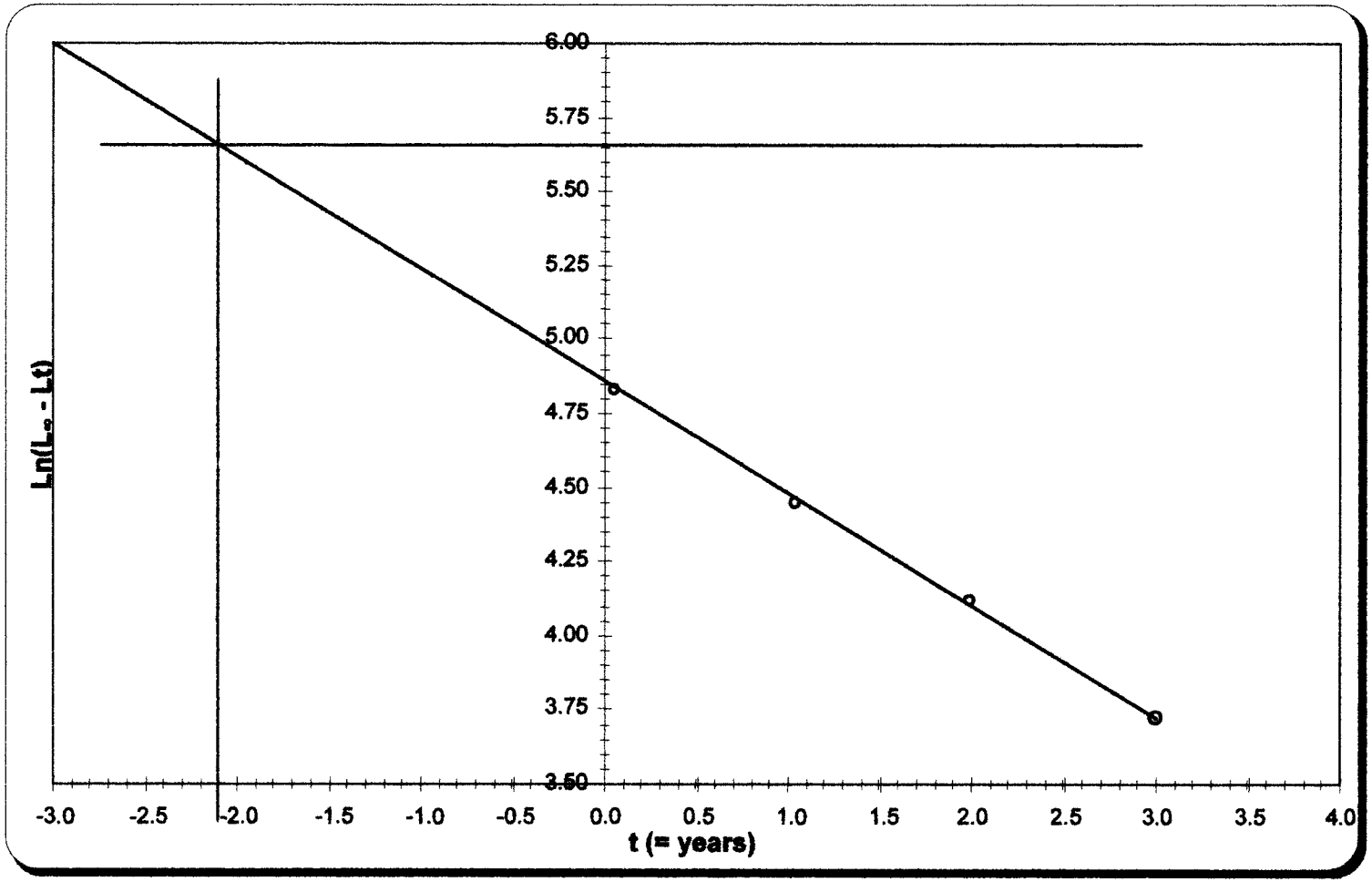


Fig. 2.4.4: *R. kanagurta*: Beverton & Holt Plot for estimating t_0 for period Aug '03 - Jun '04

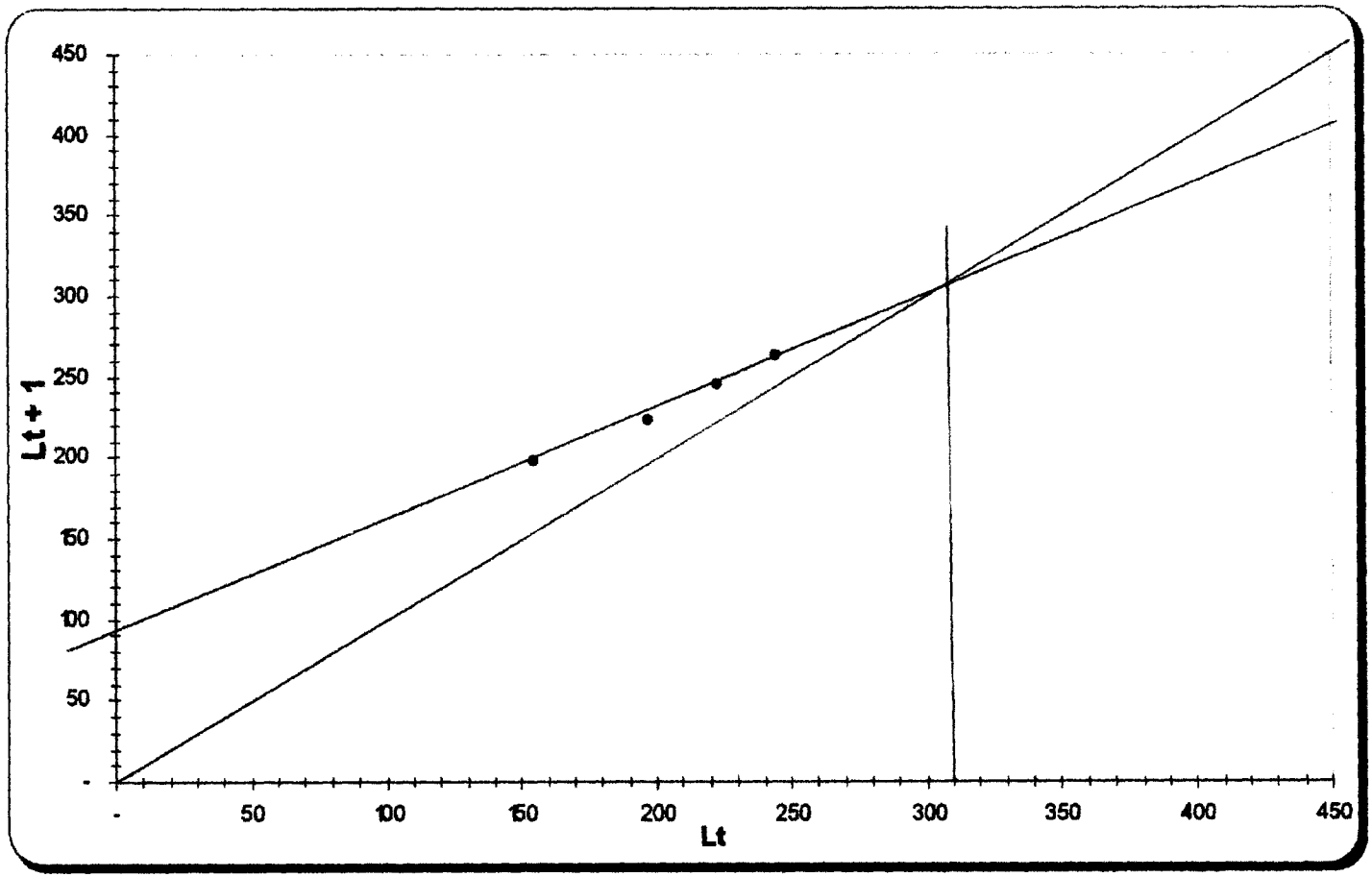


Fig. 2.4.5: *R. kanagurta*: Ford Wolford Plot for estimating L_∞ during Aug '04 - Aug '05

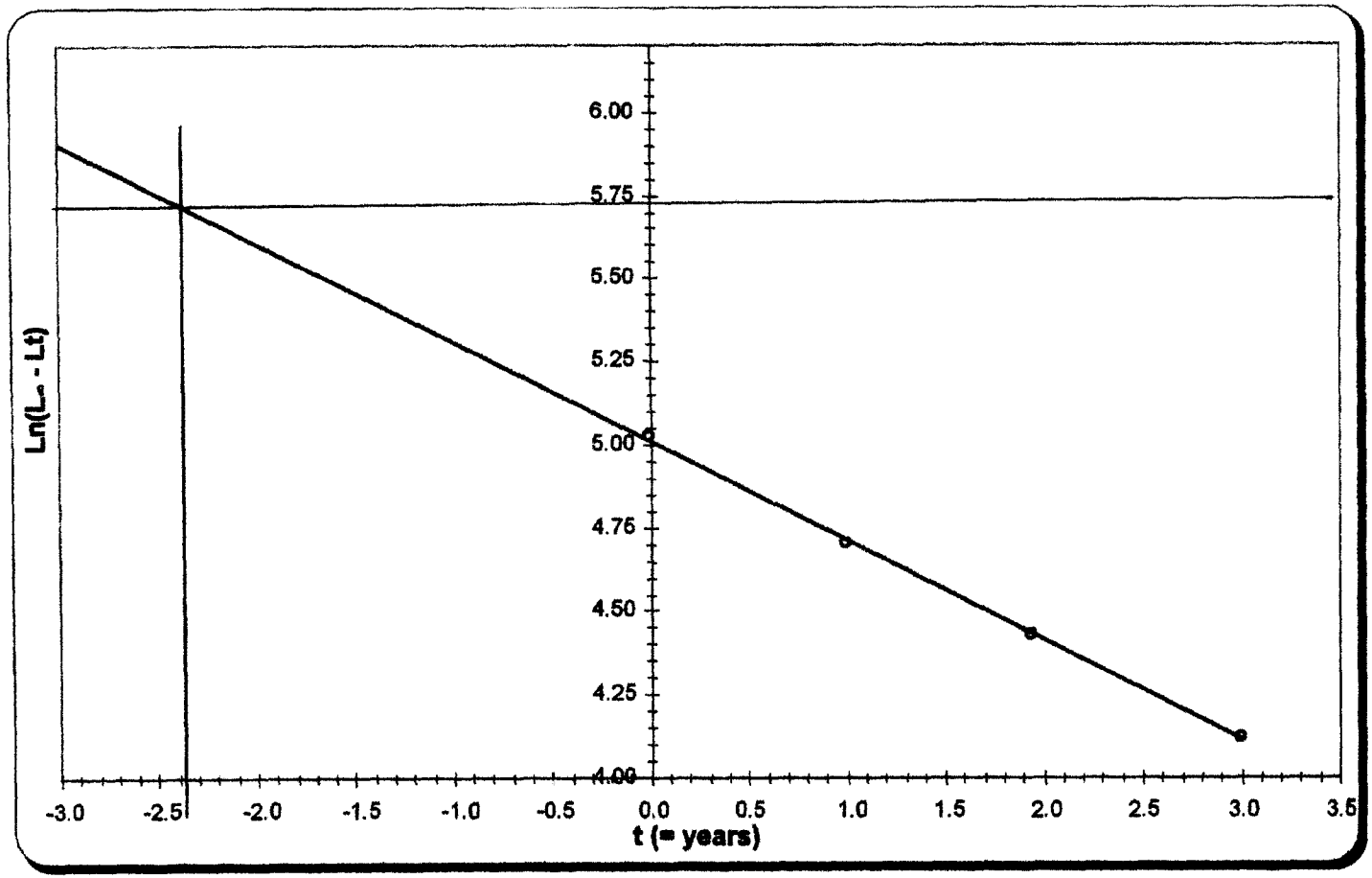


Fig. 2.4.6: *R. kanagurta*: Beverton & Holt Plot for estimating t_0 for period Aug '04 - Aug '05

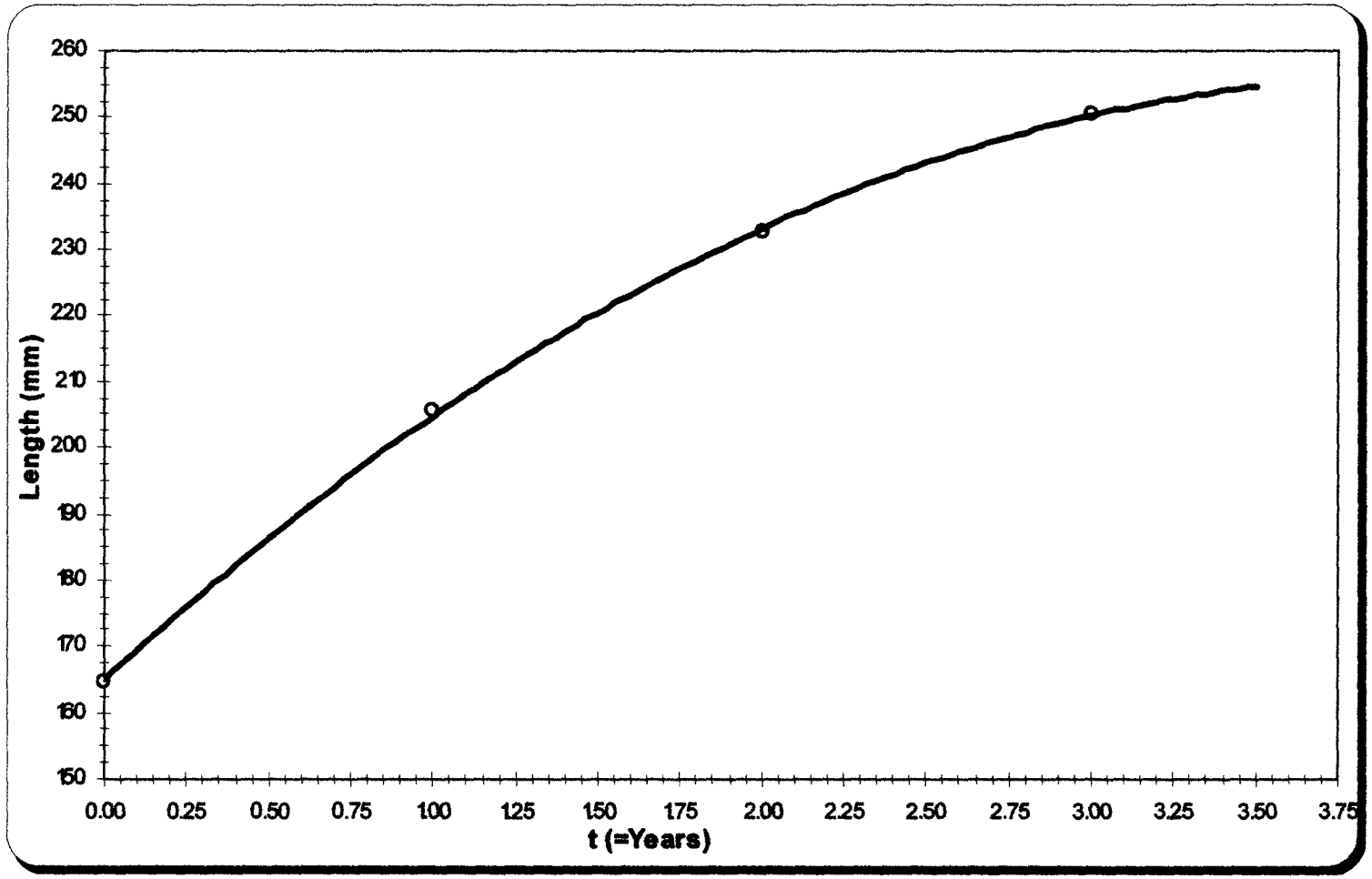


Fig. 2.4.7: *R. kanagurta*: von Bertalanffy growth curve for the period Aug '03 - Jun '04

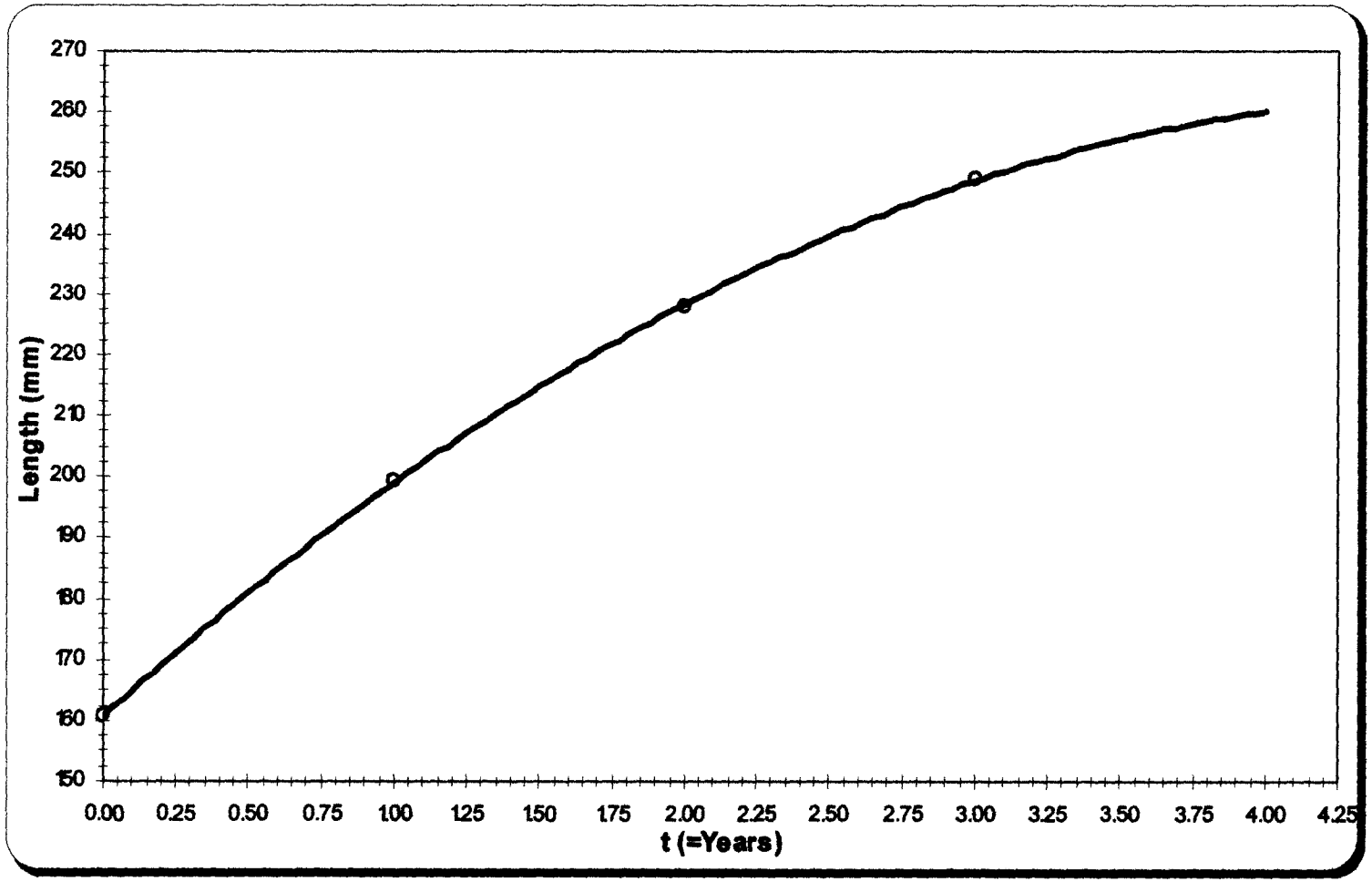


Fig. 2.4.8: *R. kanagurta*: von Bertalanffy growth curve for the period Aug '04 - Aug '05

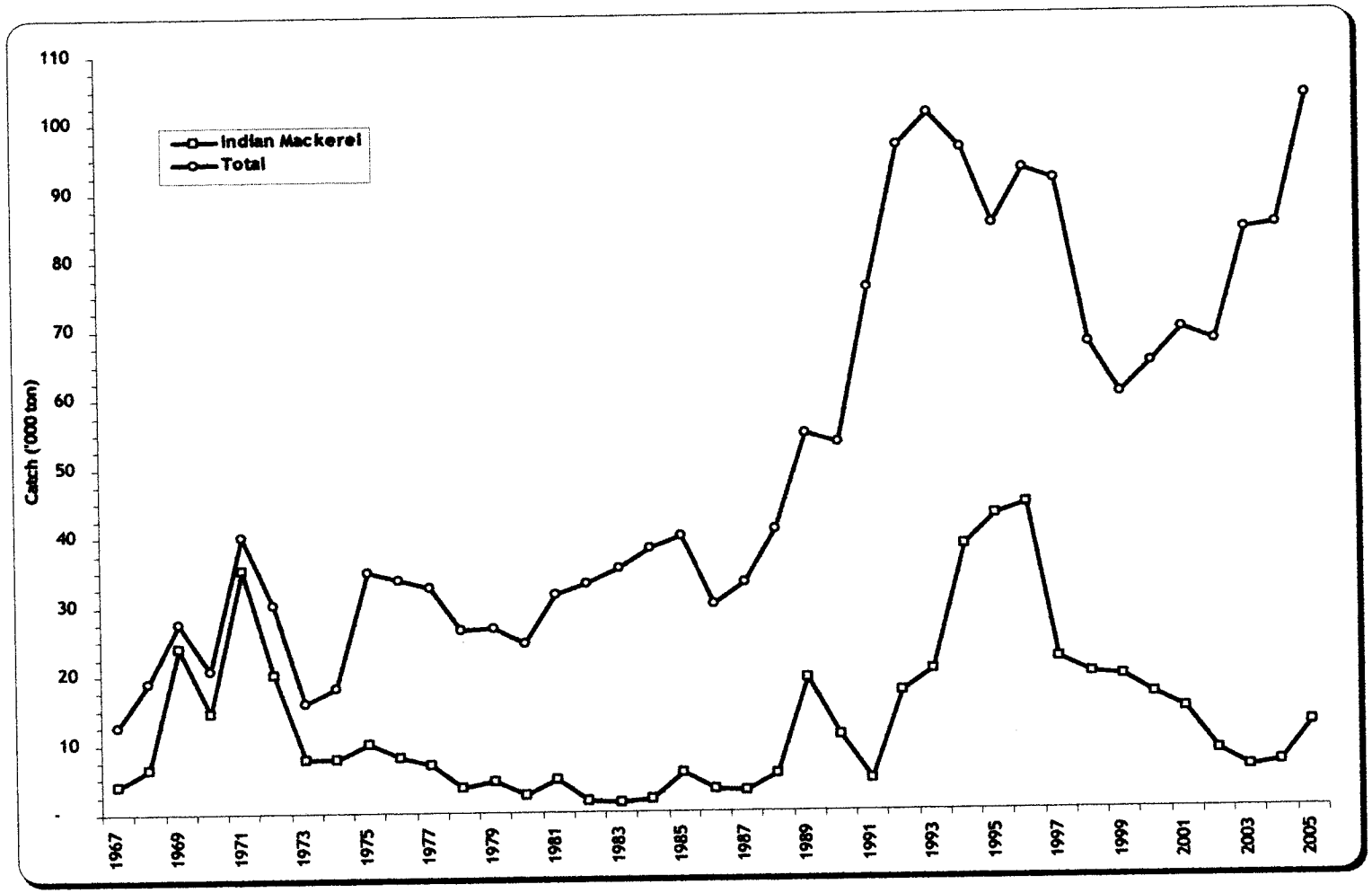


Fig. 2.5.1: Yearly catch data of *R. kanagurta* viz-a-viz the total fish landings in Goa

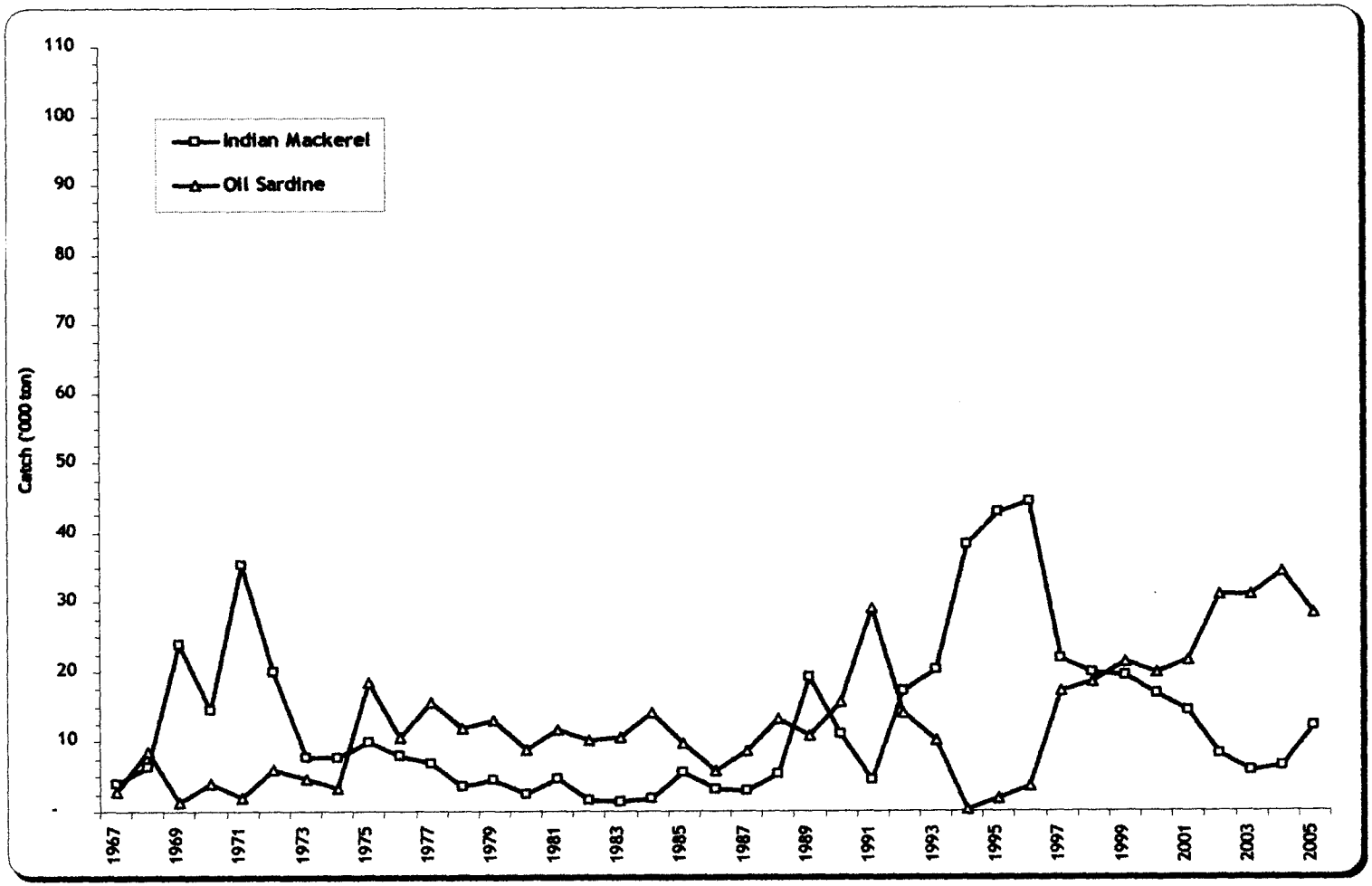


Fig. 2.5.2: Yearly catch data of two major fisheries *R. kanagurta* and *S. longiceps* in Goa

III. BIOLOGY OF METAPENAEUS DOBSONI

3.1 Introduction

Shrimps form an important component of the marine fisheries of India. Since early 1960s, the Indian shrimps have found a place in the export market fetching substantial foreign exchange. The high demand for shrimps in the international market, has led to the indiscriminate exploitation of all the shrimp species. Although penaeid shrimps are found in all the seas of the world upto sub-polar latitudes, their distribution is mainly confined to the tropical and sub-tropical waters and the most productive grounds are in the tropics. The coastal shrimp of the world belong to about forty species, divided into six genera. In India the important genera are the *Penaeus, Metapenaeus* and *Perapenaeopsis.*

Species belonging to the genus *Metapenaeus* are distributed through out the Indo-Pacific region. The commercially important species occurring in Indian Ocean are *M. monocerous*, *M. affinis, M. kuchensis* and *M. dobsoni.* These species have two phases in the life cycle, one the estuarine phase of post-larvae and juvenile and the marine phase of sub-adults and the adults. The spawning invariably takes place in the sea.

The most important species of penaeid shrimp caught along the Goa coast is *Metapenaeus dobsoni.* In Goa, it is popularly known as the **Solar shrimp**. This species is very important to the entire fishing industry, both traditional and mechanised sectors. It is the most sought after species during the south-west monsoon months. However, its fishery is facing the challenging problems of sustainable exploitation and management.

Study on the fishery biology of this species along the Goa coast is limited to a few works carried out by Anon (1975), Achuthankutty and Parulekar (1986b and c). Over the years fishing of this species has become an issue during the monsoon fishing-ban period in the state, therefore, it was selected as the demersal species of interest for the present study.

3.2 Materials and Methods

3.2.1 Biology

Weekly samples of *M. dobsoni* were collected from three main fish landing centers of Goa, viz. Malim, Vasco and Cutbona from August 2003 to August 2005. However, the samples during July (monsoon fishing ban period) for both the years were collected from motorised canoes near Vasco fish landing centre. The specimens were collected by random sampling on a weekly basis. A total of 2,199 specimens of Solar shrimp were examined of which 42.57% were males and 57.43% females.

The study was divided into two periods; the first was Aug '03 - Jul '04 and the second Aug '04 - Aug '05. The study during the first period was based on a total of 994 specimens of which 403 were males and 591 females. The second was based on a total of 1,205 specimens of which 533 were males and 672 females.

Freshly caught specimens were brought to the laboratory and the weight (g) and total length (mm) of each specimen was recorded. Further, the maturity stages and other general features of interest were also recorded for further analysis of the data.

The data were analyzed following standard procedures for studying the length-weight relationship, condition factor, reproduction and age and growth.

3.2.1.1 Length-Weight Relationship

The Length-Weight Relationship, $\mathbf{W = a\ L^b}$ (LeCren, 1951) for the study groups was fitted as;

$$\text{Log } W = \text{Log } a + b \text{ Log } L,$$

by least square method, where W = weight of each specimen and 'a' and 'b' are the constants.

The data for the two sexes were treated separately. The pattern of growth, whether isometric or allometric was tested by using the **t-test** using the formula;

$$t = b - 3 / Sb,$$

where b = Regression Coefficient and Sb = Standard Error of the estimate of Regression Coefficient.

Analysis of Co-variance (ANCOVA) (Sendecor and Cochran, 1967) was used to test the significant difference in the fitted Length-Weight relationship between the two sexes.

3.2.1.2 Relative Condition Factor

The data collected for Length-Weight relationship was utilized for calculating the Relative Condition Factor, **Kn** (LeCren, 1951) of the samples. The Kn was calculated for individual specimens by making use of the formula;

$$Kn = W / W^{\wedge},$$

where W = observed weight and W^ = calculated weight.

3.2.1.3 Reproduction

The study was based on weekly samples of Solar shrimp, *M. dobsoni* collected from the three fish landing centers of Goa.

3.2.1.3.1 Maturity Stages

Based on the external appearance, a five-stage classification for ovaries was used for describing the gross maturity stages for *M. dobsoni* (King, 1948; Rao, 1968; Cook and Lindner, 1970).

3.2.1.3.2 Size at First Maturity

Size at first maturity, which is the average size at which 50% of the individuals were mature, was estimated by plotting the cumulative frequency of the mature specimens in the successive size groups.

3.2.1.3.3 Sex Ratio

Sex ratio of the Solar shrimp was studied with respect to the months. Data on sex ratio were analyzed by X^2 **(Chi-Square)** test to find out the dominance of either of the sexes during different months.

3.2.1.4 Age and Growth

The total length measured for individual specimen was used in the statistical analysis of the data. The sexes were dealt with separately.

Monthly length measurements were classified into different size groups with class intervals of 5 mm. The percentage frequencies were calculated during each period of the study. The percentage was plotted against each size group to get frequency polygons. Then by counting the number of discernable modes and relating them to the respective length, a rough estimate of mean length of each cohort was obtained. The modes from length frequency data were plotted against time in successive months in the form of scatter diagram (Devaraj, 1983). The progression of modes was traced by free hand and extrapolated to intersect the time axis in order to identify the origin of broods and number of broods from its origin through successive months.

Thus, age determination was done using Peterson's Length-Frequency Analysis (1891) and by the method of Devraj (1983).

For the length at age data obtained by different methods of age determination, von Bertalanffy Growth Equation;

$$L_t = L_\infty(1 - e^{-K(t-t_0)}),$$

was fitted separately by analytical method (Begenal, 1978) and graphical method (Walford, 1946 and Ford, 1933 and Berveton and Holt method, 1957).

3.2.2 Shrimp Fishery of Goa

The catch data of shrimp for the period of 1967 - 2005 from the Statistics Section, Department of Fisheries, Government of Goa, was utilized for the study.

Based on the data on total landings of shrimp in Goa from 1967 to 2005 a trend graph was drawn to see the fluctuations in the landings of shrimps.

3.3 Results

3.3.1 Length-Weight Relationship

A total of 994 specimens were used in the first period of the study of which 591 were females and the rest males. In the second period a total of 1,205 specimens were used of which 672 were females and the rest were males.

The non-linear equation $W = a L^{b}$ was fitted for the data of Solar shrimp from Aug '03 to Jul '04 and from Aug '04 to Aug '05. The Length-Weight data was fitted separately for females and males for the period Aug '03 - Jul '04 (Tables 3.1.1 and 3.1.2) and Aug '04 - Aug '05 (Tables 3.1.3 and 3.1.4). It was observed that the Length-Weight relationship followed similar trend during both the periods (Figs. 3.1.1 and 3.1.2 and Figs. 3.1.3 and 3.1.4).

The t-test employed to study the growth pattern indicated that both the males and females of Solar shrimp followed isometric growth pattern during both the periods of study. The Analysis of Co-variance at 5% confidence level showed no significant difference between regression co-efficient of females and males for both the periods of study (Tables 3.1.5 and 3.1.6).

The Length-Weight relationship obtained is as follows:

For the period of Aug '03 - Jul '04;

For Females: $W = 0.00000152\ L^{3.2626}$

or

$$\text{Log } W = -5.8181 + 3.2626 \text{ Log } L$$

For Males: $W = 0.000001961\ L^{3.246}$

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or

$$\text{Log } W = -5.7069 + 3.2146 \text{ Log } L,$$

and for the period of Aug '04 - Aug '05;

For Females: $W = 0.00000118\ L^{3.3118}$

or

$$\text{Log } W = -5.9055 + 3.3118 \text{ Log } L$$

For Males: $W = 0.00000154\ L^{3.2566}$

or

$$\text{Log } W = -5.8126 + 3.2566 \text{ Log } L,$$

where W = weight in gram and L is length in mm. The linear regression for both sexes for the period Aug '03 - Jul '04 and Aug '04 - Aug '05 are shown in Figs. 3.1.5, 3.1.6, 3.1.7 and 3.1.8.

3.3.2 Relative Condition Factor

The Relative Condition Factor (Kn) – the ratio between the obtained and calculated weight – was estimated sex-wise for different months for Solar shrimp for both the periods of the study.

The monthly mean values of Kn are shown in Tables 3.2.1 (Aug '03 - Jul '04) and Tables 3.2.2 (Aug '04 - Aug '05). For the period of Aug '03 - Jul '04, the females showed the highest Kn value of 1.0026 during the month of March and the minimum of 1.0003 was observed during August. While for males the maximum was 1.0043 during January and minimum was 1.0004

during August. During the period of Aug '04 - Aug '05, the highest Kn valve for females was 1.0026 during February and for males it was 1.004 during May. The minimum Kn value of 1.0003 for females was observed in the months of August and September. The males showed minimum Kn value of 1.0004 in the month of September.

3.3.3 Reproduction

3.3.3.1 Maturity

The maturity stages of females were classified based on the external appearance of the ovary into 5 stages. Males having terminal ampoules on the coxa of 5th pereiopods were considered as matured.

The following maturity stages were identified for females

Stage I - **Immature**: Ovary is thin, translucent unpigmented and extends to the posterior part of the cephalothorax and the abdomen. The ova are not discernable to the naked eye.

Stage II - **Early Maturing**: Size of the ovary increases, anterior lobes further develop and extend forward in cephalothorax. The middle lobes and rudiments of their lobules develop.

Stage III - **Matured**: The anterior, middle and posterior lobes of the ovary fully formed. The ovary is generally light green and is visible through the exoskeleton.

Stage IV - **Ripe**: The ovary is clearly visible through the exoskeleton, dark green mostly and in few cases blackish green. The anterior and middle lobes are fully developed. Due to fullness of the ovary,

the lateral lobules of the middle lobe get folded and occupy the entire space available in the cephalothorax.

Stage V - Spent or **Recovering:** The ovaries are shrunk and resemble closely that of Stage I.

Figures 3.3.1 and 3.3.2 show the percentage of females in different stages of maturity during the periods of Aug '03 - Jul '04 and Aug '04 - Aug '05, respectively. During the 1st phase of study, impregnated mature females in the 4th stage of maturity were observed during the months of August - September and November - January (Fig. 3.3.3). During the 2nd phase also, impregnated matured females were observed during the months of August - September and November - January (Fig. 3.3.4). Mature males were recorded from April till August and again from October to January.

3.3.3.2 Size at First Maturity

The size at first maturity was determined for females for both the study periods. The samples were sorted sex wise into 5 mm size groups and the percentage occurrence in various stages of maturity was calculated. Shrimps in III to V maturity stages only were considered as mature.

From the data, it was observed that all females below 70 mm in length were in immature stage (Stage I). Maturing stages were observed from a size above 71 mm. However, the percentage was the highest for the size group 101 - 105 mm. Graphical analysis of the data indicates that for the period Aug '03 - Jul '04, the size at first maturity was 98.7 mm (Fig. 3.3.5) and for the period Aug '04 - Aug '05, it was 99.2 mm (Fig. 3.3.6).

3.3.3.3 Sex Ratio

Females dominated the catches during all the months. However, during the periods of August - September and December - January, the percentage of females was much higher than males for both the periods of study (Figs. 3.3.7 and 3.3.8). The computed Chi-Square values showed that there was a significant difference in the sex ratio during the months of August, December, February and March for the period of Aug '03 - Jul '04 (Table 3.3.1). During the period of Aug '04 - Aug '05, significant difference in the sex ratio was observed in September (Table 3.3.2). Further, a significant difference was also observed in the sex ratio regardless of months during both the periods of the study.

3.3.4 Age and Growth

3.3.4.1 Length-Frequency Distribution

Random samples of *M. dobsoni* were divided in to size groups with a class interval of 5 mm. The percentage frequencies were calculated and plotted against the mid-points of size groups in the form of Length-Frequency polygons, for each month separately for females and males for both the periods of study. Figs. 3.4.1 and 3.4.2 represent the period of Aug '03 - Jul '04 and Figs. 3.4.3 and 3.4.4 represents the period of Aug '04 - Aug '05. For both the periods, 3 modes for males and 4 modes for females were discernable.

Table 3.4.1 presents the mean lengths at monthly intervals and monthly growth rates, obtained from the scatter diagram of modes (Figs. 3.4.5 and 3.4.6) for the period of Aug '03 - Jul '04. Mean length values ranged from 14 mm to 107 mm in case of females and 11 mm to 82 mm in case males.

Table 3.4.2 gives the mean lengths at monthly intervals and monthly growth rates, obtained from the scatter diagram of modes (Figs. 3.4.7 and 3.4.8) for the period of Aug '04 - Aug '05. Mean length values ranged from 10 mm to 113 mm in case of females and 10 mm to 85 mm in case males.

3.3.4.2 Growth Equation

The von Bertalanffy growth equation;

$$L_t = L_\infty (1 - e^{-k(t-to)}),$$

where L_t = length at age t, L_∞ = asymptote of the curve of growths in length, K = a coefficient equal to 1/3rd of the catabolic coefficient and t_0 = age at which the length was initially zero, was fitted using the least square method separately for females and males since the size range obtained for each sex was different. The estimated growth parameters calculated by analytical method for the period of Aug '03 - Jul '04 for females was L_∞ = 167.84 mm, K = 0.09 and t_0 = 0.0791 and for males L_∞ = 114.47 mm, K = 0.12 and t_0 = 0.2582, whereas for the period of Aug '04 - Aug '05 the respective values for females were 167.23 mm, 0.1 and 0.6345, which in the case of males were 112.9 mm, 0.12 and 0.3387.

The growth parameter L_∞ obtained by Ford-Walford technique for the period of Aug '03 - Jul '04 in the case of females and males were 165.1 mm and 110.0 mm, respectively (Figs. 3.4.9 and 3.4.10) and for the period Aug '04 - Aug '05, it was 167.0 mm for females (Fig. 3.4.11) and 111.5 mm for males (Fig. 3.4.12).

During the period Aug '03 - Jul '04, the t_0 value obtained by Berverton and Holt plot was 0.07 for females (Fig. 3.4.13) and 0.26 for males (Fig.

3.4.14). For the period Aug '04 - Aug '05, the t_o values were 0.6 and 0.3 for females and males, respectively (Figs. 3.4.15 and 3.4.16).

The fitted growth equation was as follows:

For the period of Aug '03 - Jul '04;

For Females: $L_t = 167.84 (1 - e^{-0.09 (t - 0.0791)})$

For Males: $L_t = 114.47 (1 - e^{-0.12 (t - 0.2582)})$

and

For the period of Aug '04 - Aug '05:

For Females: $L_t = 167.23 (1 - e^{-0.1 (t - 0.6345)})$

For Males: $L_t = 112.9 (1 - e^{-0.12 (t - 0.3387)})$

The von Bertalanffy growth curves, utilizing the growth parameters obtained by analytical method for the period of Aug '03 - Jul '04 are presented in Figs. 3.4.17 and 3.4.18 for females and males, respectively. For the period of Aug '04 - Aug '05, the curves are shown in Figs. 3.4.19 and 3.4.20.

3.3.5 Shrimp Fishery of Goa

During the period 1967 - 2005, the contribution of shrimps in Goa was 0.7 - 16.2% of the total marine fish landings. The total shrimp production in 1967 was 471 mt. After hitting a low 279 mt in 1971, the landings increased steadily reaching a high of 5,699 mt in 1983. Though the catch peaked in 1988 at 6,180 mt, the following year saw a drastic reduction to a level of 599 mt. The landings, thereafter, showed an increasing trend reaching a

high of 5,193 mt in 1995. Year 2001 again saw a very low catch of 874 mt and thereafter; there has been an increasing trend reaching a peak landing of 10,599 mt in 2005 (Fig. 3.5.1).

3.4 Discussion

3.4.1 Length-Weight Relationship

The Length-Weight relationship is expressed by the equations $W = a L^b$, where the weight may be considered as a function of length. This is indicative of the fatness, general well-being or gonadal development of individuals (LeCren, 1951).

The relationship between the length and weight was at a higher rate than the cube of total length in both females and males during both the periods of the study. Further, it was observed that the Analysis of Co-variance employed to test the significance of the regression of weight on total length indicated that the Length-Weight relationship was not significantly different between the males and females ($p > 0.05$) during both the periods of the study. The t-test showed that the female and male *M. dobsoni* followed an isometric growth pattern for both the study periods.

This is in accordance with the findings of Murthy and Ramaseshaiah (1996). They found that the relationship between Length-Weight in *M. dobsoni* is not significantly different in males and females and used a common equation for both the sexes i.e. $\text{Log } W = -5.8318 + 3.2875 \log L$. In contrast, Achuthankutty and Parulekar (1986c) found significant difference in the Length-Weight relationship between male and female *M. dobsoni.* This may be due to the proportion of males and females in the samples, the sampling size and disparity in random sampling.

Rao A V P (1967) on his observation on *P. indicus* in Chilka Lake (Orissa) found significant difference in the Length-Weight relationship between the males and females. The Length-Weight relationship of *P. semisulcatus* was not significantly different between the months of the year but the difference was significant between the sexes (Thomas, 1975). Antony and Soni (1986)

recorded significant difference in Length-Weight relationship in *M. kutchensis* in Okha in Gujrat. Similar observations were also made in *M. barbata* (Ramaseshaiah and Murthy, 1997) and *M. monoceros* (Nandakumar, 1998).

The scatter diagram of weight on length of Solar shrimp in the present study conforms to the general pattern of non-linear growth in both the sexes for both the periods of study. The curve fits well with the scatter diagram of weight against length, indicating a non-linear relationship between the two parameters. Similar observations were made by Thomas (1975) in *P. semisulcatus.*

3.4.2 Relative Condition Factor

The Relative Condition Factor (Kn) was estimated sex-wise for different months for the Solar shrimp. The females showed the highest Kn value during March and the minimum during August which, for males was during January and August, respectively. For the period of Aug '04 - Aug '05, the highest Kn valve for females was observed in February and for males in May. The minimum Kn value for females was observed in August and September and only in September in case of males.

Thomas (1975) and Reddy (1991) are of the opinion that the highest value of Kn is independent of the feeding intensity, but have been shown to be associated with sexual maturity. Antony and Soni (1986) also opined that the Kn was the highest during the attainment of sexual maturity and the troughs and small peaks represent the cyclical gonadal development.

In the present study although the peak spawning months were identified as July and August, the Kn valves were relatively the lowest as compared to

the weighted average. This may be due environmental conditions that prevail in the waters of Goa coast. During these months the subsurface layers of water are low in oxygen (Naqvi *et al*, 2000) and the matured shrimp may be stressed and come to the surface. However, during all the months of both the study periods, the relative condition was found to be good (Kn > 1).

3.4.3 Reproduction

3.4.3.1 Maturity and Spawning Season

Based on the gross examination of gonads and the presence of impregnated mature females in catches from July to September and November to January, it appears that the Solar shrimp has two spawning seasons along the Goa coast. The first spawning season, i.e. July - August being more intense than the second season of December - January.

Menon (1951 and 1955) and George (1962) observed that the breeding season of *M. dobsoni* extends from May to December in south-west coast of India. However, Rao (1968) reported that *M. dobsoni* in south-west coast of India breeds through the year with a peak during April to June and November to December. (Rao, 1974) observed that the spawning season of a species differs from place to place and from year to year.

Achuthankutty and Parulekar (1986b) reported the occurrence of breeding stock of *M. dobsoni* along the Goa coast throughout the year in varying numbers with maximum population during the post-monsoon season (October - January) with the largest monthly contribution of spawners being in January. In the Matabala fishery of Mangalore-Karwar belt in Karnataka, Solar shrimp showed 14 - 18% of females in the mature condition and 6 -

16% in the spent or the recovering stage, suggesting active spawning during the monsoon months of July - August (Kakati, 2000). The present study is in conformity with the above findings.

3.4.3.2 Size at First Maturity

It was observed that all females below 70 mm were in the immature stage. Maturing stages were observed from a size above 71 mm. The percentage occurrence was the highest for the size range between 101 - 105 mm. The size at first maturity of female shrimp during both the periods of study was found to be 99.5 mm.

The present study is in conformity with the findings of Achuthankutty and Parulekar (1986b) who reported that mature females of *M. dobsoni* along the Goa coast were present in all size groups above 70 - 75 mm. However, they observed that the size group of 95 - 105 mm formed the main stay in the breeding stock of *M. dobsoni.*

3.4.3.3 Sex Ratio

Although the females dominated the catches during the entire period of study, during August - September and December - January the percentage of females were relatively much higher than males. This may be due to the fact that females after mating move to the outer boundary of the area of occurrence for spawning and are very vulnerable for getting caught in the net. The above study is in conformity with Ramamurthy *et al* (1975), Menon (1955), Lalithadevi (1989) and George and Rao (1967), who observed a significant variation in the sex distribution associated with segregated movements for breeding purpose.

A clear dominance of males in the smaller size groups and dominance of females in the larger size groups was noticed for both the periods of study. Similar observation was made by Kurup (1985) in *M. dobsoni* along Allepy coast in Kerala. Lalithadevi (1989) attributed the dominance of Solar shrimp females in larger size groups in Godavari estuary (Andhra Pradesh) to the differential growth between the sexes and also migration of smaller males to deeper waters compared with the females.

3.4.4 Age and Growth

The age related mean length of Solar shrimp was calculated by scatter diagram of modes. The growth rates recorded and its variations are in accordance with observation made for *M. monoceros* (Rao, 1969); *P. stylefera*, *M. dobsoni* (Mohamed and Rao, 1971); *M. monoceros* (Subrahmanyam, 1973); *M. dobsoni*, *M. monoceros*, *M. affinis* and *P. indicus* (George, 1975). The results of the present study are also in close agreement with the findings of Lalithadevi (1989).

The growth rates showed a declining trend with passage of time in Solar shrimp. The growth rate was faster when there was no mechanised fishing pressure, i.e. during the monsoon fishing-ban period. A similar observation was made by Ramamurthy *et al* (1978) in *M. dobsoni*, Subrahmanyam (1974) in *M. monoceros* and Anantha (1993) in *P. stylifera* and *M. monoceros*.

It was observed that females attain a larger size than males during their life span. A higher growth rate was observed before attainment of sexual maturity. Continuous emigration of shrimp of different size groups from the estuary would have been responsible for the observed differences in the growth rates in males and females (Subrahmanyam, 1973). Further, an

inverse relationship in growth rate as a function of age was observed. This may be due to the fact that crustacean growth is dependent on sex and size of the animal or geographical affiliation (Rao, 1969), food quality and quantity, population density, light, temperature and salinity (Dall *et al*, 1990). A combination of some of these factors is believed to play a role in the difference of growth rates observed in the present study as well.

The growth curves fitted as per von Bertalanffy model are more or less in close agreement with the observed values in both the periods of study. This conforms to the findings of Dall *et al* (1990) of sigmoid or 'S' shaped growth pattern.

The calculated asymptotic lengths (L_∞) obtained in the present study for females and males during Aug '03 - Jul '04 were 167.84 mm and 114.47 mm, respectively. For the period of Aug '04 - Aug '05 the respective values were 167.23 mm and 112.91 mm.

Ramamurthy *et al* (1978) reported that males of Solar shrimp grow to a length of 85 to 105 mm during the 1st and 2nd year of their life, whereas females grow to 95 to 120 mm in the same period. They further observed that during the 3rd year very little growth seems to take place since the species attains maximum size by then.

In the present study, the von Bertalanffy growth equations for the period from Aug '03 - Jul '04 were:

For females: $L_t = 167.84\,(1 - e^{-0.09\,(t - 0.0791)})$ and

For males: $L_t = 114.47\,(1 - e^{-0.12\,(t - 0.2582)})$.

For the period of Aug '04 - Aug '05, L_t calculated were:

For females: $L_t = 167.23\,(1 - e^{-0.1\,(t - 0.6345)})$ and

For males: $L_t = 112.9\,(1 - e^{-0.12\,(t - 0.3387)})$.

According to Ramamurthy *et al* (1978) the von Bertalanffy growth equation for *M. dobsoni* along the Mangalore (Karnataka) coast was $109.1(1 - e^{0.12 (t - 0.57)})$ for males and $120.9(1 - e^{-0.18 (t - 4.02)})$ for females, where t_o valve for females was found to be too high. Achuthankutty and Parulekar (1986c) gave the growth equations for males and females as $L_t = 122.4 (1 - e^{-0.0976 (t + 0.41241)})$ and $L_t = 121.7 (1 - e^{-0.1675 (t + 0.11631)})$, respectively. Lazarus and Nandakumaran (1990) calculated a combined von Bertalanffy growth equation for both the sexes of *M. dobsoni* as $L_t = 82.32 (1 - e^{0.28 (t + 3.10)})$, grown under captivity.

3.4.5 Solar shrimp Fishery along Goa Coast

It was observed in the present study that *M. dobsoni* by itself supports the fishing industry during south-west monsoon months of July and August. During this period the shrimps are caught in large quantities primarily by mini purse-seines operated by motorised canoes and purse-seiners. The catch is dominated by mature impregnated larger size females. These findings are in accordance with those of George (1962) on *M. dobsoni* from Cochin and Allepy coasts in Kerala. Such a shoaling behaviour of the *M. dobsoni* during the south-west monsoon months was also reported by Sunilkumar *et al* (1996) in the inshore waters of Malpe, Karnataka. Kakati (2000) observed bigger sized *M. dobsoni* during the monsoon months of July - August in the Matabala fishery of Mangalore coast (Karnataka).

The very fact that these shrimps are caught by surface fishing gears with least effort may be due to the severe environmental factors that are prevailing in the near-shore areas of the Goa coast during the south-west monsoon months, forcing the shrimps to move away from the deeper waters to the near-shore waters. Naqvi *et al* (2000) reported that the bottom waters of the Goa coast are deficient in oxygen during monsoon period. Banse

(1959) reported that during the monsoon months the low-oxygen bottom layer ascends on to the shelf waters along the west coast of India. As a result of the upwelling, a band of shelf bed along the south-west coast is overlaid with poorly aerated water. The demersal fish and shrimp migrate either to deeper waters or to shallower areas of the shelf. This may be the reason for forming large shoals of Solar shrimps during this period in the inshore waters of Goa coast and are caught in large quantities very close to the shore.

It was also observed that the fishing grounds of Solar shrimp during the monsoon period of July and early August were only along south Goa coast. Madhupratap *et al* (2001) reported that upwelling starts at the west-coast of India by end May - early June and propagates northwards with time. Further, they also observed that upwelling is relatively weak in northern part of Goa and this condition prevails until the end of August - early September.

It was also observed in the present study that during both the periods of the study, the catches of the Solar shrimp slowly started to drop from September onwards and the larger size group started to disappear. The Solar shrimp then made their appearance again in a smaller proportions in the trawl catches from November upto January along with other shrimps like *M. monoceros*, *P. stylefera* and other species of *Metapenaeus* and *Penaeus*. The Solar shrimp caught during this period were, however, smaller in size. From February to May, the Solar shrimp catches again started to dwindle and were caught mostly by trawlers along with other miscellaneous shrimps and fish species at depths of less than 10 m. These are comprised largely of immature females. However, males from the April - May trawl samples, although small in size, were mature with sperm sac.

3.4.6 Shrimp Fishery in Goa

The contribution of shrimp to the total marine fishery in Goa is the lowest among the coastal states of India (Ansari *et al*, 2006). It formed around 0.7 - 16.2% of the total marine fishery in the state during last 40 years (1967-2005). It was observed from the present study that the 1980s saw a steady growth in the shrimp landings. This may be attributed to the introduction of mechanised vessels (trawlers) during this period. However, due to spurt in the effort to catch the high valued shrimps, the decade ended with the lowest landings in a span of ten years.

The total shrimp production in 1967 was 471 mt. After hitting a low 279 mt in 1971, the landings increased steadily reaching a high of 5,699 mt in 1983. Though the catch peaked in 1988 at 6,180 mt, the following year saw a sharp reduction (599 mt). The landings, thereafter, showed an increasing trend reaching a high of 5,193 mt in 1995. Year 2001 again saw a very low catch of 874 mt. There has been a growing trend since 2002, reaching a peak landing of 10,599 mt in 2005. This may perhaps be due to the monsoon fishing ban that was imposed by the High Court in the year 2000. The ban was strictly enforced by the state Government, for both mechanised vessels and motorised canoes and also was adhered to by the fishermen. Such a positive impact on fish landings by the trawl ban during the monsoon period has been documented by Ammini (1999).

The shrimp fishery along the Goa coast is mainly sustained by species such as *M. dobsoni*, *P. stylifera*, *M. affinis* and *P. merguiensis* (Achuthankutty and Parulekar, 1986a). Some species such as *M. monoceros*, *M. moyebi*, *P. indicus*, *P. monodon*, *P. japonicus* and *Parapenaeopsis hardwickii* also contribute in small shares.

Bulk landings of shrimps take place during July end to early September. The shrimps are predominantly caught from a depth of 10 to 50 m.

Table 3.1.1: *M. dobsoni* female: Length-Weight Relationship for the period Aug '03 - Jul '04

Month	n	A	a	b	r	$W = a L^b$
Aug '03	57	-5.2844	0.00000520	3.0302	0.9950	$W = 0.00000520\ L^{3.0302}$
Sep '03	47	-5.4649	0.00000343	3.1099	0.9797	$W = 0.00000343\ L^{3.1099}$
Oct '03	42	-4.8360	0.00001459	2.7861	0.9919	$W = 0.00001459\ L^{2.7861}$
Nov '03	62	-4.7455	0.00001797	2.7292	0.9913	$W = 0.00001797\ L^{2.7292}$
Dec '03	59	-5.8388	0.00000145	3.2808	0.9811	$W = 0.00000145\ L^{3.2808}$
Jan '04	65	-5.1677	0.00000680	2.9375	0.9831	$W = 0.00000680\ L^{2.9375}$
Feb '04	53	-5.7516	0.00000177	3.2051	0.9719	$W = 0.00000117\ L^{3.2051}$
Mar '04	56	-5.7494	0.00000178	3.2194	0.9685	$W = 0.00000178\ L^{3.2194}$
Apr '04	57	-4.4975	0.00003181	2.5676	0.9788	$W = 0.000003181\ L^{2.5676}$
May '04	52	-4.8652	0.00001364	2.7257	0.9813	$W = 0.00001364\ L^{2.7257}$
Jul '04	41	-5.6825	0.00000208	3.2023	0.9931	$W = 0.00000208\ L^{3.2023}$
2003-2004	**591**	**-5.8181**	**0.00000152**	**3.2626**	**0.9524**	$\mathbf{W = 0.00000152\ L^{3.2626}}$

Table 3.1.2: *M. dobsoni* male: Length-Weight Relationship for the period Aug '03 - Jul '04

Month	n	A	a	b	r	$W = a L^b$
Aug '03	27	-5.2676	0.00000540	3.0104	0.9873	$W = 0.00000540\ L^{3.0104}$
Sep '03	33	-5.2551	0.00000556	3.0026	0.9949	$W = 0.00000556\ L^{3.0036}$
Oct '03	27	-4.7044	0.00001975	2.6607	0.9475	$W = 0.00001975\ L^{2.6607}$
Nov '03	51	-5.9239	0.00000119	3.3389	0.9773	$W = 0.00000119\ L^{3.3389}$
Dec '03	37	-6.1861	0.00000065	3.4884	0.9916	$W = 0.00000065\ L^{3.4884}$
Jan '04	45	-5.2967	0.00000505	3.0144	0.9705	$W = 0.00000505\ L^{3.0144}$
Feb '04	33	-5.4255	0.00000375	3.0081	0.9607	$W = 0.00000375\ L^{3.0081}$
Mar '04	33	-5.3855	0.00000412	2.9918	0.9747	$W = 0.00000412\ L^{2.9918}$
Apr '04	41	-5.3617	0.00000435	3.0488	0.9818	$W = 0.00000435\ L^{3.0488}$
May '04	46	-5.8516	0.00000141	3.2860	0.9803	$W = 0.00000141\ L^{3.2860}$
Jul '04	30	-4.5393	0.00002889	2.6029	0.9673	$W = 0.00002889\ L^{2.6029}$
2003-2004	**403**	**-5.7069**	**0.00000196**	**3.2146**	**0.9478**	$\mathbf{W = 0.00000196\ L^{3.2146}}$

Table 3.1.3: *M. dobsoni* female: Length-Weight Relationship for the period Aug '04 - Aug '05

Month	n	A	a	b	r	$W = a L^{b}$
Aug '04	57	-5.0650	0.00000861	2.9221	0.9907	$W = 0.00000861\ L^{2.9221}$
Sep '04	54	-4.8702	0.00001348	2.8231	0.9854	$W = 0.00001348\ L^{2.8231}$
Oct '04	57	-4.7589	0.00001742	2.7242	0.9911	$W = 0.00001742\ L^{2.7242}$
Nov '04	57	-4.4421	0.00003613	2.5783	0.9934	$W = 0.00003613\ L^{2.5783}$
Dec '04	57	-5.1593	0.00000693	2.9320	0.9682	$W = 0.00000693\ L^{2.9320}$
Jan '05	60	-4.4463	0.00003578	2.5681	0.9857	$W = 0.00003578\ L^{2.5681}$
Feb '05	48	-5.3507	0.00000446	2.9973	0.9595	$W = 0.00000446\ L^{2.9973}$
Mar '05	57	-5.3001	0.00000501	2.9483	0.9791	$W = 0.00000501\ L^{2.9483}$
Apr '05	61	-4.8935	0.00001278	2.7585	0.9892	$W = 0.00001278\ L^{2.7585}$
May '05	63	-4.8256	0.00001494	2.7096	0.9834	$W = 0.00001494\ L^{2.7096}$
Jul '05	42	-5.3659	0.00000431	3.0378	0.9944	$W = 0.00000431\ L^{3.0378}$
Aug '05	59	-5.0078	0.00000982	2.8647	0.9774	$W = 0.00000982\ L^{2.8647}$
2004- 2005	**672**	**-5.9055**	**0.00000118**	**3.3118**	**0.9502**	$\mathbf{W = 0.00000118\ L^{3.3118}}$

Table 3.1.4: *M. dobsoni* male: Length-Weight Relationship for the period Aug '04 - Aug '05

Month	n	A	a	b	r	$W = a L^b$
Aug '04	44	-5.2027	0.00000627	2.9703	0.9858	$W = 0.00000627\ L^{2.9703}$
Sep '04	33	-4.9259	0.00001186	2.8366	0.9945	$W = 0.00001186\ L^{2.8366}$
Oct '04	45	-5.3309	0.00000467	3.0184	0.9791	$W = 0.00000467\ L^{3.0184}$
Nov '04	48	-4.6238	0.00002378	2.6440	0.9832	$W = 0.00002378\ L^{2.6440}$
Dec '04	44	-4.5965	0.00002532	2.6325	0.9871	$W = 0.00002532\ L^{2.6325}$
Jan '05	47	-5.5764	0.00000265	3.1410	0.9714	$W = 0.00000265\ L^{3.1410}$
Feb '05	31	-5.2424	0.00000572	2.8966	0.9609	$W = 0.00000572\ L^{2.8966}$
Mar '05	51	-5.5272	0.00000297	3.0751	0.9863	$W = 0.00000297\ L^{3.0751}$
Apr '05	55	-5.3421	0.00000455	2.9785	0.9844	$W = 0.00000455\ L^{2.9785}$
May '05	51	-5.6944	0.00000202	3.1840	0.9574	$W = 0.00000202\ L^{3.1840}$
Jul '05	40	-4.6372	0.00002306	2.6498	0.9621	$W = 0.00002306\ L^{2.6498}$
Aug '05	44	-4.7140	0.00001932	2.7002	0.9782	$W = 0.00001932\ L^{2.7002}$
2004-2005	**533**	**-5.8126**	**0.00000154**	**3.2566**	**0.9394**	$\mathbf{W = 0.00000154\ L^{3.2566}}$

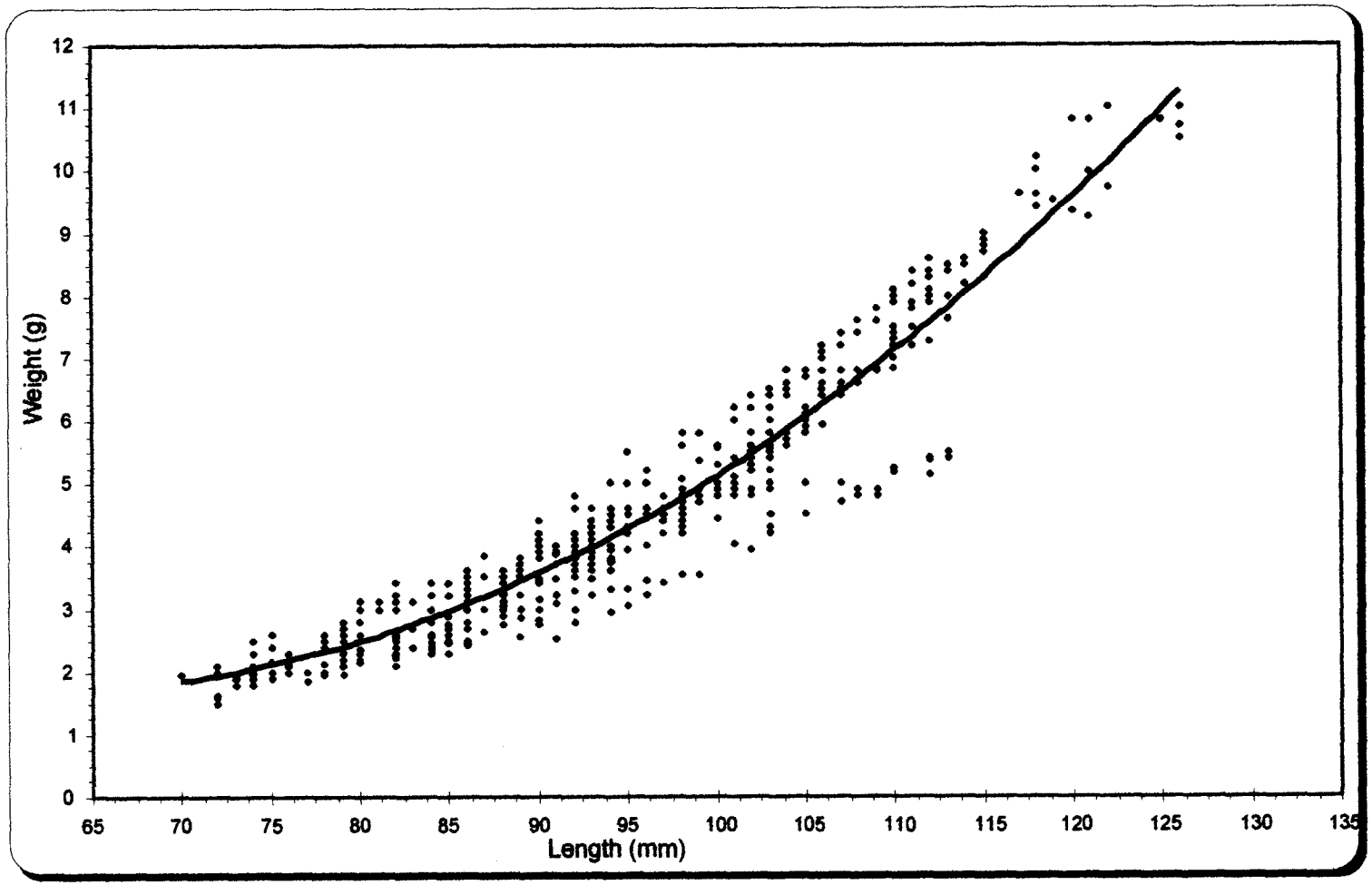


Fig. 3.1.1: *M. dobsoni* female: L-W Relationship for the period Aug '03 - Jul '04

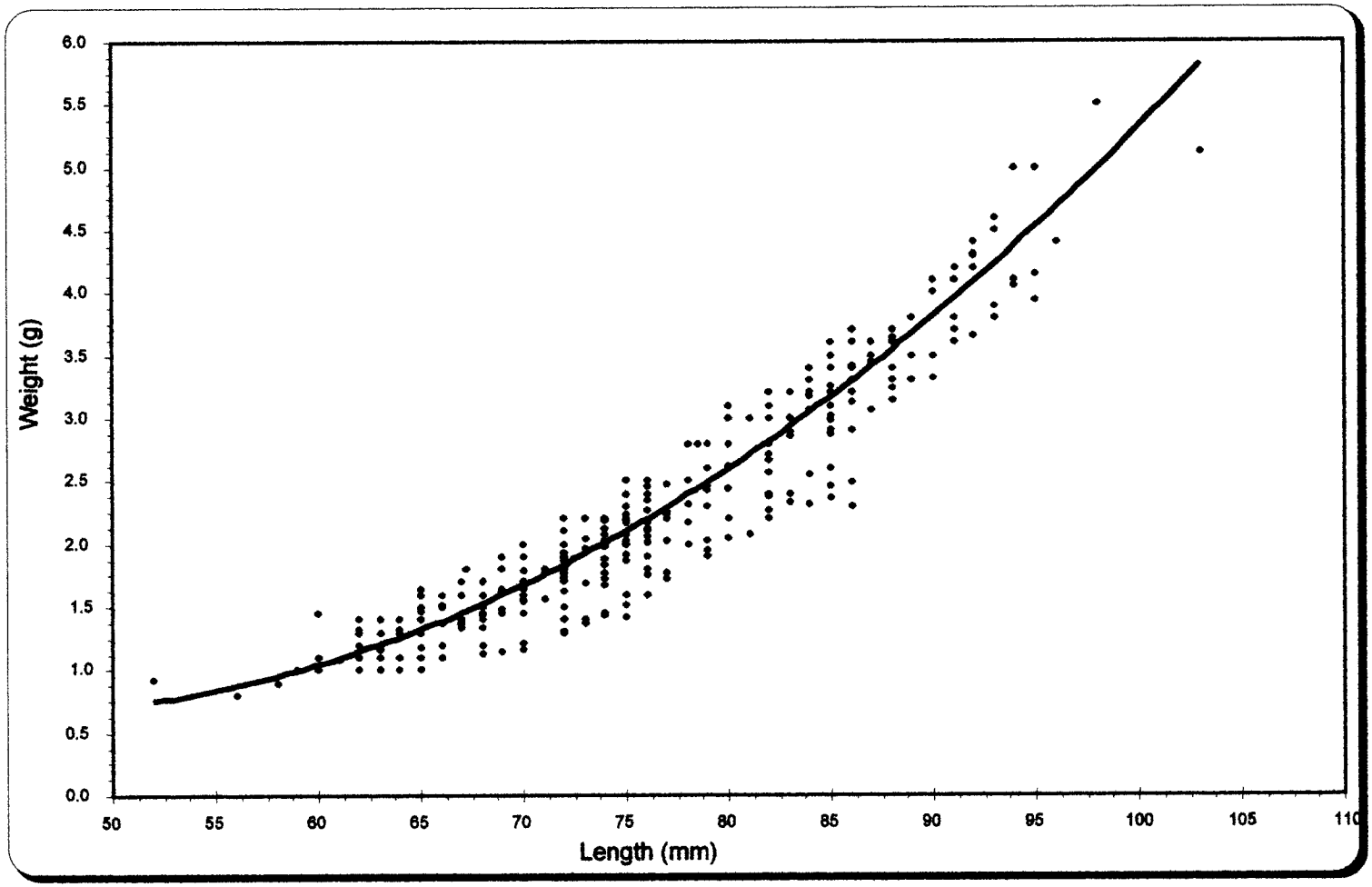


Fig. 3.1.2: *M. dobsoni* male: L-W Relationship for the period Aug '03 - Jul '04

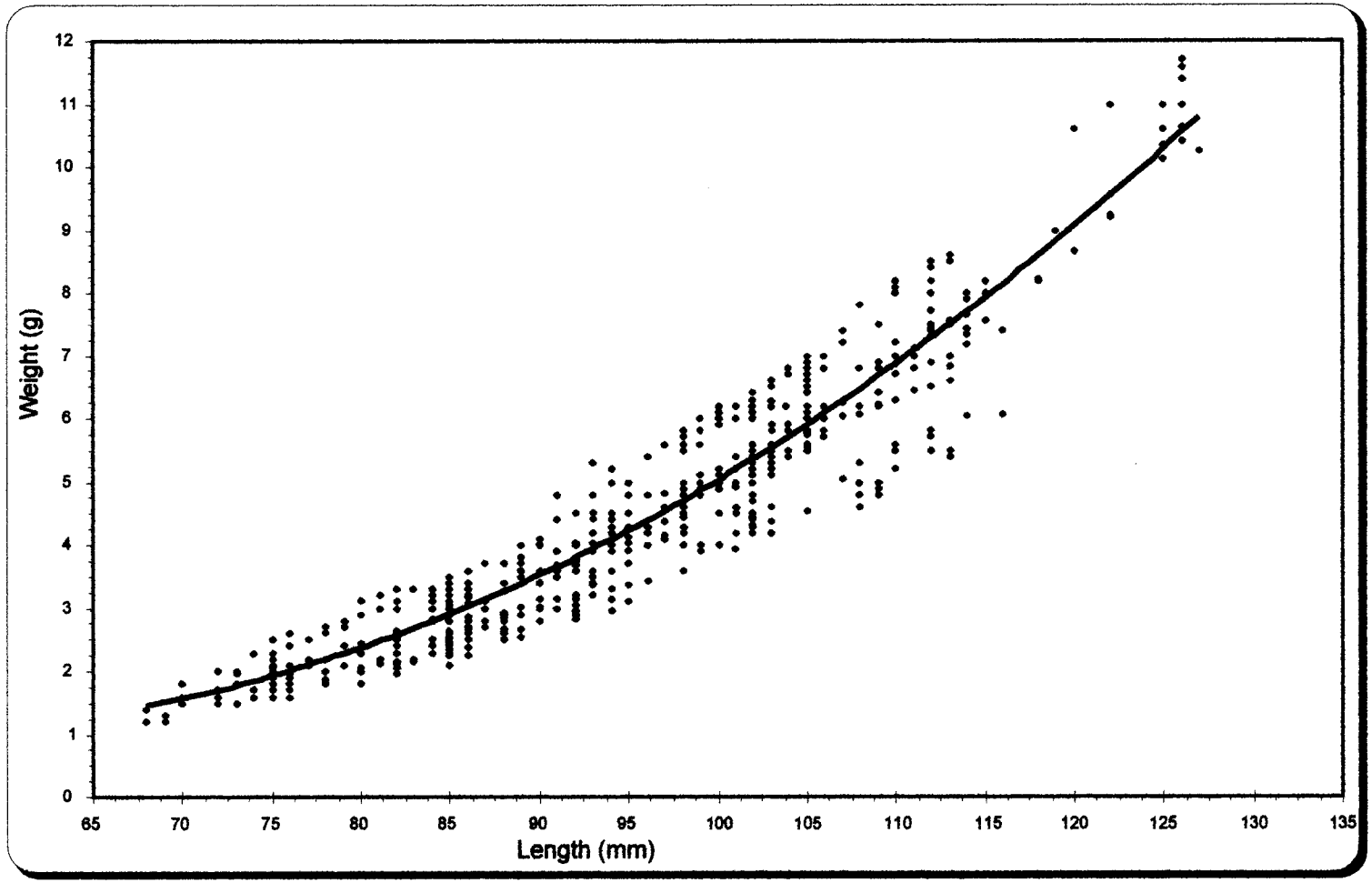


Fig. 3.1.3: *M. dobsoni* female: L-W Relationship for the period Aug '04 - Aug '05

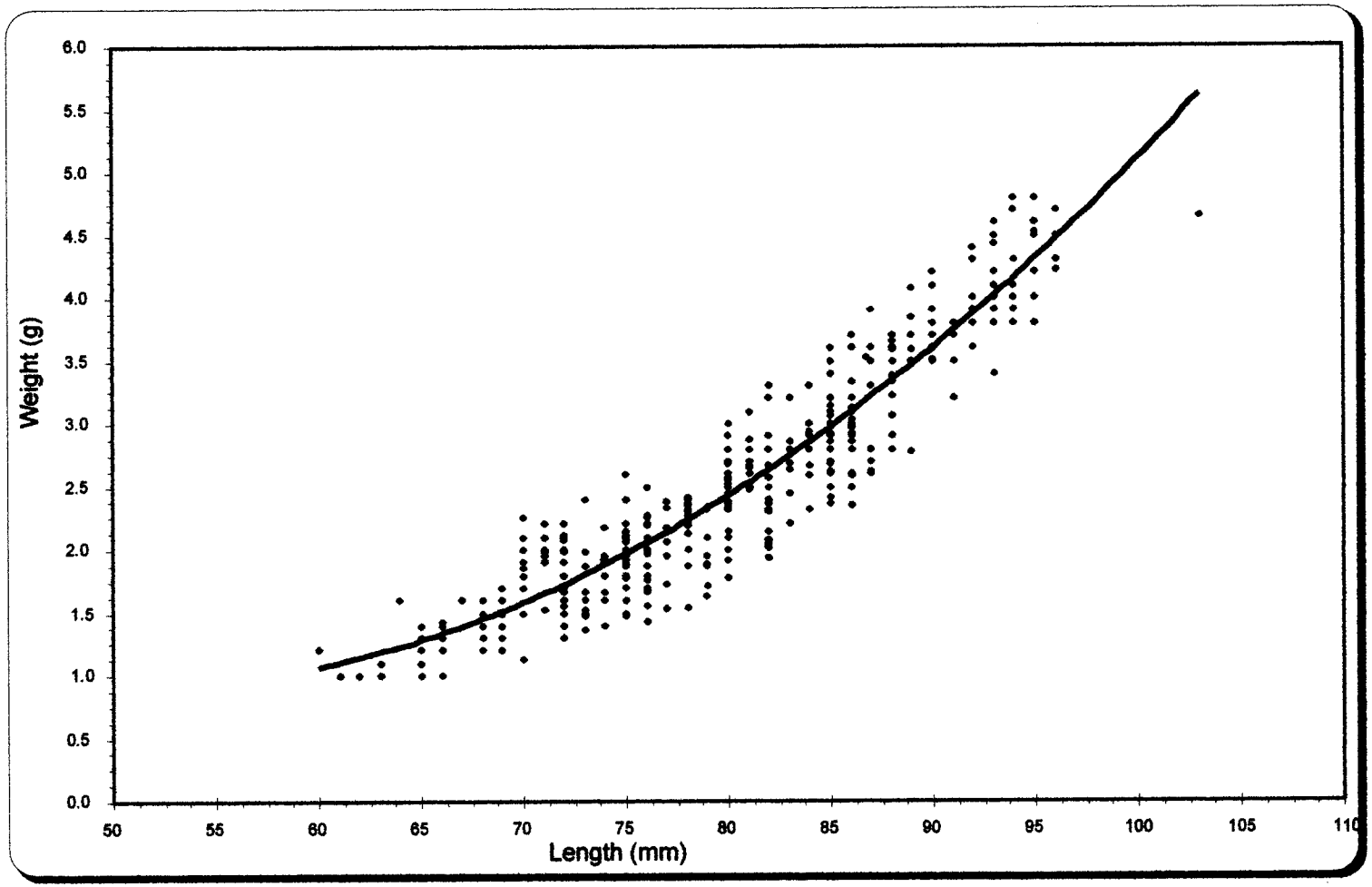


Fig. 3.1.4: *M. dobsoni* male: L-W Relationship for the period Aug '04 - Aug '05

Table 3.1.5: Analysis of Co-variance for comparison of Length-Weight Relationship of *M. dobsoni* during Aug '03 - Jul '04

Source of Variation	Degree Of Freedom (df) (n - 1)	$\sum x^2$	$\sum xy$	$\sum y^2$	b	Deviation From Regression			
						df (n - 2)	Sum of Squares	Mean Sum of Squares	F Ratio
Females	590	1.69	5.52	19.8609	3.2626	589	1.8455	0.003133	
Males	402	1.15	3.68	13.1734	3.2146	401	1.3405	0.003343	
Deviation from the Individual Regression Within Sexes						990	3.1860	0.003218	0.49
Pooled	992	2.84	9.20	33.0343	3.2386	991	3.1875	0.003216	
Difference Between Slopes							0.0016		

Table 3.1.6: Analysis of Co-variance for comparison of Length-Weight Relationship of *M. dobsoni* during Aug '04 - Aug '05

Source of Variation	Degree Of Freedom (df) (n - 1)	$\sum x^2$	$\sum xy$	$\sum y^2$	b	Deviation From Regression			
						df (n - 2)	Sum of Squares	Mean Sum of Squares	F Ratio
Females	671	2.07	6.85	25.1380	3.3118	670	2.4434	0.003647	
Males	532	1.18	3.83	14.1417	3.2566	531	1.6615	0.003129	
Deviation from the Individual Regression Within Sexes						1201	4.1049	0.003418	0.67
Pooled	1203	3.25	10.68	39.2797	3.2842	1202	4.1072	0.003417	
Difference Between Slopes							0.0023		

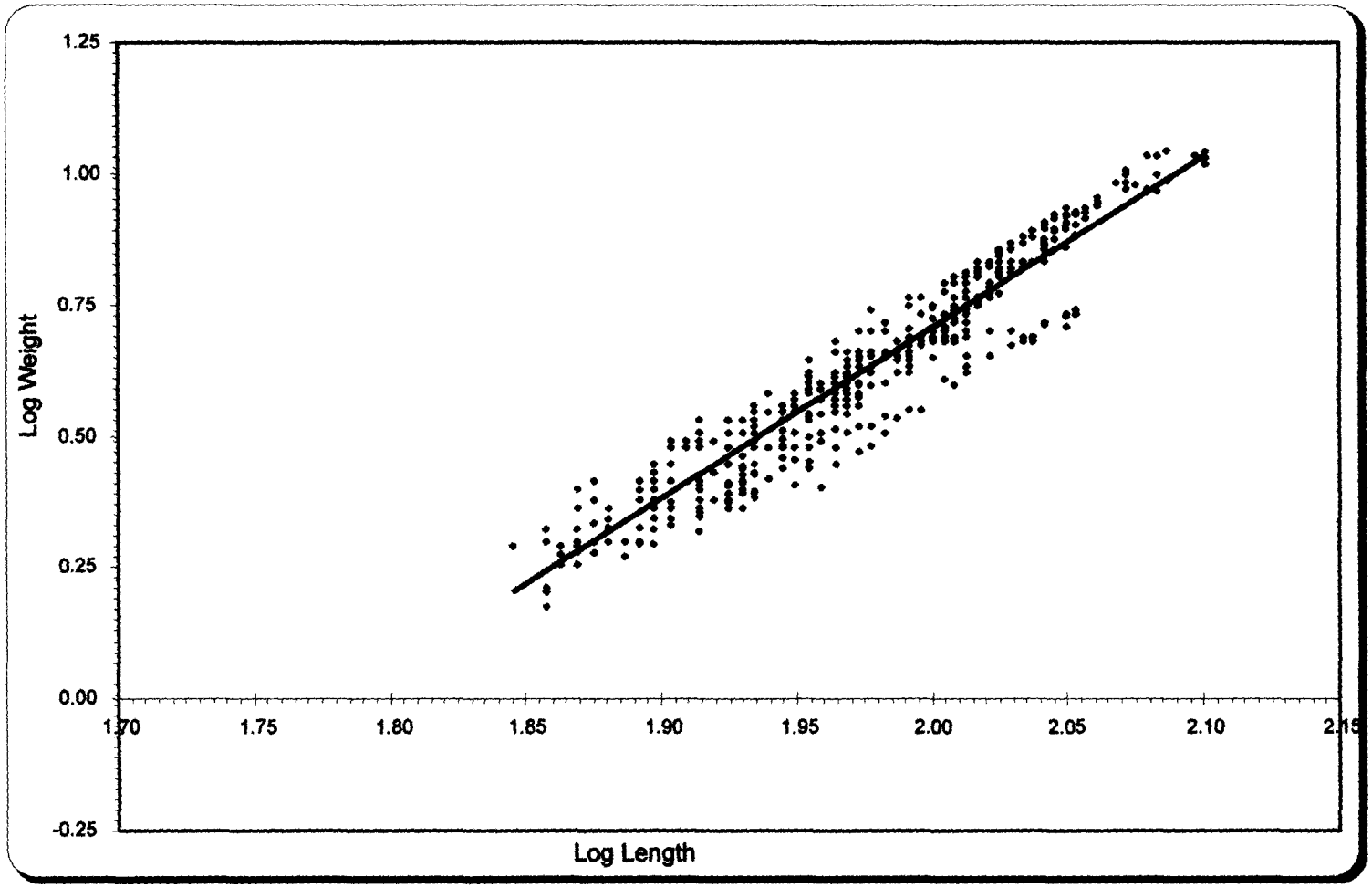


Fig. 3.1.5: *M. dobsoni* female: Logarithmic L-W Relationship for the period Aug '03 - Jul '04

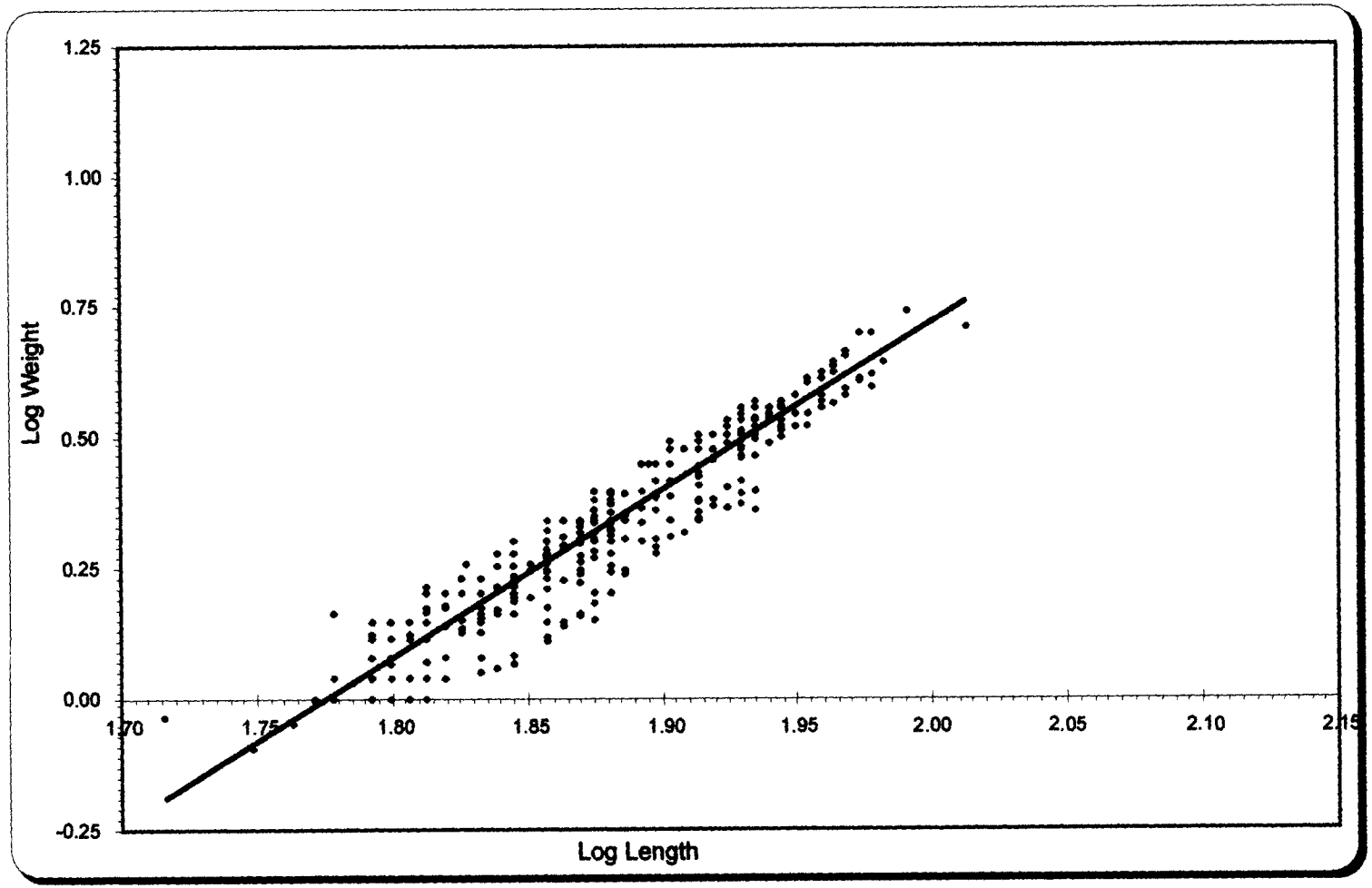


Fig. 3.1.6: *M. dobsoni* male: Logarithmic L-W Relationship for the period Aug '03 - Jul '04

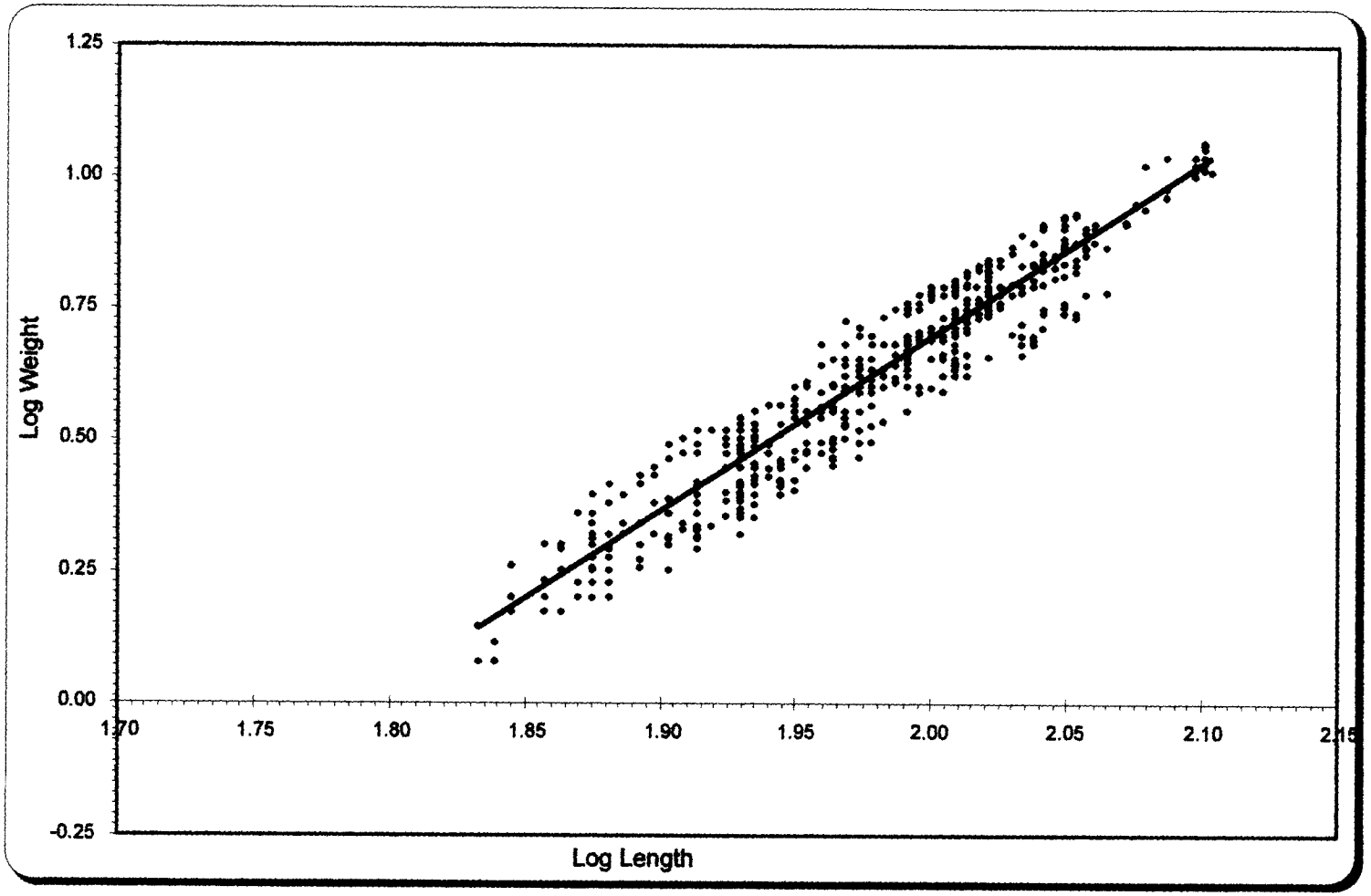


Fig. 3.1.7: *M. dobsoni* female: Logarithmic L-W Relationship for the period Aug '04 - Aug '05

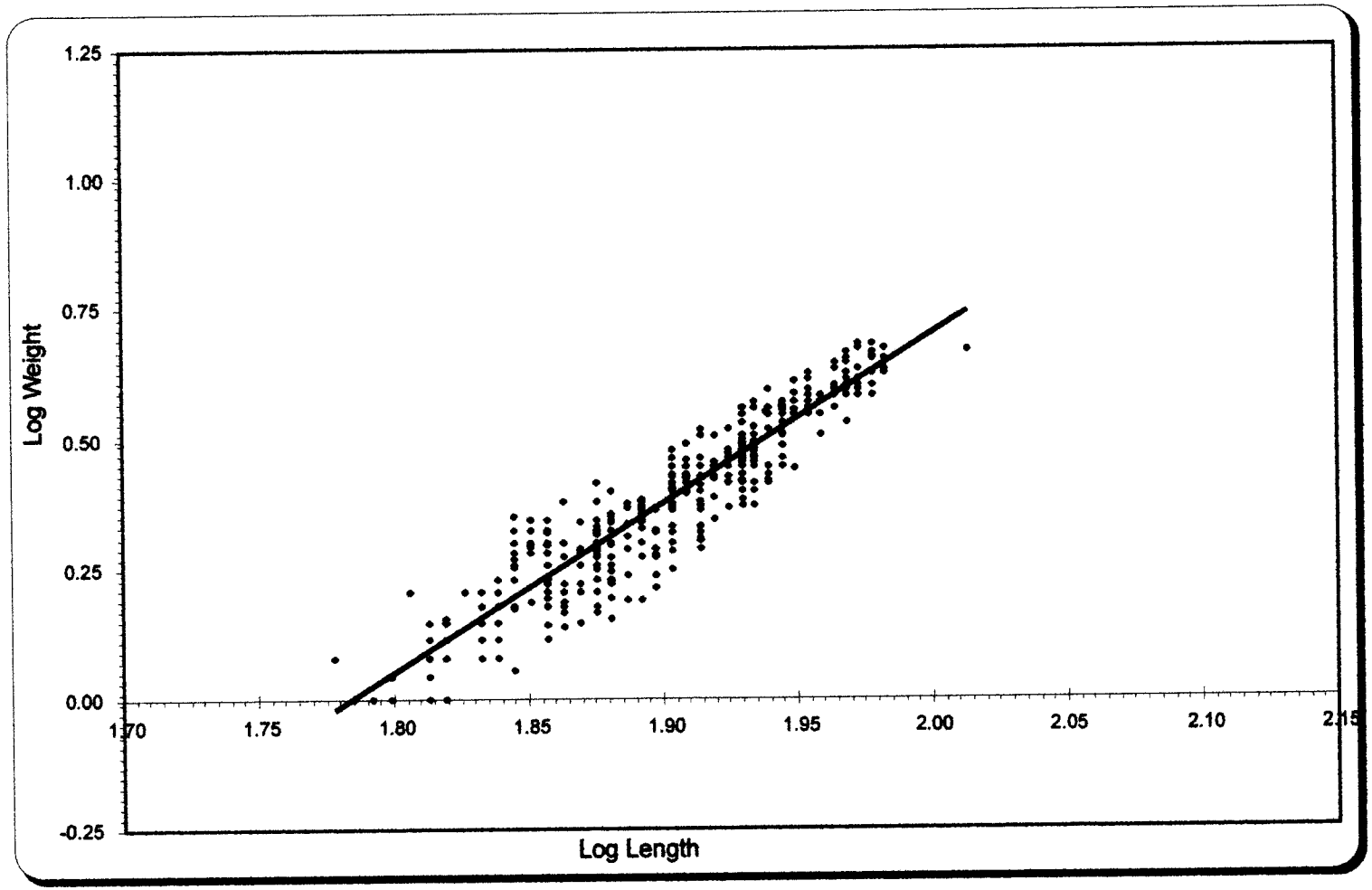


Fig. 3.1.8: *M. dobsoni* male: Logarithmic L-W Relationship for the period Aug '04 - Aug '05

Table 3.2.1: *M. dobsoni* mean Kn for the period Aug '03 - Jul '04

Month	Female		Male	
	No.	Mean Kn	No.	Mean Kn
Aug '03	57	1.0002	27	1.0004
Sep '03	47	1.0014	33	1.0008
Oct '03	42	1.0008	27	1.0024
Nov '03	62	1.0006	51	1.0031
Dec '03	59	1.0012	37	1.0014
Jan '04	65	1.0006	45	1.0043
Feb '04	53	1.0022	33	1.0033
Mar '04	56	1.0026	33	1.0023
Apr '04	57	1.0017	41	1.0013
May '04	52	1.0016	46	1.0016
Jul '04	41	1.0009	30	1.0008
Total	**591**	**1.0080**	**403**	**1.0086**

Table 3.2.2: *M. dobsoni* mean Kn for the period Aug '04 - Aug '05

Month	Female		Male	
	No.	Kn	No.	Kn
Aug '04	57	1.0003	44	1.0010
Sep '04	54	1.0003	33	1.0004
Oct '04	57	1.0009	45	1.0013
Nov '04	57	1.0005	48	1.0009
Dec '04	57	1.0005	44	1.0007
Jan '05	60	1.0005	47	1.0026
Feb '05	48	1.0026	31	1.0026
Mar '05	57	1.0020	51	1.0013
Apr '05	61	1.0014	55	1.0017
May '05	63	1.0022	51	1.0040
Jul '05	42	1.0008	40	1.0021
Aug '05	59	1.0018	44	1.0017
Total	**672**	**1.0096**	**533**	**1.0082**

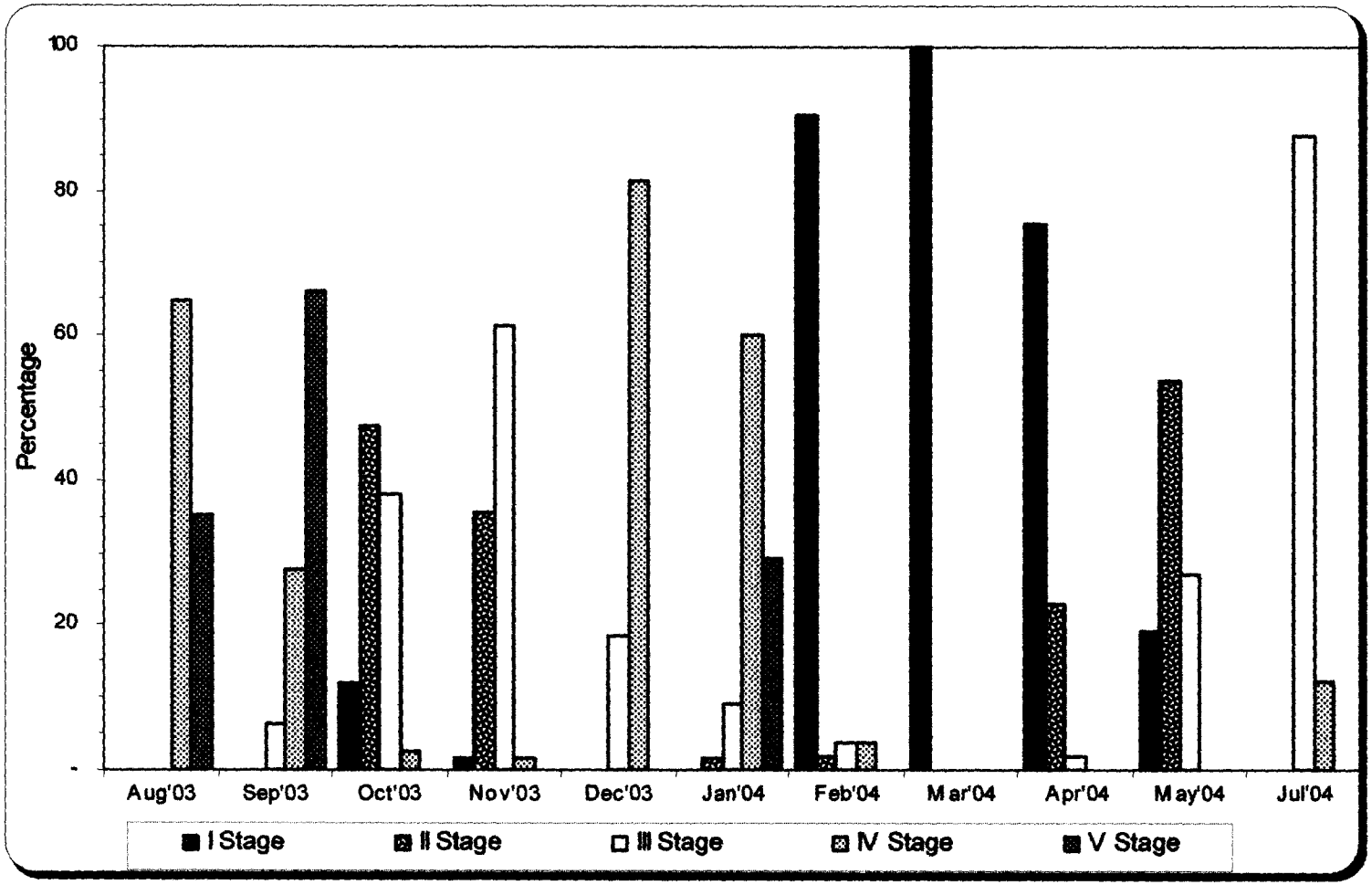


Fig. 3.3.1: *M. dobsoni* female: Percentage maturity stages for the period Aug '03 - Jul '04

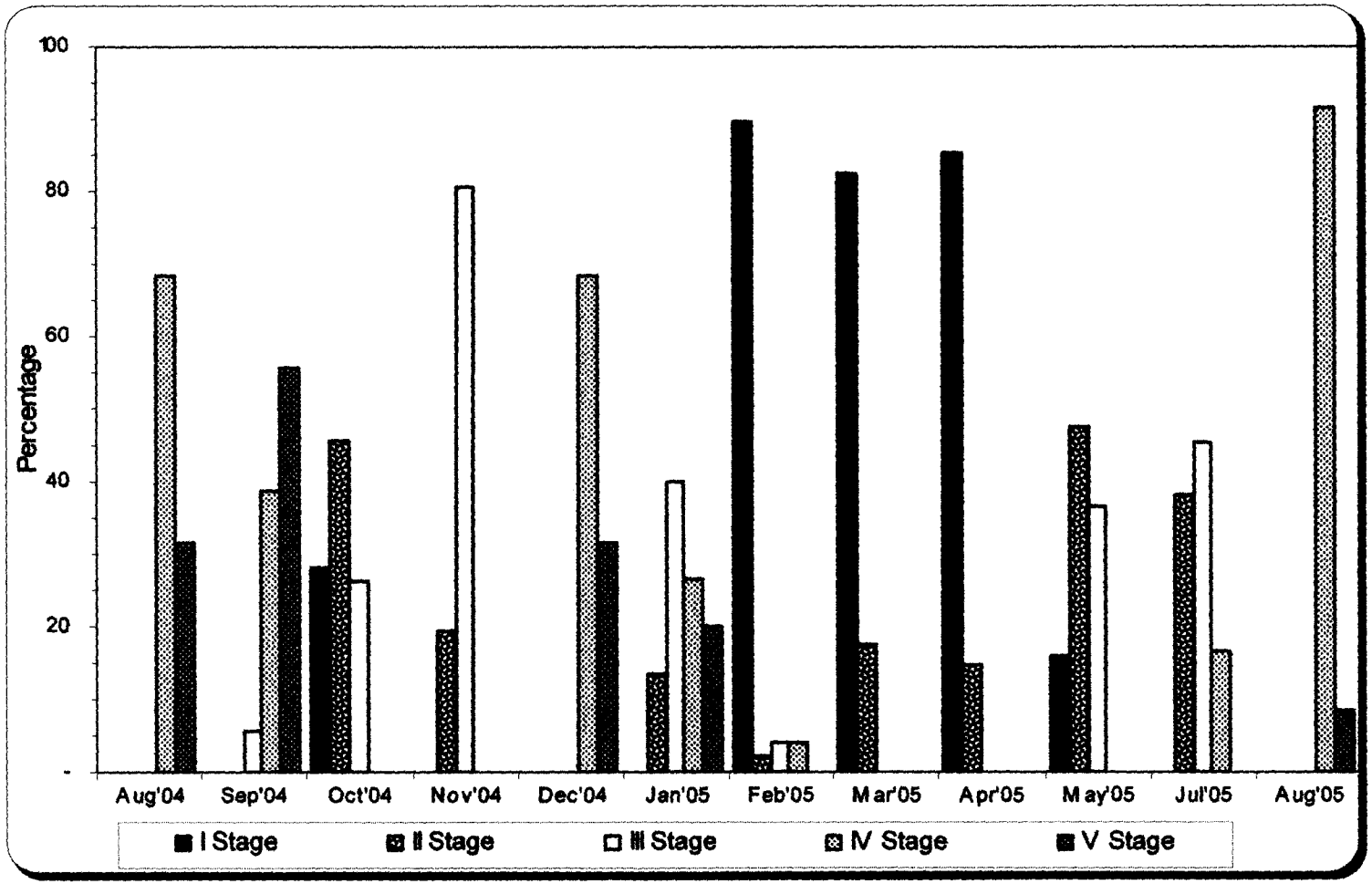


Fig. 3.3.2: *M. dobsoni* female: Percentage maturity stages for the period Aug '04 - Aug '05

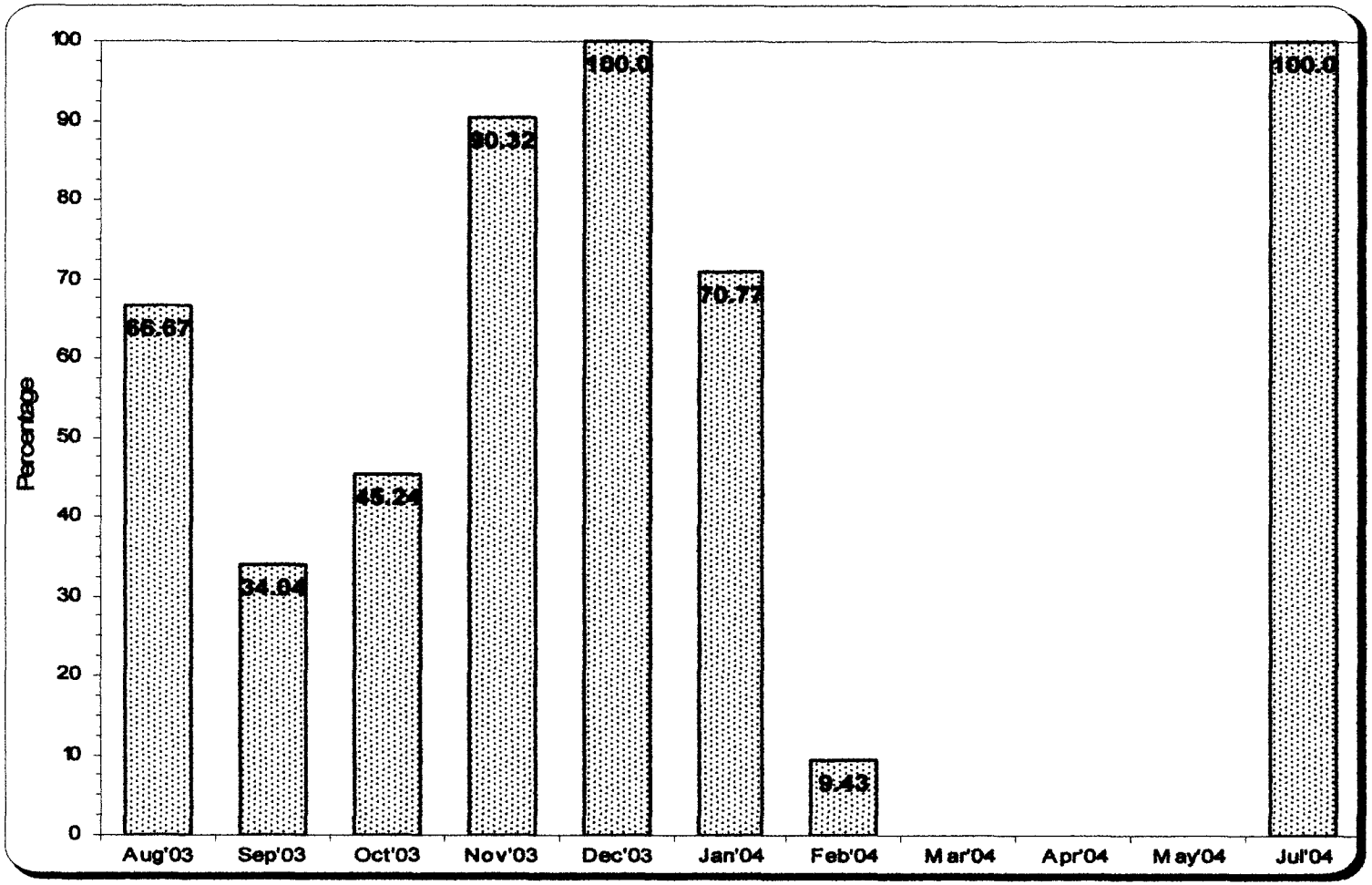


Fig. 3.3.3: *M. dobsoni* female: Percentage impregnation for the period Aug '03 - Jul '04

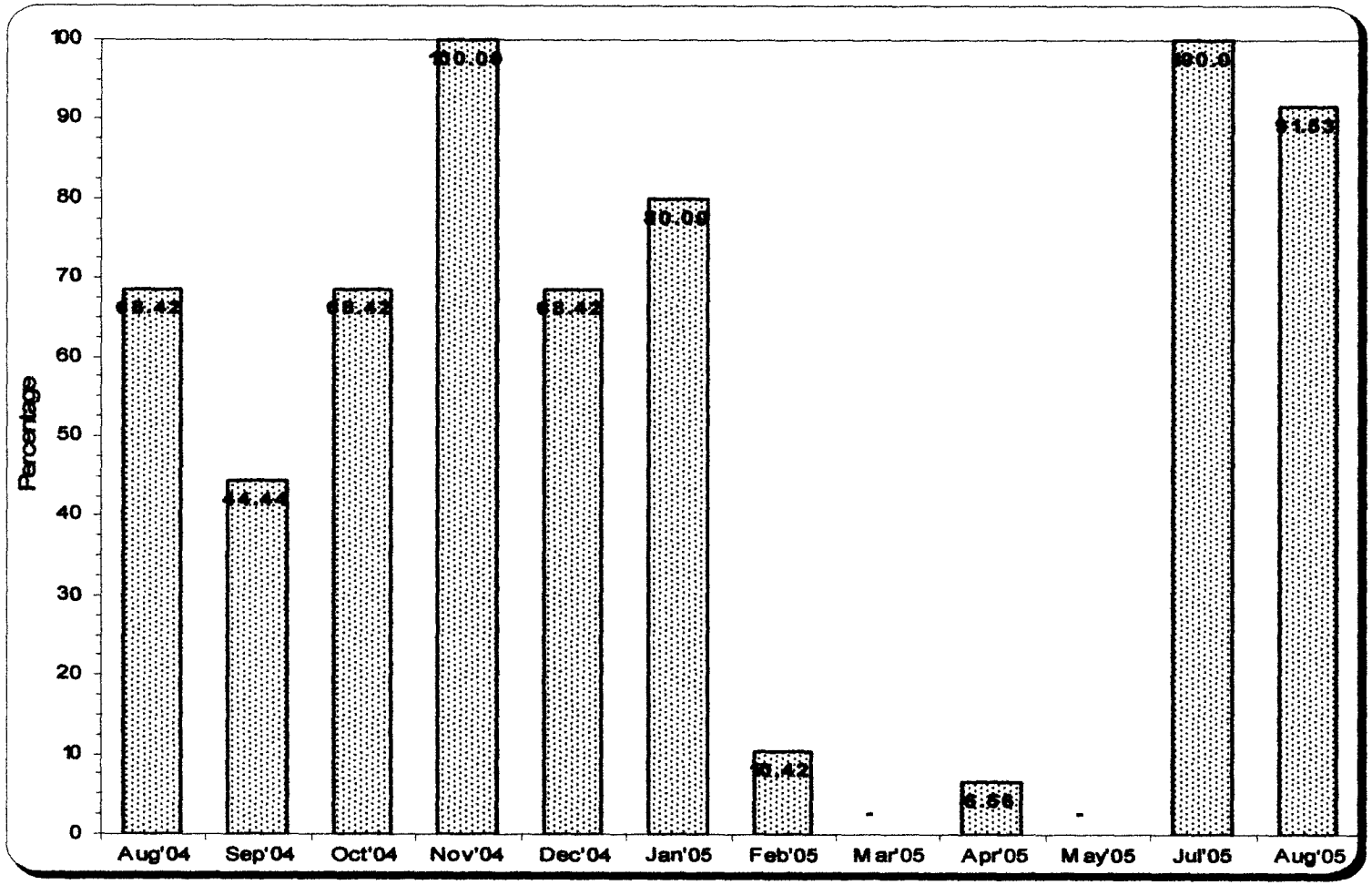


Fig. 3.3.4: *M. dobsoni* female: Percentage impregnation for the period Aug '04 - Aug '05

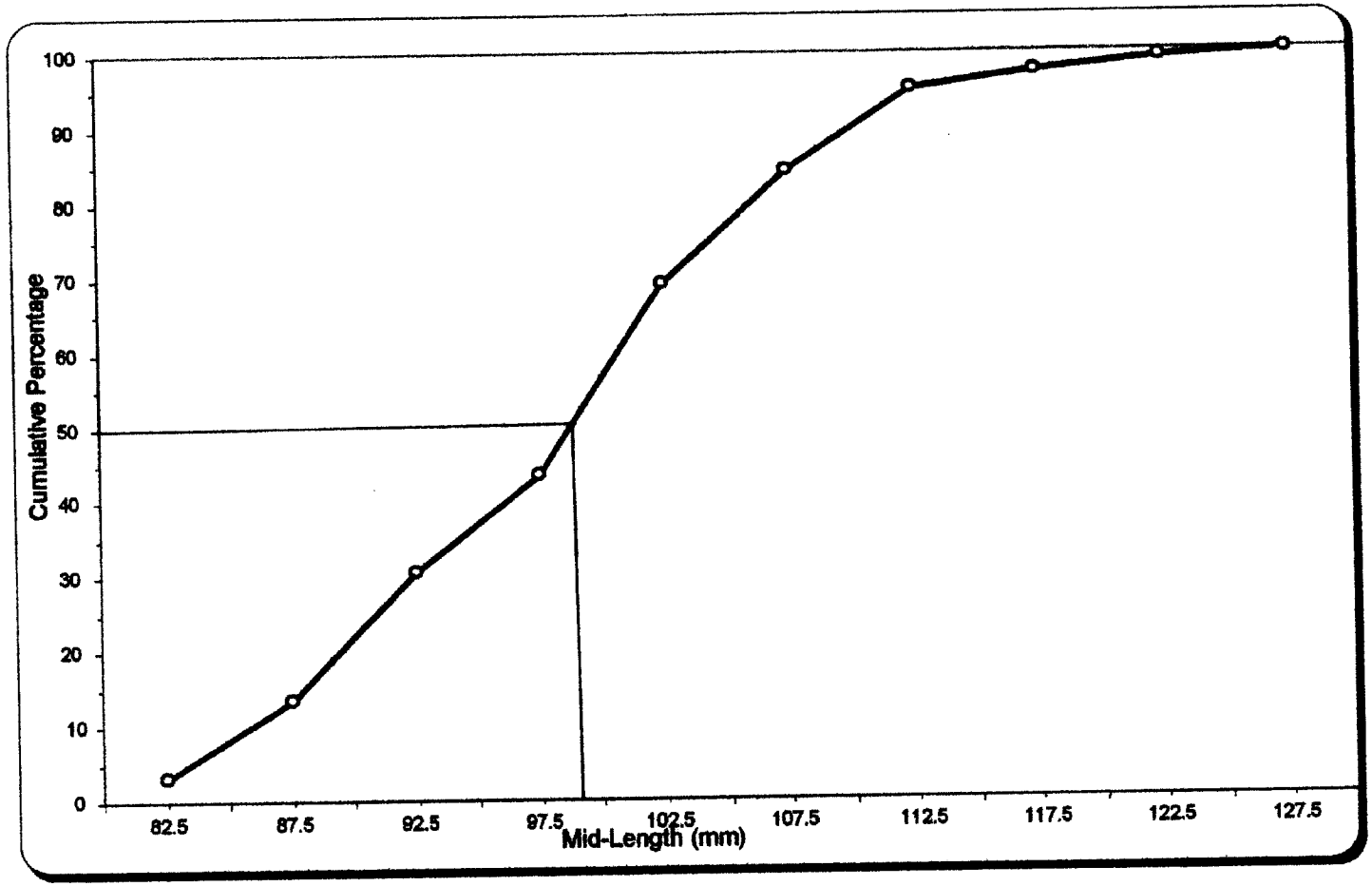


Fig. 3.3.5: Size at 1st maturity of *M. dobsoni* female for the period Aug '03 - Jul '04

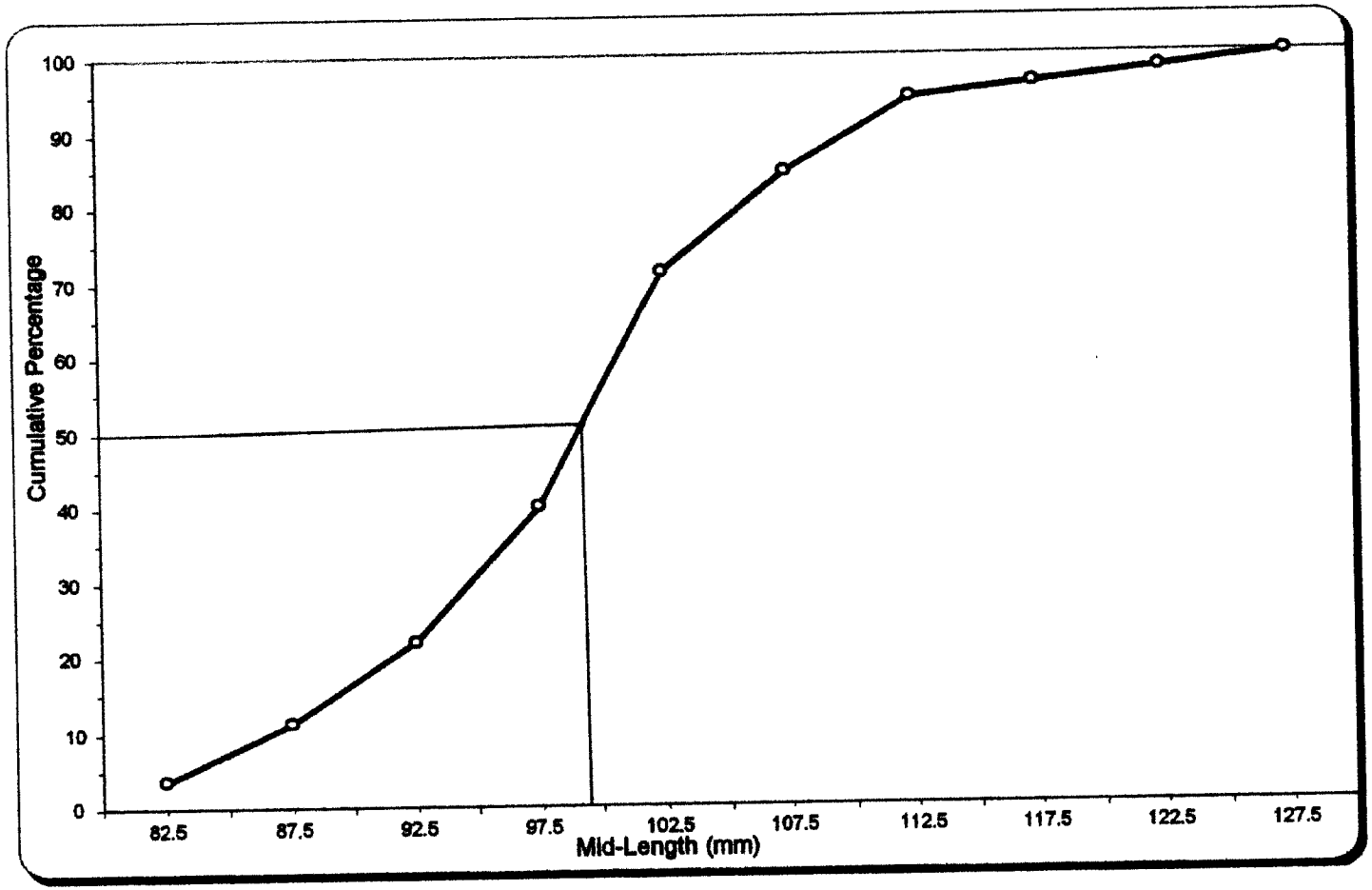


Fig. 3.3.6: Size at 1st maturity of *M. dobsoni* female for the period Aug '04 - Aug '05

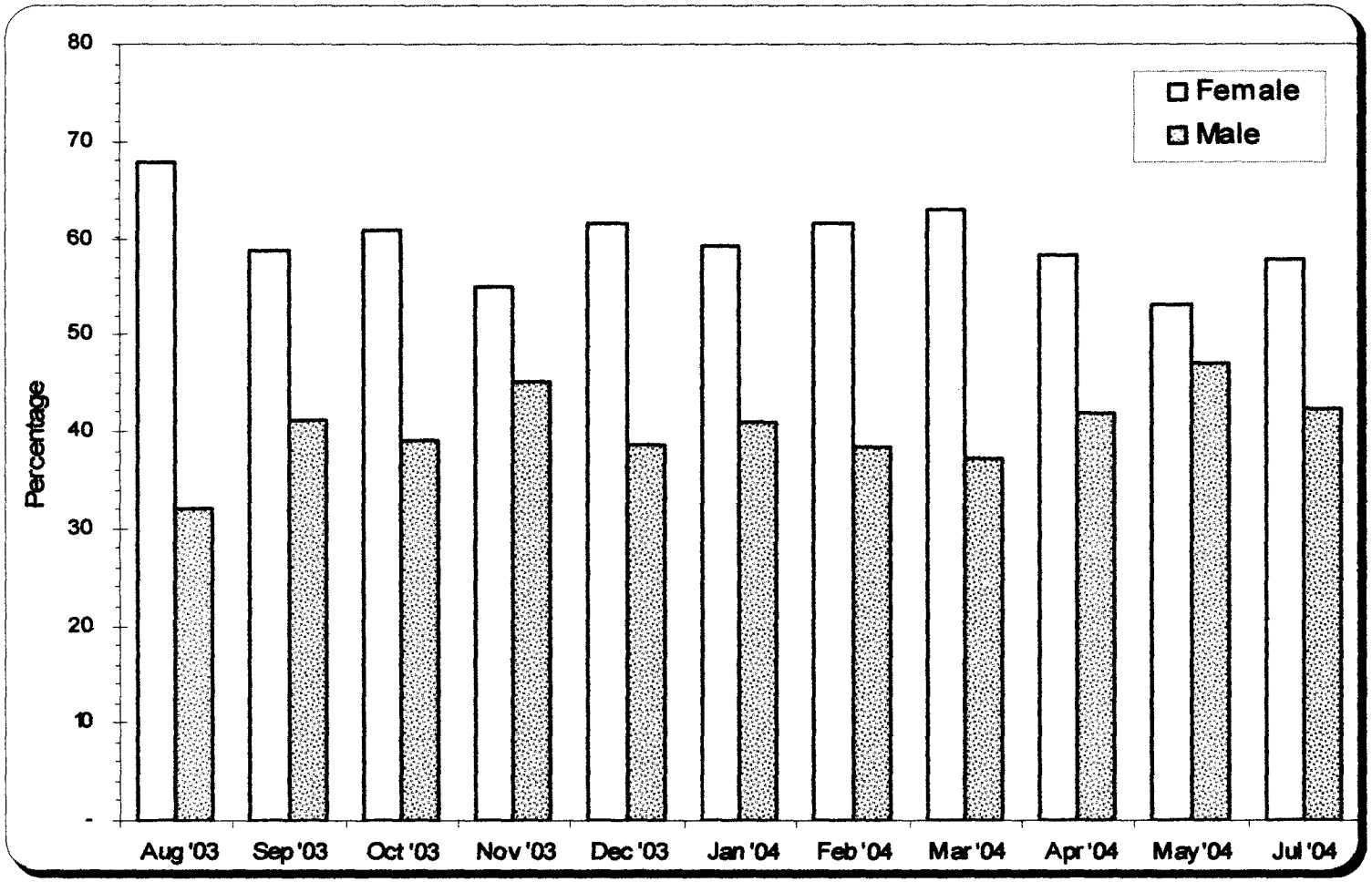


Fig. 3.3.7: *M. dobsoni*: Percentage occurrence of females and males during the period Aug '03 - Jul '04

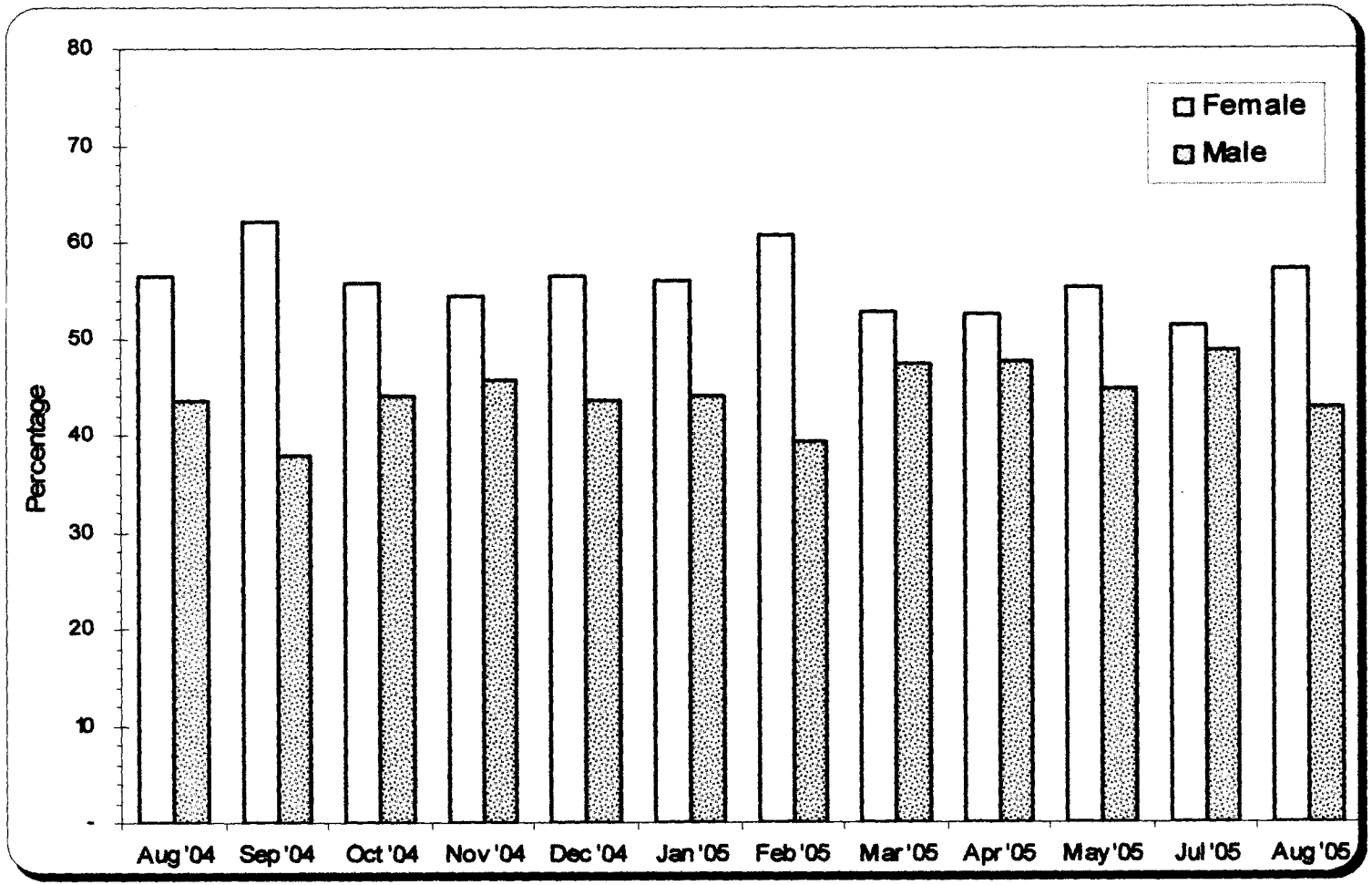


Fig. 3.3.8: *M. dobsoni*: Percentage occurrence of females and males during the period Aug '04 - Aug '05

Table 3.3.1: Sex Ratio of *M. dobsoni* in monthly samples during Aug '03 - Jul '04

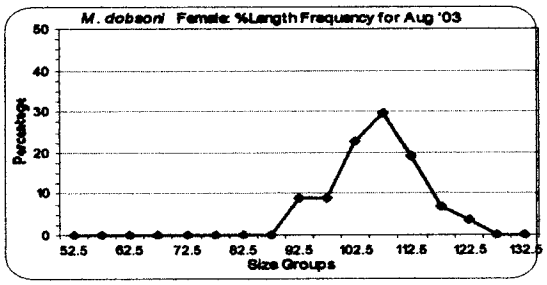
Month	Female	Male	Total	Female χ^2	Male χ^2	χ^2	F:M Ratio
Aug '03	57	27	84	5.3571	5.3571	10.7143 *	2.1111
Sep '03	47	33	80	1.2250	1.2250	2.4500	1.4242
Oct '03	42	27	69	1.6304	1.6304	3.2609	1.5556
Nov '03	62	51	113	0.5354	0.5354	1.0708	1.2157
Dec '03	59	37	96	2.5208	2.5208	5.0417 *	1.5946
Jan '04	65	45	110	1.8182	1.8182	3.6364	1.4444
Feb '04	53	33	86	2.3256	2.3256	4.6512 *	1.6061
Mar '04	56	33	89	2.9719	2.9719	5.9438 *	1.6970
Apr '04	57	41	98	1.3061	1.3061	2.6122	1.3902
May '04	52	46	98	0.1837	0.1837	0.3673	1.1304
Jul '04	41	30	71	0.8521	0.8521	1.7042	1.3667
2003 - 2004	**591**	**403**	**994**	**17.7787**	**17.7787**	**35.5573 ***	**1.4665**

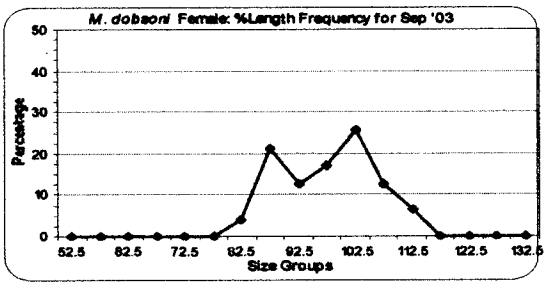
* Significant at 5% Level

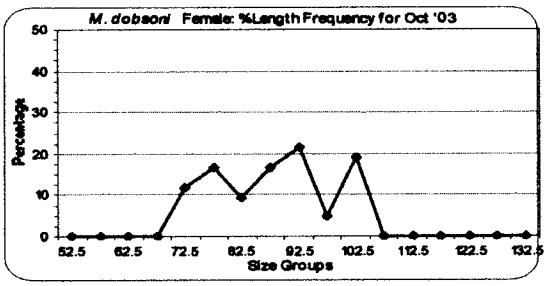
Table 3.3.2: Sex Ratio of *M. dobsoni* in monthly samples during Aug '04 - Aug '05

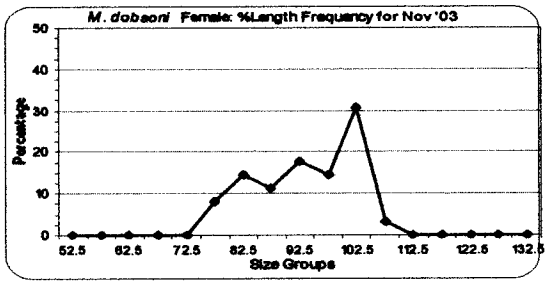
Month	Female	Male	Total	Female χ^2	Male χ^2	χ^2	F:M Ratio
Aug '04	57	44	101	0.8366	0.8366	1.6733	1.2955
Sep '04	54	33	87	2.5345	2.5345	5.0690 *	1.6364
Oct '04	57	45	102	0.7059	0.7059	1.4118	1.2667
Nov '04	57	48	105	0.3857	0.3857	0.7714	1.1875
Dec '04	57	44	101	0.8366	0.8366	1.6733	1.2955
Jan '05	60	47	107	0.7897	0.7897	1.5794	1.2766
Feb '05	48	31	79	1.8291	1.8291	3.6582	1.5484
Mar '05	57	51	108	0.1667	0.1667	0.3333	1.1176
Apr '05	61	55	116	0.1552	0.1552	0.3103	1.1091
May '05	63	51	114	0.6316	0.6316	1.2632	1.2353
Jul '05	42	40	82	0.0244	0.0244	0.0488	1.0500
Aug '05	59	44	103	1.0922	1.0922	2.1845	1.3409
2004 - 2005	**672**	**533**	**1205**	**8.0170**	**8.0170**	**16.0340 ***	**1.2608**

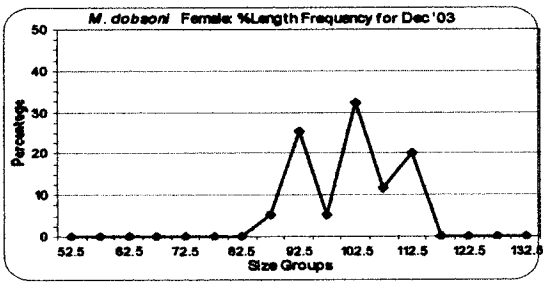
* Significant at 5% Level

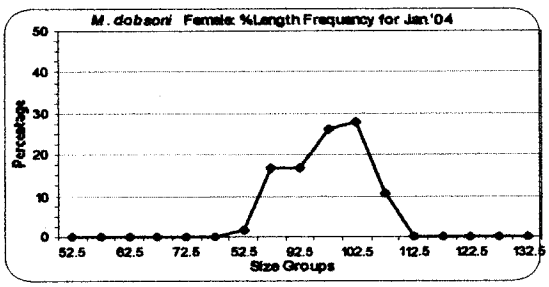


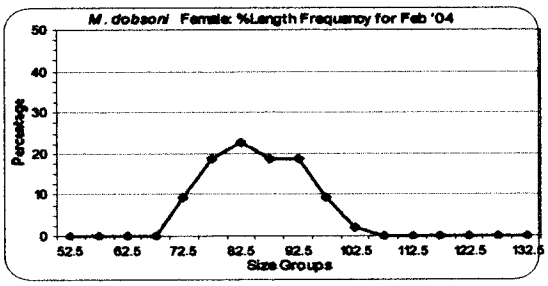


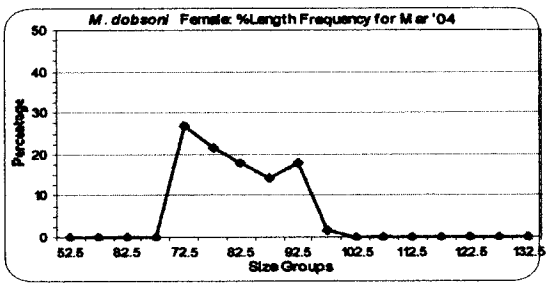


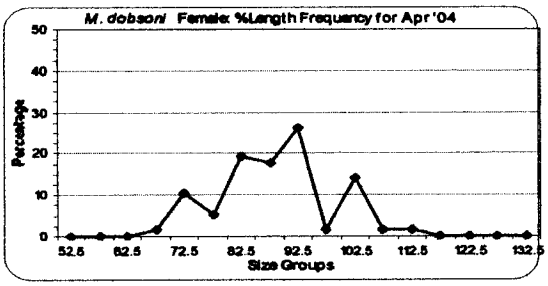


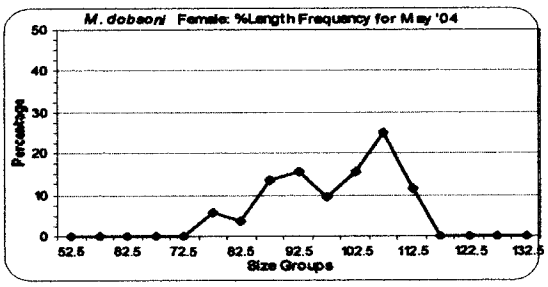












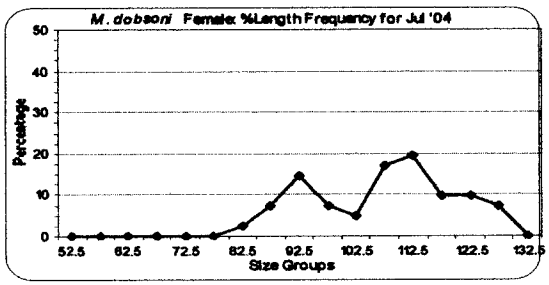
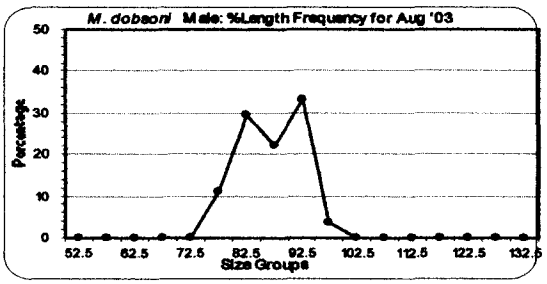
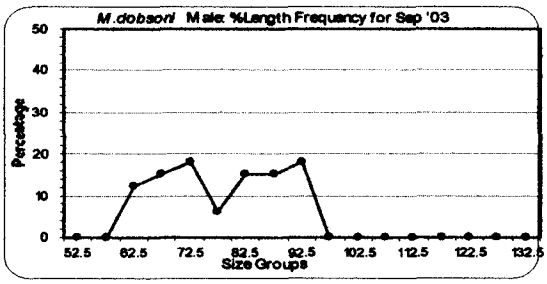
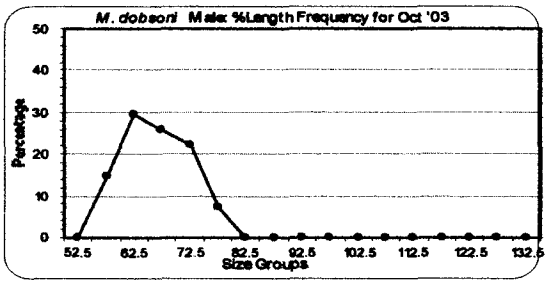
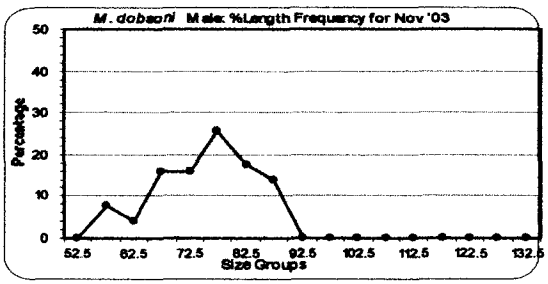


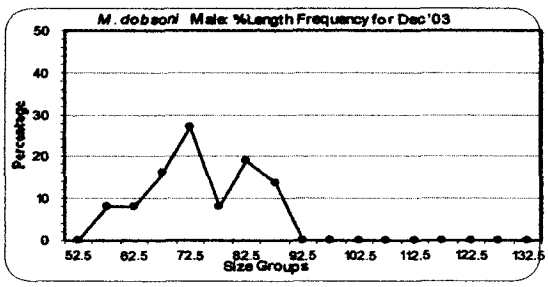
Fig. 3.4.1: Graphs depicting the percentage Length-Frequency of different size groups of *M. dobsoni* female during Aug '03 - Jul '04.

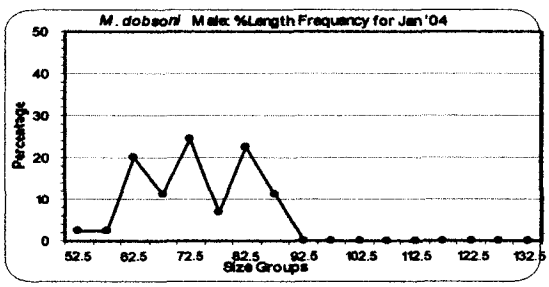


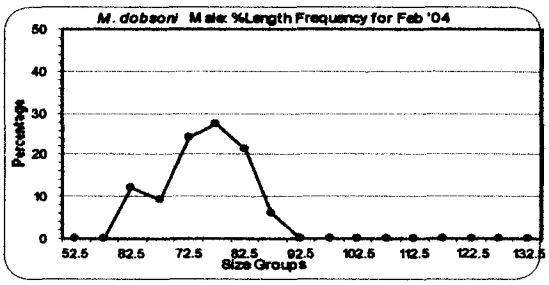


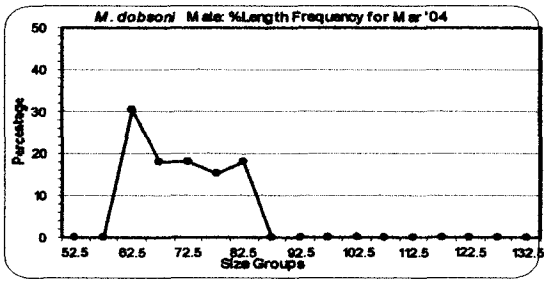


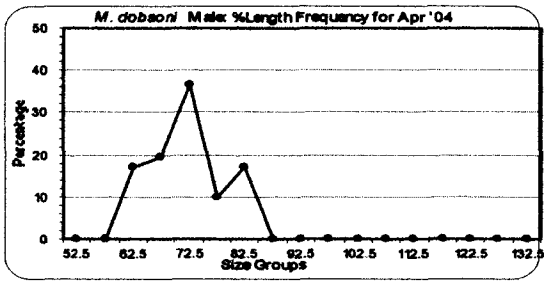


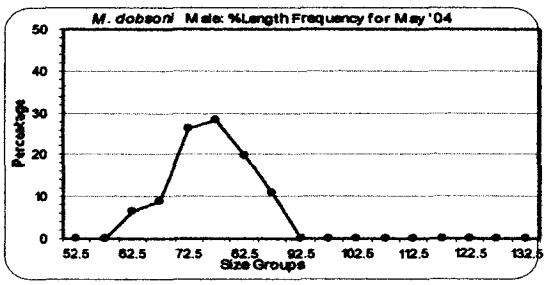












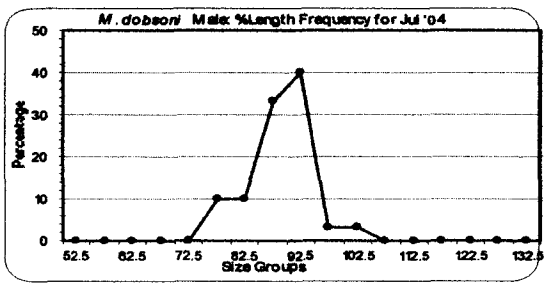
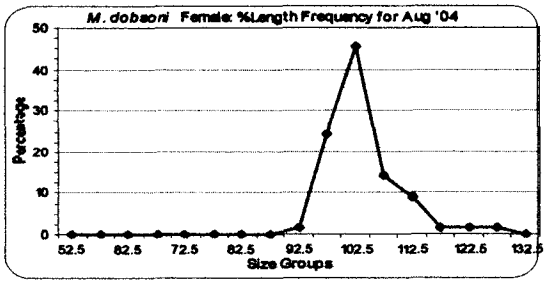


Fig. 3.4.2: Graphs depicting the percentage Length-Frequency of different size groups of *M. dobsoni* male during Aug '0 - Jul '04.



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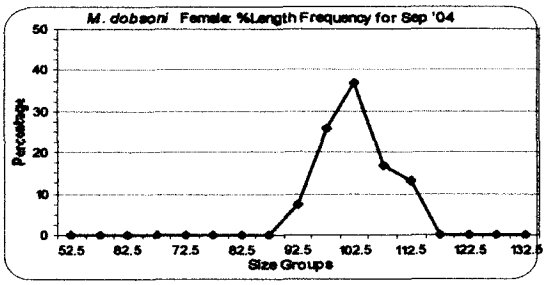

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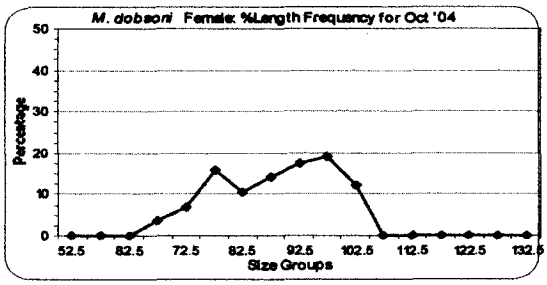

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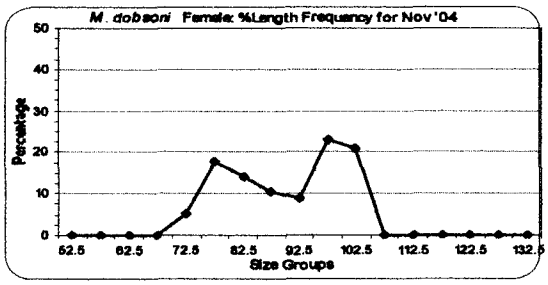

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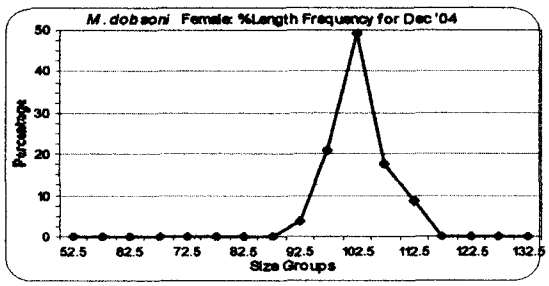

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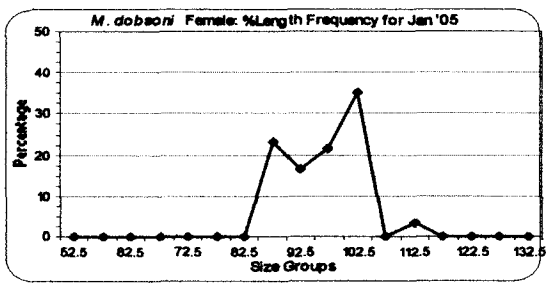

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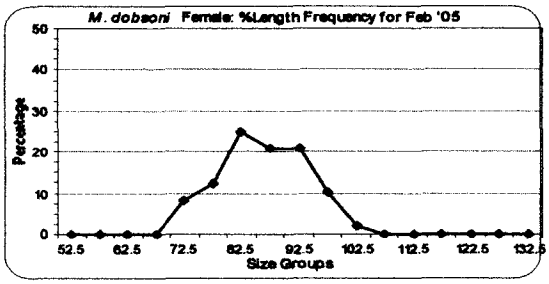

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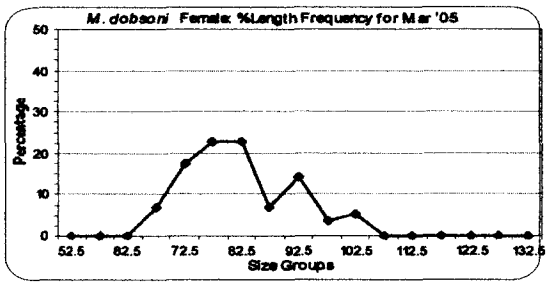

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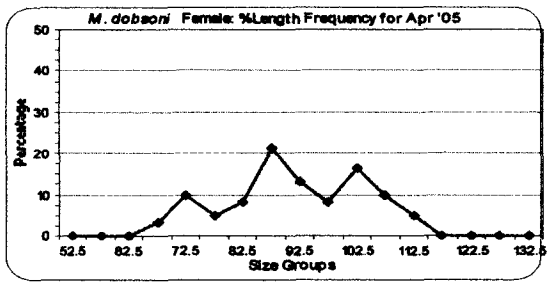

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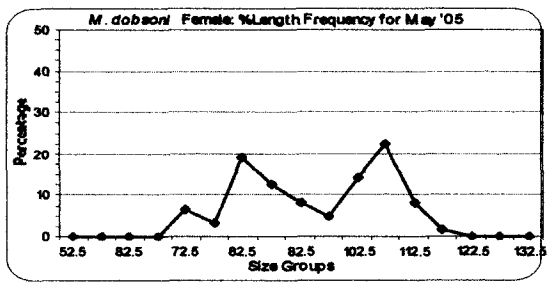

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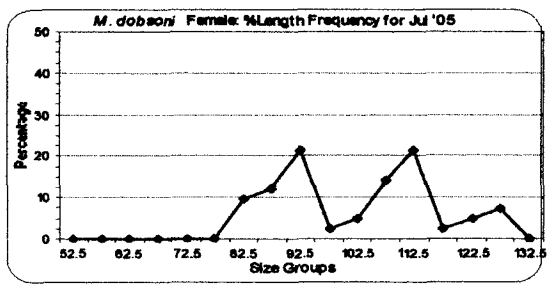

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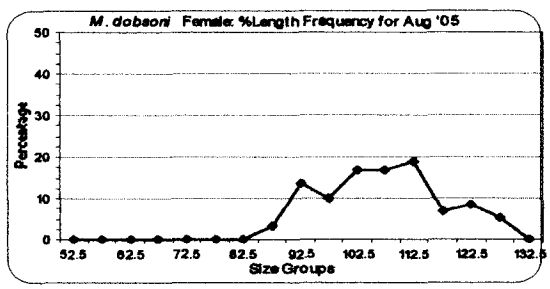

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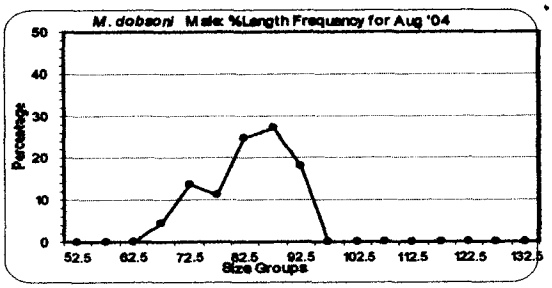
Fig. 3.4.3: Graphs depicting the percentage Length-Frequency of different size groups of *M. dobsoni* female during Aug '04 - Aug '05.



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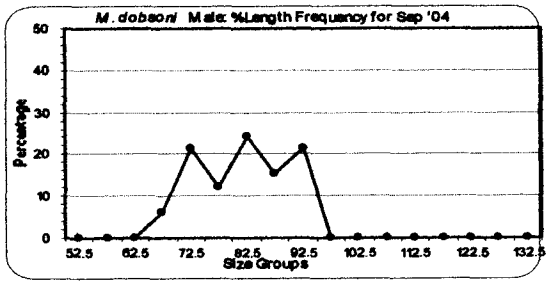

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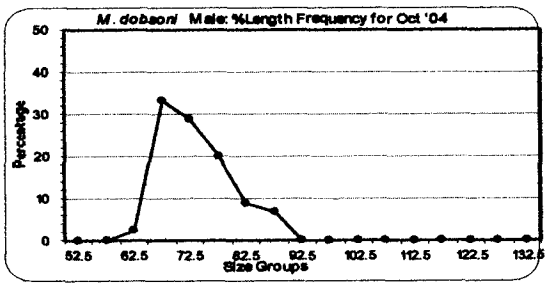

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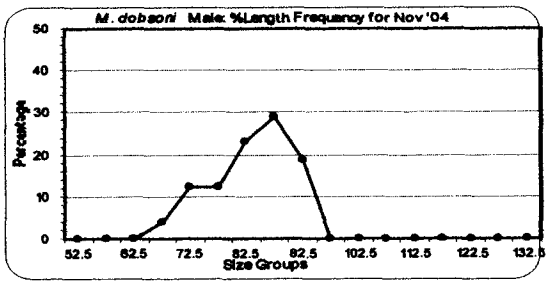

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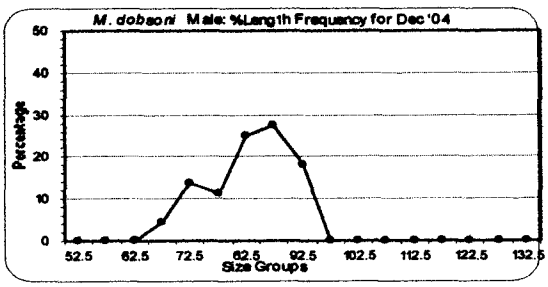

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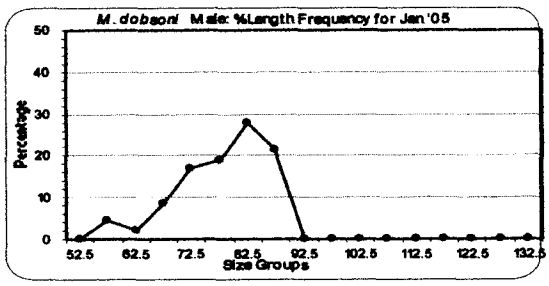

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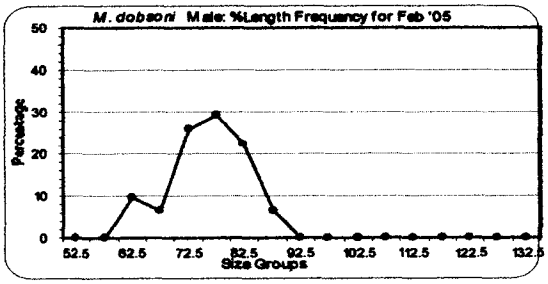

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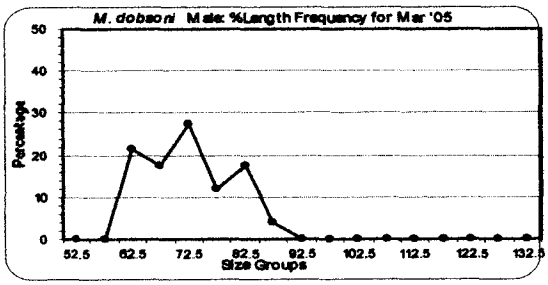

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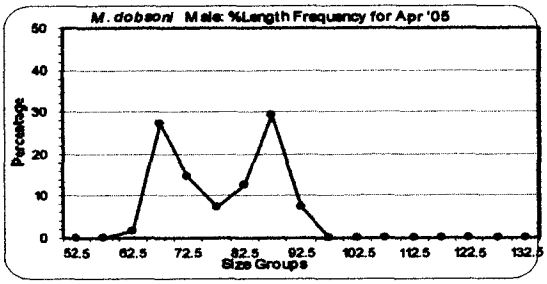

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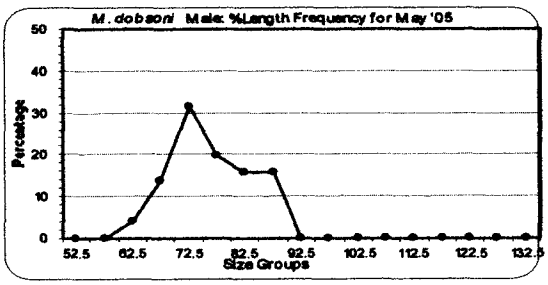

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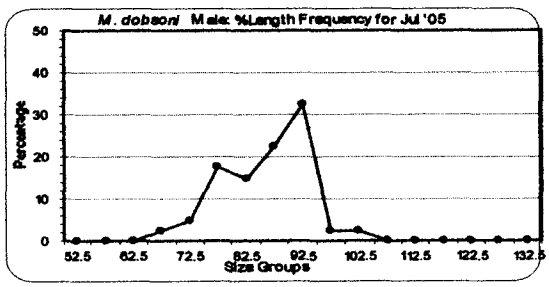

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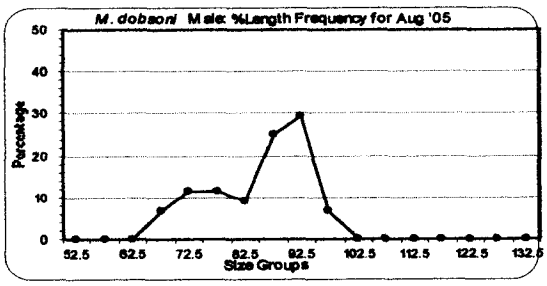

N = 44

Fig. 3.4.4: Graphs depicting the percentage Length-Frequency of different size groups of *M. dobsoni* male during Aug '04 - Aug '05.

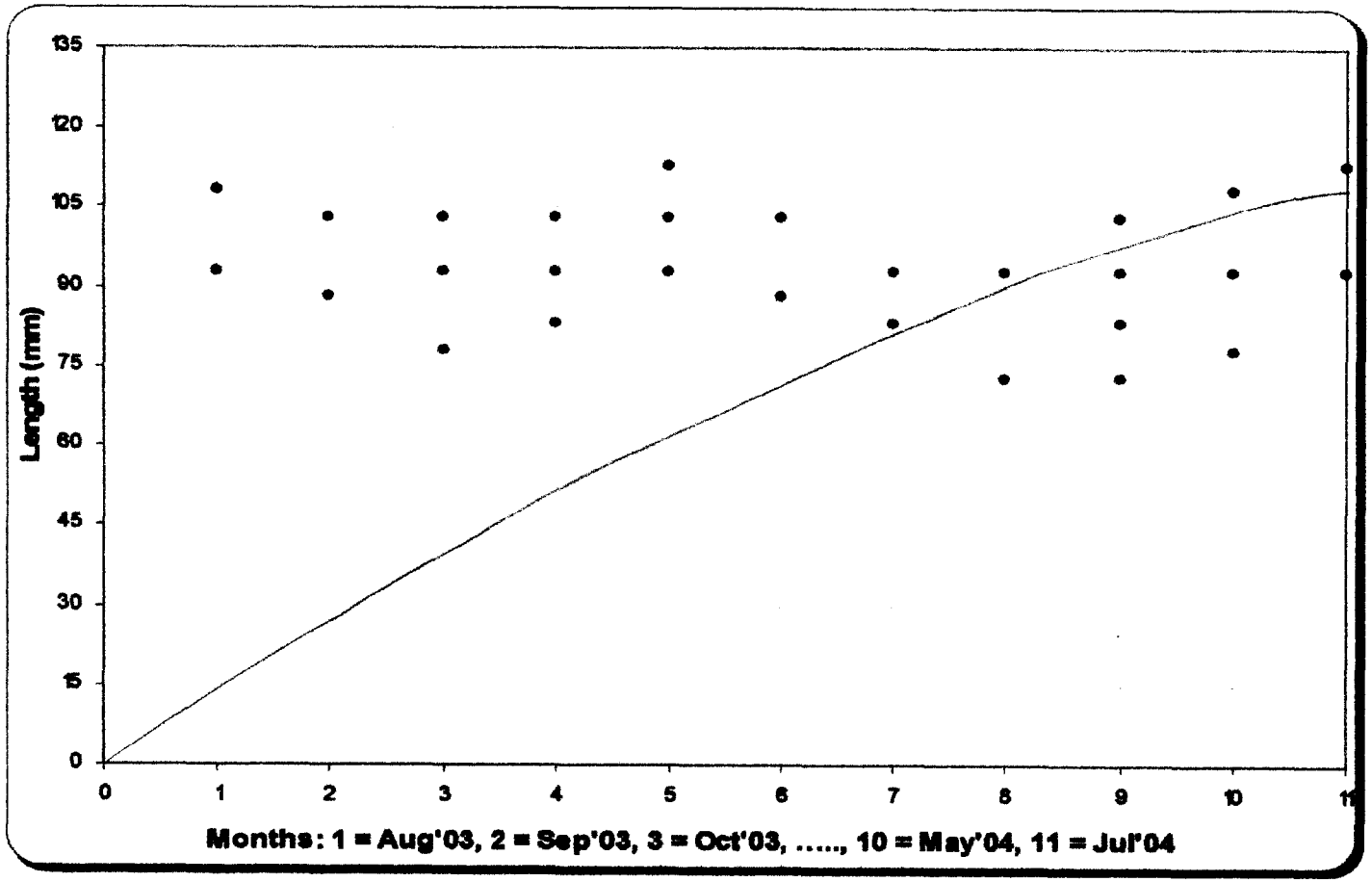

Fig. 3.4.5: Model length - month Scatter Diagram for *M. dobsoni* female during Aug '03 - Jul '04

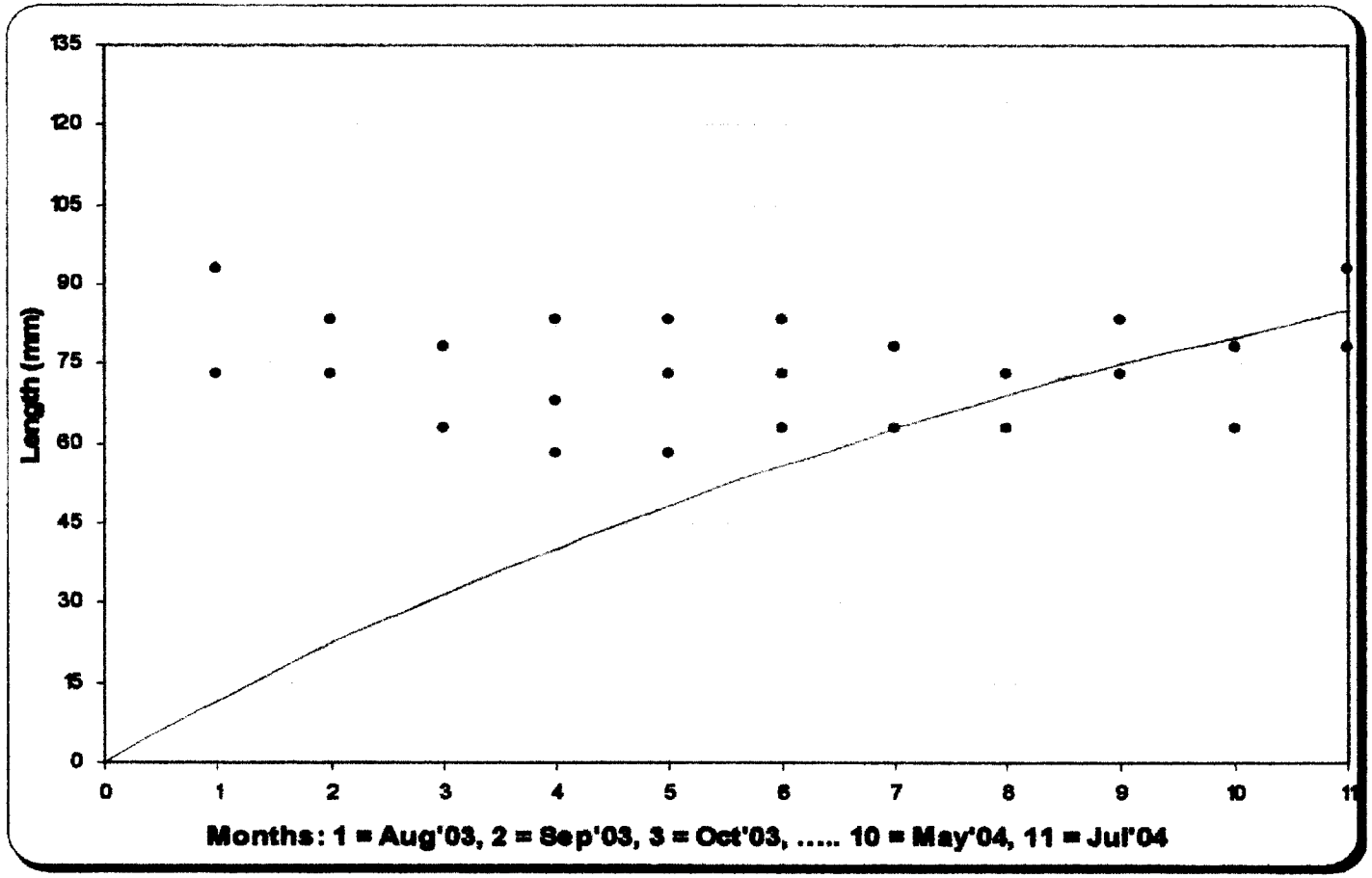

Fig. 3.4.6: Model length - month Scatter Diagram for *M. dobsoni* male during Aug '03 - Jul '04

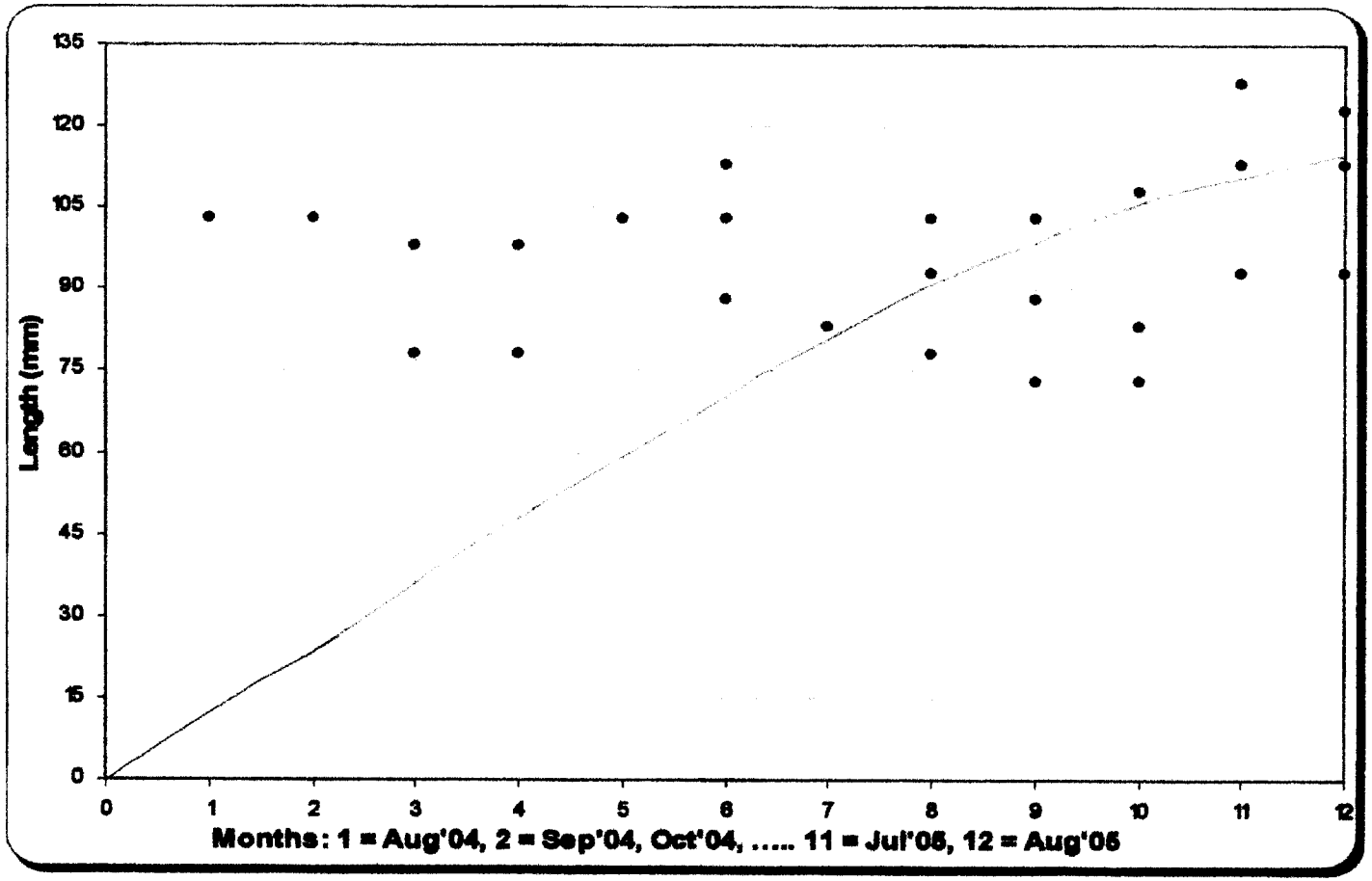

Fig. 3.4.7: Model length - month Scatter Diagram for *M. dobsoni* female during Aug '04 - Aug '05

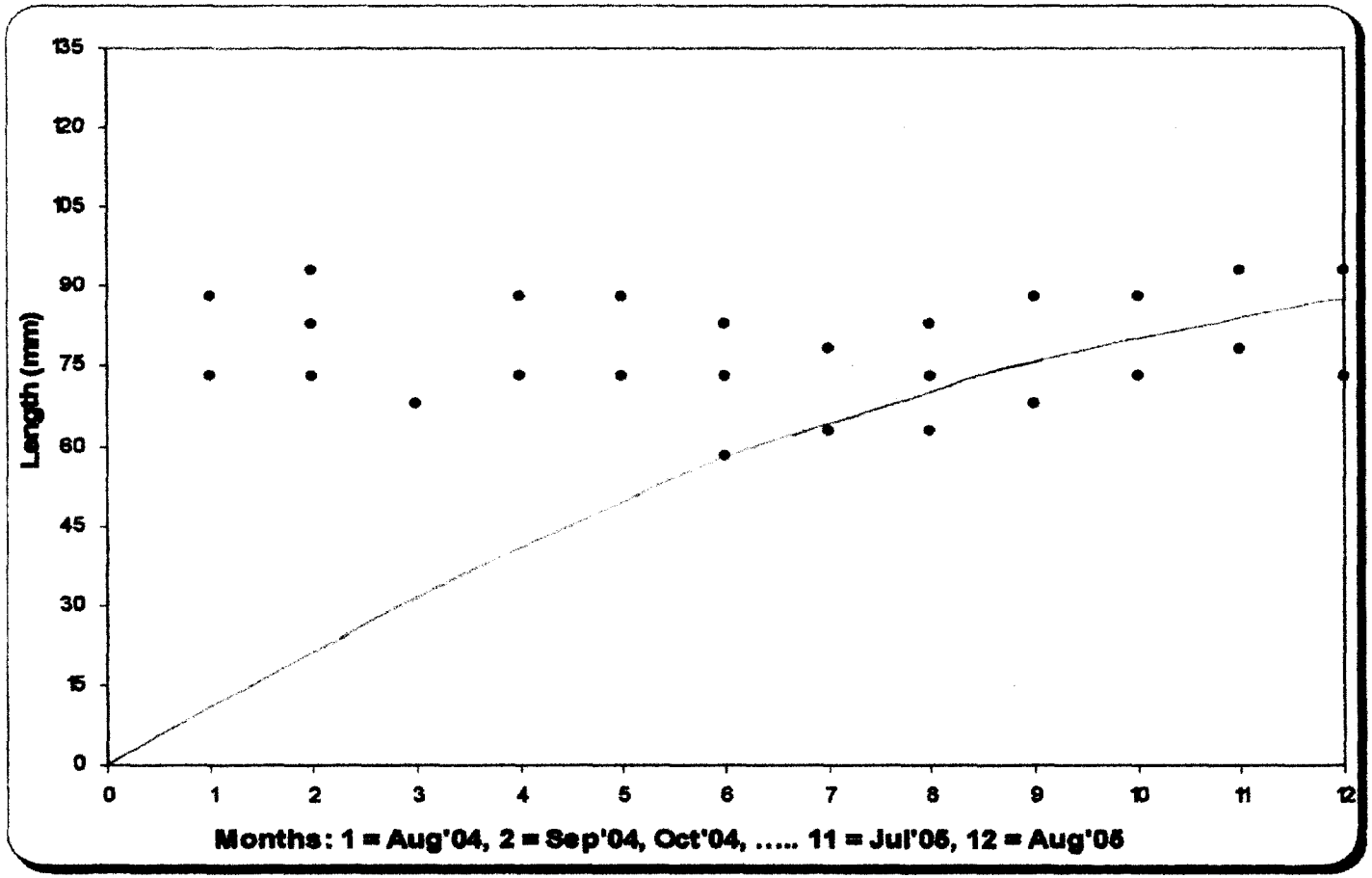

Fig. 3.4.8: Model length - month Scatter Diagram for *M. dobsoni* male during Aug '04 - Aug '05

Table 3.4.1: *M. dobsoni* mean length (mm) at monthly intervals from Scatter Diagram during Aug '03 - Jul '04

Sex	Female		Male	
Years (t)	Mean Length	Growth Rate	Mean Length	Growth Rate
Aug '03	14	-	11	-
Sep '03	28	14	22	11
Oct '03	40	12	32	10
Nov '03	51	11	41	9
Dec '03	61	10	49	8
Jan '04	71	10	57	8
Feb '04	80	9	64	7
Mar '04	88	8	70	6
Apr '04	95	7	75	5
May '04	101	6	79	4
Jul '04	107	6	82	3

Table 3.4.2: *M. dobsoni* mean length (mm) at monthly intervals from Scatter Diagram during Aug '04 - Aug '05

Sex	Female		Male	
Years (t)	Mean Length	Growth Rate	Mean Length	Growth Rate
Aug '04	10	-	10	-
Sep '04	23	13	21	11
Oct '04	36	13	31	10
Nov '04	48	12	40	9
Dec '04	60	12	49	9
Jan '05	71	11	57	8
Feb '05	81	10	64	7
Mar '05	91	10	70	6
Apr '05	100	9	75	5
May '05	106	6	79	4
Jul '05	110	4	82	3
Aug '05	113	3	85	3

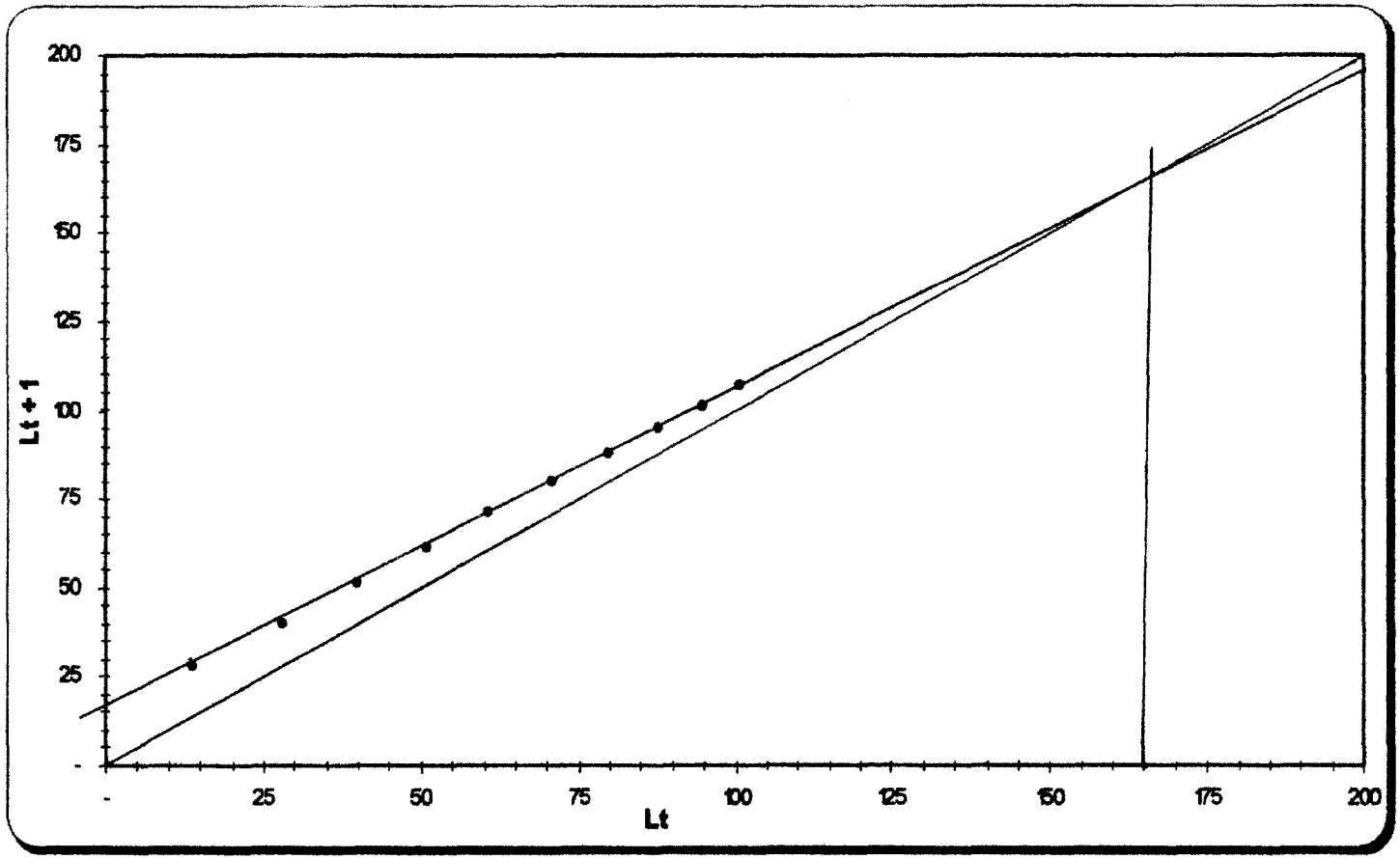

Fig. 3.4.9: Ford Wolford plot for L_∞ of *M. dobsoni* female during Aug '03 - Jul '04

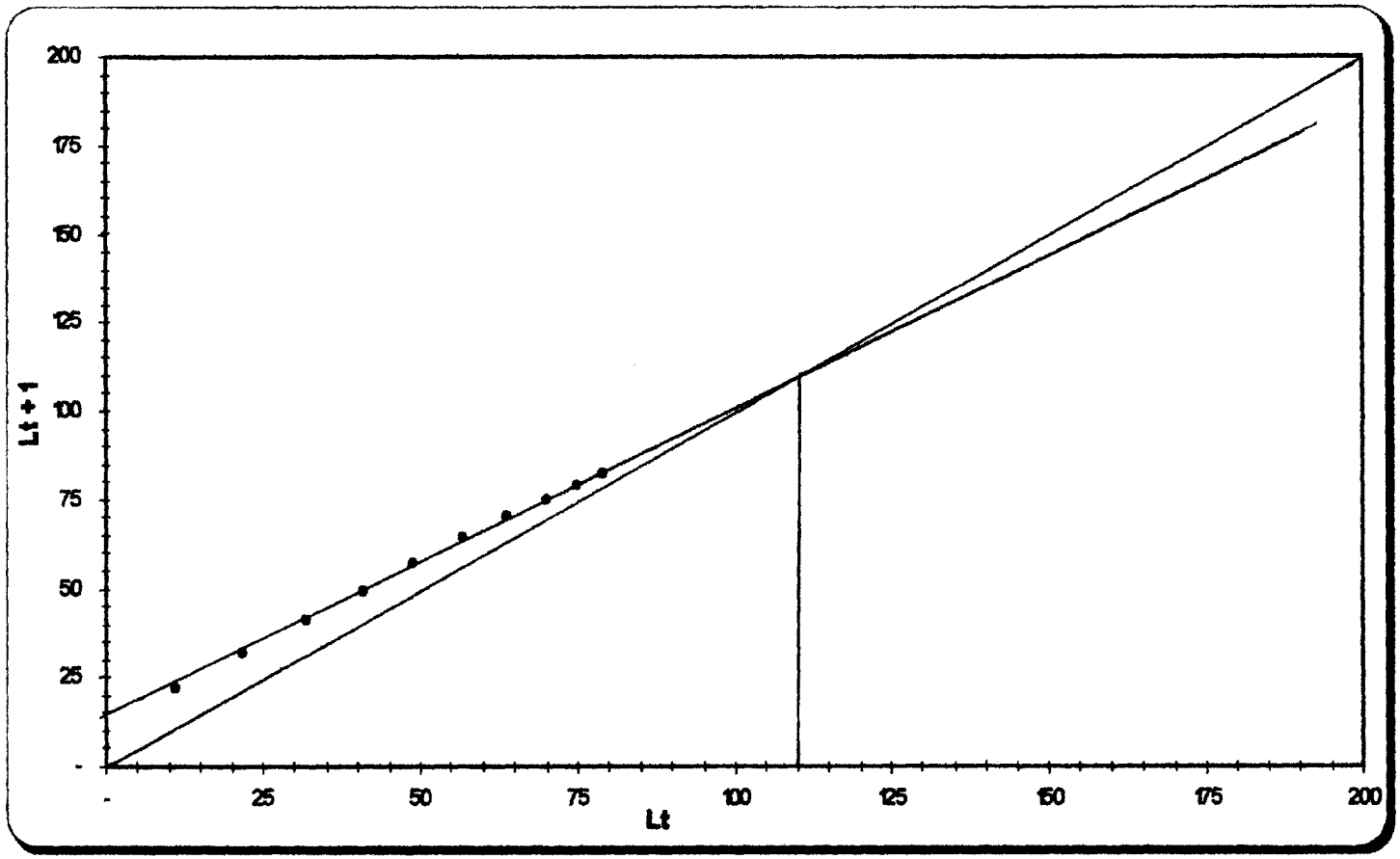

Fig. 3.4.10: Ford Wolford plot for L_∞ of *M. dobsoni* male during Aug '03 - Jul '04

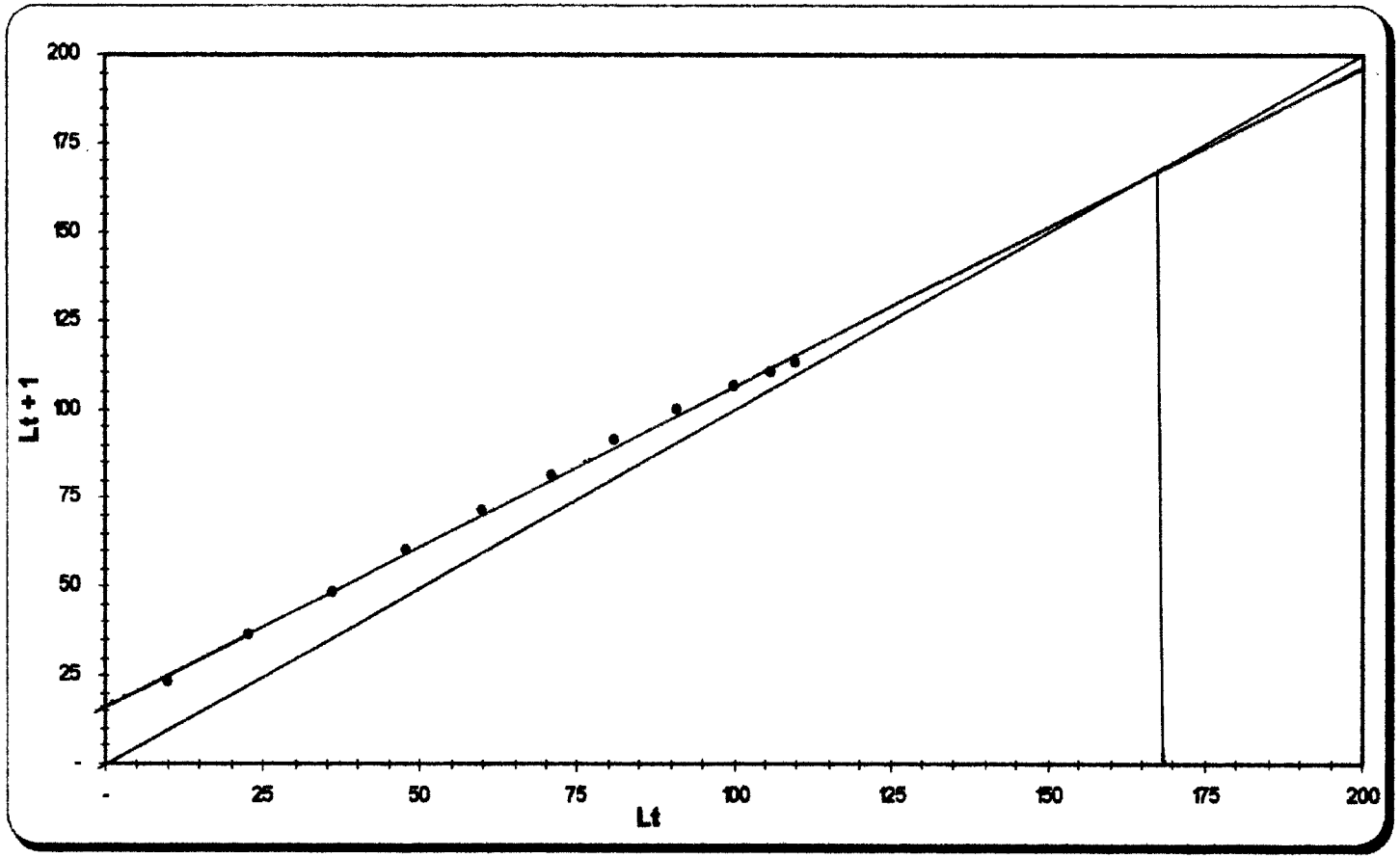

Fig. 3.4.11: Ford Wolford plot for L_∞ of *M. dobsoni* female during Aug '04 - Aug '05

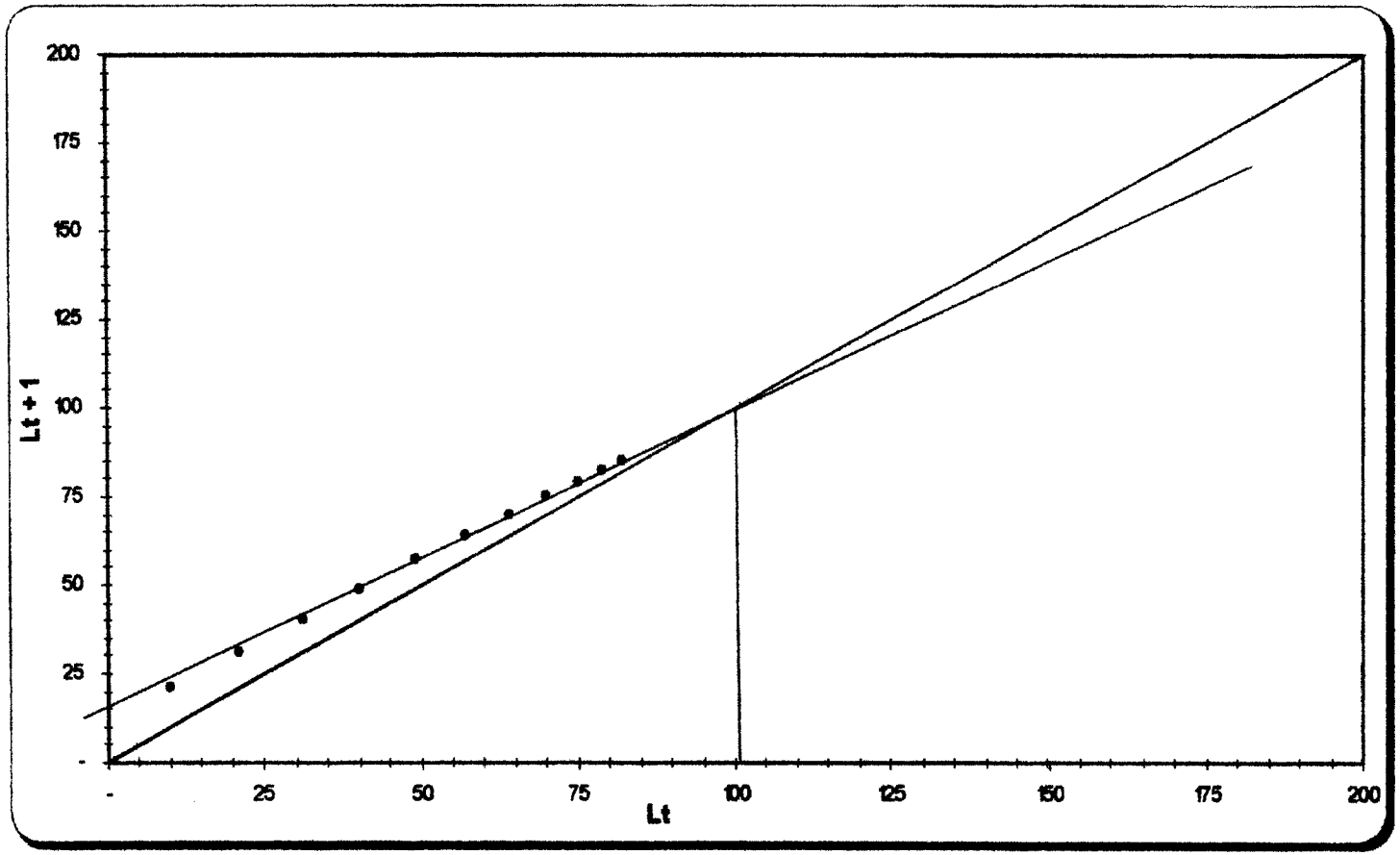

Fig. 3.4.12: Ford Wolford plot for L_∞ of *M. dobsoni* male during Aug '04 - Aug '05

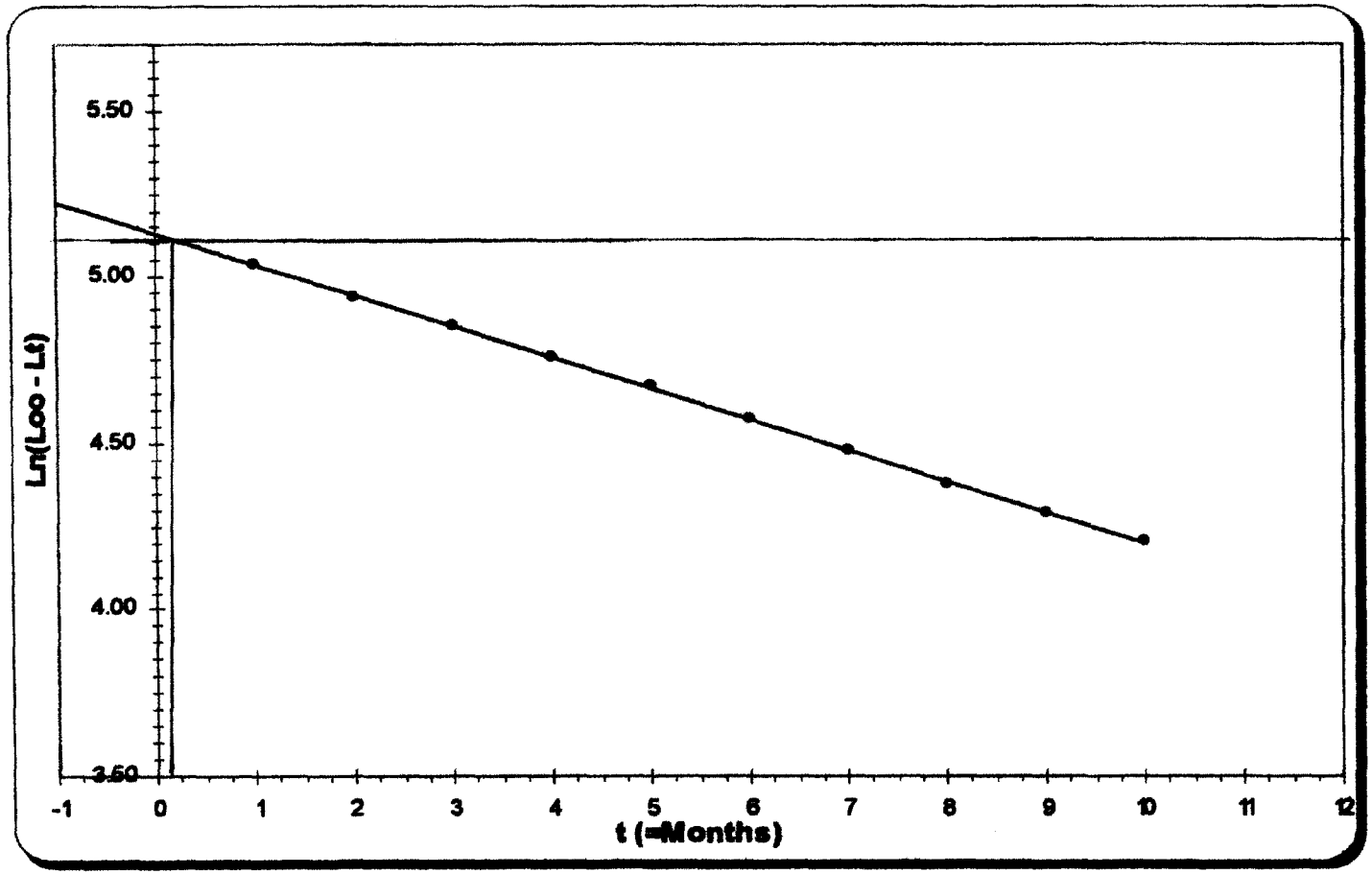

Fig. 3.4.13: Beverton & Holt plot for estimating t_o for *M. dobsoni* female during Aug '03 - Jul '04

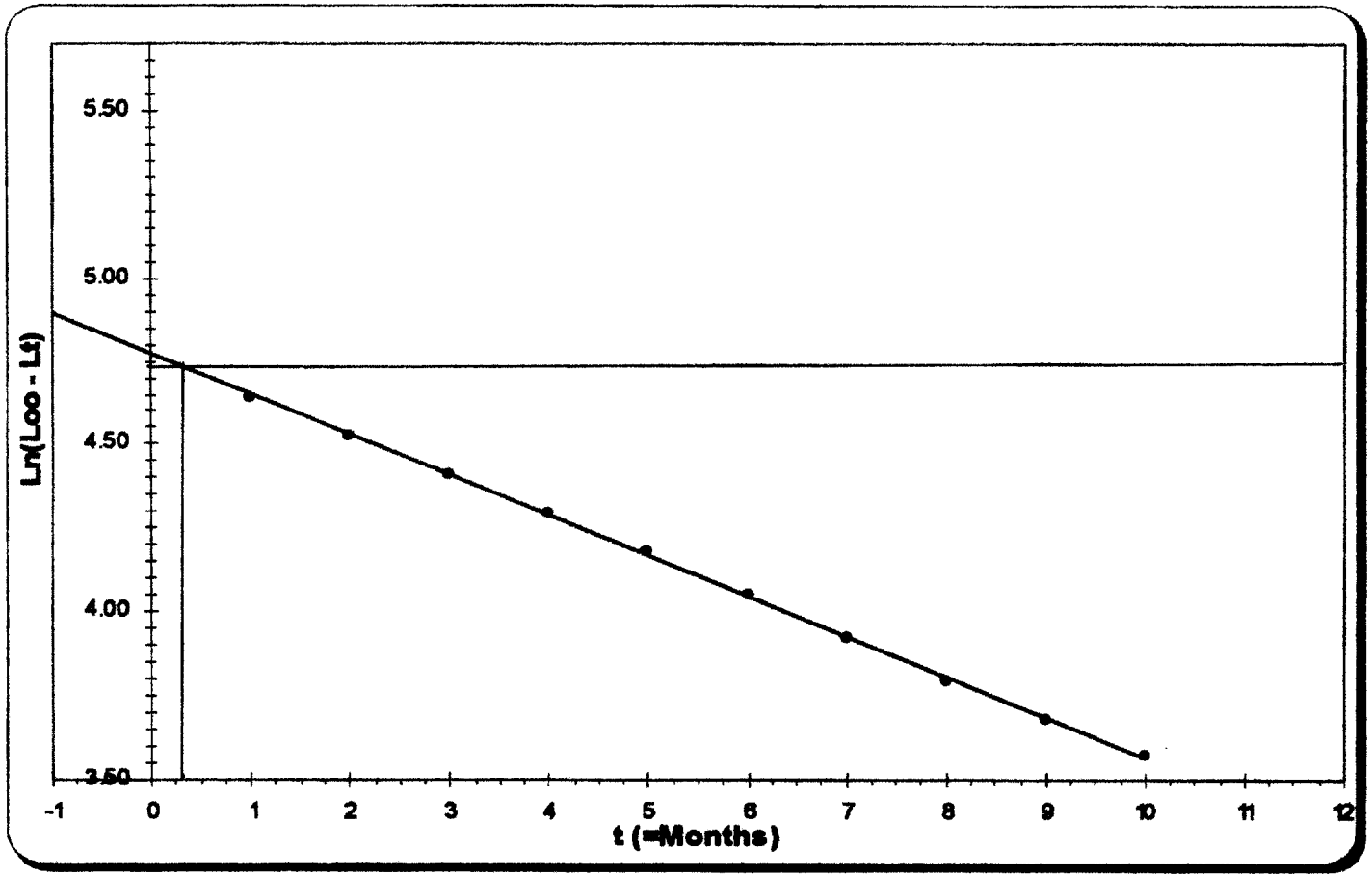

Fig. 3.4.14: Beverton & Holt plot for estimating t_o for *M. dobsoni* male during Aug '03 - Jul '04

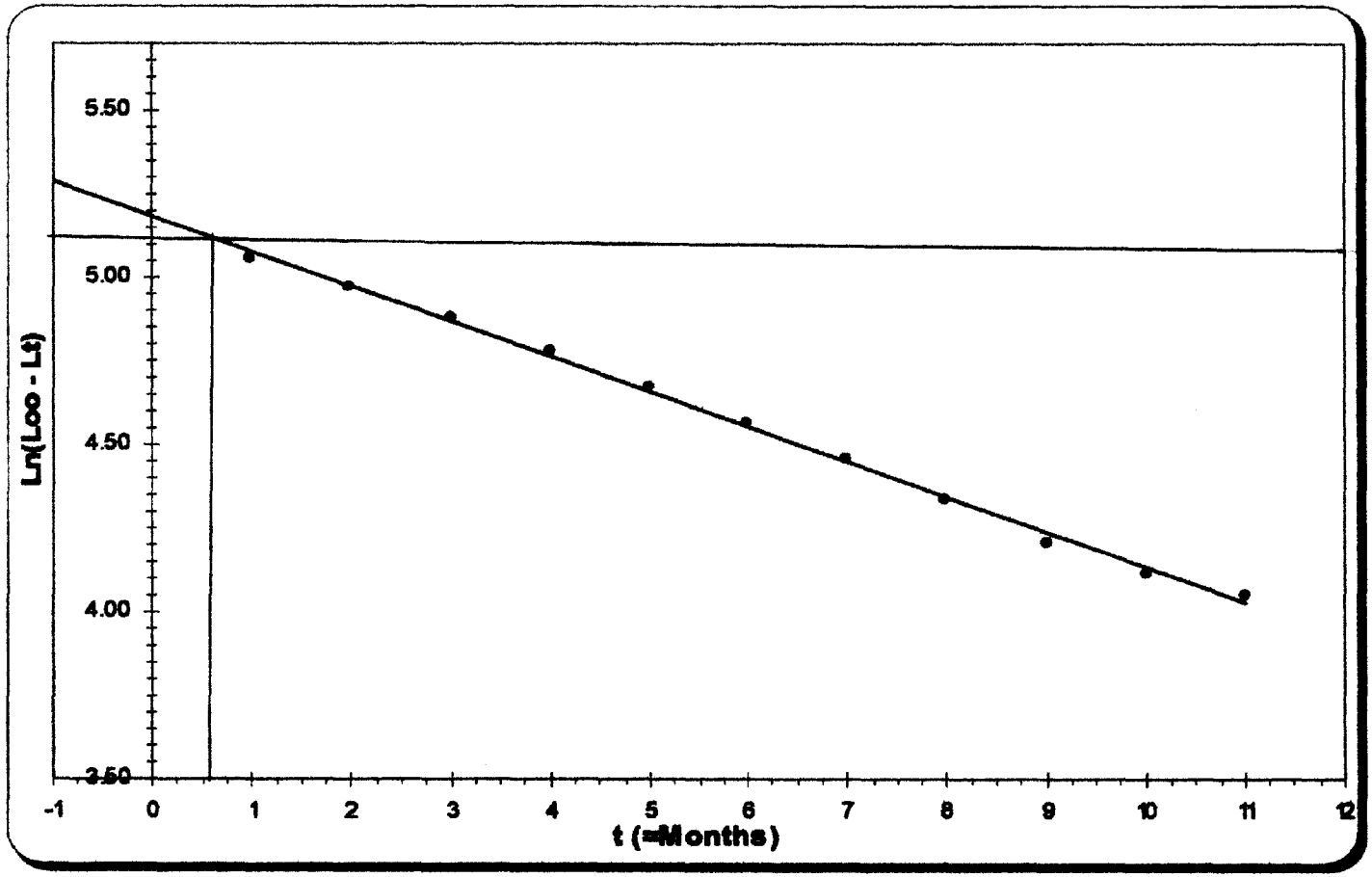

Fig. 3.4.15: Beverton & Holt plot for estimating t_0 for *M. dobsoni* female during Aug '04 - Aug '05

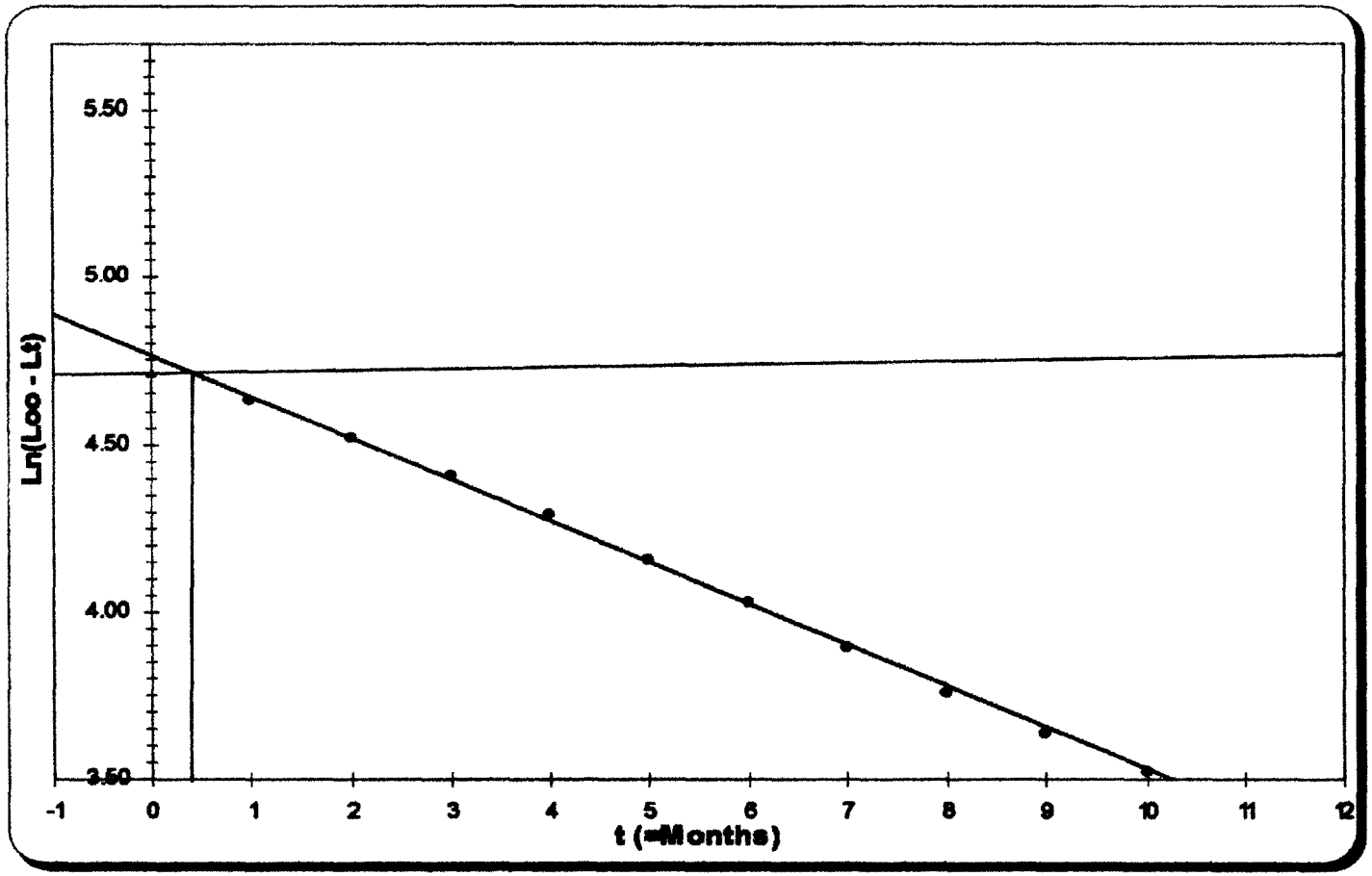

Fig. 3.4.16: Beverton & Holt plot for estimating t_o for *M. dobsoni* male during Aug '04 - Aug '05

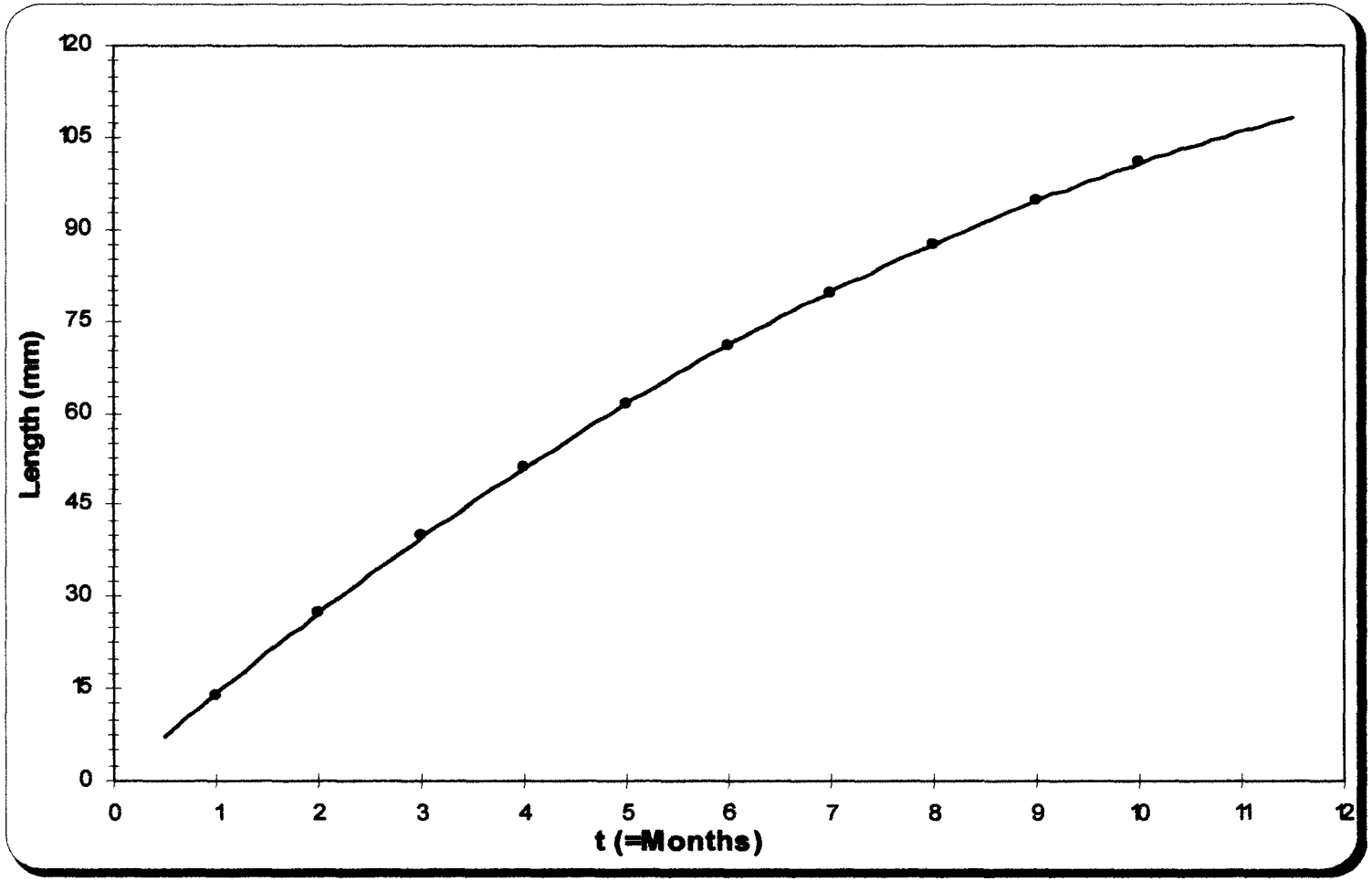

Fig. 3.4.17: von Bertalanffy growth curve for *M. dobsoni* female during Aug '03 - Jul '04

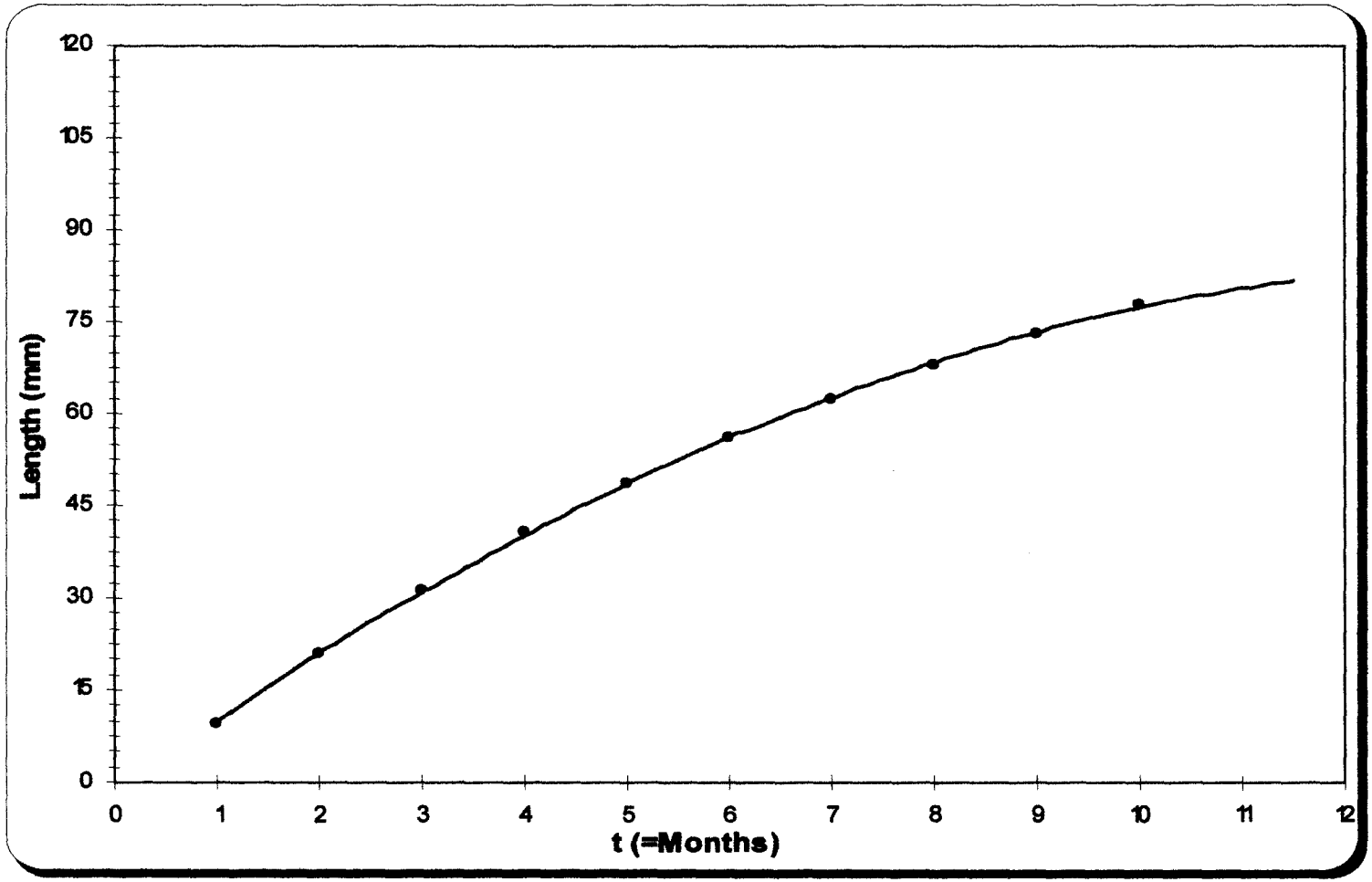

Fig. 3.4.18: von Bertalanffy growth curve for *M. dobsoni* male during Aug '03 - Jul '04

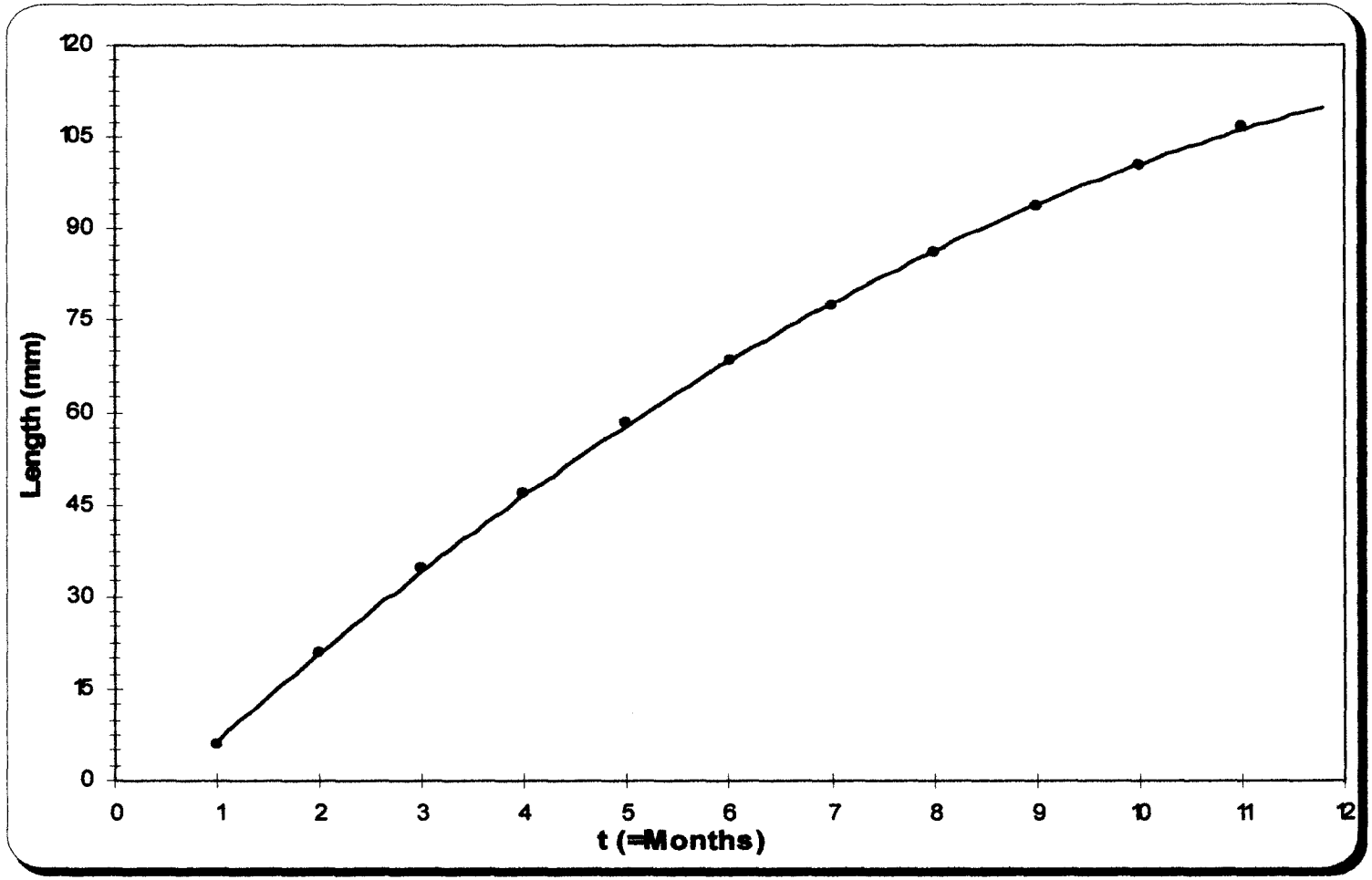

Fig. 3.4.19: von Bertalanffy growth curve for *M. dobsoni* female during Aug '04 - Aug '05

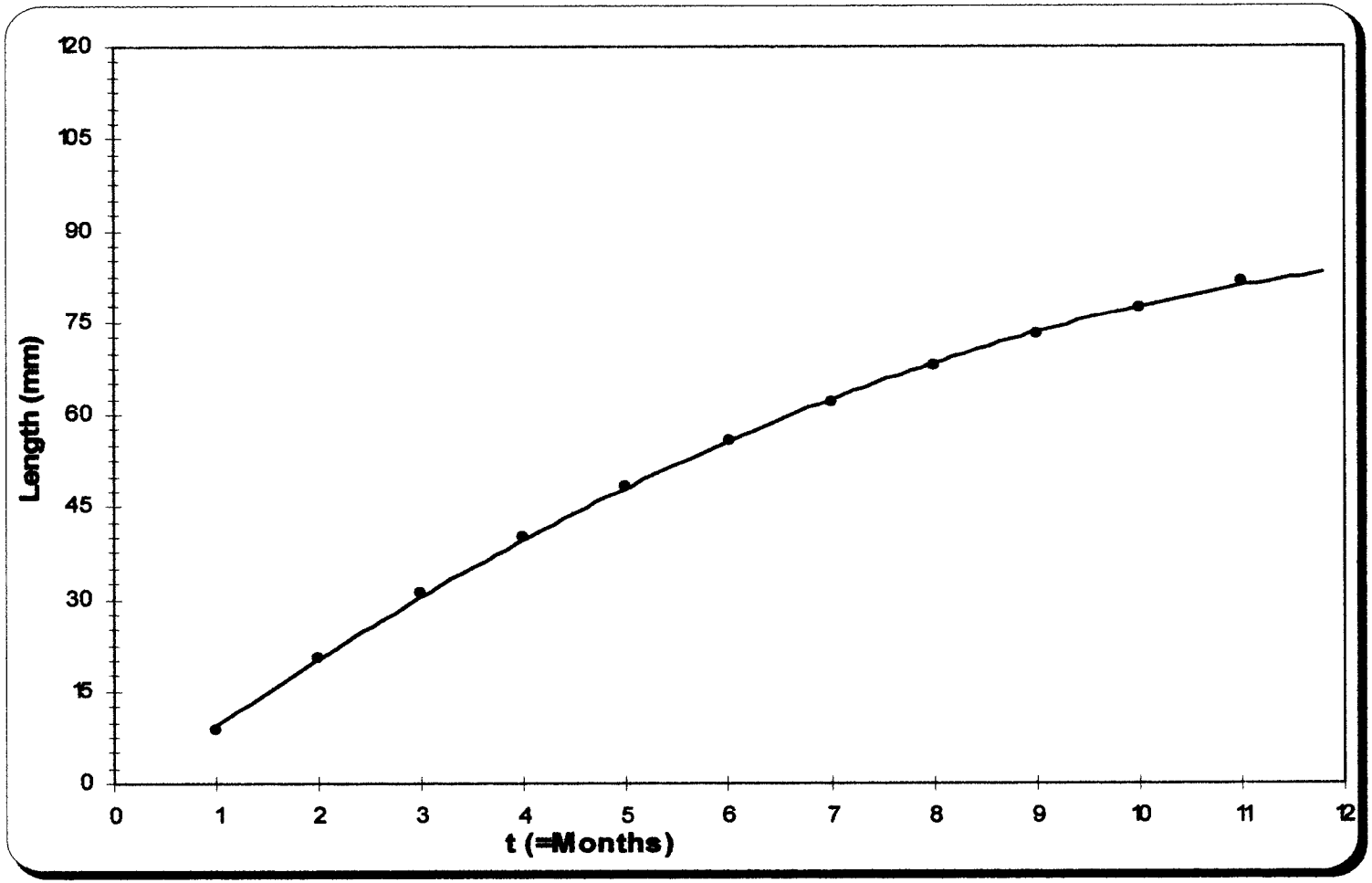

Fig. 3.4.20: von Bertalanffy growth curve for *M. dobsoni* male during Aug '04 - Aug '05

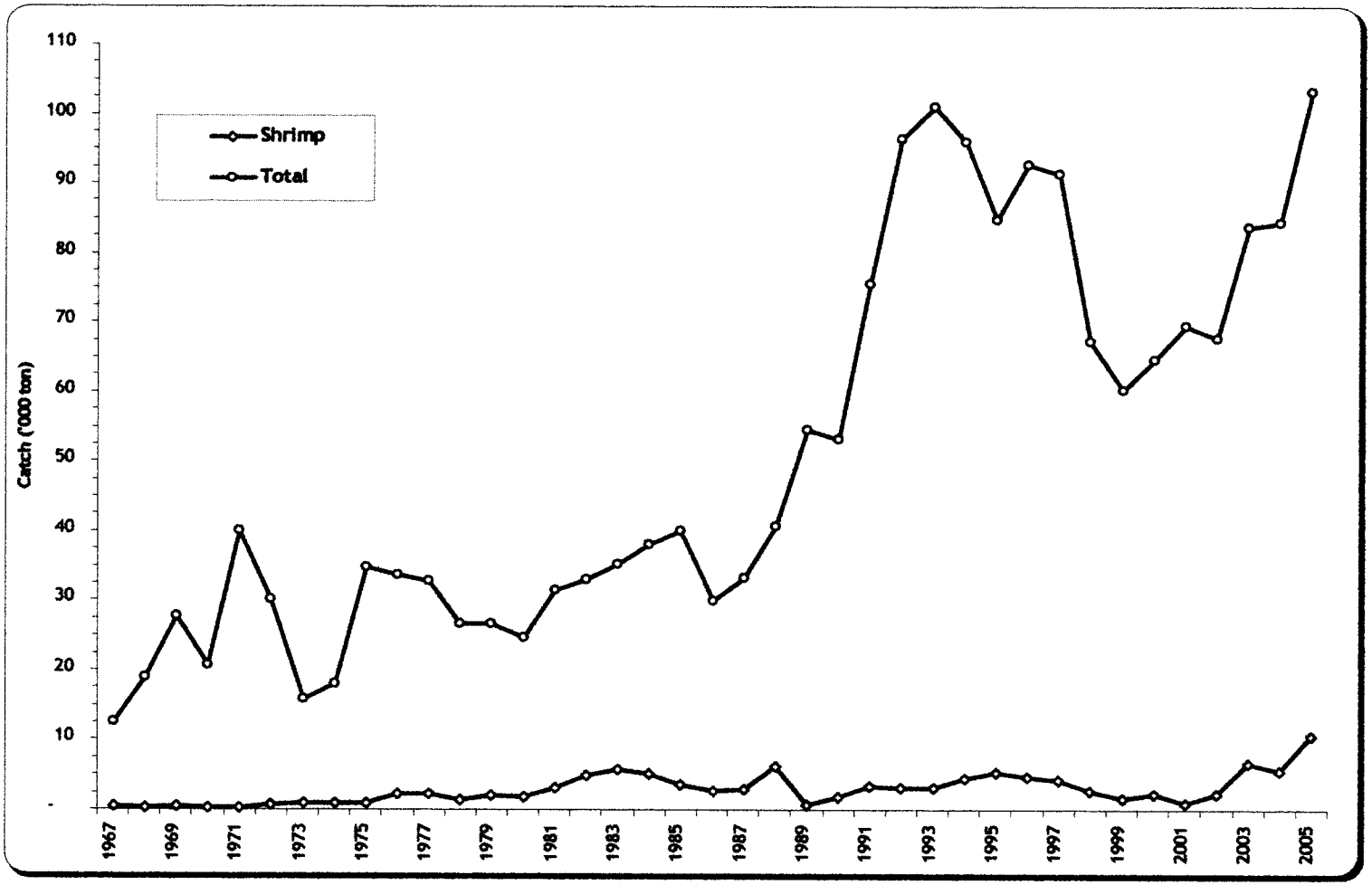

Fig. 3.5.1: Yearly catch data of shrimps viz-a-viz the total fish landings in Goa

IV. TRENDS IN MARINE CAPTURE FISHERIES

4.1 Introduction

Goa with a coastline of 104 km and a continental shelf of around 10,000 km^2 is blessed with a number of rivers and backwaters, making fishing and allied activities the major livelihood of large section of the coastal population. Fishing as an occupation is very important in the state next only to agriculture. With the beginning of the planned development in the state, there has been a concerted and systematic effort for the development of fisheries sector so as to increase the fish production to raise the living standards of the coastal community. Fisheries in Goa experienced technological improvements in the mid-1970s (Gupta *et al*, 1984) that led to the expansion of fisheries to newer grounds and offshore areas. The fishery in Goa is largely dependent on the marine capture fisheries, which accounts for 3% of the total marine fish landings in the country (John, 2006). Further, aquaculture practice also is limited to a few saline areas, being brought under the shrimp farming. With the influx of the saline water being felt upto 50 km upstream, the development of freshwater fisheries faces a lot of problems. Therefore, the Government until now has been emphasizing on the development of marine capture fisheries in the state.

4.2 Materials and Methods

4.2.1 Marine Fisheries Resources of Goa

The total marine fish landing data from 1967 - 2005 was collected from the Fisheries Department, Goa. From the catch data a trend graph was drawn to see the fluctuations in the total fish production in the state over the period of years.

4.2.2 Catch per Unit Effort

The catch and effort data for the last 22 years (1983 - 2005) was obtained from the Fisheries Department, Goa. The Catch per Unit Effort (CPUE) was calculated using total number of fishing vessels and the corresponding landings as,

$$\mathbf{CPUE = Y / f}$$

where 'Y' is the yield and 'f' the effort.

4.2.3 Maximum Sustainable Yield

The Maximum Sustainable Yield or MSY was calculated based on surplus production model by using the **Schaefer Model** (1954). The linear regression equation is given by;

$$\mathbf{Y_{(i)} / f_{(i)} = a + (b \times f_{(i)})} \text{ and}$$

$$\mathbf{MSY = - a^2 / 4b}$$

where $Y_{(i)}$ is the yield, $f_{(i)}$ is the effort and 'a' and 'b' are the constants.

4.2.4 Traditional and Mechanised Fishing Sectors

The catch data of mechanised and traditional sectors for the study period Aug '03 to Aug '05 was obtained from the Fisheries Department, Goa.

The percentage contribution of each sector to the total marine fish landing was calculated.

The contribution of Indian mackerel, oil sardine and shrimps to the total fish landings in each sector was also estimated.

4.3 Results

4.3.1 Marine Fishery Resources of Goa

The total marine fish landing in the state has shown a steady growth from around 12,640 mt in 1967 to 40,713 mt in 1988. The catch in 1993 rose to 1,00,922 mt. From 1994 the catch decreased gradually reaching to a figure of 67,237 mt in 1998 and to stagnate at around 60 - 70 thousand mt for the next few years. Thereafter, the fish catch again showed a recovering trend, reaching a peak of 1, 03,091 mt in 2005 (Fig. 4.1).

4.3.2 Catch per Unit Effort

The number of mechanised boats involved in fishing operation in Goa was 247 in 1983. By next decade the number increased almost by 350% to 872 (1993). By 2000 the number of mechanised fishing boats stood at 1,217 and reached 1,278 by 2005 (Fig. 4.2)

The CPUE was calculated for the period from 1983 to 2005. During this period the CPUE ranged from 49.44 mt to 142.37 mt, the lowest being recorded in 1999 and the highest in 1983 (Table 4.1.1).

4.3.3 Maximum Sustainable Yield

The MSY for the marine fisheries of Goa was estimated by using the surplus production model. These models are based on the assumption that the net growth rate of a stock is related to its biomass. When biomass growth is zero it assumes that the carrying capacity of the environment is saturated.

The Maximum Sustainable Yield estimated using the Schaefer's production model was found to be 85,407.61 mt (Table 4.1.1). The corresponding linear regression equation was;

$$Y_{(i)} / f_{(i)} = 108.19 (- 0.0343 f_{(i)}).$$

4.3.4 Traditional and Mechanised Fishing Sectors

The data pertaining to the landings from the mechanised and traditional sectors for the period of Aug '03 - Aug '05 was taken from Department of Fisheries, Goa. Figure 4.3.1 shows the percentage contribution of the two sectors to the total marine fish production in the state. It is seen that the percentage contribution by the traditional sector was 26%, as against the contribution of 74% by the mechanised sector.

The mechanised fishing sector contributed about 75.57% to the total Indian mackerel landed during Aug '03 - Aug '05, whereas 25.43% was the share from the traditional sector. The respective shares of oil sardine were 80.83% and 19.17%. In case of shrimp landings, the contributions from mechanised and traditional sectors were 76.46% and 23.54%, respectively. The mechanised sector also contributed 67.56% of other important fish landed during the study period and the traditional sector contributed 32.44% (Fig. 4.3.1).

However, of the total fish landings, the Indian mackerel accounted for 7.33% and 7.59% in the traditional and mechanised sector, respectively. In the traditional sector, the oil sardine constituted 29.02%, shrimps 6.02% and other fish contributed 57.63%, whereas the respective contributions in mechanised sector were 43.18, 6.89 and 42.34% of the total landings (Fig. 4.3.2).

4.4 Discussion

4.4.1 Marine Fisheries Resources of Goa

The analysis of catch data over last two decades reveals that the marine fishery in Goa is multi-species in composition. Similar findings have been reported earlier by Mohanta and Subramanian (2001). The pelagic fishery contributes to more than 50% of the total marine fish landings. Out of this the Indian mackerels and oil sardines are the most exploited. Among the demersal fish resources the shrimps are the major target group. Ansari *et al* (1995) also reported that the fisheries resources of Goa are rich in pelagic and demersal fish species.

From the catch statistics it can be seen that the marine fish production in the state has risen from a mere 12,640 mt in 1967 to 40,000 mt by 1971. It showed a declining trend throughout the 70s. During the early and mid 80s the catch fluctuated around 30,000 mt. From 1988 onwards the landings crossed 50,000 mt to reach an all-time high of over 1,00,922 mt in 1993. During the following years the total landings showed a negative growth reaching a low of 60,075 mt in 1999 and fluctuating around this quantity up to 2002. This may be due to the fact that the landings during the 60s were mostly from the traditional fishing sector. With the introduction of a few mechanised fishing vessels, the catch rose during the 70s. The pronounced increase in fish catch during late 80s and early 90s could be attributed to the rapid mechanisation and improvement in gears and fishing technique. Thereafter, the catch showed a negative trend inspite of increased fishing effort.

The declining trend in the landings from late 1990s upto 2002, inspite of increase in the fishing efforts perhaps indicates a level of over exploitation. The fish landings thereafter have started to increase again to reach a level of over 1.0 lakh mt in 2005. This upward trend could be attributed to the strict

imposition and implementation of monsoon fishing ban by the State from year 2000 onwards. The monsoon fishing ban period, which falls between the breeding season of most of the commercial fish species in Goa waters (James, 1992), is observed from 10th of June to 15th of August or till *Narali Purnima* (a festival to mark the beginning of the new fishing season). Ammini (1999) also reported a similar trend on the marine fishery resources in Kerala due to the trawl ban in the state during the monsoon season.

4.4.2 Catch per Unit Effort

From the catch and effort data, it can be seen that total catch has a direct bearing on the number of boats engaged in fishing activity. When total fish catch was plotted against the number of vessels operating, the graph (Fig. 4.2) gave an interesting picture. In early 1960s when the vessels were very few, the catch also was less. As the number of mechanised fishing vessels increased, there was a corresponding increase in the catch until mid 80s as new fishing vessels could go beyond the coastal waters. Although, thereafter the number of vessels increasing gradually from 435 in 1984 to 825 in 1990, the CPUE decreased from 87.5 mt to 64.46 mt as more number of vessels were fishing in the same fishing grounds and exploited the same resources. The CPUE reached a low of around 50 mt during the years 1986 - 1988. This low CPUE also coincided with the abnormally low catches of Indian mackerel and oil sardines, which normally form the bulk of the landings.

With the increase in number of big sized and higher powered fishing vessels in the early 1990s, new and far-away fishing grounds (50 - 100 m depth) began being explored and exploited. This may have led to the increase in CPUE from 89.39 mt to attain a maximum of 115.74 mt in 1993

(Table 4.1.1). Thereafter, the CPUE started to decline to an all time low of 49.44 mt (1999) inspite of the increased fishing effort. This clearly shows that addition of more fishing vessels to the present fleet in the same fishing zone may not lead to an increase in the CPUE indicating that there is a stress on the fishery resources. The gradual increase to attain the CPUE of 80.67 mt in 2005 may be the after effect of the monsoon fishing ban imposed from 2000 onwards.

4.4.3 Maximum Sustainable Yield

The maximum weight or yield taken from a stock without adversely affecting the future reproduction and recruitment is referred to as the maximum sustainable yield or MSY. If the intensity of fishing effort on a particular fish stock is increased beyond this level, it will lead to the problems on the existing fish stock. Firstly, young fish entering the fishery may be caught before they grow to the marketable size or commercially acceptable size. Secondly, the breeding stock may be reduced to the extent that insufficient offspring are produced to maintain the population.

In order to calculate the MSY, Schaefer (surplus production) model was made use of. The surplus production model is based on the assumption that the net growth rate of a stock is related to its biomass. The Schaefer model is a parabola that has its maximum value of $Y_{(i)}$, the MSY, at an effort level.

MSY for marine fisheries in Goa has been reported as 74,208 mt Srivastava (1999). The MSY calculated from the catch and effort data in the present study was higher at 85,407.61 mt. With the fish catch crossing the MSY during 1990s, not only has there been a decrease in the catch, but also the CPUE slumped sharply during the following years. Following the strict implementation of the monsoon fishing ban after the year 2000, as well as the policy of the State to discourage the addition of more mechanised

fishing vessel, the catch recouped to MSY levels in 2003 - 2004. The following year, the fish landings once again crossed the MSY. These findings indicate that there is a considerable pressure on the fisheries resources in Goa. Ansari *et al* (2006) have given a similar account of the state of the fisheries resources in Goa.

4.4.4 Traditional and Mechanised Fishing Sector

The fish catch from the traditional sector was compared with that of the mechanised sector. The latter contributed 74.0% of the total fish landings as against 26.0% by the former sector. It was observed that although the mechanised sector is the major contributor of oil sardines, Indian mackerels and shrimps, the catches from the traditional sector are also significant. The mechanised sector contributed 80.83% of the total oil sardines landed.

Within the two fishing sectors, there was no much difference in the quantity of Indian mackerel landed to the total landings by individual sectors at 7.33% (traditional sector) and 7.59% (mechanised sector), respectively. Similar was the case in shrimps at 6.02 and 6.89%, respectively. However, the oil sardines formed 43.18% of the total fish landed by the mechanised sector and it constituted 29.02% of the landings by the traditional sector.

The mechanised sector employs gears like trawl net and purse-seine, besides a few long lines. Trawling is in full operation from August to September, November to December and March to May. Purse-seining is carried out throughout the fishing seasons, but the activity is intense in August and September when oil sardines and Indian mackerel are available in large shoals. Mechanised vessels also operate gillnets during October - December period.

One of the important traditional fishing gears used in Goa is the beach-seine, locally known as ***Rampon***. It is an important gear during the monsoon months. Gillnet, locally called as ***Mag*** plays a major role during the rest of the months. Different mesh sized gillnets (mesh size > 24 mm) are used depending upon the type of the target fish.

Since the last couple of years a mini-purse seine or ring-seine (mesh size 16 mm) is being used as an important fishing gear from mid July to late August period in the traditional sector. It is mainly used for catching the Solar shrimp during the monsoon months when large shoals appear in the near-shore waters. Using this gear the motorised canoes are able to harvest large quantities of Solar shrimp of approximately 500 to 1,000 kg per haul. The present findings are very similar to the observations made by Alagaraja *et al* (1992) who reported that motorised country-crafts using ***Matabala*** net (a type of ring-seine) contributed more to the penaeid shrimp landings in the state of Karnataka during monsoons.

It has been observed that both the fishing sectors in Goa in order to maximize their catch use smaller mesh sized nets. This results in what is known as 'recruit-over fishing', wherein smaller fishes dominate in the catches and destruction of lot of juveniles and eggs occurs.

From the present study the monsoon months of June to August have been identified as the main breeding period for the Indian mackerel and July to September for the Solar shrimp. These two are the most important species for the marine fishery of Goa, representing the pelagic and demersal resources, respectively.

In view of these observations it becomes imperative that fishing ban during south-west monsoon must be strictly adhered to by all the stake holders. Alagaraja *et al* (1992) reported that with the advancement of mechanisation and motorization of country-crafts, fishing during the monsoon is being

carried out vigorously. They opined that since the monsoon season is considered to be the spawning season for many commercially important fish species, it may adversely affect the spawning and recruitment of the economically important fish stocks.

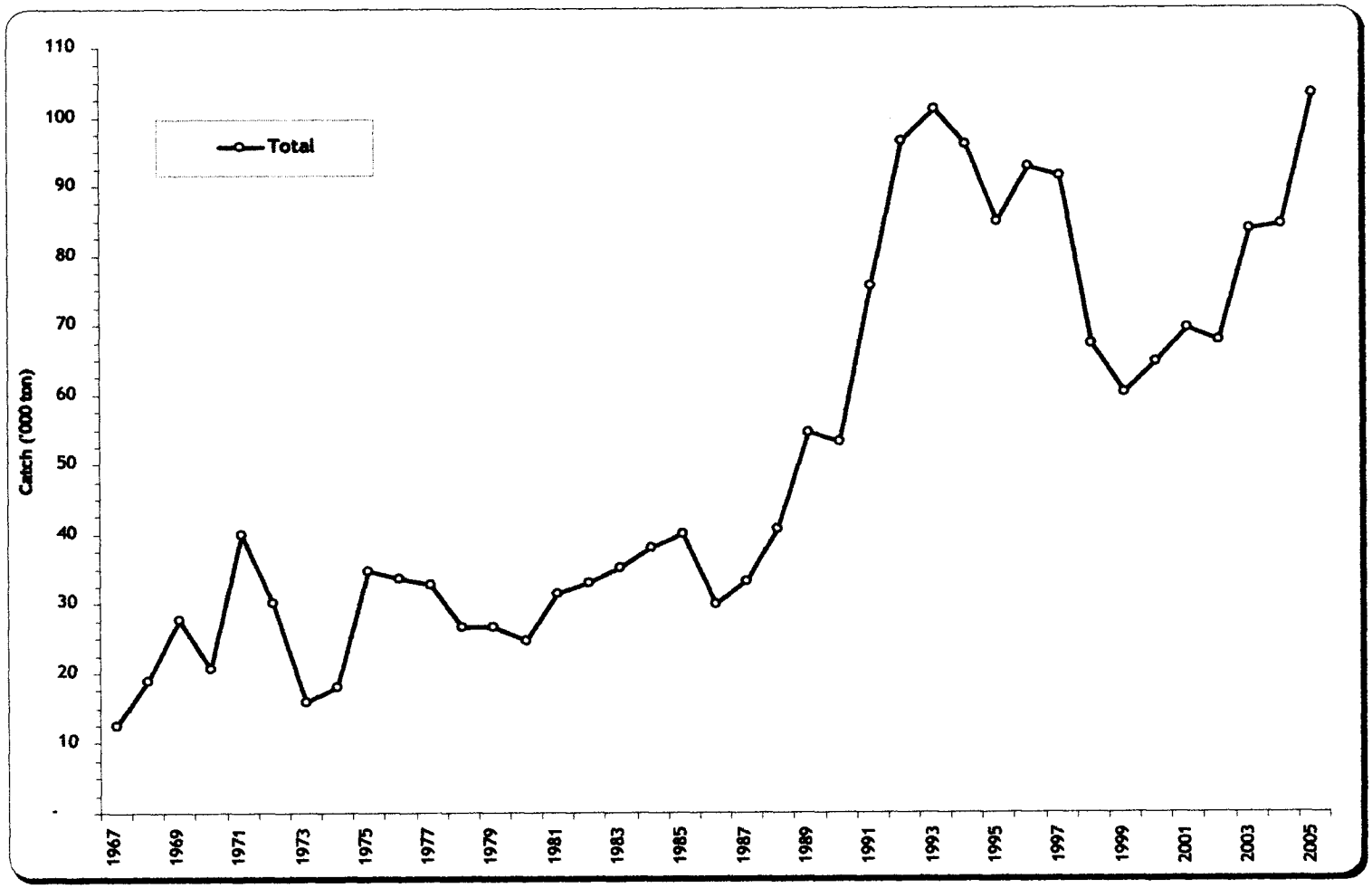

Fig. 4.1: Yearly catch data of total fish landings in Goa

Table 4.1.1: CPUE and MSY for marine fish catch in Goa

Year	Tot. Catch (mt)	Effort	CPUE
1983	35,165	247	142.37
1984	38,064	435	87.50
1985	39,926	519	76.93
1986	29,927	574	52.14
1987	33,068	648	51.03
1988	40,713	706	57.67
1989	54,550	767	71.12
1990	53,179	825	64.46
1991	75,623	846	89.39
1992	96,333	865	111.37
1993	100,922	872	115.74
1994	95,840	922	103.95
1995	84,856	1,005	84.43
1996	92,737	1,080	85.87
1997	91,277	1,152	79.23
1998	67,237	1,175	57.22
1999	60,075	1,215	49.44
2000	64,563	1,217	53.05
2001	69,386	1,219	56.92
2002	67,563	1,267	53.33
2003	83,756	1,276	65.64
2004	84,394	1,276	66.14
2005	1,03,091	1,278	80.67
Total	**15,62,245**	**21,386**	**1,755.60**

b = - 0.034260175

a = 108.1865

MSY = 85,407.61 mt

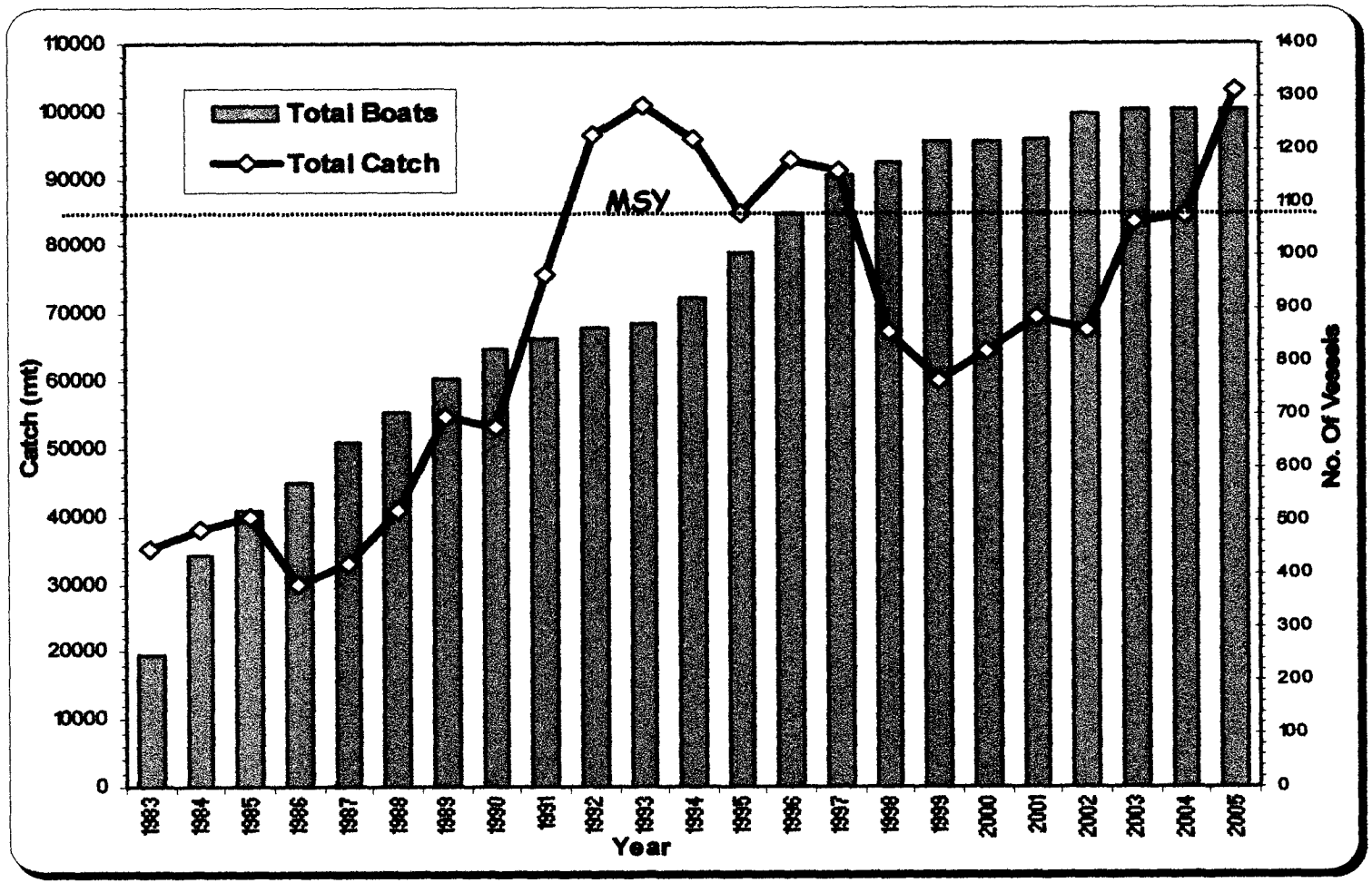

Fig. 4.2: Catch and Effort data for the period 1983 - 2005 in Goa. Also shown is the MSY

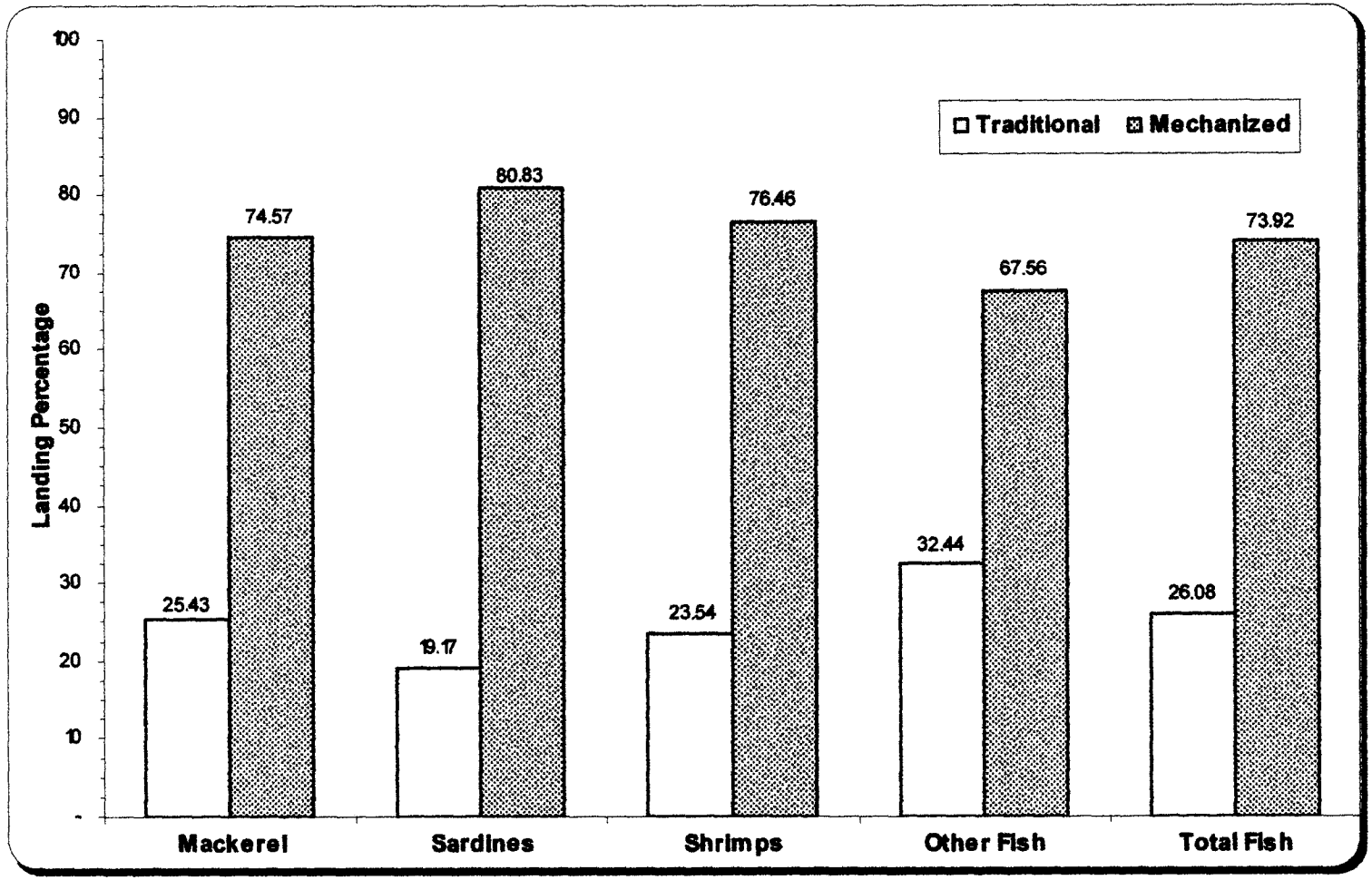

Fig. 4.3.1: Percentage landing of some important fishery by traditional and mechanised sectors in Goa

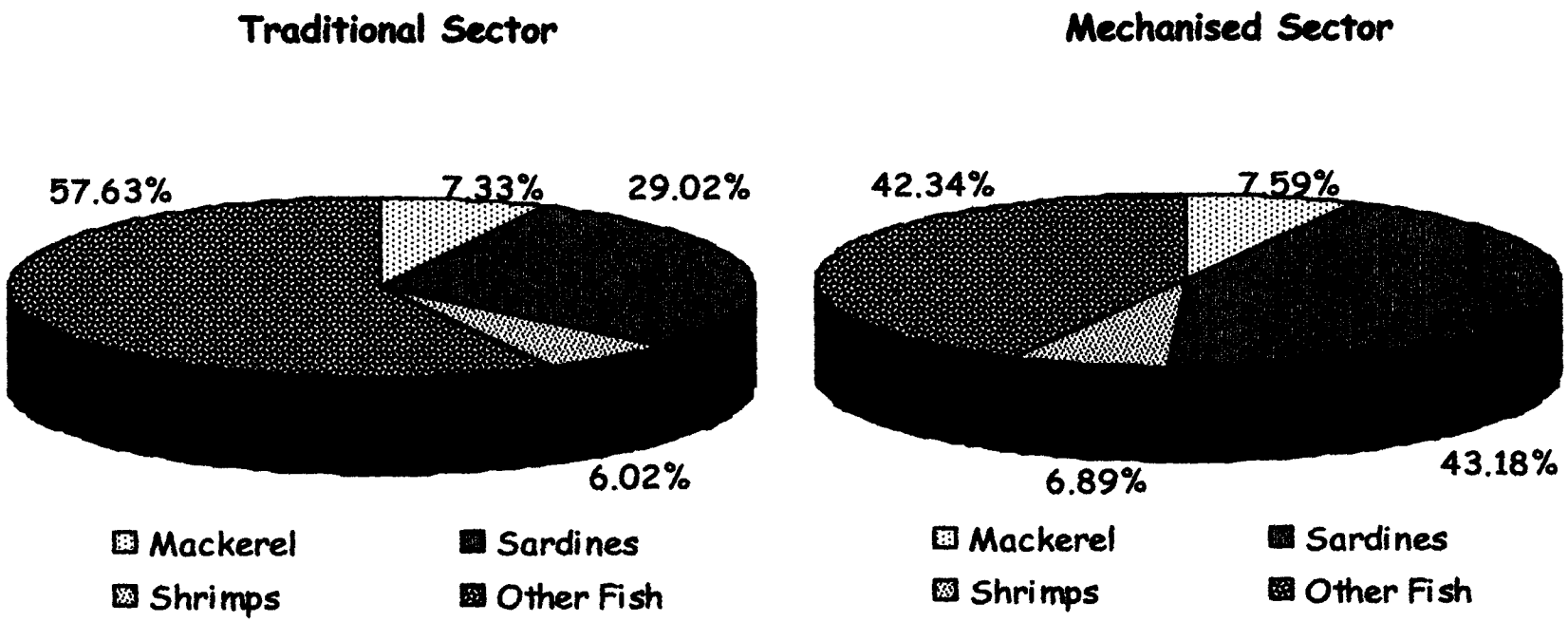

Fig. 4.3.2: Percentage contribution of some important fishery to the total landings in the traditional and mechanised sectors in Goa

V. Management Of Marine Fishery Resources In Goa

5.1 Introduction

The increased popularity of fish and other seafood in wealthier countries, where consumers have high purchasing capacity, coupled with the advanced technologies in preservation, processing and transportation have led to many important local fish species being exported from the developing countries. This has also led to over-exploitation causing stress on the local fishery resources. Out of the 200 major fishery resources of the world, 35% are showing declining yields, 25% have reached a plateau at a high exploitation level and 40% still show increasing catches (FAO, 1993). In other words, conservation and management strategies need to be urgently evolved for 35% of the major world fish resources rehabilitating the damaged resources. Another 25% of the species have to be exploited judiciously to sustain the resources.

Developing strategies to ensure the sustainable use of the marine living resources is very important for each maritime state. The immediate need is to establish the conditions for sustainable development of living marine resources within the framework of rights and responsibilities for different maritime areas and resources (FAO, 1995a).

There are growing efforts world over to manage the fisheries resources in a sustainable manner in order to conserve the fish stocks and protect certain marine life and in some cases, to distribute the catch among the various sectors of the fishing industry. Such efforts have led many countries to restrict the fishing in certain months, put restriction on the total allowable catch and setting individual quota, besides, introduction of code of conduct for responsible fisheries (FAO, 1995b).

India contributes to about 4.5% of world fish production and occupies a prominent position as fourth largest fish producing country in the world with a production of about 6.18 mmt per annum (Das and Mishra, 2006).

India, in order to compete in the global fish market is strengthening its monitoring, control and surveillance mechanisms and management conservation strategies of its fishery resources to be at par with the advanced fishing nations. The need for responsible fisheries led India to introduce a Model Bill in 1979 (Haridas and Nair, 2001), which formed the basis for the states to have fishing regulation in their territorial waters.

The state of Goa has adopted various policies for developing its own fisheries resources. These focus on developing fisheries at all levels, with the aim to increase current levels of production and to achieve continuous growth of the sector. To achieve this, special attention is accorded to mechanisation and modernization of the fishing gear and fleet and upgrading of allied infrastructure. The different stakeholders involved in various fishing activities influence the policy formulation and management strategies. To manage the fisheries resources, conserve the fish stocks and to distribute the catch among the various sectors of the fishing industry the State enacted the Marine Fishing Regulation Act in 1980 (GOG, 2000c) and subsequently framed the Rules in 1981 (GOG, 2000d), thus becoming one of the first states in the country to enact the Marine Fisheries Regulation Acts and Rules.

5.2 Materials

The following Acts and Rules were examined for recommending suitable management strategies for the fisheries sector in Goa.

i. The Indian Fisheries Act, 1987. Government of India (GOG, 2000b).

ii. The Goa, Daman and Diu Marine Fishing Regulation Act, 1980. (GOG, 2000c).

iii. The Goa, Daman and Diu Marine Fisheries Rules, 1981. (GOG, 2000d).

iv. The 1980 Report of the House Committee to study the dispute between Ramponkars (traditional fishermen) and mechanised fishing boat operators (GOG, 1980).

v. The High Court of Bombay, Goa Bench judgment in PIL writ petition No. 212 of 2000, Goa Environment Federation v/s State of Goa and others (Case, 2000).

vi. The Fisheries Acts and Rules of the states adjoining Goa, viz. Maharastra and Karnataka.

vii. The results of the present study.

5.3 Marine Fishery Issues in Goa

In order to exploit the marine fisheries resources in Goa beyond a few kilometers off the coast, the State has been encouraging mechanisation and motorisation of fishing crafts. The growth in the fishing industry, with its open access policy, where many stakeholders exploit the resources, often beyond their sustainable levels, has resulted in a number of conflicting issues. And a need was felt to regulate the fishing industry to sustain, conserve and preserve the fishery resources. It was also deemed necessary to protect the interest of the traditional fishermen.

The 1980s saw major conflicts between the traditional and mechanised fishing sectors in the state, with incidents of net damage, trawler burning, catch destruction, violence, etc., primarily on account of clash of economic interest involved in highly valued shrimps. To mitigate this serious issue a House Committee was constituted by the State to study the dispute. The salient recommendations are briefed below.

5.3.1 The Ministerial House Committee, 1980

i. Rules to regulate the mesh size of nets should be strictly enforced.

ii. Mechanized fishing should be totally banned within 10 km of the coast between 1900 to 0500 hrs.

iii. Coastal waters up to 5 km from the coast should be reserved for non-mechanized traditional fishing crafts.

iv. Diversification of fishing industry should be undertaken to adopt coastal aquaculture. Government should draw special plans for development, research and training in coastal aquaculture.

5.3.2 Indian Fisheries Act

The Indian Fisheries Act, 1897 was enacted by British Government to regulate fisheries matters in Indian waters. It is still in force and many states and union territories have introduced fishery legislations under its enabling provisions. The salient features of this Act are as under;

i. It restrains destructive methods of fishing in inland waters and seas.

ii. It prohibits use of explosives and poisons to catch fish.

iii. It provides to protect the fish in selected waters.

iv. It empowers the provisional governments to frame rules under it.

5.3.3 Goa Marine Fisheries Act

The Goa, Daman and Diu Marine Fishing Regulation Act, 1980 was enacted based on the provisions of The Indian Fisheries Act, 1897. The

Goa, Daman and Dui Fisheries Rules, 1981 were framed subsequently and enforced immediately. The Act mainly provides for:

i. Protection of fishing rights of traditional fishermen in inland waters.

ii. Prohibition of mechanized fishing in inland waters.

iii. Prohibition of use of nets with mesh size less than 24 mm for fish and less than 20 mm for shrimp.

iv. Complete ban on motorized and mechanized fishing during (south-west) monsoon period.

v. Regulation of stakes nets in inland waters.

vi. Confiscation of nets by the authorized officers for violations.

vii. Search and impoundment of vessel and auction of illegal fish catch.

It is seen from the above Acts and Rules that many provisions have been included to protect the interests of different sectors of the fishing industry. Provisions are also made to protect and conserve the fishery resources. The Acts and Rules also enable the authorized officers to take cognizance of offence and take action against the violators.

Some of the other relevant documents referred to here are listed below;

i. Statistical Hand Book of Goa, 2000-01. Directorate of Planning and Statistics, Government of Goa. Panaji, Goa (GOG, 2000a).

ii. The Indian Fisheries (Goa, Daman and Diu Amendment No. 1) Act, 1970 (GOG, 2000e).

iii. The Goa Marine Fishing Regulation (Amendment) Act, 1989 (GOG, 2000f).

iv. The Goa Marine Fishing Regulation (Relaxation of Time Limit for Registration of Vessels) Act, 1993 (GOG, 2000g).

v. Catch Statistics. Department of Fisheries, Government of Goa. Panaji, Goa (GOG, 2005).

vi. Economic Survey 2005-2006. Directorate of Planning and Statistics, Government of Goa. Panaji, Goa (GOG, 2006).

5.3.4 Marine Fishing Act of Karnataka

The state of Karnataka adjoining Goa in the south enacted The Karnataka Marine Fishing (Regulation) Act, 1986 (GOK, 1986 and GOK, 1987). The act is in four chapters, the salient features of which are;

i. Registration and licensing of the fishing vessels.

ii. Regulate, restrict or prohibit certain fishing activities within specified areas.

iii. Board, search and impound fishing vessel, if required.

iv. Area demarcation for traditional and mechanised fishing.

v. Prohibition of marine fishing by any type of mechanised vessel during monsoon season to protect the fish fauna and their breeding grounds.

Generally, the period of seasonal closure of fishing is 10th June to 15th August. However, its actual duration is decided on a year-to-year basis, normally prior to the commencement of the south-west monsoon.

5.3.5 Marine Fishing Act of Maharastra

The maritime state of Maharastra, which borders Goa to its north, enacted The Maharastra Marine Fishing Regulation Act, 1981 (GOM, 1981 and GOM, 1982), which became operational by August 1982. Some of the important provisions of the Act are;

i. Registration of fishing vessels.

ii. Licensing of the vessels.

iii. Appointment of District Advisory Committee.

iv. Closure of mechanised fishing during monsoon season.

v. Reservation of fishing area for different sectors of traditional and mechanised fishing.

As per the provisions of the Act there is a ban on marine fishing in Maharastra for a period from 10th June to August 15th or till *Narli Purnima* festival, whichever is earlier, to ensure conservation and protection of fish breeding grounds. However, as in the case of Goa and Karnataka, the actual prohibition period in Maharastra also varies on a yearly basis.

5.3.6 High Court Judgment with respect to Monsoon Fishing Prohibition in Goa

The Goa Bench of Bombay High Court gave its judgment on 24th September, 2002 in PIL Writ Petition No. 212/2000 (Case, 2000) of year 2000 on the issue of monsoon fishing prohibition in Goa. It directed a total fishing ban by all mechanised fishing vessels from 10th June to 15th August or till *Nariyal Poornima*, whichever is earlier. The ban would cover all kinds of mechanised vessels, trawlers including country-crafts / boats / canoes fitted with inbound or outbound motors and other mechanised boats

using nets for the purposes of fishing in the territorial waters of the State of Goa, i.e. 22 km from the sea coast. It clarified that traditional fishing by boats without any mechanised motors are permitted to fish and this order also shall not come in the way of the *Ramponkars* (traditional fishermen) earning their day-to-day livelihood by traditional fishing.

It directed the following measures for effective implementation of the prohibition;

i. The State shall patrol the coastal waters, beaches and landing areas where stocks of fish are found, to ensure that no mechanised vessels are permitted to go for fishing. Any fish catch brought to these areas by mechanised vessels shall be seized.

ii. During the ban period, licenses of all mechanised fishing vessels shall stand suspended. Any such vessels fishing during the ban period shall have their licenses automatically cancelled and shall not be renewed thereafter.

iii. All the fishing jetties shall be sealed during the ban period. The District Magistrates / Mamlatdars of each district are to be appointed as Receivers during this period to ensure that no activity connected with either fishing or sale of fish at the jetties takes place.

iv. Sale of diesel / petrol from the petrol pumps attached to the jetties shall be stopped completely.

v. The insurance companies shall suspend the insurance policies of the licensees of mechanised vessels during the ban period and shall not entertain any claims for compensation due to mishaps arising out of fishing activity during the ban period.

vi. Licenses of pick-up vans and other vehicles (including freezer vehicles) used for the purpose of transporting fish should be cancelled during the ban period and any vehicles found violating the ban shall be seized by the Government.

vii. The State should give wide publicity to the fishing prohibition as well as all the stern conditions imposed by the Judgment, in the first week of June, every year, so that the public would know of the ban as well as the stringent conditions.

viii. In the larger interest of justice and to conserve fish on a sustainable basis, it directed the Union government to impose a uniform fishing ban, fixing uniform dates for all the coastal states on the western coast of India during the south-west monsoon period before the onset of the next monsoon.

5.4 Discussion

With the annual growth rate of marine fishing sector in India on decline (Anon, 1997), it is becoming more imperative to lay emphasis on the management and conservation measures for the sustainable development of the fishery resources. The sector is facing problems and challenges in achieving the kind of objectives of sustainability that will ensure long term survival. The Government of India initiated reforms for responsible fisheries way back in 1979 by introducing a Model Bill to regulate coastal fishing activity (Haridas and Nair, 2001), which formed the basis of marine fishing regulation Acts enacted by various maritime states in India. The serious issue that led to the enactment and implementation of these Acts by many states was the rising number of serious conflicts between the fishermen involved in traditional and mechanised fishing sectors. This can be observed from the catch statistics trends analysed in the present study, which illustrates that the landings have increased gradually from 1960s with the rate of increase accelerating since the late 1980s. This increase, however, was limited to mechanised and motorised sector because they started fishing in new fishing grounds and open sea.

In contrast, the landing from traditional sector, mainly from coastal areas are declining since 1970s (Srinath, 2003), leading to conflicts between different fishing sectors. This clearly indicates that the coastal ecosystem cannot continue to absorb surfeit fishing effort and generate ever increasing catches (Pauly, 1994).

The Acts focus principally on registration of fishing boats and nets, regulation of operations of mechanised fishing vessels, protecting traditional fishermen and maintaining law and order. Provisions are also aimed at sustainable fishing with measures like imposing closed fishing season during monsoons, restricting fishing effort, banning destructive

gears and regulating mesh size. It is noteworthy to mention that the provisions and their implementation provide more for conflict minimisation and mitigation between the two sectors with little emphasis on the growth, development and sustainable management of the fish resources. Besides, there are no provisions that provide for effective legal action against inter-state vessel movements and infringements and intrusions. The deficiency of clear cut legal provisions in the Acts not only makes the implementation and enforcement ineffective but also hampers the management and planning processes for responsible and sustainable fisheries.

It can be seen that the provisions of the Marine Fishing Regulation Act in Goa are similar to those in Maharastra and Karnataka. Since all these three states have a continuous coastline there has to be an understanding between them as there is always an overlap of the areas of fishing operation between the states. One of the important issues that need to be addressed is the period of the closed fishing season during south-west monsoon as it can adversely affect spawning, stock replenishment and recruitment of economically important fish. In view of this, the Goa Bench of the Bombay High Court, in its Judgment in 2002 ordered strict implementation of total fishing ban by all mechanised fishing vessels including motorised canoes for the period 10th June - 15th August in Goa. Due to the different time periods of fishing ban in the adjoining states, inter-state fishing violations occurred, leading to conflicts and agitation. This lead the State to reduce the closed fishing period in 2005 by around a fortnight from 10th June to 31st July for the mechanised vessels and by approximately a month from 10th June to 15th July for motorised canoes (upto 10 HP outboard motor).

Aggrieved by this reduction made in the closed fishing period to be adopted in Goa that would adversely affect the conservation and long-term sustainability of many fish stocks, the environmental activists took the matter to the Supreme Court. The Apex Court in its interim order on 17th

July, 2006, (Case, 2006), has imposed a uniform fishing ban for the whole of the west coast of India. This ban for the mechanised fishing is from 10th June to 15th August and excludes the motorised canoes (with 10 HP outboard motor).

Analysis of the data from the present study implies that most of the breeding activity of Indian mackerel occurs during June to August and that of Solar shrimp from July to September. It becomes vital that fishing ban during south-west monsoon be austerely adhered to not only by the mechanised vessels but also by motorised canoes as they too haul large quantities of breeders and gravids besides juveniles. Moreover, the effects of the ban are reflecting in the form of improved fish landings during the last couple of years.

5.5 Recommendations for Sustainable Management of Fishery Resources in Goa

Goa being a tropical region, the marine fishery resource is multi-species in nature. Most of the species show a multi-spawning behavior, having a shorter life span. After examining the provisions of the Marine Fisheries Acts and based on the results of the present study, the following recommendations are made for evolving an efficient and sustainable management strategy for the marine fishery resources of Goa.

i. Fishing zones must be delineated for different categories of vessels and these should be strictly adhered to.

ii. Coastal waters upto 5 km should be strictly reserved for traditional fishermen and only the traditional fishing gears like *Rampon* and gillnet should be allowed to be operated. Traditional crafts as well as modern FRP canoes of less than 36 ft, without outboard and inboard motor should be allowed to fish in this region.

iii. The coastal waters between 5 and 10 km should be reserved for fishing by motorised canoes and small mechanised vessels using nets of above 20 mm mesh sizes.

iv. It was observed during the present study, that the traditional fishermen use mini purse-seine operated by motorised canoes during the monsoon months of July-August, to capture the priced Solar shrimp. By deploying this net a single canoe in a day is able to harvest approximately 0.5 to 1.0 ton of shrimp. The mesh size of this net is far below the permitted size of 20 mm. Hence, the net not only catches all sizes of the targeted species but also the juveniles of Indian mackerel, oil sardines, ribbon fish and many other fish species that migrate to the inshore waters for feeding. It

is, therefore, recommended that fishing by motorised canoes using mini purse-seine be banned in the coastal waters upto 5 km.

v. Since the size at first maturity of the Indian mackerel was found to be around 210 mm, the gears used to catch it should have a mesh size not smaller than 35 mm. Further, the size at first maturity of female Solar shrimp was found to be around 99.2 mm. It is therefore, recommended that the mesh size for the capture of this shrimp species should be above 20 mm. The mesh size regulation will not only avoid catching of juveniles of many important species but also raise the mean size of the fish caught and thereby increasing the returns.

vi. The State should fix the number of additional canoes and mechanised vessels that will be allowed to operate within their respective specified areas, as it is observed that the coastal waters are being fully exploited.

vii. As per the present study, there is an immediate need to curtail surplus fishing effort. It is necessary to regulate the number of mechanised fishing vessels operating in Goa as the CPUE is showing a declining trend. The over-capacity in terms of vessels and gear must be refurbished and redistributed to fish newer varieties in unexploited areas.

viii. From the present study it is observed that the period of June to August is the peak spawning period for Indian mackerel and the Solar shrimp. It is, therefore, recommended that the monsoon-fishing ban should be imposed and strictly enforced during these months.

ix. The monsoon-fishing ban must be observed diligently by both traditional and mechanised sectors. After implementation of fishing ban from 2000, the total fish production has been showing an increasing trend as observed during the present study. Since many species are known to breed during monsoon season, a total ban on fishing will protect not only the breeding areas but also the breeding population and thereby improving the subsequent recruitment.

x. Since pelagic and demersal fish stocks migrate over long distances, regardless of the boundaries of the states, implementation of fishing ban of different time duration by the neighboring states may not be very effective in avoiding intra-state conflicts and achieving the larger interest of protecting fishery resources. Therefore, a concerted effort should be made by the states along the west coast of India to arrive at a consensus for the most effective period for banning fishing during the south-west monsoon season and the same must be implemented uniformly. This would not only improve the fishing resources of a particular state but the overall marine fish production along the west coast as well.

xi. The Marine Fishing Regulation Act, 1980 was implemented in Goa in 1981 but the enforcement has not been very effective. It is important that the provisions are implemented strictly to ensure the sustainability of the marine fishery resources of Goa.

xii. Financial support given to the fishermen should be based on operational costs rather than on the capital cost as is being practiced presently. The fishermen should be encouraged to go for modern implements, so as to reduce the overall operational cost.

xiii. It is important to develop better infrastructure facilities at the major as well as minor fish landing centers for maintaining hygiene conditions in order to minimise post-harvest losses and improve earnings.

xiv. Special workshops should be conducted under the auspices of the State to educate the fishermen and others involved in the fisheries sector, directly or indirectly on all aspects of the fisheries management. Emphasis should be given to sustainable management practices of the resources and post-harvest handling of the catch for their own benefit.

xv. Improving the fish production by aquaculture in brackish, marine and freshwater environment is to be given priority by the State. The younger generation of the traditional fishermen and other fishermen who are likely to be displaced, on account of reduction of fishing effort, should be trained in aquaculture and associated activities. This would not generate ample job opportunities but in turn would reduce pressure on the capture fisheries resources.

xvi. The management of the fishery resources encompasses a wide range of issues, viz. increasing production, increasing employment, maximizing economic returns, conservation of stock, etc. So far the main focus primarily has been to reduce conflicts among different sectors, generate employment and food and earn foreign exchange rather than controlling fishing effort, which has not been perceived as a threat until recently. In order to effectively endorse the concept of sustainable management of fishery, which is just emerging as a serious subject, some other issues also need to be addressed, such as involvement of stakeholders in the management process and creating knowledge and understanding among fishermen and

managers about the need and advantage of fisheries resources sustainability for the common good.

I sincerely believe that the efforts put in, in the present study to arrive at the recommendations if implemented effectively would go a long way to make Goa a model state in the development and sustainable management of its marine fisheries resources.

VI. SUMMARY

6.1 Introduction

Many of the commercially important fisheries all over the world are facing the challenge of overexploitation. According to FAO (1993), out of the 200 major marine fishery resources of the world, 35% are showing declining yields, 25% have reached a plateau of a high exploitation level and 40% still show increasing catches. Several factors may be responsible for this present predicament of the world fisheries. These may range from uncertainties in stock assessment, over-capitalization, open access policy, common pool fisheries, shifting baselines, deterioration of coastal habitats, rapid expansion of unscientific aquaculture, inter-fleet and intra-fleet competition, to increasing fish consumption rates (Pauly, 1995; Burger *et al*, 2001; Watson and Pauly, 2001; Pauly *et al*, 2002), putting pressure on the worlds food security and its protein needs (Watson and Pauly, 2001).

In India, fisheries sector plays an important role in providing the low-cost source of protein needed for its people. With its population crossing 1.0 billion, constant pressure is being exerted to catch more fish. Of the annual landings of over 6.18 mmt, bulk of the catch (62%) is the contribution from coastal fisheries (Vivekanandan *et al*, 2003), of which over 70% come from the west coast.

Goa, the smallest maritime states on the west coast of India, recognizes fisheries as an important sector in providing employment and earning foreign exchange, besides providing cheap source of protein. The fisheries sector has seen considerable growth since pre-liberation era, with the total marine fish catch of 12,000 mt in 1960s crossing over 1.0 lakh mt in 2005. Though the industry has seen remarkable growth over the years, it also faces challenges of inter-sector and intra-sector competition, over-fishing and uneconomical returns, resulting in continuing conflicts between the stakeholders. Therefore, the time has come to deal with the issues that are

responsible for the present status of the sector and take effective steps for the development, conservation and sustainable management of the fishery resources for posterity.

To study, analyse and understand these important issues concerning the marine fishing industry in Goa, the present research was undertaken with the following objectives;

i. To gather biological information on *Rastrelliger kanagurta* (Indian mackerel) and *Metapenaeus dobsoni* (Solar shrimp) from the Goa waters.

ii. To study trends in the capture fisheries in the state with respect to the fishing effort.

iii. To review the fisheries management polices of the state.

iv. To recommend and frame action plans for sustainable development and management of fisheries in Goa.

The salient features of the present study are summarized in the following section.

The period of the present study was from August 2003 to August 2005.

The study was divided into two periods to arrive at logical inferences. The samples obtained for the study of biology of Indian mackerel, *Rastrelliger kanagurta* and Solar shrimp, *Metapenaeus dobsoni* were collected from three main fish landing centers of the Goa, viz. in the north of Goa – Malim, in the south – Cutbona and the 3rd in between these two – Vasco.

The outcome of the study on the biology of *Rastrelliger kanagurta* is given below;

i. The Length-Weight relationship during both the periods of the study indicated a significant difference ($p < 0.05$) between the sexes.

For the period of Aug '03 - Jun '04, it was:

For Females: $\text{Log } W = -5.2943 + 3.1528 \text{ Log } L$

and

For Males: $\text{Log } W = -5.0452 + 3.0451 \text{ Log } L$

For the period of Aug '04 - Aug '05, it was:

For Females: $\text{Log } W = -5.9850 + 3.4490 \text{ Log } L$

and

For Males: $\text{Log } W = -5.7339 + 3.3414 \text{ Log } L$

where W = weight is in g and L = length in mm.

ii. Isometric growth pattern was observed in both the sexes during both periods of study.

iii. The Kn was found to fluctuate seasonally in both the sexes. These fluctuations were attributable mostly to the seasonal sexual cycle and the intensity of feeding.

iv. Studies on the reproductive biology revealed that the Indian mackerel has a prolonged breeding season. However, the peak spawning season was identified to be from June to August and a secondary spawning season from November to January.

v. The size at first maturity for female was found to be 215.5 mm and for males 211.6 mm for the period of Aug '03 - Jun '04. The same for the period of Aug '04 - Aug '05 was found to be 217.5 mm and 212.6 mm, respectively.

vi. The sex ratio analysis indicated that the females dominated the catches during both the periods of study.

vii. The growth rate decreased with the advancement of age. The von Bertalanffy growth equation, derived by analytical method for combined sex, is as follows;

For the period Aug '03 - Jun '04:

$$L_t = 286.3\,(1 - e^{-0.41\,(t + 2.10)})$$

and

For the period Aug '04 - Aug '05:

$$L_t = 306.4\,(1 - e^{-0.31\,(t + 2.40)})$$

viii. The fishery of the Indian mackerel in Goa contributed to 3.5 - 88.2% of the total fish landings in the state over the past 4 decades.

ix. The Indian mackerel showed fluctuating trend in the landings over the years. Further, it was found to have an inverse relationship with that of the oil sardine landings in the state.

The results of the study on the biology of *Metapenaeus dobsoni* are as follows;

x. The Length-Weight relationship during both the periods of the study indicated no significant difference ($p > 0.05$) between the sexes.

For the period of Aug '03 - Jul '04, it was;

For Females: $\text{Log } W = -5.8181 + 3.2626 \text{ Log } L$

and

For Males: $\text{Log } W = -5.7069 + 3.2146 \text{ Log } L$.

For the period of Aug '04 - Aug '05, it was:

For Females: $\text{Log } W = -5.9055 + 3.3118 \text{ Log } L$

and

For Males: $\text{Log } W = -5.8126 + 3.2566 \text{ Log } L$.

xi. Isometric growth pattern was observed in both sexes during both the periods of study.

xii. The Kn was found to fluctuate seasonally in both the sexes. The fluctuations were attributable to the seasonal sexual cycle, intensity of feeding and stress exerted by some environmental factors.

xiii. Studies on the reproductive biology showed two peak breeding seasons, the primary one from July to August and a secondary one from December to January.

xiv. The size at first maturity for female was found to be 98.7 mm for the period of Aug '03 - Jul '04, and 99.2 mm for the period of Aug '04 - Aug '05.

xv. The sex ratio analysis indicated that the females dominated the catches during both the periods of study.

xvi. The growth rate decreased with the advancement of age. The von Bertalanffy growth equation, derived by analytical method is as follows;

For the period Aug '03 - Jul '04, it was;

For Females: $L_t = 167.84 (1 - e^{-0.09 (t - 0.0791)})$

and

For Males: $L_t = 114.47 (1 - e^{-0.12 (t - 0.2582)})$.

For the period of Aug '04 - Aug '05;

For Females: $L_t = 167.23 (1 - e^{-0.1 (t - 0.6345)})$

and

For Males: $L_t = 112.9 (1 - e^{-0.12 (t - 0.3387)})$

xvii. *M. dobsoni* dominated the total shrimp landings in the state. Further, it was found to support the shrimp fishery during the monsoon months of July and August. Revenue earned from the landings of this species during the monsoon months sustains some of the fishermen, particularly of the traditional sector, during the entire year.

xviii. Shoaling behaviour of this species was also noticed during the months of July and August, particularly along the southern part of the Goa coast.

The trends in the marine fishery resources of Goa over the years indicated that;

xix. The MSY calculated based on the total fish production and the number of fishing boats according to Schaffer's model was 85,407.61 mt.

xx. The mechanised fishing vessels contribute 73.9% as against the tradition sector to 26.1%.

xxi. The trends in the total marine fish production in the state indicated a stress on the overall fisheries resources of the state.

After examining the existing provisions of Indian Marine Fisheries Act (1897) and Goa, Daman and Diu Marine Fishing Regulation Act (1980), the House Committee Report (1980), and the results of the present study, the following major recommendations are made for framing the guidelines for improving the marine fishery resources of Goa.

xxii. Fishing upto 5 km from the coast may be permitted only by traditional crafts and gears.

xxiii. The mini purse-seine being operated by the motorised canoes during the monsoon season since last few years may be banned.

xxiv. Coastal waters between 5 and 10 km may be allowed for fishing only by motorised canoes and smaller mechanised vessels, using nets of above 20 mm mesh size.

xxv. Bigger mechanised vessels should fish in waters only beyond 10 km from the coast.

xxvi. It is necessary to regulate the number of mechanised fishing vessels based on CPUE and also fix the number of additional non-mechanised canoes.

xxvii. Monsoon fishing ban should be strictly implemented. A consensus among the maritime state along the west coast of India for a common closed-fishing period would be very effective in improving the fish resources of the region.

xxviii. Better infrastructure facilities may be provided at the fish landing centres and areas for hygienic handling to reduce post-harvest losses.

xxix. Steps may be taken to educate the fisher folk in all the aspects of fishing and fishery resources management.

xxx. Action plan may be prepared for expansion of aquaculture activities in marine, brackishwater and freshwater environments.

xxxi. Educated youth of traditional fishermen may also be trained in aquaculture and allied fishery activities which would generate more employment opportunities, increase fish production and reduce stress on capture fisheries.

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* Note referred to in original.

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