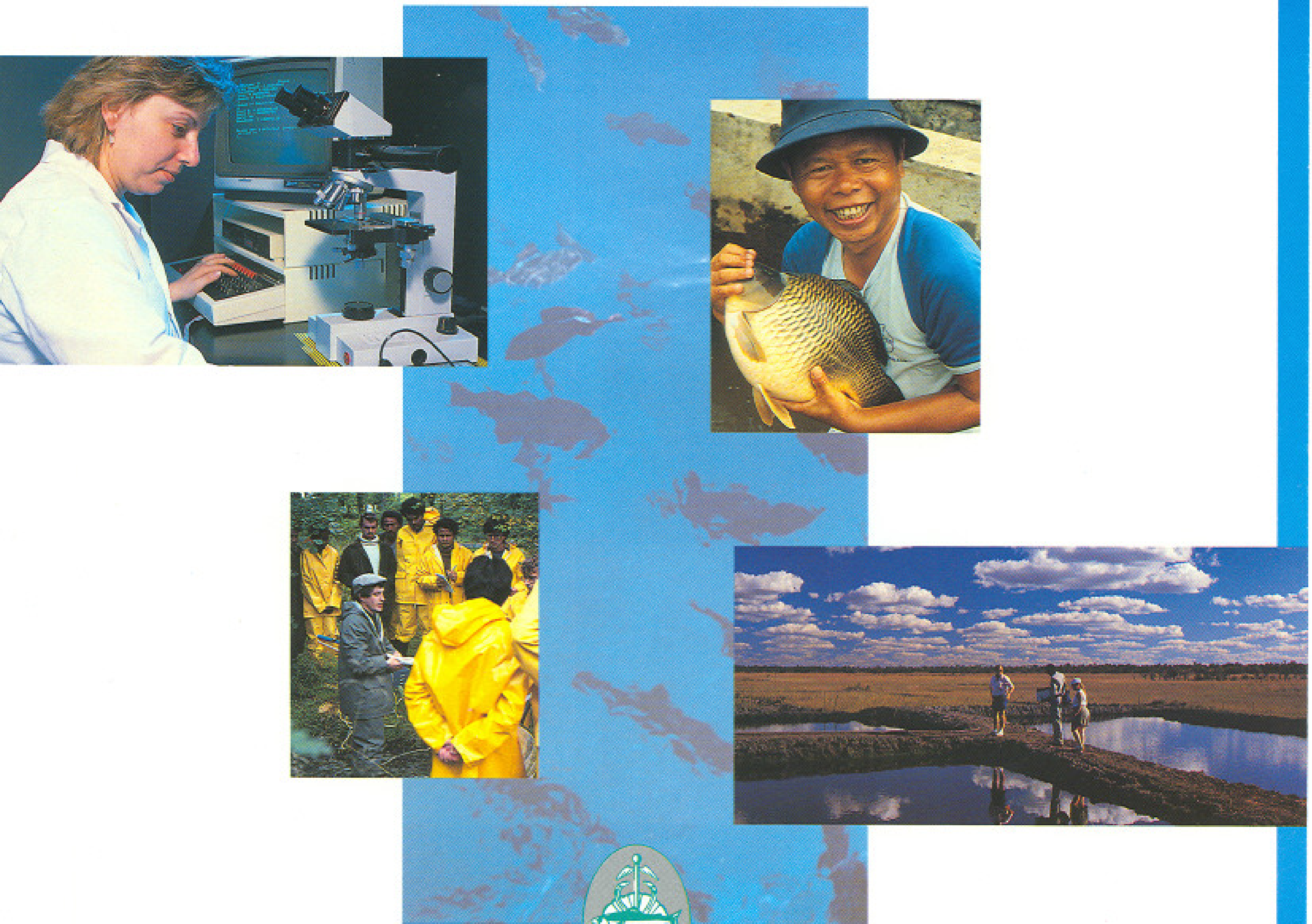
INSTITUTE OF AQUACULTURE

EFFECTS OF PARASITISM ON RESERVOIR FISHERIES IN SOUTH ASIA

R WOOTTEN & C SOMMERVILLE

MAY 1996



UNIVERSITY OF STIRLING

Effects of Parasitism on Reservoir Fisheries in South Asia

Final Report

R. Wootten & C. Sommerville

Institute of Aquaculture
University of Stirling

May 1996

CONTENTS

Executive Summary

1. In collaboration with the College of Fisheries, Mangalore, the predatory catfish *Wallago attu* was sampled from Vanivalas Sagar, a large irrigation reservoir in Karnataka State, India from July 1993 to January 1995.

2. Wherever possible 50 *W. attu* were sampled each month for the presence of the ectoparasitic copepod *Ergasilus maldanensis* on the gills. A total of 446 fish were examined.

3. Catch data for other species of fish and length and weight data for carp species in these catches were obtained on a monthly basis and submitted to MRAG for use in an associated project.

4. Most *W. attu* were infected with *Ergasilus* and the parasite was present throughout the year.

5. *Ergasilus* was most abundant in Oct-Nov and least abundant from Nov/Dec to January. The latter low abundance was due to the influx of small uninfected *Wallago* into the fishery.

6. Reproduction of *Ergasilus* apparently occurred throughout the year but may be lowest in October-January.

7. *Ergasilus* was overdispersed throughout the host population in all months in which fish were sampled. The variance to mean ratio was greatest in those months in which significant numbers of smaller uninfected or lightly infected fish were pesent in the catches.

8. In collaboration with the Pakistan Agricultural Research Council, Islamabad, various carp species were sampled from two small irrigation reservoirs, Ghumari and Mangia, in Punjab Province. Catch data is available from September - December 1994 during which time 139 fish were caught for parasitological examination.

9. The nematode *Rhabdoolchona* sp was found in *Labeo rohita* from Ghumari and the larval nematode *Contracaecum* sp was found in *Hypophthalmichthys molitrix* from Mangia. In addition the nematode *Procamallanus* sp occurred in *Cyprinus carpio* from Mangia and an unidentified cestode in *Labeo x Catla* hybrids from Ghumari.

1. <u>Objectives of the project</u>

Reservoirs are an important source of freshwater fish in Asia and especially in the Indian sub-continent. They provide an important source of good quality protein for rural and urban consumers as well as employment for socially disadvantaged groups. The productivity of reservoirs is often rather low and there has been a considerable amount of research undertaken, especially in India, to identify the reasons for this and improve the fisheries (Jhingran 1986, Moreau & de Silva 1991). Reservoirs in India encompass a wide variety of water bodies ranging from ten up to many thousands of hectares in size with fisheries based on various species. Fisheries in large reservoirs are usually based on self-perpetuating populations of various species, often supplemented by stocking of Indian major carp. Small reservoirs, which include seasonal tanks, do not usually support self-perpetuating populations of commercial species (with the exception of tilapia), hence the fisheries of these water bodies are exclusively based on stocking.

The influence of parasites and diseases on the yield from reservoir fisheries is uncertain. There are few well documented cases where direct mortalities have occurred due to disease. Perhaps the most noteworthy of these in recent years has been the widespread occurrence in southern Asia of the epizootic ulcerative disease (Jhingran & Das 1990). Other examples include heavy mortality due to *Ergasilus* infection in European lakes (Schaeperclaus *et al* 1992). Apart from mortalities, the effects of parasites and diseases can be more insidious and include loss of growth or condition, related loss of fecundity and increased susceptibility to predation due to e.g. reducing swimming speed (Sprengel

& Luechtenberg 1991), or adverse environmental conditions like oxygen depletion (Waller & Scholz 1992). The crustacean ectoparasite *Argulus* is known to act as a vector for certain fish viruses, and to increase the susceptibility of infected fish to secondary, bacterial and fungal infections (Ahne 1978, Schaeperclaus *et al* 1992). Any of these effects might lead to significant loss of fish production, but the magnitude of this loss is difficult to quantify and will depend on the management of the fishery. If parasites have a significant effect on fish production, it would be worthwhile exploring possibilities of managing the fishery in a way so as to minimise this effect.

A preliminary project (Ref. No. R4691) carried out in 1991-92 had attempted to establish whether it was possible to carry out a field programme in-country to study the impact of parasitism on reservoir fisheries in South Asia. The objectives of the preliminary project were the same as those of this project as given below. Collaboration was established with the Central Inland Capture Fisheries Research Institute (CICFRI), Barrackpore, West Bengal, India, and the College of Fisheries, Mangalore, Karnataka, India. These studies were successful and suggested that it would be possible to expand the project over a longer period to collect more detailed data to fulfill the objectives described below.

(a) Identification of economically significant parasite problems in reservoir fisheries. Although a large number of parasites have been identified as economically significant, usually in relation to aquaculture, there is little information on their impact in wild fisheries, including reservoirs. In the initial project parasites were selected which were known to be potential pathogens. Although no direct evidence for an economic impact was found in the pilot study it was hoped to continue with more detailed sampling of these model host parasite systems.

(b) Description of the population biology of economically significant parasites in reservoir fisheries.

It is of utmost importance to have a thorough understanding of the population biology of economically significant parasites. Such an understanding will enable predictions of their recruitment and abundance in the fish hosts and this in turn will be essential in devising management strategies for their control.

During the pilot scale study it was only possible to collect data over an approximately 6-month period, and it was hoped during this project to sample each system for at least a further 12 months.

(c) Elucidation of the relationship between parasite and fish host populations.

Understanding the relationship between parasite and host fish populations is crucial to devising management strategies to minimise adverse parasite effects on fish production. Recruitment or stocking and harvesting will control the total abundance and size structure of the fish population, and this in turn will influence the parasite population.

(d) Development of management strategies for fisheries in order to minimise the impact of parasite infections.

Based on an understanding of the relationship between parasite and fish populations, it may be possible to devise management strategies for the fishery that will minimise the economic impact of parasites. In a capture fishery where treatment of infected fish is impractical, parasites can only be controlled by means of ecological manipulation.

2.1 Work Carried out During this Project

2.1 Sewage-Fed Bheris outside Calcutta

During the initial project in 1991 sampling was successfully carried out on two sewage-fed bheris outside Calcutta, in collaboration with the Central Inland Capture Fisheries Research Institute (CICFRI), Barrackpore, West Bengal. This laboratory is the major research centre in India concerned with reservoir fisheries. The sewage-fed bheris were ideal choices for this study since they were fished all the year round, were easily accessible and very accurate data on fish stocking and catches were available.

During the 1991 investigations two species of Indian major carp, *Labeo rohita* and *Catla catla*, were sampled for the ectoparasitic crustacean *Argulus siamensis*. This sampling programme was very successful, as detailed by des Clers, Sommerville & Wootten (1992). it was hoped therefore to continue this sampling programme in the new project, and possibly to extend it to other host-parasite systems.

Unfortunately, the Director of CICFRI, Dr A G Jhingran, who was instrumental in setting up the original programme left for an FAO appointment in Bangladesh during the programme. Subsequently CICFRI had a series of temporary Directors who were in office for less than one year and who did not appear to have the status or influence wielded by Dr Jhingran. A visit was made to Barrackpore in 1993 to discuss a new sampling programme with the then Acting Director Dr Rao, but although cooperation was promised subsequently no help was forthcoming and no new programme could be initiated. It has never been made clear to us why the promised cooperation did not materialise but we appear to have fallen foul of disputes between CICFRI and the Indian Council for Agricultural Research (ICAR) headquarters in Delhi. Because of his seniority and influence Dr Jihngran had been able to act more or less independently of ICAR, but on his departure the subsequent Acting Directors did not have this freedom of action.

Unfortunately these "negotiations" took a considerable time, especially as we never received a definite negative response from CICFRI or ICAR.

2.2 Freshwater Fisheries Station, Malacca, Malaysia

As part of attempts to find alternative sampling sites, and following a visit by the then Director, Dr Joshi, to the Institute a visit was made to the Malaysian Government, Department of Fisheries, Freshwater Fisheries Station at Malacca. This laboratory was known to have an EC funded research programme on reservoir fisheries in conjunction with the University of Wageningen, The Netherlands. Although full cooperation was forthcoming it was ultimately decided not to pursue this link because the reservoirs involved were very large, and such sites were already available in India, and because suitable local personnel for sampling and examination of fish could not easily be identified.

2.3 Small Reservoirs in Punjab, Pakistan

The failure to establish a collaborative programme with CICFRI meant that it became an urgent necessity to try and set up an alternative programme elsewhere in South Asia. By coincidence at this time Dr Nasim Akhtar, Deputy Director (Fisheries) of the Pakistan Agricultural Research Council, Islamabad, was working in the Institute with Dr Wootten as an EEC Research Fellow. Dr Akhtar suggested that PARC would be able to participate in the project, particularly as they already had an existing programme on small reservoir fisheries.

After Dr Akhtar returned to Pakistan in late 1993 a visit was made to Islamabad in March 1994. A number of possible sites were visited and a sampling protocol and budget agreed. Project staff were identified and it was agreed that the work would be based in the laboratories of the Fisheries Section of the National Agricultural Research Centre also in Islamabad. A Memorandum of Understanding was signed between PARC and the Institute of Aquaculture during this visit. Funding was provided by the project to pay for local staff to be employed by PARC to carry out this work and to pay for fish and transport costs.

Following the visit experimental fishings were carried out on a number of possible sampling sites. Those at Ghumari and Mangia were finally selected and sampling started in September 1994. This was obviously very late in the life of the project and therefore the 12 month sampling period extended until July 1995.

A further visit was made to Islamabad in January 1995 to review progress. Both field sites at Ghumari and Mangia were visited during regular sampling trips. Fishing was carried out efficiently and with some success. Examinations of parasite specimens already collected were made, and laboratory facilities and methodologies used for the examination of fish and parasites were assessed and discussed with Dr Akhtar and his staff. No serious problems with the sampling programme were identified, although it was clear that the bottleneck would be in the parasitological examination of frozen samples. This is a time consuming procedure, and at that time the previous two months samples remained unexamined. The need for urgency was impressed upon project staff. A detailed interim report was presented during the visit and forms the basis of this report.

Unfortunately no further data has yet been received, despite faxed reminders. There is no reason to suppose that all data will not be forthcoming but it is not possible to put a date on this. Every effort will be made to obtain the complete set of data and to prepare a further report based on this.

3.1 Sampling Sites in Pakistan

A. Ghumari Mini-Dam

This reservoir is privately owned and situated near the village of Nurpur, some 25km from the town of Fateh Jang. The reservoir was established in 1991 with the assistance of the Agency of Barani Area Development (ABAD) for commercial fishery and irrigation purposes. In May 1993 the reservoir was stocked for the first time with 5000 fingerlings of various fish species, mostly major and Chinese carp. There has been no further stocking or commercial fishery until the start of this project. The reservoir is 10 ha in surface area, is situated in a range of low hills and fed by two small tributaries. *Typha* and other emergent plants are abundant in the shallow parts of the reservoir. The major physico-chemical characteristics are given in Table 1.

Catch data from September-December 1994 (Table 2) shows that the major carp, rohu, *Labeo rohita*, the Chinese silver carp, *Hypophthalmichthys molitrix*, and a hybrid of the major carps, *Labeo rohita* x *Catla catla*, were most abundant. Smaller numbers of common carp, *Cyprinus carpio,* and grass carp, *Ctenopharyngodon idella,* were also caught.

B. Mangia Mini-Dam

This reservoir is also privately owned and situated near the village of Mangia, about 9 km from Fateh Jang. Although established in 1980, the reservoir was first stocked in 1990 with 10000 fish of various species, but mostly carps. There was irregular harvesting until 1993 when the reservoir was restocked with 2500 fingerlings of *H. molitrix*. The reservoir is 7.5 acres in surface area and fed by a small stream. The margins of the reservoir are choked by *Typha*. The major physico-chemical characteristics of the reservoir are given in Table 1.

Catch data from September-December 1994 (Table 3) shows that *H. molitrix* is by far the most abundant species in the catch, with much smaller numbers of *C. carpio* and the major carps *L. rohita* and *Cirrhina mrigala*.

3.2 Materials and methods

The total length, standard length, sex and gutted weight of each fish were measured at capture. The gut, gills, kidney, liver and swim bladder were removed and preserved in 4% formalin for later study in the laboratory. External surfaces of the fish, including the gills, were examined with a magnifying glass, and then skin and gill smears were taken and fixed in absolute methanol for later examination.

Preserved organs from each fish were dissected under a stereo microscope and parasite specimens preserved in an equal volume of 70% alcohol and pure glycerol for later identification. Specimens were identified according to published keys.

Background information regarding management of the fishery and its history was obtained from the reservoir owner. It is important to note that during the period of this project the only fishing at both reservoirs was that associated with the project.

Water chemistry parameters were obtained for each reservoir on each sampling occasion using a Hach Test Kit Model FF-2.

3.3 Results

The results from the parasitic examination of 108 carp of different species caught from both sites in September and October are so far to hand and are shown in Table 4.

At Ghumari 2 parasite species have been identified thus far. A species of the nematode *Rhabdochona* occurs in the intestine of the rohu, *Labeo rohita*, at a prevalence of 19% and with up to 6 parasite specimens per host.

A single *Labeo* and *Catla* hybrid from Ghumari was infected with two specimens of an unidentified cestode.

Table 1

Summary of Physico-Chemical Characteristics of Ghumari and Mangia Dams

Parameters	Ghumari Dam	Mangia Dam
Depth of Dam (ft)	6-30	3-30
Euphotic Zone (m) depth	up to 1	1
Air/Water Temp (°C)		
July	34.1/29.3	34.1/28.7
August	33.9/28.3	34.7/28.3
September	32.1/27.6	32.6/26.9
October	30.0/25.1	31.2/25.6
November	25.6/20.3	25.2/21.6
December	20.2/18/2	20.0/14.8
pH	6.8-8.5	6.9-7.5
Dissolved oxygen (Do) mg/l	6.2-9.4	4.6-5.8
Alkalinity (mg/l)	60-80	40-95
CO_2 (mg/l)	23.0-46.1	23.0-46.1
Hardness (mg/l)	100-120	124-157
Ammonia (NH4) (mg/l)	0.4-0.8	0.58-0.61

Table 2

Fish Catch at Ghumari Reservoir, Fetah Jang, Sept-Dec 1994

Species	Size Range (cm)	Weight Range (g)	No.	Total Weight (kg)	Total Catch (%)
Labeo rohita	30.5-36.9	850-1306	43	52.71	30.93
Hypophthalmichthys molitrix	31.3-36.9	868-1383	36	37.4	25.89
Ctenopharyngodon idella	50.8-54.1	2500-2900	3	8.1	2.15
Cyprinus carpio	12.8-16.7	300-392	13	6.0	9.35
Labeo x Catla hybrid	30.0-73.6	845-1225	44	41.66	31.65

Table 3

Fish Catch at Mangia Reservoir, Fetah Jang, Sept-Dec 1994

Species	Size Range (cm)	Weight Range (g)	No.	Total Weight (kg)	Total Catch (%)
Hypophthalmichthys molitrix	17.5-21.7	269-594	57	28.5	79.16
Cyprinus carpio	12.9-17.9	253-601	9	3.00	12.5
Labeo rohita	15.6-17.5	243-356	4	2.4	5.55
Cirrhina mrigala	14.3-14.5	0-201	2	422	2.77

Table 4

Parasitic Infections of Carp from Ghumari and Mangia Reservoirs, Sept-Oct 1994

	Parasite Species	No. fish examined	No. fish infected (%)	Parasite Burden Range	Total
GHUMARI *Labeo rohita*	*Rhabdochona sp*	21	4(19)	1-6	14
Labeo x Catla hybrid	Cestode	28	1 (3.5)	2	2
Hypophthalmichtys molitrix	-	20	-	-	-
Ctenopharyngodon idella	-	2	-	-	-
Cyprinus carpio	-	8	-	-	-
MANGIA *H. molitrix*	*Contracaecum sp*	21	6(28.6)	2-4	12
C. carpi	*Procamallamus sp*	6	1	2	2
Cirrhina mrigala	-	2	-	-	-

The silver carp, *Hypophthalmichthys molitrix*, from Mangia were quite commonly infected with larval nematodes of the genus *Contracaecum* within the viscera. From two to four parasites were found per infected fish. Silver carp from Ghumari were not infected.

A single common carp, *Cyprinus carpio,* from Mangia was infected with two individuals of the nematode *Procamallanus* sp in the intestine. Common carp from Ghumari were not infected with this parasite.

All the parasite genera found at Mangia and Ghumari are represented by only a single species.

Small numbers of grass carp, *Ctenopharyngodon idella*, from Ghumari and mrigal, *Cirrhinus mrigala,* from Mangia were not parasitised.

3.4 Discussion

The relatively small numbers of fish examined from each site, and the short time period involved, preclude any detailed conclusions from being drawn. Similarly no conclusions can be drawn concerning the water quality characteristics of the reservoirs and the parasite fauna.

At both sites the metazoan parasite fauna is impoverished in terms of numbers of species and numbers of individuals. This perception may change as more fish are examined over a longer period, but it may be a true feature of both sites. These reservoirs were both artificially created and then stocked with carp juveniles. As far as is known there were no natural populations of carp in the very small streams which were the original water source for the reservoirs. Thus, the fish population, and probably their parasite fauna, is derived largely from hatchery fish. The latter are reared in artificial conditions where a lack of suitable intermediate hosts usually means few metazoan parasites occur. When such fish are stocked, their parasite fauna will usually remain impoverished in the absence of inputs of parasite species from other sources.

The most potentially significant parasite species found so far is the nematode *Contracaecum*. Adults of this parasite are found in the gut of piscivorous birds. Fish acquire the parasite by feeding on copepods infected with early stage larvae. If sufficient numbers of parasites are present there may be severe adhesions of the viscera of the fish, leading at least to poor growth. It is not yet clear whether fish from Mangia are adversely affected by *Contracaecum*. However, the numbers of parasites found were low relative to the size of fish and it seems unlikely that they would cause significant pathological effects. The available literature is rather imprecise on this point, but personal observations on marine species suggest that numbers in excess of 50 would be necessary to cause serious damage.

4. Vanivalis Sagar Reservoir, Karnataka, India

Vanivalis Sagar is a large, poorly productive irrigation reservoir. It was created in 1907 by the building of a dam and is situated on the Deccan Plateau in Karnataka, Southern India. The reservoir has a potential area of water spread of 21,645 acres (8,760 hectares), with a potential maximum water level of 130 feet (40 metres). However, due to low rainfall in recent years, the reservoir has not reached the 100 ft (30.5 metres) mark since 1982. The reservoir supports a nomadic fishing community who live around the reservoir and fish from small round coracles. Commonly gillnets are operated by one or two men from a coracle and suspended 2-3ft deep in water. The total fish yield from this artisanal fishery is low. *Wallago attu* is the largest fish species caught and commands a good price. Fish are collected at landing points around the reservoir and some are sold there or taken to local markets.

The predatory catfish *Wallago attu* is found throughout South Asia. It can grow to a very large size, but most specimens caught in Vanivalis Sagar are below one metre in length. *W. attu* matures at about 40 cm in length and spawns during the monsoon, in May-August (Sarkar and Das 1990). The diet of *W. attu* is primarily fish and invertebrates, particularly crustaceans. It is both a valuable commercial species, and at the same time can be a major source of predation in culture-based fisheries.

Ergasilid copepods spend most of their life free-swimming. Only after copulation do the females adopt a parasitic way of life. They attach to the gills of fish, where they feed on epithelial and mucous cells. In contrast to many other parasitic copepods, they do not undergo any major morphological changes at this stage. Each female produces about 200 eggs and carried them in egg pouches until hatching. Development takes place in the free water via several larval stages. The host specificity of *Ergasilus* species varies, some are very host specific, other less so. Differences in the infestation of various host species may be linked to their behaviour, in particular, slow swimming species appear to be more prone to infection than more active ones.

The life cycle of the parasitic copepod *Ergasilus* is not fully understood. Only adult females are obligatory parasites. All other eleven stages in the life cycle are believed to be free living. Fertilised females attach to the gills by their hooked second pairs of antennae. They are considered to remain in the same location once attached. Eggs are produced in paired sacs and hatch into free-swimming nauplii.

The pathogenicity of *Ergasilus* sp relates to both its attachment and feeding. Being a large parasite and maintaining its position on the gills it sets up irritation where it is in contact with the gill. This causes hyperplasia of the gill epithelium and usually results in adhesions and a marked reduction of respiratory surface in the locality of the parasite. Thus high parasite burdens may reduce the respiratory surface area to a critical level. In addition to the gill damage due to attachment the feeding activity can result in necrosis of gill tissue. There is thought to be external digestion resulting from enzymatic secretions from the mouth.

4.1 Materials and Methods

Sampling of *Wallago* from artisanal fishery catches was carried out monthly. Logistical difficulties prevented more frequent sampling since several remote landing sites had to be visited by local bus over a period of several days in an attempt to obtain sufficient fish. Where possible 50 *Wallago* were examined in each month, although it was often impossible to obtain this number of fish.

The lengths and weights of individual fish were measured (total length in cm; weight in gm). All gill arches were removed from both sides of the fish and the fish returned to the market. All fish used were paid for from the project budget. The gills were fixed in 10% formalin in individually labelled pots indicating fish length and weight. The gills were then examined at the College laboratory at Mangalore with a x10 lens. Parasites were recorded as either gravid or non-gravid females, on each gill arch and each side of the fish.

In addition to data on catches of *Wallago attu* project personnel also collected data on other fish catches for Dr K Lorenzen of MRAG. Numbers and total catch weights for 14 categories of fish from commercial catches were collected each month. In addition length and weights for individual fish within catches were taken for all carp species.

Only a single species of *Ergasilus* was found on *Wallago attu* from Vanivalis Sagar. This appears to be identical to *Ergasilus maldanensis* Venkateshappa, Seenappa & Manohan 1988, described from *W. attu*, in Vanivalis Sagar.

All raw data was transferred to computer and print outs sent to Stirling. Fisheries data was then sent to Dr Lorenzen.

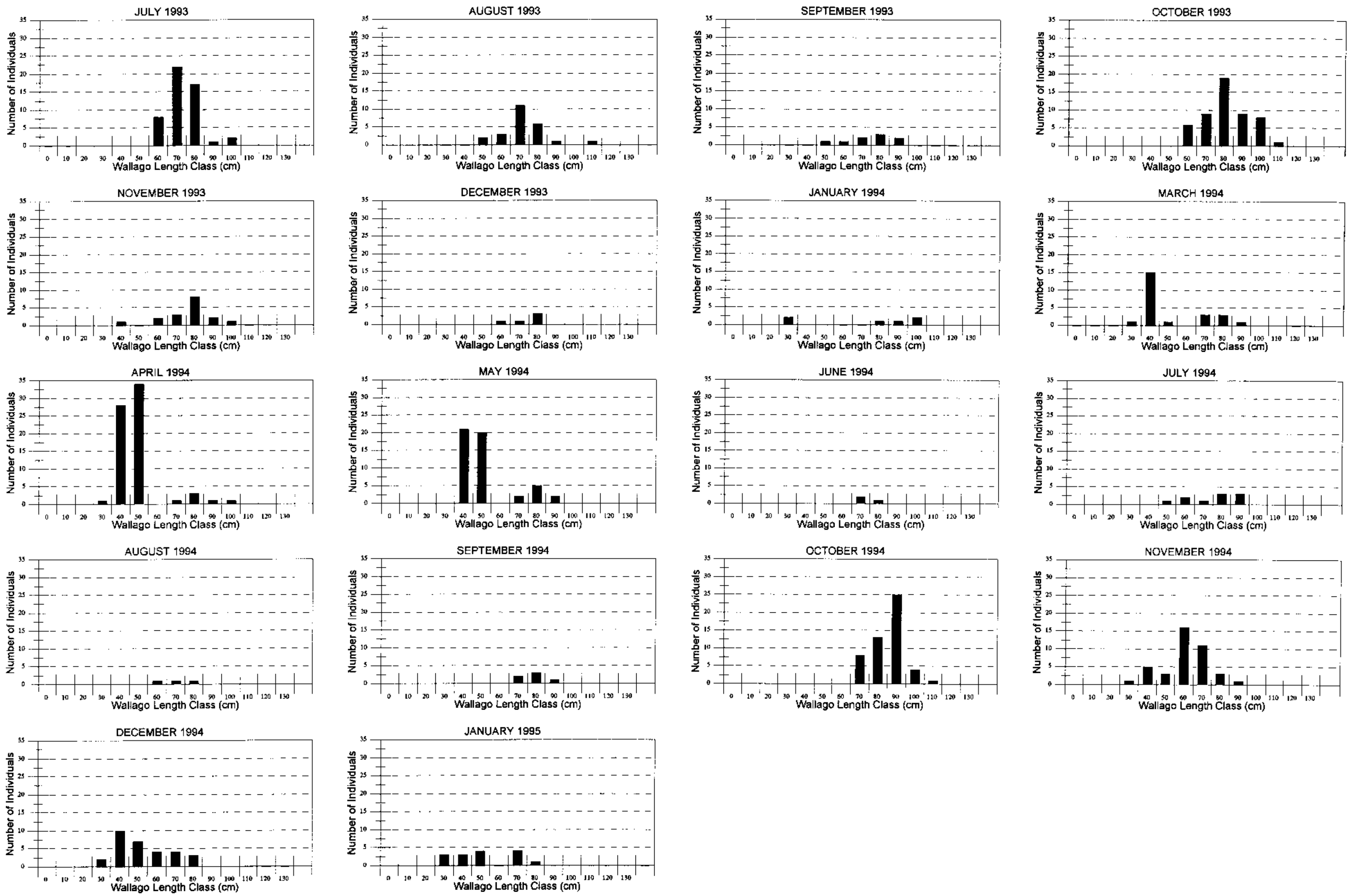
4.2 Results

4.2.1 Numbers and Size of Fish

Fish were obtained from July 1993 to January 1995 with the exception of February 1994 and April 1994. The numbers of fish examined in each month, and their mean length, is shown in Table 5. Catches were very erratic and the planned number of 50 fish was only obtained in 4 samples, although reasonable catches of over 20 fish were obtained in a further four samples. There was no obvious pattern to the size of catch, high and low catches occurring in all seasons.

The size of fish in monthly samples also varied considerably. The length frequency of *Wallago attu* sampled is shown in Figure 1. Mean length was greatest during the monsoon and post-monsoon periods ie. from June until approximately the end of the year. During this period the mean length remained above 60 cm and was at a maximum in October in both 1993 and 1994. During the winter months much smaller fish entered the fishery resulting in a considerable drop in the mean length. In 1993/94 small fish less than

Figure 1. Length of captured Wallago:- July '93 - January '95



50 cm in length did not enter the catch until January 1994 and were predominant in March, April and May 1994. However, in winter 1994/95 such small fish first appeared in catches in November 1994 and were also relatively abundant in December and January. A bimodal length distribution in the catch was observed during January-May 1994 and November 1994 - January 1995

4.2.2 Prevalence Rate of *Ergasilus*

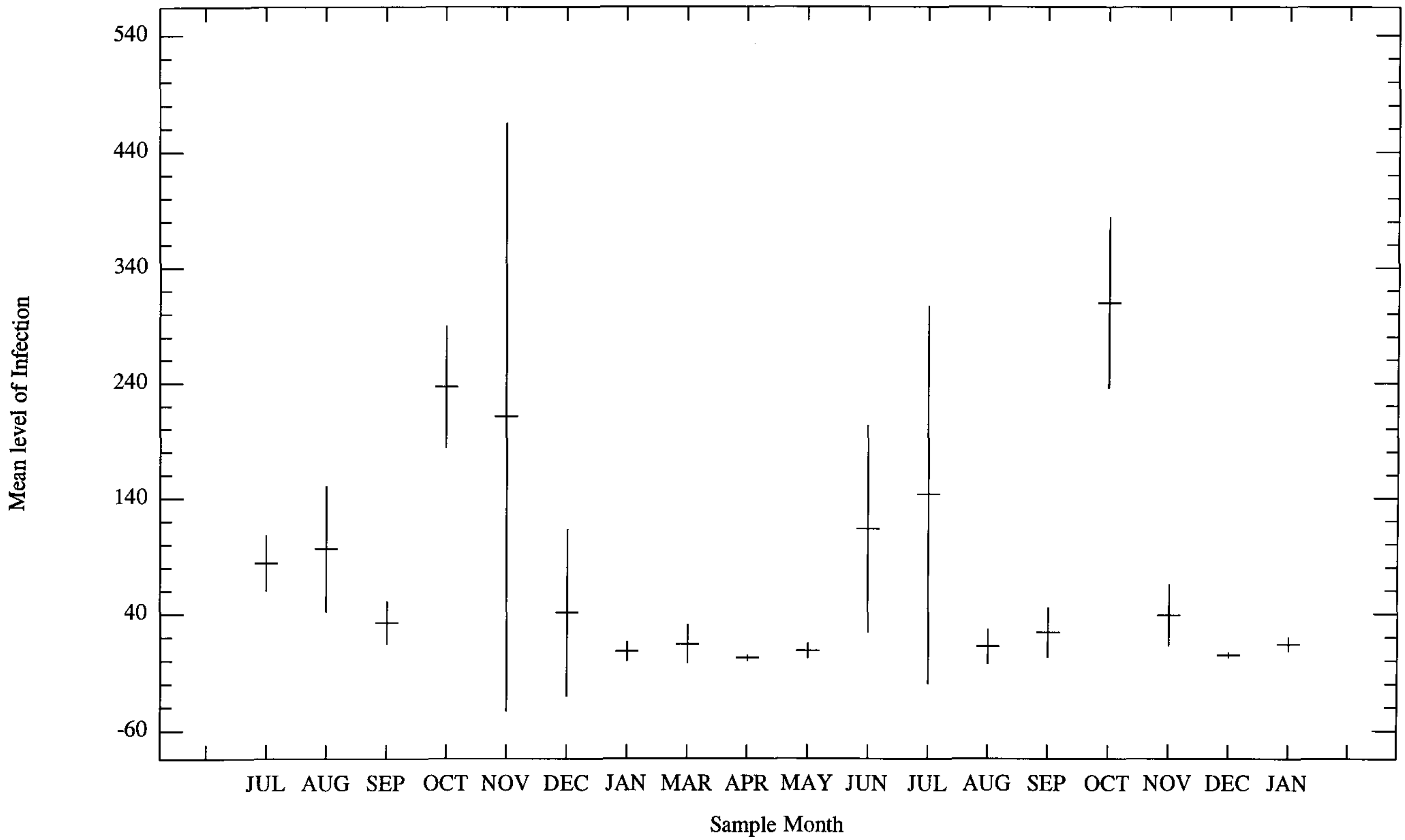
The prevalence rate of *Ergasilus* on *Wallago* is shown in Table 5. The prevalence remained high throughout most of the sampling period, in most months over 50% of fish being infected. In several months the small numbers of fish examined means that prevalence rates should be treated with caution. A lower prevalence rate was recorded in March, April and May 1994 from reasonable samples of fish. There was no consistent variation in prevalence rate throughout the remainder of the sampling period.

4.2.3 Intensity of Infection of *Ergasilus*

The intensity of infection of *Wallago* with *Ergasilus* fluctuated a great deal over the sampling period, as shown in Table 5 and Fig. 2. Once again the small numbers of fish obtained in some months means that intensity values should be treated with caution in these cases. The highest values for mean intensity were found in October and November 1993, and there is some suggestion that this is followed by a drop from December 1993 to May 1994 and from November 1994 to January 1995. The mean intensity varied throughout the remainder of the sampling period.

Figure 2.

Mean level of infection of captured Wallago infected with *Ergasilus* (+/- 95% confidence limits)



4.2.4 Host Distribution of Ergasilus

The frequency distribution of *Ergasilus* on *W. attu* from July 1993 - January 1995 is shown in Fig. 3 and the variance to mean ratio for each month is shown in Fig. 4. The population of *Ergasilus* on *W. attu* was overdispersed in all months in which fish were sampled. Overdispersion was highest in March - May 1994 at a time when relatively large numbers of uninfected fish were present in the catch.

There was a significant positive association between variance and mean monthly level of infection of *Ergasilus* on *W. attu* (Fig. 5).

4.2.5 Reproduction of *Ergasilus*

Ergasilids on the gills of *Wallago* were categorised as gravid and non-gravid. Both categories of copepods were found throughout the sampling period although gravid parasites far outnumbered non-gravid individuals in all months. There was no obvious seasonal pattern although the highest ratio of gravid to non-gravid parasites was found from October 94 to January 95 (Table 6). Except in March 1994 when 61.6% of the *Ergasilus* were gravid, the percentage of gravid parasites was over 70% in all months. Apart from November 94 - January 95 most fish were infected with both gravid and non-gravid *Ergasilus*, in the latter months the reduction in prevalence of non-gravid parasites reflects the higher gravid to non-gravid ratio reported earlier.

Table 5 The Infection of *Wallago attu* from Vanivalis Sagar Reservoir with *Ergasilus attu*

Year & Month	No. fish examined	Mean length fish (cm)	Prevalence rate %	x parasites per infected fish
1993				
July	50	66.5	98	85.5
August	24	66.4	95.8	100.3
September	9	70.2	(100)	(32.6)
October	52	76.4	100	236.4
November	17	71.7	94.1	223.8
December	5	69.4	(60)	(68.3)
1994				
January	6	67.0	(66.7)	(11.8)
February	-	-	-	-
March	25	46.3	36	38.4
April	69	44.3	8.7	23.5
May	50	47.4	18	44.7
June	3	70.0	(100)	(113.3)
July	10	71.1	(100)	(143.6)
August	3	66.3	(100)	(12)
September	6	72.9	(66.7)	(35.8)
October	51	80.9	100	309.3
November	40	56.7	77.5?	48.7
December	30	48.0	80	5.8
1995				
January	15	46.7	80	16.9

Figure 3. Level of infection by Ergasilus on gills of Wallago:- July '93 - Jan '95

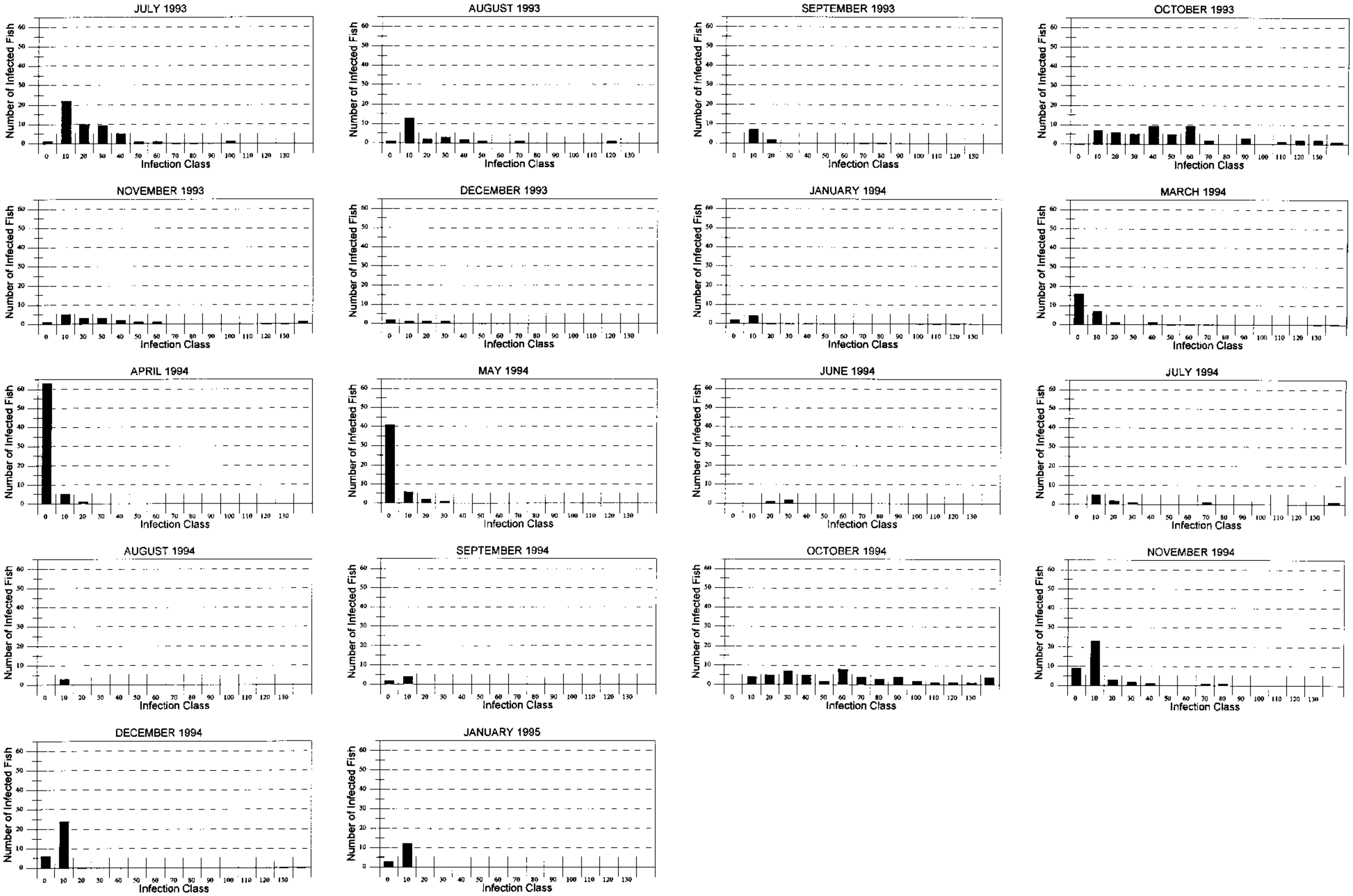


Figure 4.

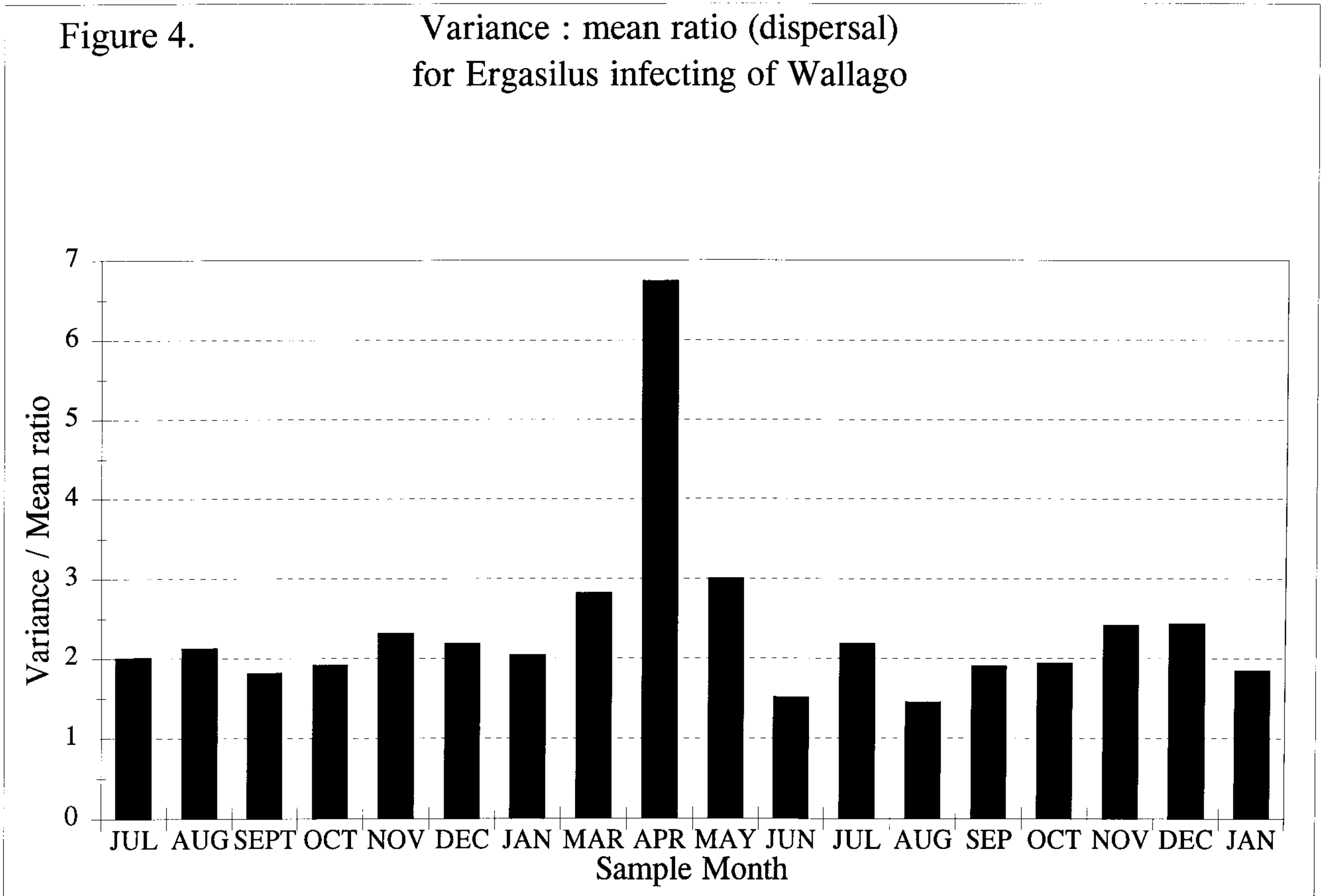

Variance : mean ratio (dispersal)
for Ergasilus infecting of Wallago
Variance / Mean ratio
0
1
2
3
4
5
6
7
JUL
AUG
SEPT
OCT
NOV
DEC
JAN
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN
Sample Month

Figure 5. Regression of mean infection level against variance for *Ergasilus* infecting captured Wallago - July 1993 - January 1995

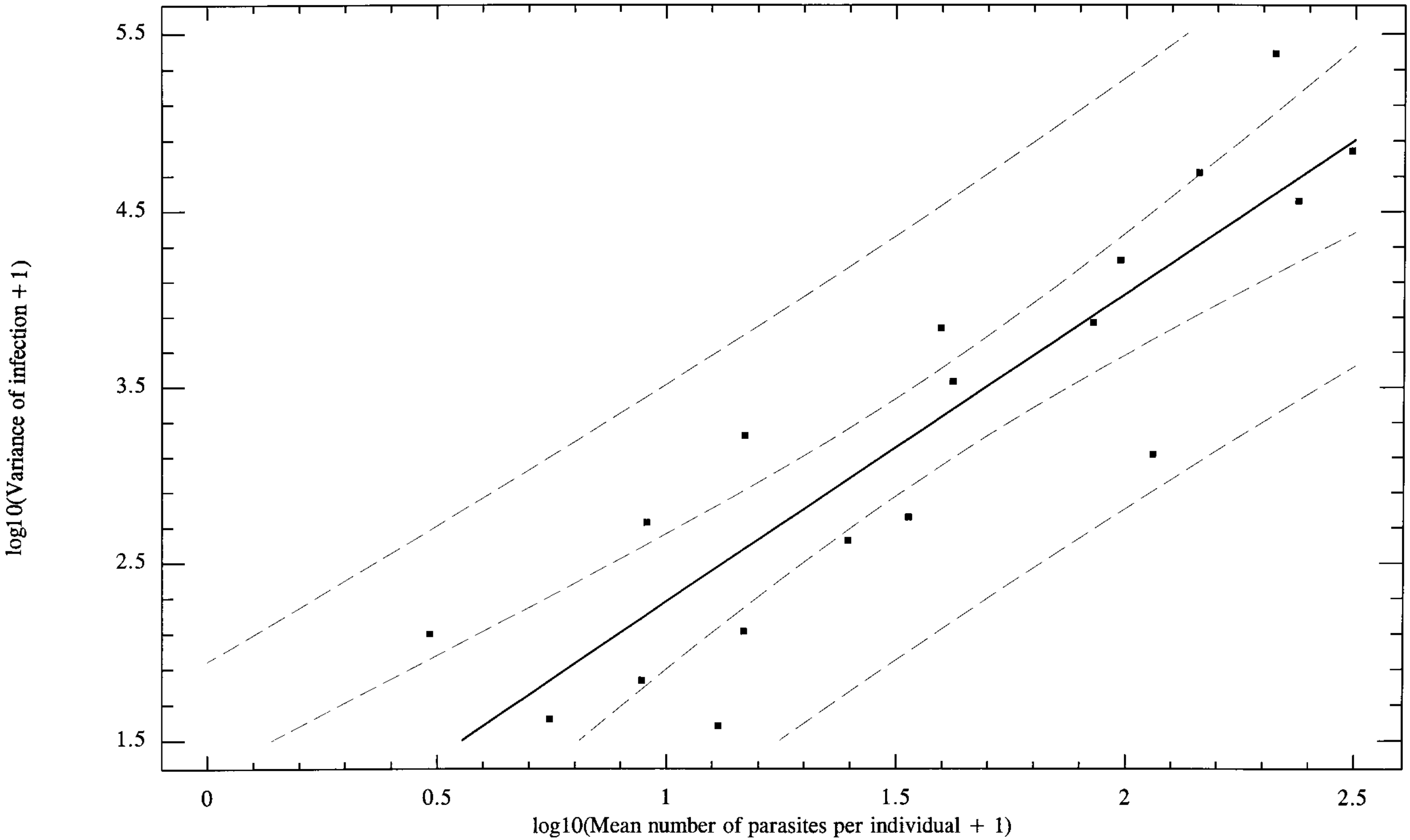


Table 6 The Occurrence of Gravid and Non-Gravid *Ergasilus* on *Wallago attu* from Vanivalis Sagar Reservoir

Year & Month	No. fish examined	Prevalence gravid *Ergasilus*	Total no. of *Ergasilus*	*x* gravid *Ergasilus* fish	Prevalence non-gravid *Ergasilus*	*x* non-gravid *Ergasilus*/ fish	% *Ergasilus* gravid	Gravid:non-gravid *Ergasilus*
1993								
July	50	98	4191	70.5	94	15.7	82.4	4.7:1
Aug	24	95.8	2307	82.3	91.7	18.9	82	4.6:1
Sept	9	100	293	23.4	100	9.1	72	2.6:1
Oct	52	100	12202	179	98.1	58.5	75.7	3.1:1
Nov	17	94.1	3581	194.2	94.1	29.6	86.8	6.6:1
Dec	5	60	205	52.7	40	23.5	77.1	3.4:1
1994								
Jan	6	66.7	47	8.5	66.7	3.3	72.3	2.6:1
Feb	-	-	-	-	-	-	-	-
Mar	25	32	346	26.6	32	16.6	61.6	1.6:1
Apr	69	87	141	23.1	7.2	4.3	18.4	4.4:1
May	50	18	402	39.4	12	7.8	88.3	7.6:1
June	3	100	340	88.3	100	25	77.9	3.5:1
July	10	100	1436	112.8	80	38.5	78.6	3.7:1
Aug	3	100	36	9	100	3	75	3:1
Sept	6	66.7	143	26.5	66.7	9.3	74.1	2.9:1
Oct	51	100	15775	277.4	96.1	33.2	89.7	8.7:1
Nov	40	77.5	1511	43.8	45	8.6	89.8	8.8:1
Dec	30	80	138	5.4	13.3	2	94.2	163:1
1995								
Jan	15	80	203	12.1	46.7	3.1	89.2	8.2:1

4.3 Discussion

The levels of infection of *Ergasilus* on *Wallago* from Vanivalis Sagar Reservoir were high throughout most of the year. This corresponds with the results obtained in the previous study in June 1991 - February 1992 . The combined data suggests that the parasite population has remained fairly constant between 1991 and 1995. Little is known of long-term fluctuations in parasite populations in tropical waters, but Vanivalis Sagar is a long established reservoir which is probably fairly stable in terms of physico-chemical characteristics. In addition it seems doubtful that the *Wallago* population is heavily fished and thus it too may not be subject to very large changes. Both these factors may tend to ensure the relative stability of the *Ergasilus* population. *E. maldanensis* is recorded only from *W. attu* and is believed to be host specific. It was not seen on other species from Vanivalis Sagar.

Parasite populations in tropical fresh waters are normally considered to show little seasonal variation because of the relatively stable conditions which persist in such environments. This may be contrasted with the situation in temperate waters where parasites often show marked fluctuations in abundance and reproductive state associated with seasonal changes in environmental conditions.

However, there are marked environmental variations in tropical waters, such as between dry and monsoon conditions in South Asia which have a significant influence on, for example, spawning in fish, and which might be associated with changes in the parasite farm. This area is poorly understood. *Ergasilus* does show some evidence of a seasonal cycle of abundance with a peak in October/November, post-monsoon, as water temperatures fall. Some of this rise may be due to an increase in the size of the fish caught in this period which is at the maximum for each year. However, the levels at this time are much higher than in preceding months and the length differences of the fish does not seem sufficiently different to account for this level of parasite numbers.

The drop in parasite numbers after this peak is due to the appearance in the fishery of smaller uninfected or lightly infected fish and the disappearance of most fish over 60 cm in length. In the absence of detailed knowledge of the biology and age structure of *Wallago* in the reservoir it is not possible to account for the low level of infection in these smaller fish, or the fate of large *Wallago*. Do the latter migrate to parts of the reservoir where they are inaccessible to the fishing methods used or can they not be caught by these methods when they reach a certain size? Either way, if a sizeable population of these fish exists they may actually harbour the bulk of the parasite population.

Reproduction of *Ergasilus* on *Wallago* proceeds throughout the year as judged by the continuous presence of gravid and non-gravid parasites. The high ratio of gravid to non-gravid parasites throughout the year probably reflects the relatively short time it takes for an individual parasite to produce egg strings and the longer duration of the egg bearing stage. There is no obvious indication from this study of any seasonal change in the rate of reproduction of *Ergasilus*, even though there is an increase in parasite numbers in the last quarter of each year. Most probably sampling was not sufficiently detailed to demonstrate any changes in parasite reproductive rate. The high gravid:non-gravid ratio seen from October 1994 to January 1995 might suggest a reduction in parasite reproduction and hence recruitment during this period, but the pattern was not seen in the same period the previous year and its significance, if any, is not known. A similar reduction was also seen in 1991-92 in the previous study (des Clers *et al* 1992).

Interestingly the appearance of smaller *Wallago* in catches at the end of each year, and hence a reduction in parasite numbers, differed slightly in timing. Thus in 1993 this did not occur until December, whilst in 1994 it occurred in November. The reasons for this are not clear, but it is tempting to speculate they are due to climatic variation. In the absence of data this must remain speculation. It does indicate however that there will be year to year variations in the timing of changes in parasite populations even in relatively stable tropical environments.

A general tendency for overdispersal has been reported for host-crustacean relationships so far described (Van Damme & Hamerlynk 1992). Whilst examination of the dispersion of *Ergasilus* on *Wallago* using the small sample sizes obtained at some times of year is somewhat insecure (Elliot 1971) it seems clear that an overdispersed distribution is generally the rule. It is only possibly to speculate how the overdispersion has arisen but it may for example, relfect uneven distribution of host and/or parasite larval stages in the environment or perhaps differences in individual host susceptibility.

Some disagreement exists in the literature as to the suitability of the use of an estimation of the k exponent of a negative binomial or alternatively the use of the ratio of variance/mean as measures of aggregation. Heip (1975) suggests that the ratio of variance/mean will approach unity as density decreases and that therefore it is not a good indicator of aggregation and proposes that the calculation of k is preferable. More recent work by Scott (1987) argues on the other hand that because the value of k is not corrected for the mean (as is the former value), comparisons in magnitude between samples are not useful since, if the sample means differ, lower values of k will not be indicative of a higher degree of aggregation. In addition she notes that the value of the variance/mean ratio will be particularly sensitive to the presence of singly heavily infected hosts whereas k is more useful in the description of the spread of values about the mean. Because the use of k requires agreement with a negative binomial model (Elliot 1971) and because this latter requirement is not fulfilled by all the samples in the present study, the variance/mean ratio has been used here instead. Furthermore, attempts to estimate k by the moments method proposed by Elliot (1971) give such variable results according to the differing means and samples sizes that it is impossible to calculate a common k (k), for the sample series using a regression analysis. Given the variation of sample sizes and the bimodal nature of the *Wallago* population at certain times of year, it is worth noting the observation of Iwao (1970) that descriptions of distributions using mathematical models can only be "superficial and approximate".

The effect of *Ergasilus* on the population of *W. attu* on Valivalis Sagar is uncertain. Infected fish appeared to be in good condition. Pathology, even on heavily infected fish, appeared minimal, at least by gross observation, with no indication of severe disruption of gill structure or excess mucus production. Numbers of parasites on fish below around 50 cm in length were generally too low to be likely to be of real significance. In larger fish it cannot be ruled out that *Ergasilus* may have had some impact on fish growth but such a relationship is notoriously difficult to quantify, even under closely defined experimental conditions. A proper assessment of the effect of the parasite would need to be assessed by a histopathological study and experimentation. Unfortunately both were outside the scope of this study.

5. General Discussion

The problems encountered in establishing suitable sampling programmes during this project has unfortunately meant that it has been very difficult to meet the initial objectives. The sewage-fed bheris in Calcutta sampled in the initial project in many ways represented an ideal sampling system in terms of the availability of host and population data. Regrettably for what appear to have been internal political reasons these sites were unavailable to us.

The sites in Pakistan appeared to be a satisfactory alternative, and although a reasonable start was made, for unknown reasons this was not continued. Although the *Wallago-Ergasilus* system in Vanivalis Sagar was sampled as planned throughout the project the catches of fish proved more erratic than had been hoped from the evidence of the pilot project. This does not appear to have been due to any lack of effort on the part of the staff from Mangalore College of Fisheries but to have reflected either a lack of fish or perhaps a reduced fishing effort. The data obtained has been of reasonable quality in terms of the parasite population, but not detailed enough overall to address all the project objectives .

No evidence was obtained that any of the parasites found were economically significant in the fisheries studied. As mentioned earlier, *Ergasilus* as a genus is known to be potentially very pathogenic, although *E. maldanensis* does not appear to be so, despite the very large numbers found in some fish. This does indicate that caution must be exercised in interpreting the presence of parasities on fish. There is always a temptation to ascribe harmful effects to large numbers of obvious parasites, but in many host-parasite systems such effects can be minimal, at least at a population level. More subtle, sub-lethal effects may be significant, but these by their very nature are difficult to determine. Where parasites such as *Ergasilus* can be very dangerous is if host fish are potential aquaculture candidates, in which case parasites may multiply dramatically in high host densities. With the *Ergasilus* - *Wallago* system, the low level of infection of smaller fish possibly represents an ecological separation of parasite and host. Fish of this size can be infected and in an aquaculture system they might become heavily infected at levels which would cause severe pathology.

Of the parasitic species found in carp from the Pakistan sites the larval nematode *Contracaecum* sp is the most likely candidate as a significant pathogen. In general larval parasites found within the viscera cause the most severe pathology (Wootten 1989), since they may cause a marked host reaction affecting one or more organ systems. Such parasites are normally long-lived and thus accumulate in fish with increasing age, so that larger fish are often the worst affected. Economic loss can often be the result of consumer rejection because of the presence of large numbers of unsightly parasites. Conversely, such parasites may be dangerous in very young fish where only one or two individuals can do sufficient damage to cause mortality and morbidity.

This study has provided interesting data on the population biology of *Ergasilus* from *Wallago attu*. There are relatively few such studies on parasites from tropical systems and this project has demonstrated that although the parasite is present and reproducing throughout the year there are peaks of abundance which appear to be associated with climatic conditions. It would be interesting to study the occurrence of *Ergasilus* throughout the wide geographic range of *Wallago attu*, to see if the same pattern of occurrence occurs elsewhere. The present study has also shown that the parasite population is overdispersed with the host population, as might have reasonably been expected from other studies on metazoan parasites of fish.

A knowledge of the population biology of the parasite is important in the development of possible management strategies for their control both in fisheries and aquaculture. For example, if it was desired to stock *Wallago attu* into a fishery which contained hosts already infected with *Ergasilus maldanensis* then the results of the present study suggest that stocking post-monsoon when parasite numbers are high might be best avoided. Similarly the high levels of infection in larger fish and the overall overdispersion of the *Ergasilus* within the *Wallago* population suggests that if it was desirable to reduce the overall level of infection then selective or increased fishing pressure on the larger more heavily infected fish would be most effective at driving parasite numbers down. If the parasite in question was of low host specificity and a number of fish species were involved then it would be necessary to identify which of the latter were of most importance as hosts before any policy of selective fishing could be formulated.

The available fish population data on *Wallago attu* from Vanivalis Sagar does not permit any detailed elucidation of the relationship between host and parasite populations. In particular there is no indication of host population size, age structure and fishing mortality. Such data, combined with parasite population data, might allow some quantitative predictions of the effects of fishing strategies or stocking on parasite numbers. It was hoped that appropriate data would have been available from the small reservoirs in Pakistan and it certainly would have been obtainable from the Calcutta sewage-fed bheris.

It has not been possible to formulate a detailed management strategy for any of the host-parasite systems found during this study. However, it it possible to make some general observations which might be relevant. Reductions in parasite numbers in fisheries are usually likely to be difficult to obtain . Remedial measures are probably going to be fairly long-term, involving months, if not years, usually because they would involve the reduction in population size of one or more of the hosts in the parasite life-cycle. In the case of a parasite with a direct life-cycle such as *Ergasilus* this will involve only the host fish population(s), but in the case of parasites with indirect life cycles, such as many of the helminths, it might involve efforts to reduce numbers of invertebrates or other vertebrates such as birds, mammals or other fish.

The economic and ecological impact of such measures could be very severe in terms of loss of fish stock or fauna and might have very marked impacts on fishing communities. For these reasons such measures would only normally be undertaken if the scale of the problems caused by parasites warranted such drastic action. It is important therefore that the effects of parasitism on the fishery are properly elucidated before action is taken.

As described earlier in this section one of the most likely methods of control would be selective fishing of a stock to remove the most heavily infected fish, or fish species, and thus to lower overall parasite numbers. This might practically be achieved by altering mesh size or fishing gear. Within a single host species it would normally be the larger individuals that would harbour most of the parasite population and would need to be removed. If the impact of parasitism was extremely severe then a drastic mangement method might be the complete harvest or kill of all fish stocks, or affected stocks if this were possible. Such a method could only be realistically achieved in a relatively small reservoir and might cause severe economic hardship. However, there are parallels in the campaign by the Norwegian authorities to remove the monogenean *Gyrodactylus salaris* from salmon rivers, by eradication of fish stocks, which has been successful in some cases.

Treated waters would need to be restocked after a suitable "fallow period". This would need to be long enough to ensure that any free-living stages of the parasite would die.

Restocking would be necessary at some point and stocks used would need to be carefully screened to ensure that the same or new species of parasites were not reintroduced (des Clres 1994). Screening of fish used for stocking would be important in any context, in order to prevent the introduction of potentially pathogenic parasites.

Fish species obviously vary in their susceptibility to parasites and other pathogenic agents. It may be possible to stock fisheries with fish that are relatively non-susceptible to any pathogenic parasites that are abundant, e.g. varying the species mix of Indian and Chinese carps. In theory this might in time reduce numbers of pathogenic species due to a lack of suitable hosts. A potential problem with this approach is that the fish species allowed to become dominant might be economically less valuable.

Efforts to remove intermediate hosts of parasites that may be causing economic damage are difficult, both in a practical and ecological sense and can probably only be reasonably attempted in small water bodies.

Invertebrates are particularly difficult to eradicate. Molluscs, which are intermediate hosts to digenean trematodes, the larval forms of which can be a cause of significant economic loss, may be controlled by the use of molluscicides, at least in small reservoirs. Personal experience has shown this to be effective in the UK, although costs can be high and fish populations may also be eradicated, thus necessitating restocking. The control of crustaceans which are important hosts in the life-cycles of many helminth parasites is practically extremely difficult, although the use of insecticides may be possible, again at a cost. Such methods may also be used in small water bodies against *Argulus* and copepod parasites, including *Ergasilus*.

Where fish are important as hosts for economically important parasites, if the fish species in question is not of great economic importance then the possibility arises of selective fishing to remove it as far as possible. The control of birds or mammals which act as final hosts of parasites is practically extremely difficult and little success can be expected, even by drastic measures such as sustained shooting. In the smallest reservoirs and fisheries it may be possible to resort to bird scaring.

Control of parasites in reservoirs and fisheries is thus difficult and certainly not without costs. Total eradication is probably unrealistic in most circumstances. However, a variety of control methods are possible depending on the precise situation of the fishery and the parasite involved.

REFERENCES

Ahne, W. (1978) Uptake and multiplication of spring viraemia of carp virus in carp, *Cyprinus carpio* L. J. Fish Dis. 1: 265-268.

des Clers, S., Sommerville, C. & Wootten, R. (1992) *Effects of Parasitism on Reservoir Fisheries in South Asia.* Institute of Aquacultutre, University of Stirling.

Elliot, J. M. (1971) Some methods for the statistical analysis of samples of benthic invertebrates. *Scientific Publication of the Freshwater Biological Association* **25**.

Jhingran, A. G. (1986) Reservoir fisheries management in India. CICFRI Bulletin 45, 65pp.

Jhingran, A. G. & Das, M. K. (1990) Epizootic ulcerative syndrome in fishes. CICFRI Bulletin 65, 14pp.

Heip, C. (1975) On the significance of aggregation in some benthic marine invertebrates. *Proceedings of the 9th European Marine Biological Symposium* 527-538.

Iwao, S. (1970) Problems of spatial distribution in animal population ecology. In *Random Counts in Scientific Work, Vol. 2* (ed. Patil, G). Pennsylvania State University Press: University Park and London, 117-149.

Moreau, J. & de Silva, S. S. (1991) Predictive fish yield models for lakes and reservoirs of the Philippines, Sri Lanka and Thailand. FAO Fish. Tech. Pap. 319, 42pp.

Sarkar, S. K. & Das, R. N. (1990) Biology of catfish (*Mystus vittatus* and *Wallago attu*). Environment and Ecology 8 (1): 440-443.

Schaeperclaus, W., Kuhlow, H. & Schreckenbach, K. (1992) Fish Diseases (5th Edn). Rotterdam: Balkema. 1398 pp.

Scott, M. E. (1987) Temporal changes in aggregation: a laboratory study. *Parasitology* **94**, 583-595.

Sprengel, G. & Luechtenberg, H. (1991) Infection by endoparasites reduces maximum swimming speed in European smelt *Osmerus eperlanus* and European eel *Anguilla anguilla*. Dis. Aquat. Org. 11: 31-35.

Van Damme, P. A. and Hamerlynk, O. (1992) The infection dynamics and dispersion pattern of *Lernaeocera branchialis* L. on 0+ *whiting (Merlangius merlangus* L.) in the Oosterschelde (SW Netherlands). *Journal of Fish Biology* **41**, 265-275.

Waller, U. & Scholz, U. (1992) Oxygen requirements of some fish species from the German Bight with emphasis on the effect of parasites. J. appl. Ichthyol.

Wootten, R. (1989) Parasitology of teleosts. In: Fish Pathology (ed. Roberts, R. J.). pp. 242-288. Bailliere Tindall. London.