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EFFECTS OF PARASITISM ON RESERVOIR FISHERIES

IN SOUTH ASIA

FINAL REPORT

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EXECUTIVE SUMMARY

1. In conjunction with the Central Inland Captive Fisheries Research Institute, Barrackpore, India, two Indian major carp species *Labeo rohita* and *Catla catla* were sampled from two sewage-fed bheris, Nalban and Goltala, in the vicinity of Calcutta from June to November 1991.

2. Thirty fish of each species were examined at two week intervals for the presence of the ectoparasitic branchiuran *Argulus sinensis*. A total of 781 fish were examined.

3. *Argulus* was much more abundant at Nalban than at Goltala bheri and was also more abundant on *Labeo rohita* than *Catla catla*.

4. *Argulus* was more abundant in both bheris during the early part of the study period, but decreased to a low level in November, coinciding with lower water temperatures.

5. There was no obvious relationship between the abundance of *Argulus* and host size in either fish species, over the limited size range of fish examined.

6. There was some indication that abundance of *Argulus* was linked to host biomass. Very high fishing pressure is likely to control parasite numbers.

7. There were no significant differences in condition of either species of carp in relation to *Argulus* infection in either bheri.

8. In collaboration with the College of Fisheries, Mangalore, the predatory catfish *Wallago attu* was sampled from Vanivilas Sagar, a large irrigation reservoir in Karnataka State, from May 1991 to February 1992.

9. Wherever possible sixty *W.attu* were sampled each month for the presence of the ectoparasitic copepod *Ergasilus* on the gills. A total of 436 fish were examined.

10. Most *W.attu* were infected with *Ergasilus* (94%) and the mean abundance of parasites per fish increased markedly with host size, probably reflecting an increase in gill surface area as fish size increases.

11. Mean abundance of *Ergasilus* per fish was much lower from December to February, reflecting the much smaller size of *W.attu* caught in this period.

12. Recruitment of *Ergasilus*, as expressed by the ratio of non-gravid to total females, probably takes place throughout the year, but apparently slows down during November - February.

13. The management implications of parasitism in the sites sampled and suggestions for future work are discussed.

FINAL REPORT

1 Objectives of the project

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. reduced 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.

This project was an attempt to explore this problem using the objectives listed below. It was carried out over a limited period and was a pilot study largely concerned with the feasibility of successfully carrying out a field programme in-country aimed at collecting data to fulfil the given objectives.

(a) Identification of economically significant parasite problems in reservoir fisheries.

A large number of parasite species have been identified as economically significant in relation to aquaculture systems. Although many of these parasites are also found in reservoir fish stocks, there is little information on their significance in this situation. Given the short time available, it was decided to select for study parasites known to be of at least potential pathogenic significance, even if actual losses were not documented in the sites sampled.

(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.

(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. Work carried out during the period

2.1 Sewage-fed bheris outside Calcutta

Planning

The Central Inland Captive Fisheries Research Institute (CICFRI) at Barrackpore, West Bengal is the major research centre in India concerned with reservoir fisheries, and as such was a natural choice as a collaborator in this project.

Initial approaches were received enthusiastically. The then Director, Dr. A.G. Jhingran, arranged for us to meet and discuss with all relevant staff the rationale of the study and its objectives. Various alternative study sites and host-parasite systems were assessed during these discussions. It was decided to use the sewage-fed bheris in close proximity of the Institute, and to study the crustacean ectoparasite *Argulus* on Indian major carp. *Argulus spp.* is a large (ca 6 - 8mm) ectoparasitic crustacean, easily visible to the naked eye without dissection of the fish. Furthermore, *Argulus* is a well known for its pathogenic effects on fish. Various species occur worldwide and several are serious pests in culture systems in India, and one of the major problems in the developing pond fish culture industry in Andhra Pradesh. This programme appeared to fit in well with the experience of Dr. A. K. Ghosh, a CICFRI scientist who had previously studied *Argulus*. A sampling protocol was then developed and field work commenced in June 1991.

General description

The bheris are wetland impoundments south and east of Calcutta. The freshwater bheris in the vicinity of Calcutta are fed with raw sewage from the city. After a short period of settlement the bheris are stocked with fish. The two bheris selected, Nalban and Goltala, have a surface area of approximately 90 ha each, and are about one metre deep. Bheris are drained from time to time, but Nalban has been in continuous operation for the last 15 years, and Goltala for at least three years.

The bheris are stocked more or less continuously with Indian major and Chinese carp fingerlings, and in addition harbour populations of tilapia. Harvesting is effected with a seine net of small mesh size (Fig. 1a), and fish are then selected by hand for landing (Fig. 1b,c). Approximately 10 to 12 boats operate on each bheri as a cooperative throughout the year. The average size of the fish landed is

Fig. 1.

A. Fishing operations in Nalban bheri. Men in water are keeping bottom line of net on substrate to prevent escape of fish.

B. Sample of total catch consisting of mixed carp species. Small fish are not landed.

C. Project associate Dr A K Ghosh supervising unloading fish samples.

D. Dr A K Ghosh examining major carp for *Argulus*.


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rather small, about 20-30 cm. Growth is very rapid, and fish probably spend only about 3 to 6 months in the bheris.

The host-parasite system

Indian major carp normally live and spawn in the major rivers of the Indian sub-continent. The group comprises three species two of which, *Catla catla* and *Labeo rohita*, were selected for this study. Indian major carp do not reproduce naturally in lacustrine waters, so that the yield of these species from reservoirs is exclusively based on the stocking of fingerlings. Fry is produced by induced spawning or collected in the rivers, and raised to fingerling size (about 10 cm in length) in nursery ponds. *Catla catla* occupies the upper layer of the water where it feeds mainly on zooplankton, while *Labeo rohita* adopts a more catholic lifestyle, feeding on benthic vegetation and invertebrates as well as zooplankton. Indian major carp are extremely valuable commercial species and are widely cultured throughout South Asia, often in "composite culture", i.e. polyculture with Chinese carp species.

Parasites will initially be introduced into bheris after the latter have been filled with stocked fish. Once the bheris are in operation and some parasites are present however, even the stocking of unparasitised hosts will promote growth of the parasite population. Stocking with parasitised fish will of course add to the parasite population, but reproduction of existing parasites in the bheris may be more important than new introductions in determining infection levels. Hatchery reared fish may be heavily infected and such fish are likely to do poorly following the stress of stocking and may grow slower, suffer secondary infections or be more susceptible to predation than clean seed fish.

When the study was initiated, there was little information on the parasite fauna of the bheris. However, the two bheris chosen were known to harbour the crustacean parasite *Argulus sinensis* which had been the subject of a study by Dr A K Ghosh.

Argulus is a branchiuran crustacean parasite common on cyprinids but not specific to them. Several species have been identified from India, although identification to the species level is not very reliable in historical records.

Fertilised adult females leave the host to lay eggs on the substrate. Batches of eggs are cemented to surfaces of vegetation, stones etc. where the young *Argulus* develops to an advanced stage before hatching out and becoming infective. It actively swims to seek out the host where it becomes a full adult and able to reproduce. Its behaviour in the water column is not well-studied but it possesses a pair of well-developed eyes and responds to light stimuli. It's position in the water column may influence or be influenced by its host choice. Though it is not usually host specific it may exhibit preferences given a choice of host species. This has been studied in other species but not in *A.sinensis*. Its distribution amongst the potential hosts within the bheris is unknown.

Argulus spp is a well recognised pathogen of fish. It is a major pest in pond fish culture and is currently causing a serious problem in the rapidly developing fish culture systems in Andhra Pradesh. It is capable of causing reduced growth rates, morbidity and death. Its pathogenicity relates to its mode of feeding during which it penetrates the fish skin using a pre-oral stylet. Some external digestion is carried out by enzymatic secretions from associated glands. The products are then taken up by the mouth. The stylet penetrates the skin and the secretions cause considerable irritation and inflammation. The fish is debilitated but death is usually due to secondary bacterial, fungal or even viral pathogens which are able to enter the resulting open lesions. *Argulus* is known to act as a vector for viral pathogens. In addition, even lightly infected fish show signs of stress.

Sampling protocol

The sampling protocol was determined by several factors and was a function of a) sample size, b) frequency of sampling, c) number of bheris sampled and d) number of fish species. The criterion used to determine these parameters was the accuracy of the data. A minimum sample size of 30 fish was selected. Since the sampling period was to be limited to 6 months, a relatively frequent sampling was required. Fortnightly samples were therefore taken and ir was decided to select *Labeo rohita* and *Catla catla* as fish hosts owing to their greater economic value. On this basis, 2 bheris could be sampled given the staff and funds available.

Nalban and Goltala were selected due to their proximity to the lab at CICFRI, Salt Lake City near Calcutta. Both are managed by the West Bengal Development Corporation and thus had good fishery data available. Both were known to harbour the parasite *Argulus sinensis*. In addition to the above, it was necessary to have a uniform catch method so that data was comparable. We also required that the water bodies should have been stocked for at least a 2 year cycle and have been harvested for at least 6 months. These latter factors ensured that they were relatively stable and not subject to wild fluctuations in either catch data or parasite population characteristics.

Sampling fish

Argulus sinensis is ectoparasitic. Males and females are active, motile animals which parasitize the body surface of the fish using a browsing style of activity. They are active swimmers and can survive relatively long periods off the fish. We required that the exact number of parasites per fish was counted and thus, each fish had to be collected individually into a plastic bag as it was drawn out of the water, in order to avoid loss of parasites. Instructions were given to collect the fish as noted above, taking them randomly directly from the commercial catch from the seine net together with some water. Fish were landed from the boat already in separate polythene bags since the sample was taken directly from the net.

The fish were then transported in the bags in baskets by landrover to the laboratory. Bags were opened one at a time. The fish examined for parasites using a hand lens, (Fig. 1d). Fish were then weighed and measured (Standard length, condition and sex were also recorded.

The water from the bag was then passed through a sieve and free swimming individual parasites counted and added to the total for each fish. Parasites were recorded as either adults or juveniles.

Fishery Statistics

Fishery statistics for both Nalban and Goltala were provided by the West Bengal State Fishery Department who manage the fisheries. For both bheris stocking data giving total numbers and weight were provided for Indian major carp (all species combined), silver carp and common for each month of the study in which stocking occurred. Catch data for Goltala was provided as total weight of Indian major carp, silver carp, common carp and tilapia in each month of the study. For Nalban data on total catch weight and numbers of Indian major carp, silver and common carp was provided for each two week period of the study.

Physico-chemical parameters

The number of parameters measured depended on the capability of the CICFR laboratory in Salt Lake City. Water temperature, salinity, alkalinity and pH were measured from bi-monthly samples where possible.

Other parasites

A full study of the parasite fauna of the sampled fish was outwith the scope of this study owing to financial and time constraints. An attempt was made, however, to obtain data on the fish parasites from 15 fish per month from both *Catla catla* and *Labeo rohita* from both bheris.

This information was essentially qualitative in nature but, where numbers of parasites could be obtained these were recorded. Otherwise the identity of the parasites, to species level, where possible, was requested together with their tissue location.

2.2 Vanivilas Sagar reservoir in Karnataka

Planning

IOA has had links with Mangalore Fisheries College of Bangalore Agricultural University since 1980 and Prof. Shetty, the now retired director of instruction is known personally. In addition one of Dr. Sommerville's ex-PhD Students holds a lectureship in the College. Reliability of the personnel and hence the data collection was a major consideration in the selection of this study site. Dr Sommerville has been involved in a study of *Ergasilus* sp. on the catfish *Wallago attu* at Vanivilas Sagar reservoir earlier, and it was decided to expand this study. Field sampling commenced in May 1991.

General description

Vanivilas 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 year, 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 (Fig. 11a). Commonly gillnets are operated by one or two men from a coracle and suspended 2-3 ft deep in the water. The total fish yield from this artisanal fishery is unknown, but certainly low. *Wallago attu* is the largest fish species caught and commands a good price (Fig. 11b). Fish are collected at landing points around the reservoir and some are sold there or taken to local markets.

The host parasite system

The predatory catfish *Wallago attu* is found throughout South Asia. It can grow to a very large size, but most specimens caught in Vanivilas 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.

Wallago was known to be infected from a previous study at Mangalore.

Ergasilids spend most of their life free-swimming in the water. It is only after copulation that the

Fig. 11. A. Coracle fishing gillnets in Vanivilas Sagar.

B. A large specimen of <u>Wallago attu</u> from Vanivilas Sagar obtained from a local market.

C. A typical catch from a single boat. Note mixture of mostly small fish, including carps, catfish, featherbacks and eel.

D. Examination of preserved gill of <u>Wallago attu</u> at College of Fisheries, Mangalore.

II A

II B

II C

II D

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 carries them in egg pouches until hatching. Development takes place in the free water via several larval stages. The host specificity of *Ergasilus* is low, 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.

There is no information on other fish or parasite species in the reservoir. However, the presence of a known pathogen, easy to observe and on an economically important fish prompted the choice of this host-parasite system.

Sampling

It was decided to sample at least thirty fish on each occasion. A two months pilot study, in June and July, showed that several remote landing sites had to be visited by local bus over several days in order to obtain the thirty fish. It was therefore decided to sample only at monthly rather than bi-weekly intervals. Local scientists showed considerable effort and tenacity to obtain the necessary samples.

The length of individual fish was noted, but ages are unknown and weights are only available at the end of the study, after a suitable spring balance was purchased in the UK and sent to India.

A preliminary identification of parasite species on the gills showed that only one species of *Ergasilus* was present. All gill arches were removed on both sides of the fish and the fish returned to the market at a reduced value. All fish used were paid for from the project budget. The gills were fixed in 10% formalin in individually labelled pots indicating the fish length and possibly weight. The gills were examined at the College laboratory in Mangalore with a x10 lens (Fig. 11d). Parasites were recorded as either gravid or non-gravid females, on each gill arch and each side of the fish.

3. Results

3.1 Sewage fed bheris

Physico-chemical parameters

Four parameters were measured bi-weekly, at the same time as fish were sampled. This was meant to provide some indication of the physico-chemical environment. The data is probably inadequate to give a reliable description of the water quality, or its changes, which presumably take place very quickly in these shallow and extremely productive ecosystems. Average values and ranges are given in Table 1. The water temperature varied between 21 & 30°C during the study, but decreased with the arrival of the monsoon. Variations in salinity, alkalinity and pH are difficult to interpret in the absence of details on water management of the bheris.

Table 1. Average values and ranges for bi-monthly measurements at sampling time.

	Nalban		Goltala	
Water temp. (°C)	28	(23 - 30)	27.6	(21 - 30)
Salinity (‰)	0.24	(0.10- 0.41)	0.41	(0.27 - 0.56)
Alkalinity	117	(78 - 174)	140	(90 - 182)
pH	7.5	(7.0 - 8.0)	7.7	(7.0 - 8.7)

Fish catches

Fish species caught in both bheris include Indian major carp (*Catla catla*, *Labeo rohita* and *Cirrhinus mrigala*), silver carp (*Hypophthalmichthys molitrix*), common carp (*Cyprinus carpio*), grass carp (*Ctenopharyngodon idella*), tilapia (*Oreochromis mossambicus*), and possibly some other species. Only Indian major carp, common carp and silver carp catches are reported to the project in Nalban, and the same species plus tilapia in Goltala. Hence it is difficult to compare total yields, but the available information suggests that Nalban is far more productive than Goltala. Monthly yield by species or species group (Fig. 2) during the study period for both bheris show that Silver carp (SC) dominate the catch followed by Indian major carp (IMC) in Nalban (a) and tilapia in Goltala (b). Indian major carp constitute only 11% of the reported catch (in weight) in Goltala compared to 40% in Nalban. Since catches for tilapia (which is known to be present) in Nalban was not reported, the actual fraction of IMC in this bheri may be lower. However, absolute catches of all reported species are much higher in Nalban than in Goltala.

Stocking

Limited data (June and July only for Nalban and June to October for Goltala, Fig. 3) is available, which allows only preliminary conclusions to be drawn. Stocking appears to be continuous but with distinct peaks in time. Numbers of fry stocked in Nalban (2) may be slightly higher than in Goltala (2), with the exception of silver carp.

Size composition of landings

Fish are caught with seine nets of very small mesh size, but only fish above a certain size are landed. The average individual weight of fish landed and total catch for Indian major carp (IMC (a)) and silver carp (SC (b)) in Nalban are given in Fig. 4. In both cases, average size in the catch (from 180 g and 220 g, respectively) decreases between July and August. This may be due to a new cohort

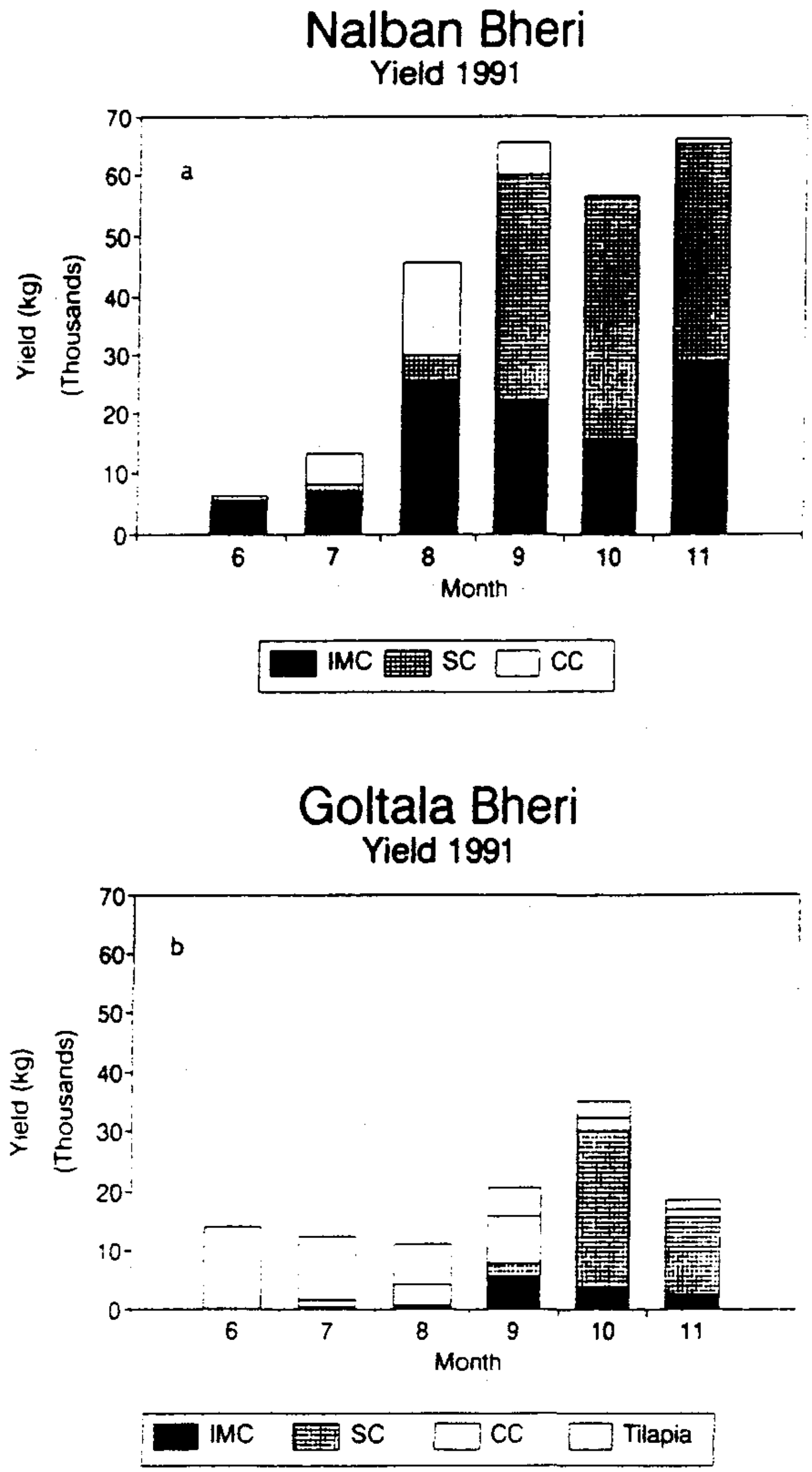
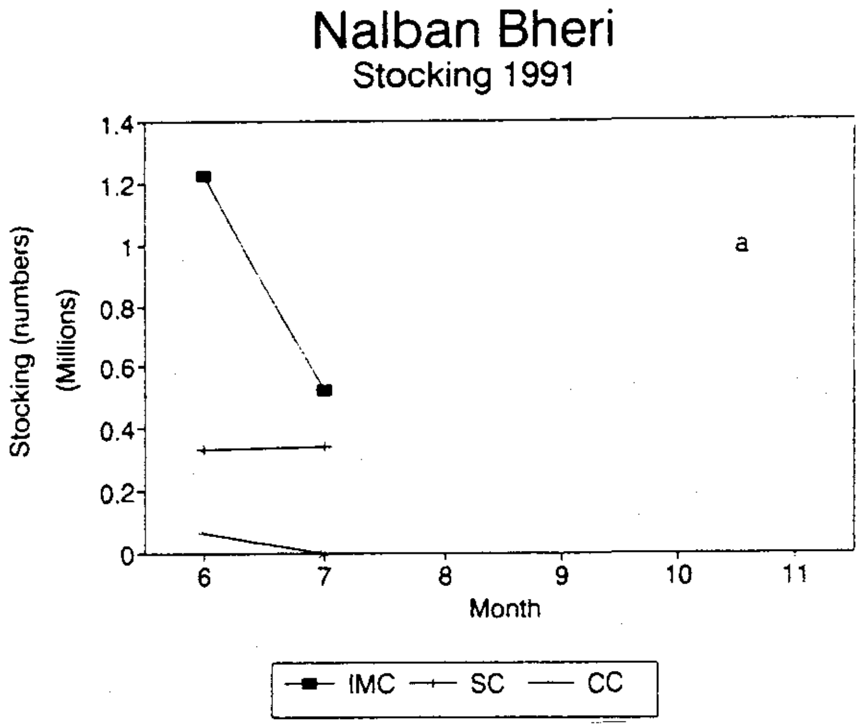


Fig. 2. Yield by species for Nalban (a) and Goltala (b). Note that tilapia are present in both bheries, but are not reported for Nalban.



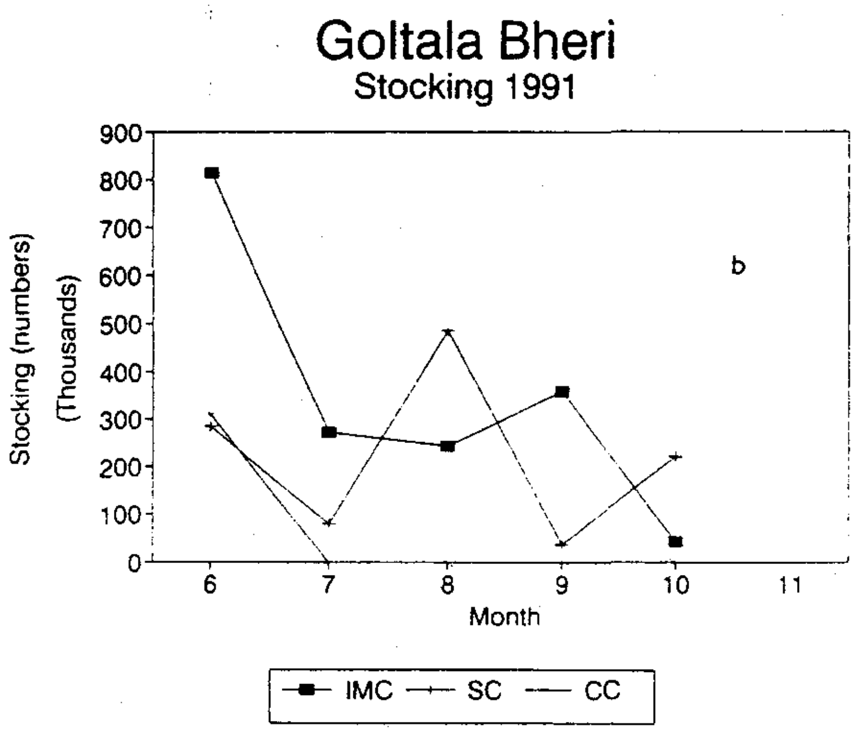
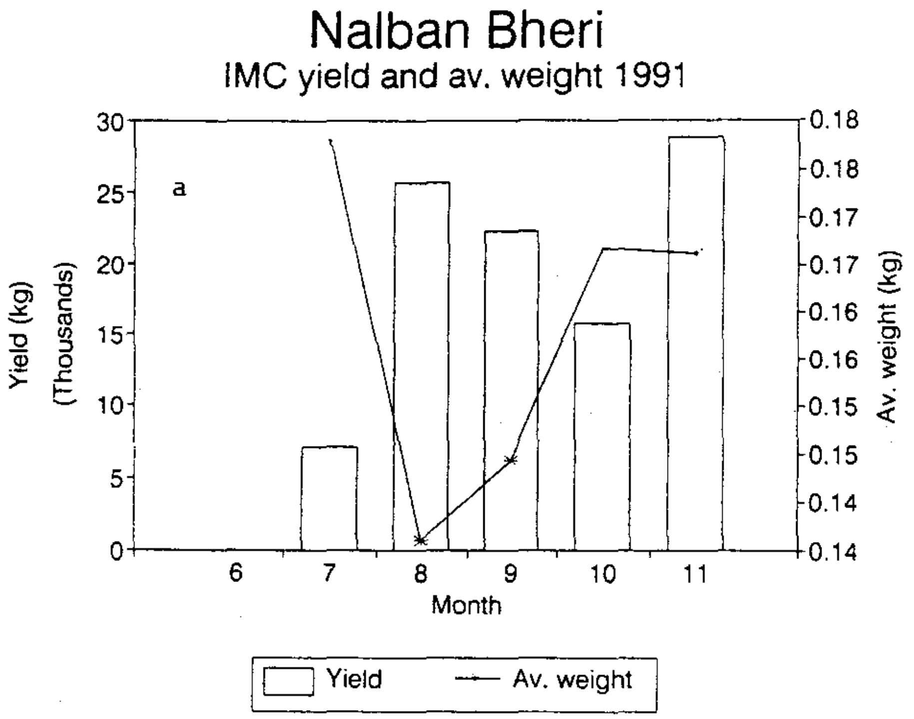


Fig. 3. Stocking in numbers in Nalban (a) and Goltala (b). No information is available where data points are lacking.



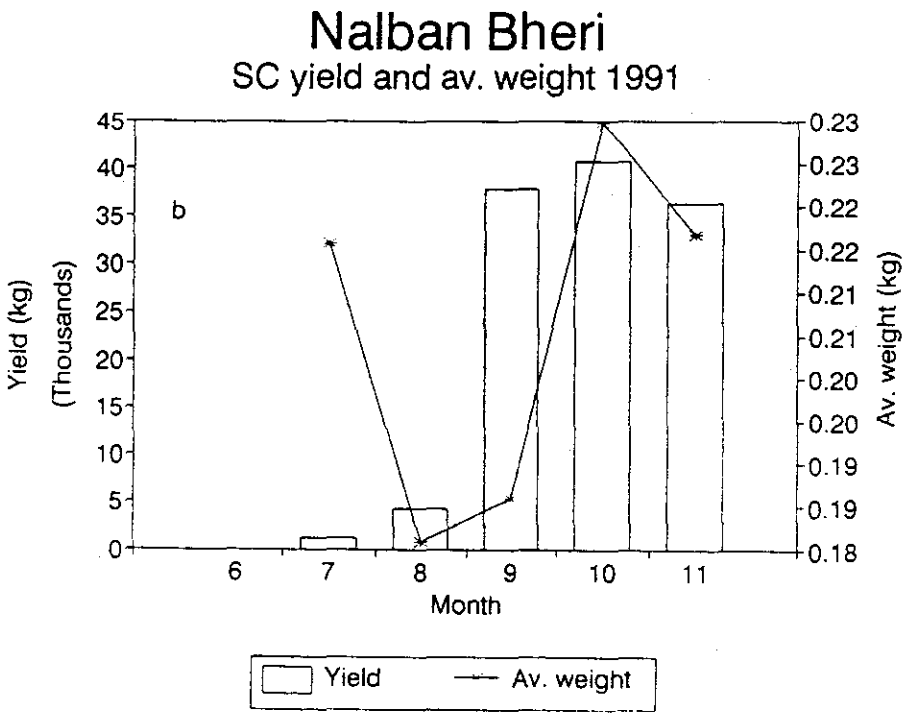


Fig. 4. Yield and average individual weight in the catch for Indian major carp (a) and silver carp (b) in Nalban.

growing into the landed size range. This is supported by a simultaneous increase in catch figures.

On the whole, individual weights of fish in the catch are quite low, between 140-180 g for Indian major carp and between 180-230 g for silver carp. The variations in average weight are also low, probably as a result of extremely high fishing pressure in the bheris: fish are landed as soon as they reach marketable size.

Size of fish sampled for parasitology

The average sizes of both fish species in the two bheris over the study period are not significantly different (Tab. 2.).

Table 2. Average length and weight of fish during the study period (coefficient of variation = standard error/mean), per fish species and per bheri (n = 390)

	Fish species			
Bheri	*Labeo rohita*		*Catla catla*	
	Length	Weight	Length	Weight
Nalban	229cm (0.14)	176g (0.48)	248cm (0.17)	240g (0.51)
Goltala	230cm (0.12)	155g (0.40)	229cm (0.15)	170g (0.52)

The sampling variability of length and weight averages range between 12% and 17% for length and between 40% and 52% for weight. This reflects measurement variability (larger for weight than for length) as well as some seasonal variability.

If *Catla catla* and *Labeo rohita* are pooled, the monthly average weight of individual fish in the samples examined for parasitological investigations are similar to the average weight reported for Indian major carps in the catch (Fig. 5.). The only notifiable difference is in June, for which the catch data seem rather unreliable. Therefore, it can be assumed that fish were sampled at random from the landings as planned and are representative of the rest of the catch.

Condition of fish sampled for parasitology

Both fish species have comparable conditions, as illustrated by the log(weight) - log(length) curves in the two bheris (Fig. 6. a-d).

An analysis of covariance of the weight at length data, by bheri and fish species using Generalised Linear Models (GLIM's) shows that both fish species have similar conditions in each bheri, and that both are significantly ($p<0.05$, reduction in deviance of 5.76 for -1 degree of freedom) heavier for their length in Nalban.

Therefore, Nalban which is more productive than Goltala, also appears to produce slightly fatter fish.

Though the prevalence is high, the mean abundance appears to be relatively low and the parasite is not considered to be pathogenic at these levels.

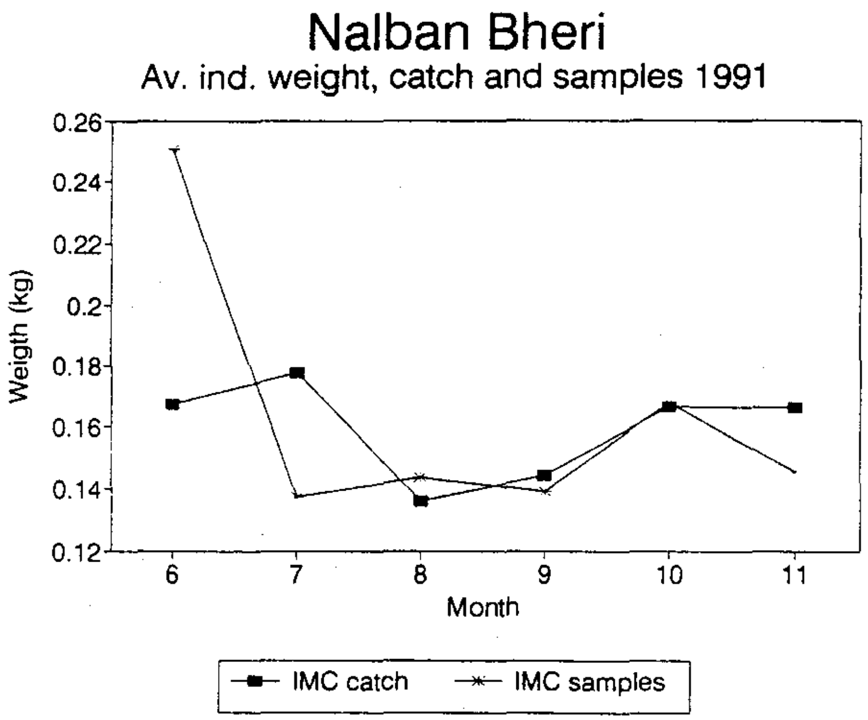


Fig. 5. Average individual weight of Indian major carp in the total catch in the samples taken for parasitological investigation in Nalban.

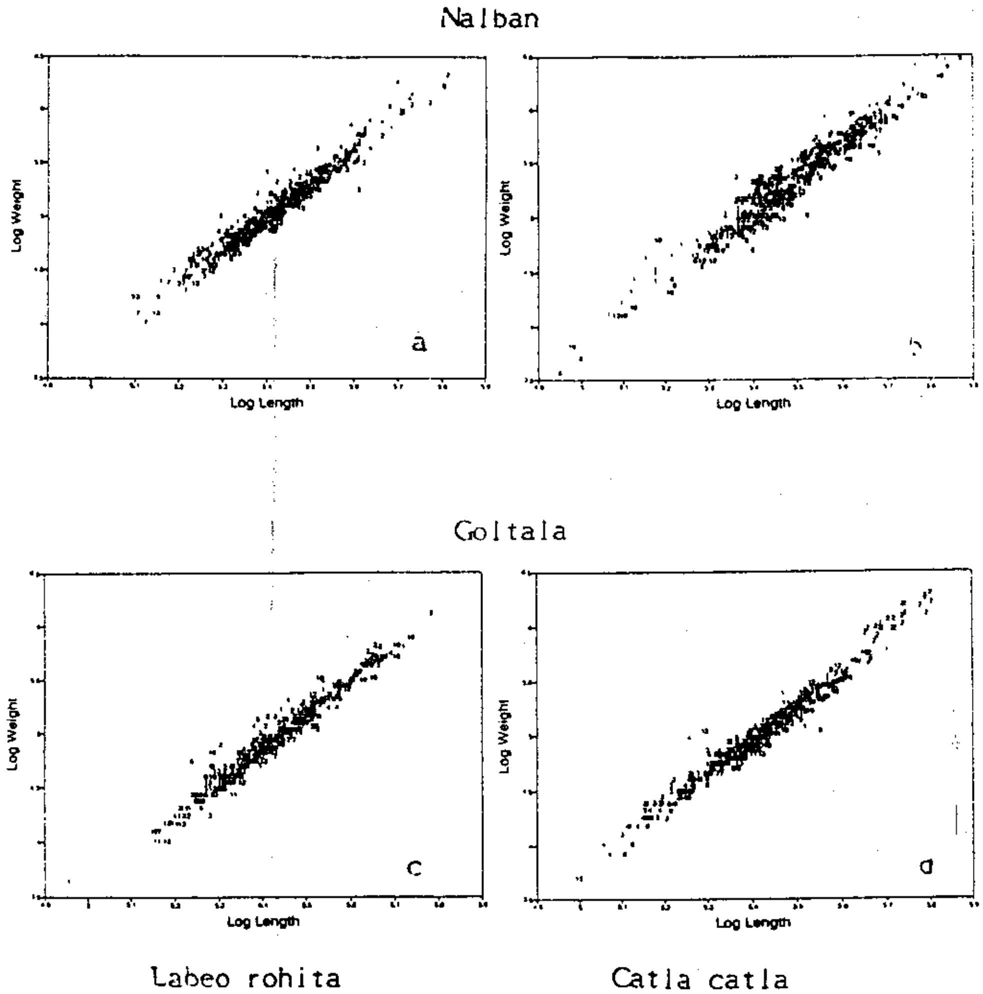


Fig. 6. Length-weight relationships (on log-log scale) for <u>Labeo rohita</u> in Nalban (a) and Goltala (c), and <u>Catla catla</u> in Nalban (b) and Goltala (d).

Argulus sinensis

Both the severity of infection, given by the average numbers of *Argulus* per fish, and its prevalence, given by the percentage of infected fish, are much higher in Nalban than in Goltala for the two host species (Tab. 3.). Both *Labeo* and *Catla* bear at least ten times more parasites in Nalban than in Goltala, with the proportion of infected fish being five times higher.

Table 3. Average adult and juvenile parasite abundance (coefficient of variation = standard error/mean), and prevalence (% infected fish/total fish) per fish species and per bheri (n = 390)

	Fish species			
Bheri	*Labeo rohita*	Prevalence (%)	*Catla catla*	Prevalence (%)
	Ad + juv		Ad + juv	
Nalban	2.19 (2.09)	62.25	1.20 (1.87)	48.72
Goltala	0.14 (2.93)	12.31	0.14 (3.34)	11.28

The variation is very large, with coefficients of variation ranging between 187% and 334% of the average parasite (Ad + juv) numbers per fish. This is customary for the distribution of parasites per host where individual variations of exposure and susceptibility between hosts are large. Even for *Labeo* in Nalban where each fish carries an average of 2 *Argulus*, nearly 5% of the fish carry more than 10, while nearly 40% of the fish have none (Fig. 7(a)). The relatively larger variability in parasite burdens in Goltala can also be attributed to small sample size effects as a sampling effort of 30 fish per sample can only detect infections prevalent in 7% of the fish, 95% of the times, and misses, in all probability, infections below that level.

Other sources of variations are apparent on the detailed values per sampling date, bheri and host species (Tab. 5.). There are relatively large variations of both adult and juvenile parasite numbers per fish and of prevalence. High infection levels observed at the beginning of the study in June-July decrease after the monsoon at the end of the summer and stay low in the autumn, for both species in both bheris. However, individual parasite abundances are known to vary with water temperature, host size and host density, which have been shown to vary during the same time. Unfortunately, all three factors are confounded, with host size a function of water temperature and density as well. However, the examination of each independently contributes some explanations. Individual parasite abundances are log-transformed using Log(abundance +1) to reduce the variance inherent to the data.

Seasonal variations in parasite abundance

Average (log-transformed) parasite abundances per fish show definite variations in time in both bheris, with a seasonal high for both adults and juveniles in the first part of the study.
The high infection levels in *Labeo* in Nalban (Fig. 8.(a)) appear to peak twice, once in June and then in August-September, presumably from the recruitment of juveniles and adults produced by the June cohort. Low infection levels in both bheris in November coincide with lower water temperatures and the onset of winter. At any given time, there are more adults than juveniles.

Fish size, parasite abundance per fish and prevalence in each bi-monthly sample

L. rohita Nalban

		N	Av Length	Av weight (g)	Av adults	Av juveniles	Prev (%)
1	10-Jun	30	239.90	201.83	8.60	1.47	93.33
2	24-Jun	30	269.00	288.83	0.80	0.37	50.00
3	08-Jul	30	224.97	173.83	2.90	0.27	86.67
4	19-Jul	30	266.07	298.50	2.00	0.13	86.67
5	02-Aug	30	207.50	131.83	1.27	0.40	63.33
6	17-Aug	30	212.33	138.00	1.43	0.47	70.00
7	31-Aug	30	204.03	118.33	4.37	0.50	100.00
8	14-Sep	31	208.61	131.00	1.26	0.39	83.87
9	01-Oct	30	221.23	152.50	0.70	0.03	46.67
10	14-Oct	30	233.57	171.21	0.67	0.33	60.00
11	30-Oct	30	240.63	195.50	0.43	0.17	43.33
12	12-Nov	30	226.37	161.17	0.17	0.03	20.00
13	25-Nov	30	217.10	133.00	0.10	0.07	13.33
	Total	391					
	Global avg		226.68	176.44	1.90	0.36	62.92

C. catla Nalban

		N	Av Length	Av weight (g)	Av adults	Av juveniles	Prev (%)
1	10-Jun	30	218.47	209.80	1.50	0.40	60.00
2	24-Jun	30	242.60	224.87	0.40	0.20	36.67
3	08-Jul	30	249.17	275.67	3.00	0.55	93.33
4	19-Jul	30	270.37	319.83	0.40	0.07	30.00
5	02-Aug	30	275.47	312.14	1.60	0.20	100.00
6	17-Aug	30	262.93	262.67	2.47	0.50	76.67
7	31-Aug	30	272.07	290.83	1.67	0.17	76.67
8	14-Sep	30	225.00	165.83	0.47	0.20	40.00
9	01-Oct	30	259.50	268.00	0.60	0.03	46.67
10	14-Oct	30	247.90	241.83	0.10	0.00	10.00
11	30-Oct	30	255.03	244.00	0.27	0.07	30.00
12	12-Nov	30	225.27	164.50	0.13	0.03	6.67
13	25-Nov	30	222.13	150.00	0.33	0.03	26.67
	Total	390					
	Global avg		248.15	240.24	1.01	0.19	48.72

L. rohita Goltala

		N	Av Length	Av weight (g)	Av adults	Av juveniles	Prev (%)
1	15-Jun	30	238.38	173.47	0.07	0.03	10.00
2	29-Jun	30	254.87	219.63	0.20	0.07	16.67
3	11-Jul	30	218.47	133.00	0.53	0.10	53.33
4	26-Jul	30	251.27	200.00	0.13	0.03	16.67
5	08-Aug	30	238.90	169.33	0.10	0.03	13.33
6	23-Aug	30	222.87	137.17	0.10	0.00	10.00
7	06-Sep	30	228.57	147.00	0.00	0.07	6.67
8	16-Sep	30	214.17	119.33	0.17	0.00	16.67
9	04-Oct	30	228.10	147.83	0.00	0.00	0.00
10	24-Oct	30	252.60	211.90	0.03	0.00	3.33
11	07-Nov	30	206.77	104.50	0.00	0.00	0.00
12	19-Nov	30	224.77	141.83	0.00	0.00	0.00
13	28-Nov	30	211.60	113.33	0.10	0.03	13.33
	Total	390					
	Global avg		230.08	155.11	0.11	0.03	12.31

C. catla Goltala

		N	Av Length	Av weight (g)	Av adults	Av juveniles	Prev (%)
1	15-Jun	30	253.50	224.47	0.10	0.03	13.33
2	29-Jun	30	293.50	385.00	0.60	0.03	43.33
3	11-Jul	30	200.37	120.50	0.53	0.13	50.00
4	26-Jul	30	190.17	96.00	0.07	0.10	10.00
5	08-Aug	30	219.23	145.17	0.03	0.00	3.33
6	23-Aug	30	209.33	123.00	0.10	0.00	10.00
7	06-Sep	30	221.27	143.83	0.03	0.00	3.33
8	16-Sep	30	225.59	145.00	0.03	0.00	3.33
9	04-Oct	30	210.87	123.33	0.00	0.00	0.00
10	24-Oct	30	245.40	188.50	0.03	0.00	3.33
11	07-Nov	30	236.17	170.83	0.03	0.00	3.33
12	19-Nov	30	238.27	178.97	0.00	0.00	0.00
13	28-Nov	30	230.90	164.33	0.03	0.00	3.33
	Total	390					
	Global avg		228.82	169.89	0.12	0.02	11.28

Table 5

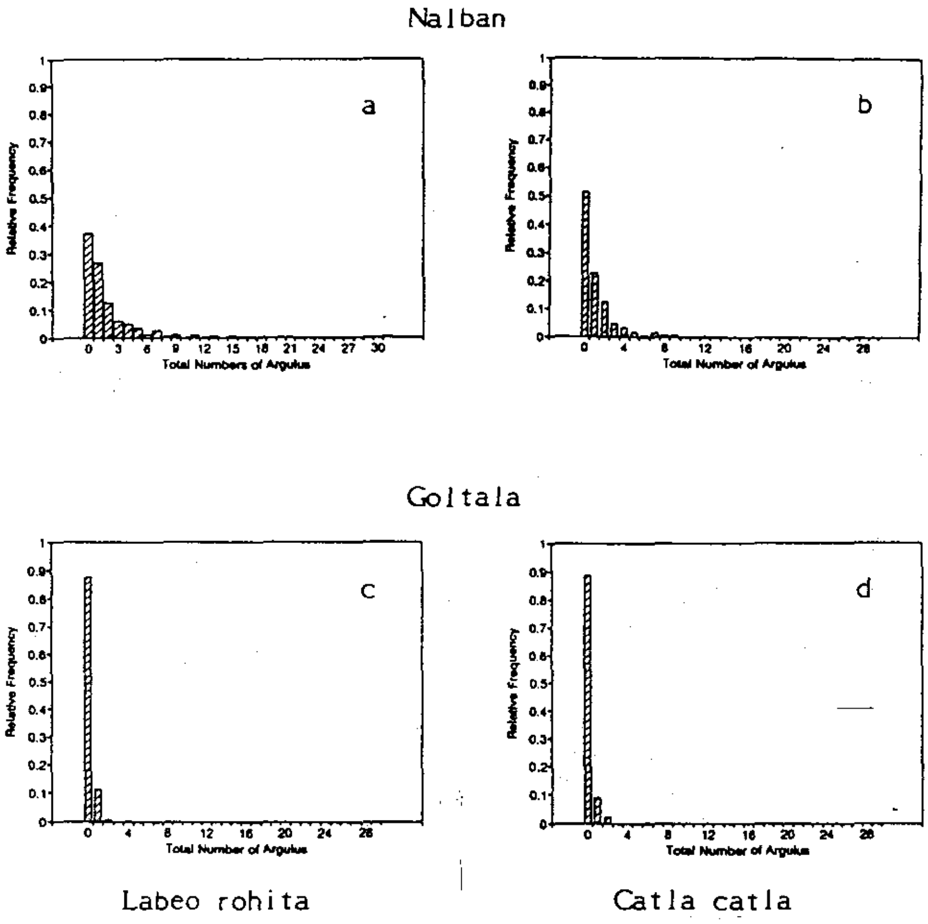


Fig. 7. Frequency distribution of parasite numbers per host for Labeo rohita in Nalban (a) and Goltala (c), and Catla catla in Nalban (b) and Goltala (d).

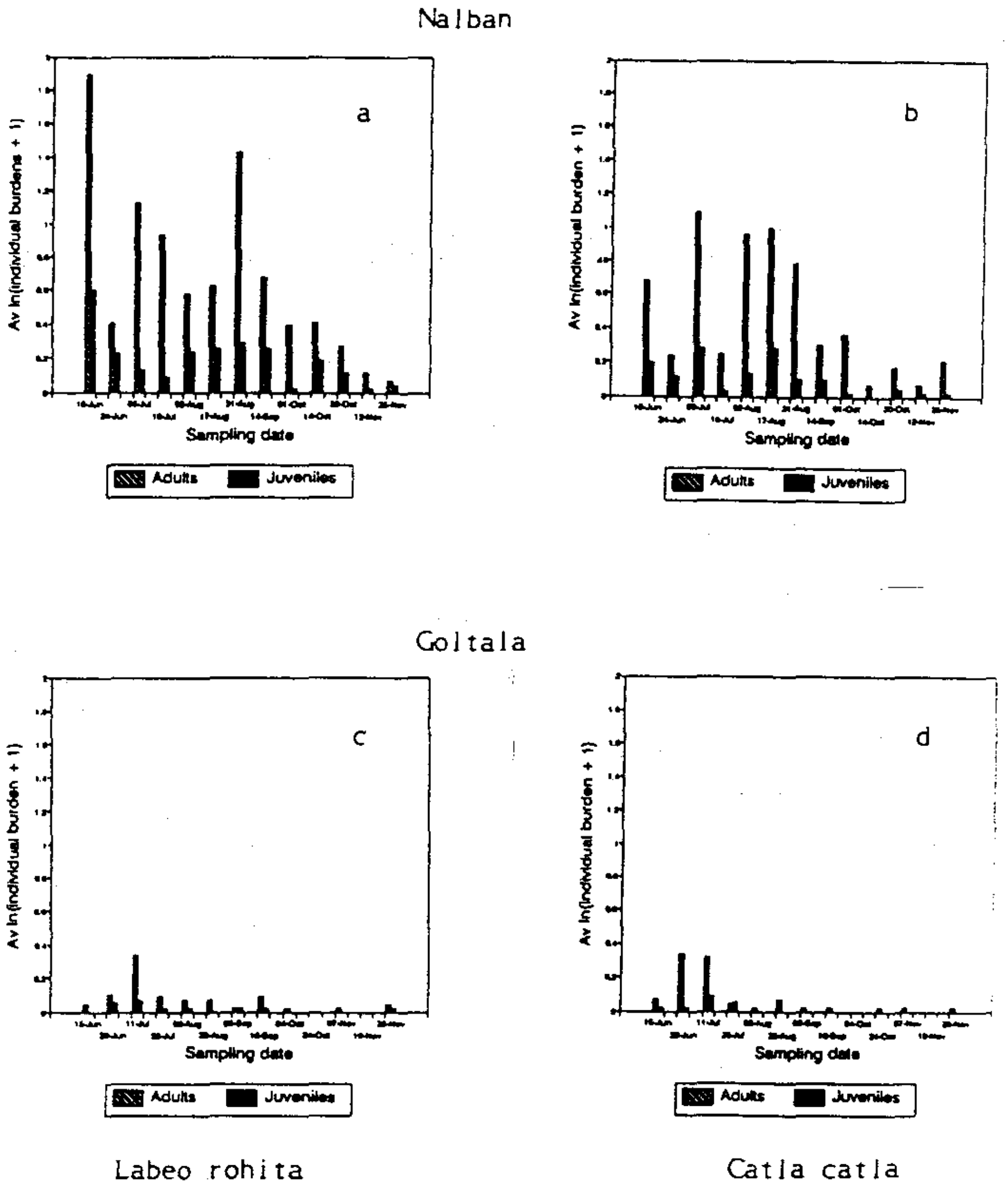


Fig. 8. Average log-transformed parasite abundance per fish for <u>Labeo rohita</u> in Nalban (a) and Goltala (c), and <u>catla catla</u> in Nalban (b) and Goltala (d).

Parasite abundance and host size

The abundance of ectoparasites has been shown to increase with host size as a result of increased exposure for fish with larger surface areas and prolonged exposure for older fish. This is not so obvious from average infection levels (on log-transformed data) given as a function of average length of fish in the samples for either host species in Nalban (Fig. 10.). In both cases infection levels peak between June and the end of August, but the size of the fish varies extensively during that period, especially so in Nalban, the most productive site. Obviously, any causal link between fish size and age, and parasite burden must be masked by the complicated population dynamics of the hosts, which spend an amount of time in the bheris which is inversely related to their growth rate. Therefore, high water temperatures which promote parasite population increase also promotes fish growth which in turn reduces the time spent by fish in contact with the parasites.

Parasite abundance and host densities

Unfortunately, no data is available for fish densities in the bheris, and to date, it has been impossible to obtain data on the relative densities of all fish species. However, using harvesting figures for Indian Major Carps as a surrogate for biomass, it appears that seasonal variations in parasite abundances on *Labeo* and *Catla* put together (ad + juv, log-transformed) may be, at least partly, linked to variations in host biomass (Fig. 9.). The link between the two is likely to be two-fold, with high densities of hosts driving infection levels up, while a periodic removal of all bigger fish sends the parasite population down. Hence the very high fishing pressure is likely to control parasite numbers. However, there is too little information on fish densities at present to analyse the data further, and at least all carp species are likely to play a part for a parasite with low host-specificity like *Argulus*. More complete information on fish stocking times, stocking densities and growth rates are essential to obtain a clearer picture of the interaction between parasite and host densities.

Parasitism and host condition

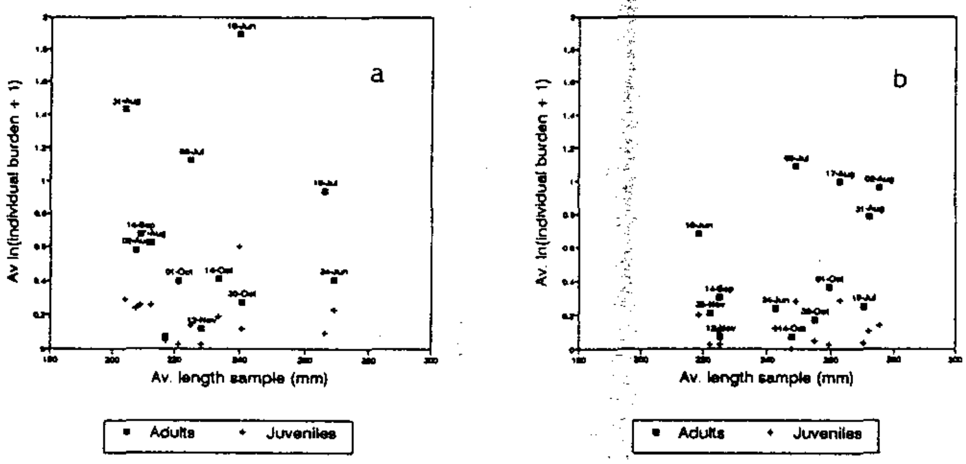
In the absence of population data to analyse the effect of parasitism on growth and/or yield, the effect on fish condition has been examined by analysing the log(weight) - log(length) data for parasitised and unparasitised fish separately using GLIM (cf. condition of fish reported above). Using the presence or absence of parasite as a factor, there is no significant differences in fish condition for either fish species in either bheri. Again, the very high production of the bheris makes it very difficult to analyse the effect of parasitism without a detailed description of the fish population dynamics. Usually, the size of the fish is used as an indicator of its age, hence the duration of exposure to an infection. Clearly, in a highly productive system like the bheri in Nalban, fish spend a variable amount of time which will in turn determine the magnitude of a parasite-induced effect.

Incidental reports

All parasitic infections present were described on *Catla catla* and *Labeo rohita* in both bheris at some stage of the study. However, apart from *Argulus*, the data collected proved most unreliable. The following observations were made by Stirling staff on a visit to Nalban during which a sample was examined (Table 3). It is not comprehensive and only indicates the parasites present on that one occasion.

The data for *Acanthosentis* was provided by Dr Srivastava who examined fish from both bheris.

Nalban



Labeo rohita   Catla catla

Fig. 9. Average log-transformed parasite abundance per fish plotted against average length of fish in the sample for Labeo rohita (a) and Catla catla (b) in Nalban.

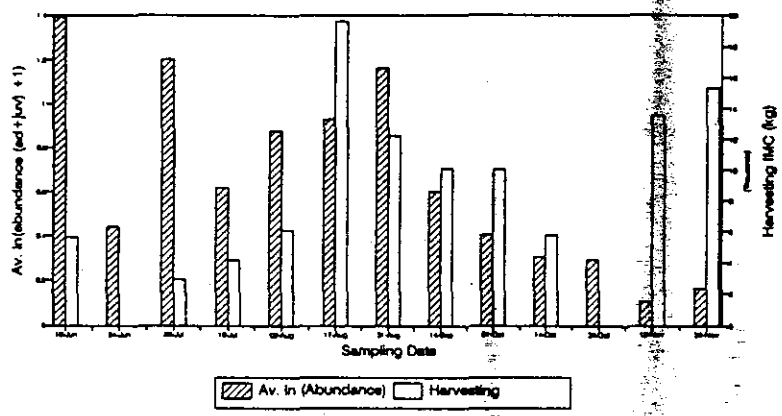


Fig. 10. Average log-transformed abundance of parasites per fish and yield of Indian major carp (as a surrogate for biomass).

Table 4. Various parasitic infections described on one occasion in Nalban

Ciliata:	Peritrichous ciliates, *Trichodina spp.*
Mixosporea:	*Thelohanellus spp.*, several species *Myxobolus spp.* " "
Apicomplexa:	Coccidia, two species
Monogenea:	*Dactylogyrus spp.*, 5 species
Digenea:	Heterophyid metacercaria
Acanthocephala:	*Acanthosentis*, on three occasions, not found in Goltala, but found in Nalban (unknown sample sizes) as follows.

Date	% Prevalence	Mean abundance
24/6/91	73.3	4.45
19/7/91	93.3	4.57
17/8/91	93.3	6.43

3.2 Vanivilas Sagar

Fish catches

The fishery at Vanivilas Sagar is small and includes several different species. During a visit, the catch consisted of *Labeo spp.*, *Mystus sp.*, *Fluta sp.*, *Notopterus sp.* and *Heteropneustes sp.*. No information is available on the total yield or relative species composition of the catch from Vanivilas Sagar reservoir. At present there is no stocking.

Four hundred and thirty six (436) *Wallago* were collected from nine monthly samples between June 1991 and February 1992.

Fish size

Individual weights for the fish are only available for fifteen fish in October 1991, and then in January and February 1991. From these, and data on the total weight of the catch, *W. attu* in Vanivilas Sagar are apparently much leaner than river populations.

Size composition of *Wallago* landings and samples

The fish are caught by gillnets with an approximate mesh size of 2-3". All fish captured are landed, and the whole catch of certain days was purchased for the parasitological study. Hence the size distribution in the samples is the same as for the total catch.

The total length of fish caught ranges between 20 and 120 cm, with the smaller fish caught mostly in the winter. From June to November the average length of the fish in the samples remained above 55 cm, it suddenly dropped in December to 23 cm and slowly increased in January and February (Fig. 12.). It seems unlikely that the fishery removes all large fish. In the absence of further information, one may speculate that either large fish move to deeper waters, out of reach of the fishery, or that arrival of new and more abundant recruits induces a switch of effort, or possibly a combination of both.

Gillnets fishing the top surface waters can be highly selective of certain size classes of fish at certain times of the year, but no information is available on selectivity given the size composition in this fish stock. Hence the monthly length frequency distributions for *Wallago* catches are difficult to interpret biologically. Despite conspicuous modes, there is no simple growth pattern, and attempts to fit a von Bertalanffy growth model did not result in sensible parameter estimates. Modal length in the samples are probably corrupted by some pattern of gear selectivity and/or by migrations of fish or fishermen.

Parasites

Parasites and host size

Most fish (94% of 436) are infected, and the average abundance of female *Ergasilus* (gravid+non-gravid) per fish increases steadily from a mean of 11 in fish less than 30 cm, to 101 in fish larger than 70 cm (Tab. 6.).

Table 6. *Ergasilus* infection by length groups of *Wallago attu*.

Length group	n	Av length (cm)	Gravid	Non - gravid	Total	Coef of var	Prev (%)
≤30cm	157	23.64	9	2	11	1.27	90
30< ≤50	68	36.37	39	9	51	1.38	99
50< ≤70	127	63.67	60	26	84	1.13	95
> 70 cm	84	78.98	101	35	115	1.16	98
Totals	436	47.95	40	14	60	1.55	94

This may be explained by an increase in gill surface area as host size increases, as suggested by des Clers (1991) and reproduced experimentally by Poulin *et al* (1991). Accordingly, average parasite burdens increase as a power function of host length. This is illustrated by the quasi-linear increase of the log-transformed abundances with the average size of the fish per size group on a log scale (Fig. 13.).

Seasonal variations in infection levels

Average parasite abundances per fish show a ten-fold seasonal variation, with a global average total (gravid and non-gravid females) of 60 *Ergasilus* per *Wallago*, ranging from a minimum of 10-15 in the winter and 70-100 in the summer and autumn (Tab. 7. some monthly samples have been regrouped (June to August and Sept+Oct) to make numbers large enough for computations).

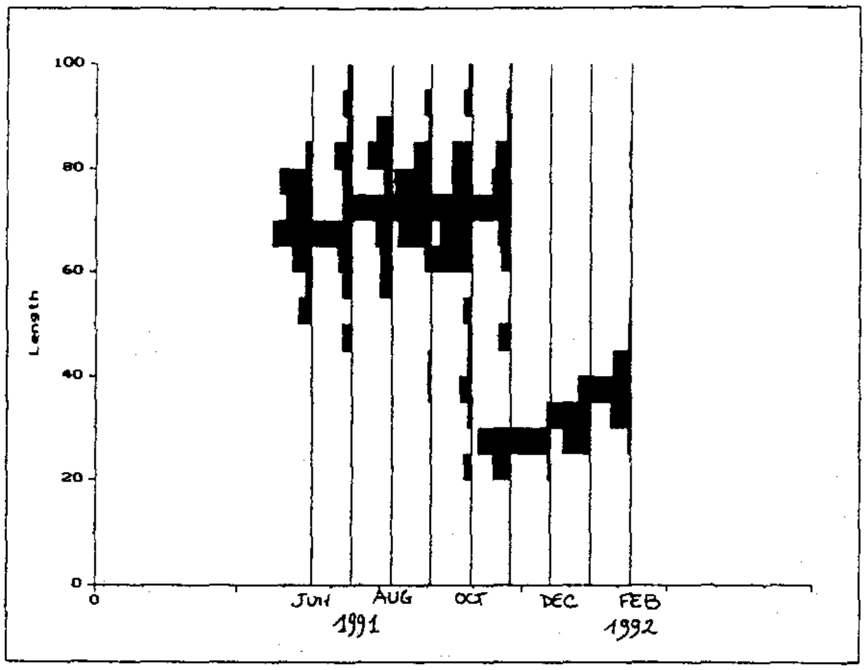


Fig. 12. Length frequency distributions of Wallago attu caught in the Vanivilas Sagar reservoir at monthly intervals between June 1991 and February 1992.

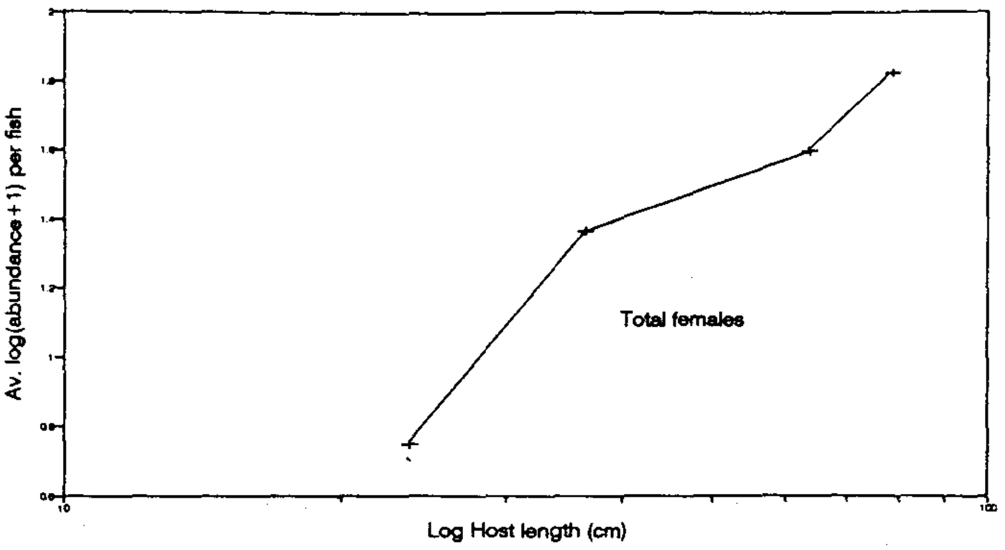


Fig. 13. Average individual Ergasilus burdens (log-transformed data) in Wallago as a function of the average size of the host (log scale). All fish are grouped in four size intervals (n=436).

Table 7. Seasonal variation in infection levels.

Months	n	Av length (cm)	Gravid	Non - gravid	Total	Prev (%)
Jun-Aug	82	66.93			78	98
Sep-Oct	94	65.00	62	29	92	98
Nov	76	55.53	71	19	100	83
Dec	78	23.61	9	2	11	90
Jan-Feb	128	24.82	13	2	15	94
Totals	436	47.95	40	14	60	94

The increase of parasite abundance with host size is also linked to seasonal changes in the size composition of the catch, with large fish caught in the summer and autumn, and mostly small fish in the winter.

However, there is such a seasonal difference in sizes caught that no size-group can be followed throughout the year. An analysis of variance of the total parasite burden in the 50 to 70 cm size group on log-transformed data revealed no significant differences in samples from June and November .

Seasonality in parasite maturation

Although it is difficult to examine the effect of seasonality on host-parasite interactions at this stage, the percentage of non-gravid to total females possibly suggests some seasonality in the parasite life-cycle. Unfortunately the proportion of gravid and non-gravid is not known before the month of September (Tab. 8.).

Table 8. Seasonal pattern of parasite maturation.

Month	n	Av length (cm)	Gravid	Non - Gravid	Total	%NG /Total
Sep	43	69.64	74	38	112	33.73
Oct	51	61.08	51	21	75	24.28
Nov	76	55.53	71	19	100	18.64
Dec	78	23.61	9	2	11	15.58
Jan	50	26.72	18	2	20	11.25
Feb	54	34.10	23	7	30	23.51

However, one can discern a gradual decrease in the proportion of younger parasites (%NonGravid) until February, when it goes up again (Fig. 14). This suggest that parasite recruitment which has been said to take place throughout the year in Vanivilas Sagar (Vankateshappa et al. 1988) may slow down during the winter, either as a results of lower water temperature or because of change in size of the fish population locally.

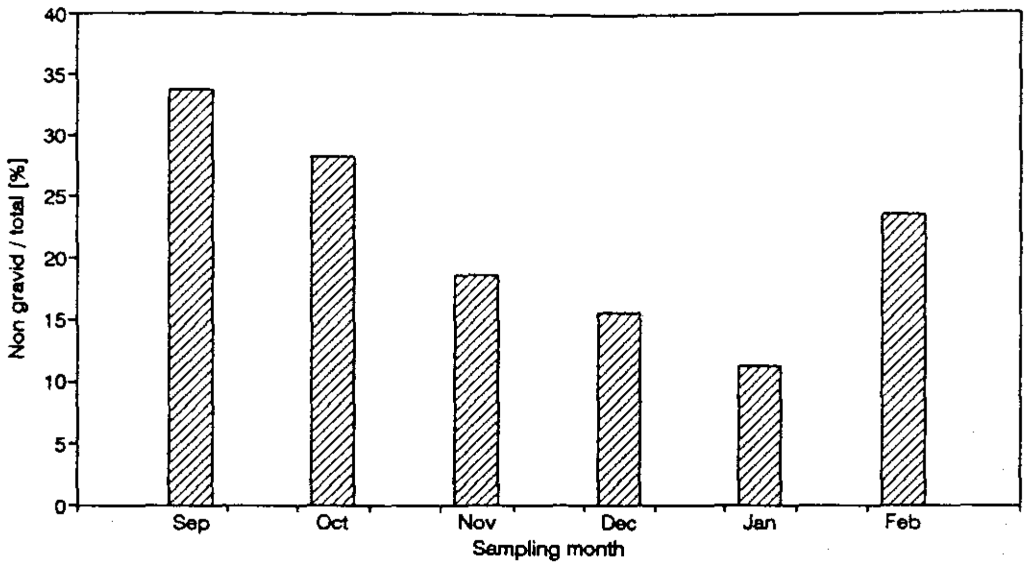


Fig. 14. Percentage of non-gravid female Ergasilus in the total female average parasite burden per fish in monthly samples for which the detail is known.

4 Implication of the results for achieving the objectives of the project

4.1 Sewage fed bheris

Assessment of data collection

The current lack of information on the bheri fisheries has been a major constraint to the interpretation of parasitological data. It is hoped to continue sampling in the bheris during the follow-up projects. In this case data collection will be intensified on both the fisheries and the parasitology side. In particular:

(1) Information on the water and sewage management of the bheris will be acquired from the fisheries cooperative.

(2) A longer time-series of stocking and harvesting data will be collected, and additional sampling will be initiated to keep track of the density of all species. This data will allow the determination of growth and mortality rates for each species present.

(3) Parasite sampling will be extended to all species present in the bheris. This will allow for the low degree of host specificity of *Argulus*, which may spread from other hosts on to Indian major carps.

(4) Seed fish prior to stocking and small fish in the bheris will be sampled for *Argulus* to gain further understanding of the source of parasites. In particular, this will make it possible to design an optimal stocking policy taking to maintain low parasite levels and maximum yield.

(5) Sampling will be continued at both bheries if possible, in order to understand the reasons for the difference in productivity between the two sites, and the influence of productivity and host density on the parasite population dynamics.

Management implications

Prophylactic chemical treatment of hatchery-reared fish before release may help removing some external protozoans or helminth parasites. However, fishery managers should inspect fish before purchase and select only hatcheries producing good quality disease-free stocks.

It is proposed to improve our existing knowledge of bheri fisheries and their management in a follow-up project "Potential yield of small reservoir fisheries in South Asia". At present, a comparison of the two bheris indicates that, despite much similarities, Nalban is much more productive than Goltala, but the reasons for this are not yet understood. *Argulus* infestation levels are higher in Nalban, the more productive bheri, most probably reflecting higher fish densities. There is no detectable direct effect on fish condition, but secondary infections due to *Argulus* infections may be a problem. However, the lack of fish population dynamics data makes it difficult to separate the confounded effect of productivity, fish growth, harvesting schedule and parasite population dynamics. In any case, the severity of parasite induced host morbidity is likely to increase with increasing host density and thus with productivity. Management strategies which takes into account parasitological aspects are most likely to optimise yields. Given the intensive management of the bheri systems, such strategies can easily be adopted and thus tested in practice.

4.2 Vanivilas Sagar

Studies on the *Wallago - Ergasilus* host parasite system at Vanivilas Sagar have provided very good data which has elucidated some of the relationships between. Sampling over a longer period of time is now required to further explore this and enable more quantitative estimates to be made. The study should make a valuable comparison with the more intensively managed bheri systems.

5. Priority tasks

This study has been a successful pilot-scale exercise and has shown the feasibility of carrying out such work using local in-country scientists in collaboration with UK based researchers. Excellent relationships have been established with our cooperating laboratories in India.

The data collected is of good quality and has contributed towards meeting the scientific objectives of the project. At least two publications will result from this initial study.

The study has clarified which host population data is most useful and has also identified other host parasite systems which may be worthy of study. In order to reap maximum benefit from this initial study it will now be necessary to expand sampling over a longer period to properly determine the interactions between host and parasite populations in a variety of habitats and different types of fisheries. Some suggestions for further work in the waters used in this project have been made elsewhere in this report.

Acknowledgements

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