FISHERIES MANAGEMENT SCIENCE PROGRAMME

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RIVER AND FLOODPLAIN FISHERIES

IN THE GANGES BASIN

FINAL REPORT

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OBJECTIVES

The Ganges River drains an area of approximately 814,400 km^2, which is home for 200 million people in India, 13 million in Bangladesh, and an unspecified number in Nepal and other regions in the headwaters. Fish is an important element in the diet of people in India, and especially people in Bangladesh, where religious beliefs otherwise restrict the availability of animal protein. A true understanding of the status of fish as a resource to these communities, as well as an indication of future prospects, would assist in future planning for the industry. The scope in the headwater areas is totally unknown. Beyond this, by developing models applicable to the water climatic zones, a planning tool of much wider applicability becomes a significant objective.

The scientific and technical objectives of the project were as follows:

1. To compile and review catch data from the Ganges Basin in India, Bangladesh and Nepal.

2. To compile a hydrological picture from recent hydrological records in the Ganges Basin.

3. To construct a current overview of recent hydrological changes, fisheries development and the status of the fish stocks throughout the Ganges Basin.

4. To produce a "snapshot" of annual events throughout the entire basin over a two-year period, with respect to hydrology, fishing activity and fish communities.

5. From detailed observations at selected sites in the upper, middle and lower regions, to obtain details of the population parameters, state of expoloitation and natural characteristics of the fish stocks.

6. To incorporate these observations into a dynamic model for management of floodplain fish stocks.

7. To make recommendations for fisheries management and estimates of fisheries benefits for the Ganges in Nepal, India and Bangladesh.

EXECUTIVE SUMMARY

The Ganges Basin drains an area of approximately 814,400 km^2, spans three countries, India, Nepal and Bangladesh and is occupied by around 200 million people. This project was directed towards an investigation of the basin-wide condition of the fisheries and the problems of their management in the context of the conditions prevailing in the basin as a whole. Integrated management of resources within river basins as a whole will ultimately be the only way forward, as pressure on resources increases. Most existing information on the Ganges has been carried out on a country basis. This has been assembled for the three constituent countries as a separate review document (Temple and Payne 1995), to facilitate understanding within the basin as a whole.

In order to collect concurrent data at different points within the basin, collaborative operations were carried out with the local universities at two lowland sites, Patna and Allahabad. Both had been used as sites in earlier fisheries surveys within India. Allahabad is at the junction of the main stem of the Ganges (or Ganga) and one of its principal tributaries, the Yamuna, on which lie some way upstream, the major cities of Agra and Delhi. In the lowermost part of the river, around the delta and floodlands of Bangladesh, an extensive study of the river fisheries was already underway as part of the Flood Control Action Plan. This study, FAP 17, provided comparative data for the lowermost sector. In addition, the fishery for the migratory herring, *Hilsa*, the single most important component of the fishery on the lower river, was monitored at the major landing and marketing site at Swarighat in Dhaka. At all sites details of gear, catch rates and species composition were recorded, as well as observations on the hydrology and socio-economic conditions.

To obtain concurrent data on the upland fisheries, a collaborative study was set up with the University of Garhwal to examine the upland areas of the headwaters of the mainstream Ganga. The major northern tributaries of the Gandaki on the Sun Kosi sub-basins in Nepal were surveyed by intermittent observation. Surveys extended between altitudinal ranges of 650 m amsl through the transitional zone with the plains, which is quite marked at around 80 m amsl, down to the delta, just a few metres above sea level.

At Allahabad, Patna and Swarighat daily records of catch and effort were recorded. At Allahabad and Patna daily or weekly records of temperature, water level, conductivity, pH and a variety of other limnological characteristics were made. In the upland areas, seasonal observations were made on the same factors.

There are two main types of tributaries in the upland zone, snow-fed and spring-fed rivers. The snow-fed are typically cold and silt laden, whilst the spring-fed tend to be clear, slightly warmer and to exist at rather lower altitudes.

The main stem of the Ganges in the upland zone is snow-fed and typified by the heavy grey/white silt load coming down from a relatively recent mountain block, the Himalayas. There is a seasonal pattern to transparency. The river is clearest and turquoise in colour, due to refraction of mica flecks, during the winter, but as snow-melt begins in the montane glacier zone, the grey silt load increases through May becoming most intense during the rains, and can be maintained until early winter. The other main stem tributaries which arise at similar altitudes, the Trisuli and the Sun Kosi, are similar.

Annual temperature variation of upland snow-fed rivers below 600 m ranged from 15°C to 18.7°C and even at the transitional zones at Haridwar and Naryanghat, rarely exceeded 20.5°C and never went beyond 21°C. This temperature is probably very significant in the division of upland from lowland fisheries since it coincides with the tolerance limits of snow trout (see below). Spring-fed rivers may be warmer: for example, the Seti in the Gandak system had a temperature of 20°C to 22°C when the snow-fed Trisuli, which it joined, had a temperature of 15.8°C. The difference between snow-fed and spring-fed rivers is of great significance for the fisheries.

Once the river reaches beyond the transitional zone it becomes broad and meandering, although mainly between well defined banks. Exceptions are the northern tributaries, where seasonal overtopping gives expansive and occasional catastrophic flooding, such as can occur particularly in the North Bihar wetlands around the Gandaki. The water is generally warm and silt laden. Extreme river temperatures at Patna ranged from 18.6°C to 33°C, with a distinct seasonal cycle. Hydrographs also follow the seasonal rains pattern with a seasonal increase in depth of 3.5 m in the Ganges and 13.5 m in the Yamuna between dry season and the peak of the flood in August. Other limnological factors tended to follow this cycle.

The dissolved mineral content of the Ganges water is relatively high with an essentially alkaline pH (8.08 to 8.7). Conductivity ranged from 164 to 362μS and total dissolved solids (TDS) 87 to 179 mg l^{-1}. This is high compared to many tropical and sub-tropical river systems. A linear predictive relationship was found between the more conveniently measured conductivity and the more meaningful TDS.

The social and economic structure of the fisheries is strongly influenced by culture, faith and tradition within the basin. The strong trend towards vegetarianism in the Hindu faith means that local markets for fish throughout the basin in India and Nepal are patchy, although restrictions in the upland regions are less marked. By contrast, the people of Bengal in the delta, both east Bengal (Bangladesh) and West Bengal (India), are renowned eaters of fish and Calcutta provides an insatiable market. The existence of Calcutta and the few other urban centres, combined with the relative lack of local and peripheral demand, serves to centralise the fish landing and distribution systems, at least in India. In Bengal, by contrast, demand is widespread and markets are much more diffuse.

The sanctity of the Ganges also means that there are several locations which have a particular religious significance and around which fishing is forbidden. These include the junction of the Yamuna and Ganges at the Sangan, Allahabad; the junction of the Aleknanda and Bagirathi which forms the Ganges proper at Devpryag; and the junction of the upland reaches with the plains at Haridwar.

There are also considerable social restrictions as to who should participate in the fishery. Within India only sub-groups of category 4 caste can traditionally do fishing and this still largely holds. The same is also true in Nepal although divisions are less distinct. In Bangladesh the Muslim majority traditionally do not fish and leave this activity to sectors of the residual Hindu population. This, however, is changing as population pressure increases on the land and more people, including Muslims, are forced into fishing as a last resort.

To an unusual extent, therefore, socio-religious pressures influence access to and participation in the fishery. The free-for-all open access to common property resources seen in other regions need not be the case in the Ganges Basin.

The concern with the upland, cold water fisheries as largely being for sport purposes, has distracted attention from the robust artisanal fishery which exists in the upland region. In the upland regions of both India and Nepal, wherever markets exist fishing goes on. Markets depend upon local centres of population or where roads cross or run alongside rivers. The torrential nature of most rivers in the upland region makes fishing very difficult and has led to considerable ingenuity in developing fishing methods. A particularly effective device used in the upland areas of the Ganges in India and also in some rivers in Nepal, such as the Sun Kosi, is the mountain gill net or "paso". This is a longline to which are attached not hooks, but monofilament traces each ending in a noose tied with a slip knot. These nooses are placed on the line at intervals of a metre. The fish swim into the nooses which automatically tighten around them. This and the cast net are probably the commonest gears. Dynamite, however, is also frequently used, both in India and Nepal, and is particularly damaging and wasteful. It is a practice which must be stopped.

Around 7 to 15 people per kilometre may fish these fast flowing, cold rivers on an occasional basis. Most are essentially farmers or landholders who fish part-time.

There is a clear trend for fishermen from lowland areas of the terai and India to move into the upland fisheries. This appears to be due to increasing pressures on the lowland fisheries. Immigrant fishermen are usually full-time professionals and can dominate a fishery.

Fish and fisheries were examined at a number of sites on the Aleknanda, Upper Ganges, Gandaki and Kosi systems. Catch rates were of the order of 2 - 5 kg day^{-1} $fisher^{-1}$ in these upland rivers. Dynamite fishing can produce 5 to 10 kg per blast. With the recorded fishing frequency and at an average price of 75-80 Rupees per kilogramme, the monthly income would be some NRs 3,000 (US $50). The total yield from these cold rivers is around 1.5 mt km $^{-1}$ yr $^{-1}$, which is surprisingly similar to lower order rivers in lowland tropical Africa. The complex endemic cold water cyprinid community of these Himalayan rivers may allow an efficient production system.

The total freshwater fish species recorded for the Ganges Basin is 161. The lowland reaches of a montane tributary, such as the Kosi, has 110 species. In the montane areas, the Aleknanda, for example, has 41 species at an altitude of 600 m. A proportion are endemic types. In the cold, turbid snow-melt rivers, the fishery is dominated by mahseer, *Tor tor* and *Tor putitora*, and by snow trout. Both are migratory but have different temporal cycles. The juveniles, however, may stay in the upland streams where they are particularly vulnerable. The adults are vulnerable during migration to capture and to barriers such as dams and barrages. The clearer spring fed upland rivers, such as the Seti, are warmer than the snow-melt rivers and mahseer and snow trout can be absent. Other species dominate here.

Observations suggest that the "cold water" zone tends to end where water temperatures exceed 21°C. This is where snow trout disappear and a more typical lowland fish community emerges. Fish extend up to 1,640-1,800 m in these Himalayan rivers, although in lakes, Rora Lake for example, they may be found up to 3,000 m.

Two of the sites examined in the Lowland Sector, Allahabad and Patna, were selected because they had been used up to 30 years previously for surveys by the Inland Capture Fisheries Research Institute of India. Allahabad, since it is at the confluence, allowed sampling in both the main Ganges River and also in its major tributary, the Yamuna. Daily sampling was conducted over an 18 month period. The mean water temperatures at Allahabad were 15.1^{o}C - 29.1^{o}C. Equivalent values at Patna were 18.9°C - 31.9°C and 18.4°C - 33°C. Peak temperatures are in June and low points in January. Much interest in the lowland fishery has centred around the major carps. These normally spawn at temperatures above 22°C, which is achieved in March at Patna.

The upstream migration of riverine species is responsible for the regular pre-monsoon peak in fish catches, which can be in early June, but appears earlier in the Yamuna. It is at this time that major carps are most commonly caught. Contribution to the annual catch is, however, relatively small, being 13% at Allahabad, 4% at Patna and 7% in Bangladesh. The first two values are substantially less than in earlier years. The major carps caught at Allahabad, particularly in the Yamuna, includes a high proportion of large fish of 5 - 10 kg. The proportion of *Labeo rohita* caught generally is exceptionally low, sufficiently so to indicate that this once common fish may be endangered.

Major carps are now a small component of the fishery. The most abundant species in the fishery are the smaller riverine species including *Clupisoma garua, Oxygaster* spp, *S. phasa* and *A. aor* generally, and *Mystus seenghala, Eutropichthys vacha* and *Rita rita* featuring at Allahabad. All except *A. aor* are smaller species. One further larger species, *Walago attu*, can also be a significant component. There is a fundamental lack of understanding of he dynamics of the smaller species upon which the fisheries depend. Most of these species are migrating and appear in successive waves at the monitoring points between April and June.

One other traditional component of the fishery is *Hilsa*. The migratory routes between the estuary and the river are believed to have been disrupted by the Farrakah Barrage. Some observations have been made at the barrage site. A special study was conducted on *Hilsa* in Bangladesh during this project, but the general survey showed that *Hilsa* could still be found up as far as Allahabad, although in small quantities during April and May. *Hilsa* contributed 40-60% of river catches in Bangladesh, 1% at Patna and 0.6% at Allahabad. Observations are consistent with the fish moving into coastal waters in March and progressing into the lower estuary of the Padma in July to November. Further movement to positions further upstream appear to occur from October to May. Length frequency analysis allowed some identification of age cohorts in the *Hilsa* population and gonad maturation phases were monitored.

Spawn collection from wild major carps is still common. Around Patna some 244 nets at 21 sites were noted operating over a 2½ month period, with the peak activity being in the last two weeks of July. There is also a very active fishery for juvenile major carps at the mouth of the Gandak river in September. Both of these activities will contribute to the reduced role of the adults in the main fisheries in the river.

A socio-economic study at Allahabad showed that almost 90% of fishers owned or had access to a boat, which is not necessarily the case in other types of floodplain. Investment cost can limit access. Gill nets and seine nets were the commonest gears and more than 50% of the fishers were full-time. Average catches for boat users were 12.05 kg day^{-1} with a value of around Rs 90 day^{-1}.

Status of the River

Comparison with historical data shows that the contribution of major carps to the fishery has declined greatly. At Allahabad between 1958 and 1966 they contributed 43.5% of the catch; between 1972 and 1976 they amounted to 29% and in the present study in 1992 to 1993, only 13%. This was still higher than at any other location observed.

An analysis of the time series of Bangladesh river catch data in relation to hydrology and rainfall showed a positive correlation with discharge and rainfall, either of the same year or two years previously. An analysis with time showed a significant decline in catches between 1982-89 particularly in "other groups" category, which made up the bulk of the catch. Historical data suggested declines in catches in the Indian Sector but the present survey suggests some recovery.

Regular measurements in physico-chemical factors showed that conductivity of the water has fallen, pH has increased and the BOD reduced to 20% of previous values at key urban sites. This indicates some recovery in urban areas. Observations in rural areas indicate normal water quality. All stretches examined conformed to category D water under Indian standards, i.e. water acceptable for fishing. Only BOD in urban areas detracted from category A status.

All events in the river are linked to the hydrology. This leads to considerable natural variation in measurements through time. For example, analyses showed that 50-60% of variability in year to year catch data was due to natural variations. This makes year to year comparisons difficult without a time series of data and emphasises the need for long-term monitoring.

The ultimate objective of this work has been to provide a unifying view of the Ganges Basin and to support management measures or to help resolve conflicts, such as those which are currently taking place over the basin as a whole (See Appendix 4).

RECOMMENDATIONS

1. A full socio-economic study should be carried out at representative sites to ascertain the scale and value of the resource of upland, cold water fisheries.

2. Reinforce measures to prevent dynamite fishing in upland rivers.

3. The spawning and nursery areas of mahseers and snow trout need urgent protection by instigation of closed season or sanctuaries.

4. Conduct study of the impacts of dams and barrages on riverine fish stocks, for example, at Haridwar and on the Gandaki and Kosi rivers.

5. Include consideration of shared fish stocks in future negotiations amongst India, Nepal and Bangladesh in water and other basin uses.

6. Given the status of major carps and particularly the endangered status of *L. rohita*, consider curbs on juvenile fishery and / or stock enhancement of major carps to assist in rehabilitation.

7. Continue monitoring of fish and fisheries as key indicator of effectiveness of Ganga Action Plan and other efforts to improve basin management.

8. Extend fundamental research on population dynamics of key common species which are the mainstay of the fishery, in order to prepare management strategy for maintained production.

9. Integrate existing hydrobiological and fish production models to increase predictive and management capacity for basin fisheries.

1. INTRODUCTION

The cardinal intention of this study was to view the river and its fisheries in a basin-wide context. It is becoming clear that because of the increasingly diverse demands upon water, major rivers and their resources cannot be managed in a piecemeal way, but only in terms of the basin as a whole. The Ganges Basin is one of the largest in the world and it also has one of the largest human population densities with the majority of the basin housing more than 550 people per km^2. Fishing is a traditional activity on the Ganges and is almost exclusively carried out by one of the poorest sections of society. This project is intended to analyse the fisheries in relation to the prevailing physical, environmental and social processes which are taking place within the basin as a whole.

The Ganges Basin is currently dealt with largely in national terms. There are three principal constituent countries, India, Bangladesh and Nepal, and each has developed their own managerial policies and research literature on the Ganges and its fisheries. There is no basin management body. The first step in the present study, therefore, was to review all existing activities and research experience of those constituent nations to attempt to produce an overall view of the basin rather than just its national sectors (Temple and Payne 1995). This can act as a baseline reference point for this and subsequent work.

Since the objective was to examine processes happening within the basin, an essential feature of the present work was to attempt to obtain concurrent data on a number of principal elements related to fisheries and factors which influence them, at different representative points within the basin. Consequently, collaborative surveys were initiated with national institutions to collect this data. Collaborative research studies were set up with Dr S K Sinha of the Environmental Laboratory, University of Patna, in the lower Ganges, Professor H R Singh of the Zoology Department, University of Allahabad, in the middle Ganges and Professor A Chandola-Saklani of the Zoology Department, University of Garhwal, in the upper Himalayan sector of the basin. Funding was provided from this ODA Fisheries Management Science Programme (FMSP) project to staff and equip the principal investigators, and to enable small teams of researchers to conduct the requisite data collection.

Lower down the Ganges, in Bangladesh, very detailed observations on the fish and fisheries were already being collected by the Flood Control Action Plan, Study 17, on Fisheries, funded by ODA (FAP 17, 1994). In addition, however, a separate study was funded under the present ODA FMSP project to monitor the *Hilsa* fishery of the lower Ganges since this was not directly within the remit of the FAP 17 study, but the *Hilsa* fishery is the largest component of fisheries in Bangladesh and some areas of the lower Ganges in India.

The difficult conditions in the upland regions of Nepal presented particular logistical problems. This was dealt with by MRAG conducting direct fisheries and hydrological surveys, in addition to those supplementary observations by the same team in India and Bangladesh. It also became apparent that each of the three countries has developed a rich but localised scientific literature which has greatly facilitated understanding of the present work, but which has also gained by being drawn together in the wider context.

The project began on 1st April 1993 and contacts for collaboration with the participating institutions were finalised and operational by 1st September 1993. Considerable assistance in achieving early contacts was received from Thames Water International, who had contributed to the early work underpinning management of water resources, dealt with under the Ganga Action Plan (GOI 1986). It is anticipated that the present study will provide complementary indicators to the progress of the Ganga Action Plan, which is concerned with improving and maintaining water quality in the Ganga for all economic and social sectors. The Universities of Patna and Allahabad already contribute to other aspects of this programme.

This document summarises the findings of all the collaborative work and provides a view of the most important deterministic factors influencing fisheries at the present time, together with a way of using these to predict production from the fisheries.

2. APPROACH AND METHODS

2.1 LOWLAND SITES

2.1.1 Patna

The city of Patna (25°37'N latitude and 85°21'E longitude), which is situated at 53 m amsl along the southern bank of the Ganga, records an average annual rainfall of 71,250 mm with the heaviest precipitation during July to September.

The actual study was carried out over an 8 km stretch of the River Ganga at Patna from September 1993 (Figure 2.1). Four sampling stations were selected: Kurji (Station I), Dujra (Station II), Bansghat (Station III) and Adalatghat (Station IV).

The river enters the city of Patna at Digha, about 4 km upstream of Kurji, where an old channel of the River Sone joins the main stream of the Ganga. The stretch of river between Station I and Station IV receives effluent from Patna through four major drains, as well as human ashes from the funeral ghats, and animal carcasses. Approximately 4 km downstream of Station IV the Gandak joins the Ganga from the north. The Gandhi "Setu" (bridge) is located just downstream of the confluence of the river Gandak.

The four sites are situated along the south bank where fishermen, mostly from rural areas, operate various fishing gears in the Ganga and adjoining floodplains at different seasons. The fishermen migrate seasonally, sometimes monthly, sometimes daily from one section of the river to another in order to obtain the best catch. Due to these migratory tendencies, it is often difficult to maintain contact with all the fishermen during the course of one sampling programme.

Fish are generally sorted according to species and size, and sold by the kilo. The price depends upon the fish species and size, large specimens attracting a premium price. The remaining catch consists of mainly low value species. The fishermen generally bring the catch to the banks of the river to sell to vendors or middlemen, who in turn sell to consumers or to fish sellers in the market. Common fishing patterns could be seen at all sites, with bamboo barrier traps, basket traps and hook and line being used mainly during the monsoon and scoop nets predominating in the post monsoon and winter seasons. The fishermen use seine nets and various gill nets throughout the year. A full list of gears is shown in Table 2.1 and these are also illustrated in Appendix 2.

- **Kurji Centre**

  There is a large fish landing site at Kurji, the exact location of which is constantly shifting, according to the water level of the Ganga. It moves closer to the city during the monsoon season and about 1 km away from the city onto a sandbar during the dry season. Approximately 11 vendors, or middlemen, including four fishermen's wives, purchase the catches from this landing site.

  The site is located approximately 9 km from Patna University campus. The fish are generally landed unsorted, at about 0600 each day. Around 600 fishermen, including full-time, part-time and occasional, use this landing site, bringing in large pots or baskets of mixed fish with the larger and more valuable species, such as *Hilsa*, carps, bagrids, silurids, catfishes, snakeheads, eels and *Macrobrachium*, separated from the bulk of the catch. The less valuable species caught by simple seine nets are not sorted.

The fishermen prefer to fish in the main channel of the River Ganga during low-water periods when the currents are less strong. Most commonly, nylon mono- or multi-filament gill nets and seine nets are used throughout the year, whereas bamboo traps, barrier traps, cages and hook and line are used mainly during the flood season. Just below Kurji, on the opposite bank, is a vast floodplain (Figure 2.1) which is inundated during the monsoon season and transformed into a good fishing ground, from which the catches are brought to Kurji. This was the main consideration in selecting Kurji as one of the study sites.

- **Dujra Centre**

This is a landing site and small market where fish are sold by four vendors every afternoon between 3 p.m. and 7 p.m.

- **Bansghat Centre**

This small market is situated on the Ashok Rajpath Road near Golghar, where both fresh and dried fish are sold by several vendors, although it is frequented by fewer fishermen than the other centres. Gears used are various mono- and multi-filament gill nets, seine nets, scoop nets and longlines. Daily sampling at this site was carried out after completion of the survey at the Adalatghat centre. The largest cremation site at Patna is also located at Bansghat and several thousand people visit it each day to perform last rites on the bank of the Ganges. Samples of Ganges water (taken 3 m from the bank to avoid interference from bathers) were collected daily from this site in 1.5 litre plastic bottles for physico-chemical analyses.

- **Adalatghat Centre**

This is a large and important fish market and landing site situated on the south bank of the Ganges, 1 km from Patna University campus. 120 seine net fishermen and 150 fishermen employing other types of gear, land their catches here daily, migrating to different sections of the river to fish. These migratory fishermen generally fish at night and land their catch between 5.30 and 6 a.m. There is also rampant fishing for fry, fingerlings and broodstock at this site, using various small mesh size seine nets and large mesh gill nets. Catch is roughly sorted, with mixed fish placed in large baskets, and the larger and more valuable fish species, such as *Notopterus*, *Hilsa*, the major carps, other cyprinids, silurids, bagrids, channids and eels, sorted and packed into small baskets. Small and large *Macrobrachium* are also separated from the main catch. Fish are generally sold by kilo and weighed by either vendors or fishermen. Approximately 15 vendors operate in this market during the peak season. Some of the gill net fishermen sell their catch to "fixed" vendors, whilst many of the seine net fishermen auction their catch. Approximately 20-30 large boats are used by the seine net fishermen, the net being operated by between 8 and 15 men during the dry season and 20-30 men during monsoon or flood season. At highwater during the flood season, boats cannot be easily controlled because of the fast currents in the river, and so more manpower is required.

Figure 2.1 Ganges River and Sampling Sites at Patna

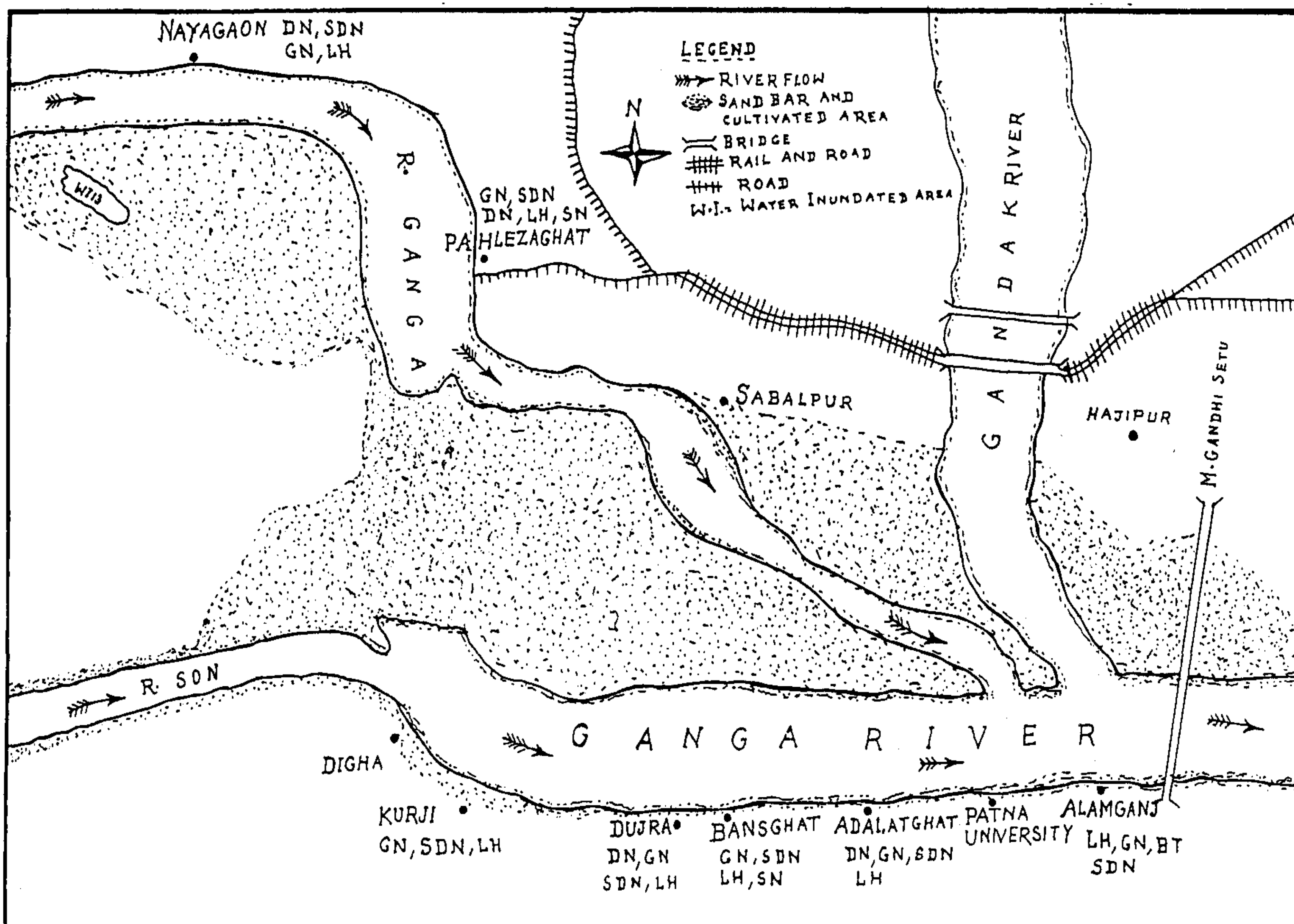

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Table 2.1 Different types of nets and gears, details of mesh size, used in the River Ganga at Patna, with local and English names

Local Name	English Name	Mesh size (where applicable) in stretched condition (mm)
Chattjal	DRAG NET	1-2
Barsatijal (Ghannijal) or Paurijal	DRAG NET	6-2
Johajal	DRAG NET	70-100
Chhantijal	SIMPLE SEINE NET (SDN)	8-14
Jharalka Chhantijal	SIMPLE SEINE NET (SDN)	12-25
Dherijal / Sutrailijal	GILL NET (use of the river types of gill dherijal/ Sutrailijal in deep water depends on mesh size)	20-28
Donhijal	GILL NET	30-40
Currentjal / Bachailijal	GILL NET	28-40
Chaondhijal	GILL NET	40-70
Pachaondhijal	GILL NET	70-100
Satavnajal	GILL NET	100-140
Bhansajal	GILL NET	140-250
Bisharhjal	SCOOP NET	6-10
Pelnijal	DIP NET / LIFT NET	6-10
Dondi jal	DIP NET / LIFT NET	4-8
Phekail jal / Jhingru jal	CAST NET	6-22
Bansi Doni	LINE HOOKS	Different gape size (4, 6, 7, 9 & 19)
Jhangi fishing	BAMBOO TRAP (plunge basket trap): used in deep water - several small baskets joined by a rope made from split bamboo pieces	Size of the gap between the two bamboo pieces
Beerti-Chilaon	BAMBOO TRAP *Beerti* is a hemispherical or oval shaped basket made of split bamboo pieces while *chilaon* is a barrier trap made of bamboo splits	size of the gap - 10
Barijal	BAMBOO TRAP (Barrier trap) Used in shallow water and small stretches, made up of 1.5 m long bamboo pieces tied together to form a 12-16 m long screen like structure called a Janjha	NA
Arsi / Pinjra	BAMBOO TRAP Cubical trap made up of fine split bamboo pieces, size 120 x 45 x 45 x 60 cm	NA
Korwa	BAMBOO TRAP Used in shallow water made up of fine split bamboo pieces	size of mouth gap
Kholnai Dengi	FISHING WITHOUT GEAR (White shallop - trap)	

2.1.2 Allahabad

Allahabad lies at the junction of the two major arms of the Ganges (Figure 2.2). The main channel of the Ganges or Ganga proceeds a distance of around 600 km, up through the industrial city of Kanpur to Haridwar, where the upland section of the river first reaches the plains from the Garhwal Himalaya. The Yamuna has also flowed down from Garhwal and through the major cities of Delhi and Agra which, like Kanpur, are centres of pollution (Temple and Payne 1995). Below the confluence of the Ganges and the Yamuna the main stem of the Ganges flows on to Patna some 300 km downstream.

Due to its central location Allahabad has featured in previous sampling programmes. In the mid 1950s the Central Fisheries Research Institute at Barrakpore devised a sampling programme to monitor the fisheries in the Indian sector of the Ganges. Initially a full frame survey of the river was envisaged, but this proved logistically too difficult (Jhingran, 1991). Consequently, monitoring at key indicator points was used instead. One of those most continually employed was Allahabad and, until the mid 1980s, sampling at Patna had been carried out as part of this programme, only more intermittently. No direct estimate of the fish yield from the Indian Sector of the Ganges basin has ever been undertaken.

The historical role of Allahabad as a monitoring site emphasises its importance for the present study and also went some way to dictating the sampling sites. Allahabad offers the potential of monitoring both the Ganges and the Yamuna. There are three main landing areas at Allahabad. The Daraganj centre on the Ganga was previously included in the CIFRI survey system. It is a centre controlled by four or five middlemen where fish are landed early in the morning.

On the banks of the Yamuna is the largest, most well-established landing area in Allahabad, that of Sadiapur. Sadiapur is a community of fishermen and middlemen totally devoted to fishing. In the middle of the community is a paved square which is the centre of all landing and marketing activity. Around this area, in addition to direct fishing activity, there is considerable manufacture of transport baskets in which catches are transported by rail to Calcutta, and the various fishing gears are also manufactured. There is a wide range of gears in use around Allahabad and a list with their characteristics is given in Table 2.2. There was also a previous CIFRI monitoring site at Sadiapur and regular fish sampling was carried out here for the present study during the early morning landing period.

Downstream of Sadiapur is the much smaller landing area of Gaughat. Landings only take place here at around 4.30 pm in the afternoon and are the result of daytime catches rather than of night time fishing, which is the case in the other centres.

At Gaughat there is a road bridge across the Yamuna which has a water level gauge upon it. This was therefore selected for the water sampling site to provide data on hydrology and physico-chemical features. On the Ganges branch there is also a bridge at Shivkuti with a similar gauge which was consequently selected as a water sampling site. The Sangam is at the confluence of the Yamuna and Ganga rivers and a water sampling site was also established here. Surveys were carried out by the team from the Zoology Department, University of Allahabad.

2.1.3 Bangladesh

In order to obtain current data on the *Hilsa* fishery which remains the largest element of fish catches in the lower reaches of the river and has historically been important all the way to Allahabad (Jhingran 1991), an intensive daily sampling programme was initiated through the Bangladesh Centre for Advanced Studies (BCAS). A team of three field assistants visited the Swarighat landing centre in Dhaka at 0630 most mornings in a month. Swarighat is the main landing centre for *Hilsa* from the lower Padma (Ganges) and Meghna rivers and also receives fish from the coastal areas from as far away as Chittagong and Cox's Bazaar. Each morning the number of baskets landed by single fishermen or "trawlers" were counted and also the number arriving by lorry from the coast. The baskets were of a standard size and weight. Estimates of incidental landings were also made. From the daily records monthly totals were derived. In addition up to 1000 fish per month were sampled for length frequency determination.

With regard to the freshwater fisheries there are a number of fisheries projects operating in Bangladesh, particularly the Flood Control Action Plan Study 17 on Fisheries (FAP 17, 1994), which are producing comparable data to that being collected at the upstream lowland sites. These, therefore, have been used as points of reference.

In addition, the MRAG team made a series of measurements of the physico-chemical characteristics of the Padma (Ganges) and its floodplains in the south west of the country.

2.2 METHODS

2.2.1 Sampling Procedures

- **Catch weight and composition**

This was estimated at all sites in Patna and Allahabad. The fishermen sorted the catch according to species and size, viz. featherback, *Hilsa*, carp, bagrids, schilbeids, silurids, sisorids, live fishes, croackers, eels and other groups, such as small and giant *Macrobrachium*. Weight was measured in kilos. Smaller species fish were weighed by group whilst the larger and more valuable species of fish were individually weighed. The weight of individual small size fishes was visually estimated from their relative contribution to the total catch weight. This was carried out on a daily basis from which monthly estimates were derived.

- **Catch effort**

Catch effort (CE) and length frequency (LF) data were collected daily from September 1993 by interviewing the catch effort respondent (CER) or fishermen at landing sites. These fishermen fish over a 12 km stretch of the Ganges and bring their catches to the landing sites in the early morning. As well as the daily survey, and information and data collection programme, a sample of river water was collected from Bansghat each day between 8 a.m. and 10 a.m. (the sample being taken 3 m away from the bank to avoid interference to bathing), and brought immediately to the laboratory for analysis.

Table 2.2 Types of Nets used in Allahabad Region

Local name of net	Length (m)	Width (m)	Mesh size (cm)	Operated by no. of persons	Size of fish caught	Months used
Chaundhi	350	1.94	1.7	2	small	throughout the year
Fasla	500-500	2.30	8.8	2	big	monsoon
Chhanta (seine net)	250	1.80	3.1	6-8	medium	throughout the year except monsoon
Guriya	200	1.50	3.5	6-8	medium	throughout the year except monsoon
Kuriyar (circular net)	2.60 (radius)	--	5.7	2	medium and large	throughout the year except monsoon
Machhardani (mosquito net)	175	2.00	0.1	8-10	very small	monsoon
Mahajal (drag net)	300	3.00	0.8	8-12	small to large	throughout the year except monsoon

Figure 2.2 Sampling sites at Allahabad

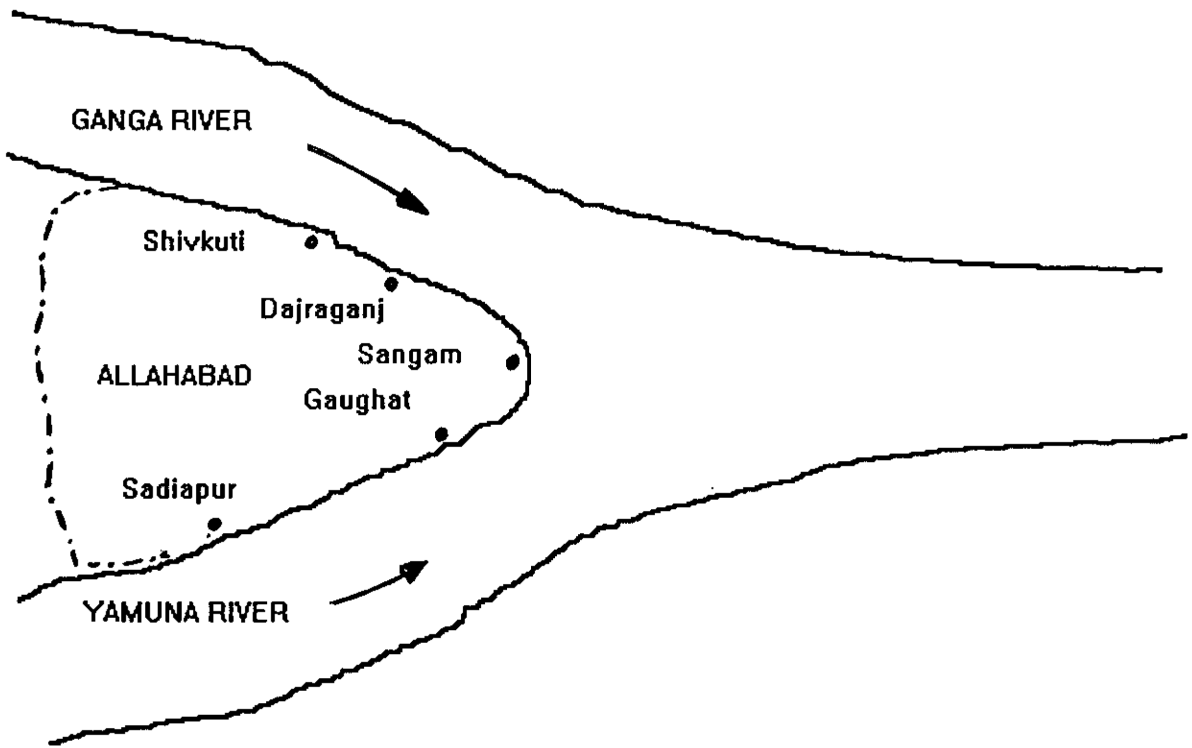


Table 2.3 Fishing villages in the Allahabad region

Site Number	Village	Fisher family population	Fishermen families
1	Rasoolabad (g)	150	25
2	Mehdauri (G)	122	19
3	New Jhusi (G)	294	48
4	Meerapur (G)	195	21
5	Daraganj (G)	180	38
6	Gaughat (Y)	115	17
7	Jhusi (Y)	108	19
8	Sadiapur (Y)	359	44
	TOTAL	1523	231

G = village along Ganga
Y = village along Yamuna

Mean 6.6 persons per family

Table 2.4 Questionnaire for Allahabad Socio-economic Survey

INFORMATION REGARDING FISHERMEN FAMILIES OF ALLAHABAD REGION

NAME OF THE VILLAGE:

TOTAL POPULATION

NUMBER OF FISHERMEN FAMILIES:

---

1. Name of the Head of the family:

2(a) Total No. of adult members of the family(M-----; F-----)

(b)No. of children(below 5 yr----; 5 to 10 yr------------)

(c) How many children go to school? -----

3. No. of family members who go for fishing(full time----;part time-----; rarely----)

4(a)Main period of fishing(months) ------to-------

(b)Stretch of the river where fishing is done(----------- to--------)

5(a) Nets used(write their names)1---------; 2-----------;3--------------

(b) Do you make nets? yes/no

(c) Do you purchase nets? yes/no

(d)Financial support for making/purchasing nets(Govt/Cooperative society/ money lender/other source)

6. Chief means of fishing(own boat/hired boat/others)

7. Average wt of per day catch of fish -----Kg

8. where do you sell your fish?(Sadiapur/Daraganj/Gaughat/Katra/Teliarganj/ other place(name))

9. Average income from per day catch of fish Rs.------

10. Other sources of income(service/Agriculture/business/labour/other)

11(a) Do you want your children to adopt fishing profession: yes/no

(b) Any other opinion/~~difxthe~~ problems of the Head of fishermen family:

Signatures with date of Field Assistant

Signature of the Head of the fishermen family

- **Fishing Effort**

Fishing effort data was collected at Patna from May 1994 by interviewing individual fishermen or CER and the following details were recorded:

- Total hours spent fishing
- Soak time (i.e. period for which nets and gears were in operation underwater)
- Number of gill net metre hours
- Number of bamboo trap hours
- Number of fishermen and boats involved in the operation of various gears
- Total catch weight and species composition
- Gear type and dimensions (length, mesh size, hook gape, bamboo trap gap)

This survey is still being carried out and will be analysed upon completion.

- Length Frequency

Sampling was designed to provide data for assessing growth and mortality rates. Ten abundant and economically important species were chosen for length frequency sampling. Initially, standard length was measured. However, since this method was not recommended by either FAO or MRAG it was decided in May 1994 to switch to fork length measurement. Key species for length frequency sampling were also revised at this time. Sampling was conducted within a 10 day "window" every two months. Each sample comprised 200-300 individual fish, randomly selected from unsorted catches landed by non-selective gear types (e.g. drag net, seine net, bamboo trap, hook and line). If samples from non-selective gears were not available, they were then taken from semi-selective and other gears. This exercise was carried out jointly by scientists from Patna University and MRAG, taking account of locations, gear type and related mesh sizes, number and gap of hooks and in bamboo traps. This survey is also continuing.

Information on the spawn collection survey was gathered between 25 July and 15 August 1993. The historical data from the District Gazetteers were collected before the actual work began in September 1993. Information on the patterns of fish consumption was also recorded initially over a two month period.

2.2.2 Water Quality Parameters

A 1.5 litre sample of surface water was collected regularly each day from the River Ganges at Bansghat (Station III) three metres from the bank. The ambient and water temperatures were recorded on site and the sample was then brought to the laboratory for immediate analyses of pH, conductivity, TDS, turbidity, dissolved oxygen and biochemical oxygen demand (BOD). These analyses were made according to APHA (1992). Free CO_2, alkalinity, total hardness and chloride were recorded from the ongoing Ganga Water Quality Monitoring Project in the laboratories of Patna University by the following means:

- temperature was taken by immersing a centigrade mercury thermometer of 0-100°C graduation into the sample immediately after collection; checked with electronic thermometer.

- pH was measured by electronic pH metre (Wards featherweight ™ pH metre).

- conductivity was measured by electronic analysis kit (Century digital portable kit, Model CK 710).

2.2.3 Socio-Economic Survey

A study sample of 231 fishing families was drawn from 8 villages around Allahabad (Table 2.3). To facilitate comparison, the respondents were classified into four categories:

(a) those who own boats
(b) those hiring boats
(c) those without boats
(d) others

The primary data was collected from the sampled families through a prepared and pre-tested schedule (Table 2.4) using personal interviews.

2.3 UPLAND SITES

2.3.1 Garhwal Himalayas

The main channel of the Ganges, the Ganga River enters the upland drainage area of the Garhwal Himalayas after passing through the transitional region with the plains at Haridwar and Rishikesh. Within Garhwal, the Ganga is formed by the junction of two main tributaries, the Bhagirathi and the Aleknanda at Devpryag (Figure 2.3).

The surveys were centred upon Srinagar, a medium-sized town lying at 580 m amsl, where the University of Garhwal is based. Srinagar is in a valley where the river meanders over about 15 km. Beyond this valley the river descends rapidly through steep-sided valleys and gorges, past Devpryag to the plains. Fisheries surveys have been conducted at villages along this stretch and some physico-chemical parameters have been monitored throughout this whole sector. Some fishing surveys have also been conducted on the River Narar, a tributary which enters below Devpryag. Physico-chemical samples were taken at accessible sites along the course of the main river from the plains to Srinagar and above.

2.3.2 Nepal

Most of the northern tributaries that feed into the Ganges from the heights of the Himalayas originate in or pass through Nepal. From west to east these tributaries are the Mahakali, Karnali, Gandaki, Buri Gandaki and Sun Kosi. The last three feed the North Bihar wetlands before reaching the main stem of the Ganges.

Surveys were centred on the Gandaki and Sun Kosi basins. Within the Gandaki basin (Figure 2.4), observations were made at different times down the main Trisuli River to Naryanghat and beyond, to a point bordering on the Royal Chitwan National Park, including a visit to the inflowing Rapti River. In addition to Naryanghat, main centres along the Trisuli are Gaighat, just below the confluence with the Seti, and Mugling and Malaku.

Access to most rivers is difficult, since they generally run in steep gorges where the rivers cut through the Maharabat Hills (Temple and Payne 1995), but it proved possible to take a rubber boat from Damali near Pokhara, on the Modi Khola, all the way down the Seti River to Gaighat on the Trisuli, which enabled continuous observations to be made on this sector of the river basin.

In the eastern Kosi Basin the work centred around Dolalghat (550 m amsl), a small town at the confluence of the Indrawati and Sun Kosi Rivers (Figure 2.5). Just before the Indrawati joins the Kosi it receives a small inflow from the Cha Khola which drains a relatively intensively farmed and eroded catchment. The valley of the Kosi itself at this point is still naturally wooded.

The basin of the Kosi contains the Arun River on which is sited the controversial World Bank funded Arun III hydroelectric scheme. There is also an irrigation barrage across the Kosi near the Nepal / India border (Temple and Payne 1995), where there is reputed to be much fishing activity. These sites were not visited but the results could be of relevance to what is happening there.

2.4 METHODS

Logistics in these areas are very difficult, with access being a major problem. During the monsoons many roads become impassable due to landslides and flooding. It is difficult, therefore, to set up regular sampling stations, but wherever possible the same sites have been visited more than once.

Fishing surveys have been conducted through interviews and direct observation of active fishing groups and communities. Those at Garhwal were carried out by the group from the University of Garhwal with additional material from the MRAG team. Those from Nepal were conducted by the MRAG team.

Amongst physico-chemical factors, temperature, pH and conductivity were measured by the same standard methods used at the lowland sites (Section 2.2.2). Altitude was measured at all sites using an Avocet digital altimeter calibrated to local mean pressure at sea level which has an error of ± 5 m. All physico-chemical observations on the upland areas were carried out by the MRAG team.

Figure 2.3 The drainage pattern of the Garhwal Himalaya, Uttar Pradesh, India

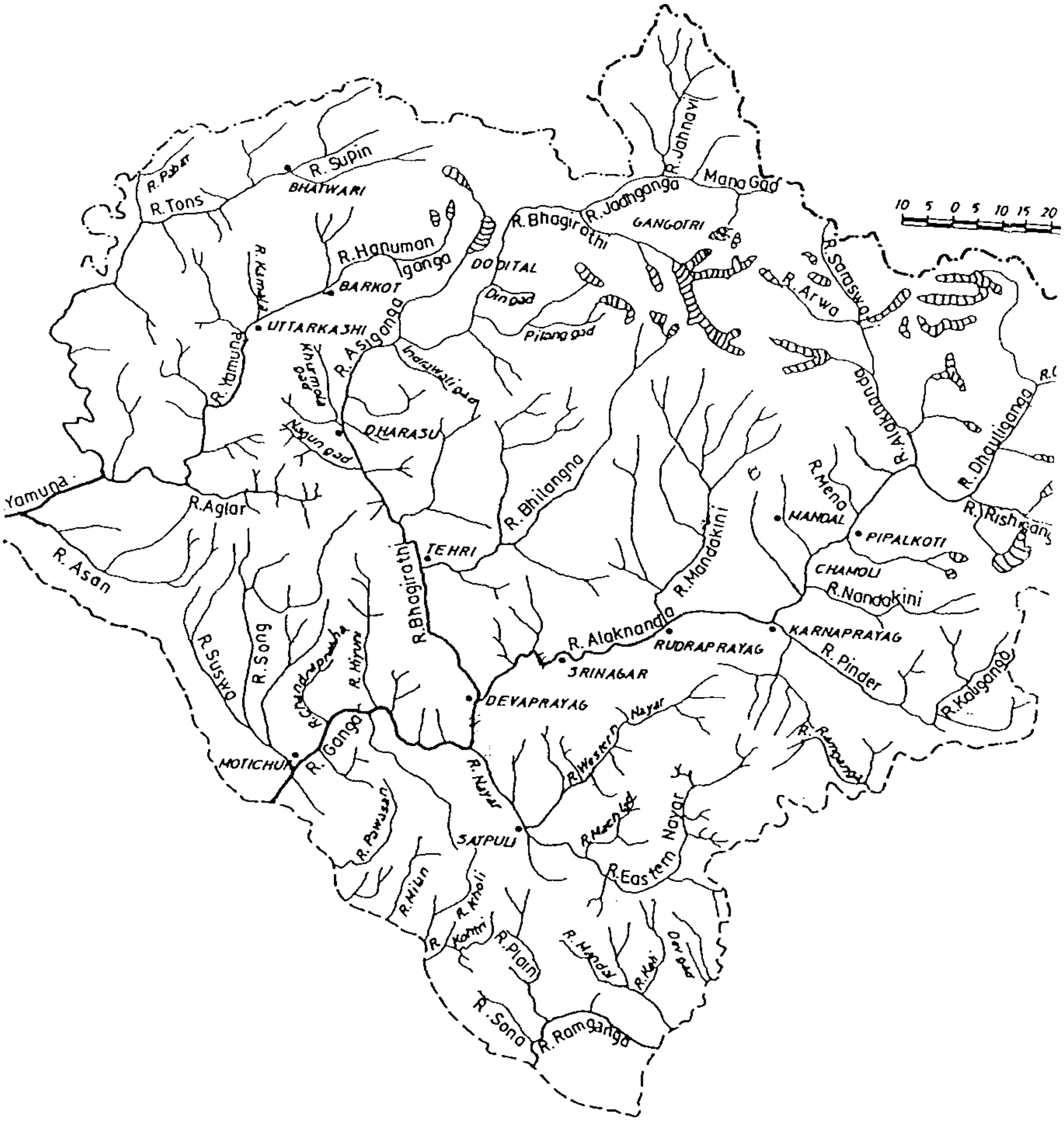


Figure 2.4 Drainage pattern of the Gandaki Basin, Nepal

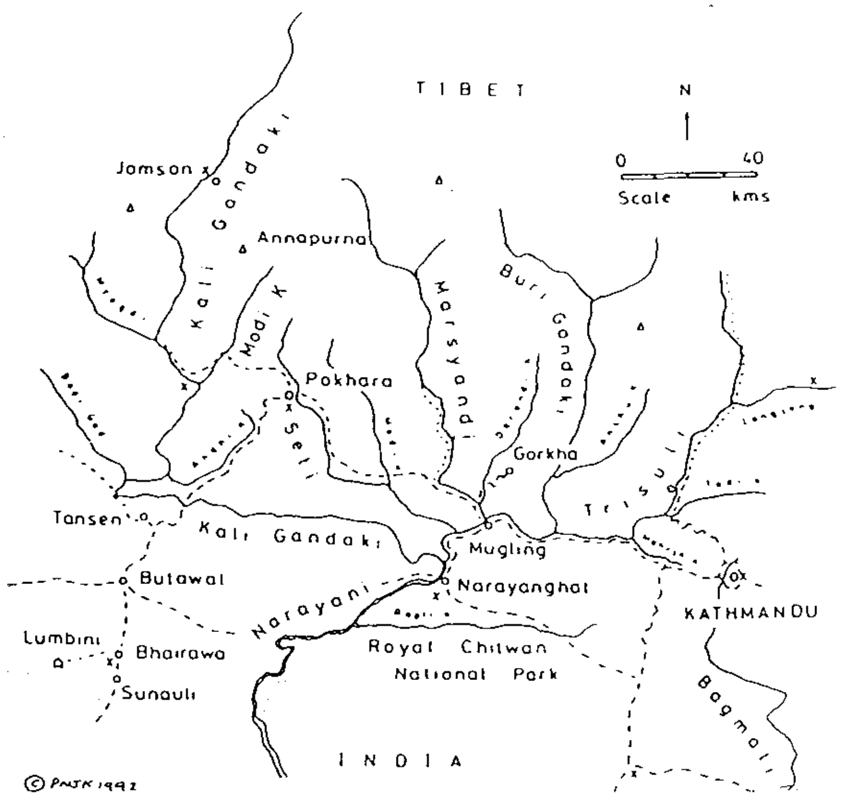
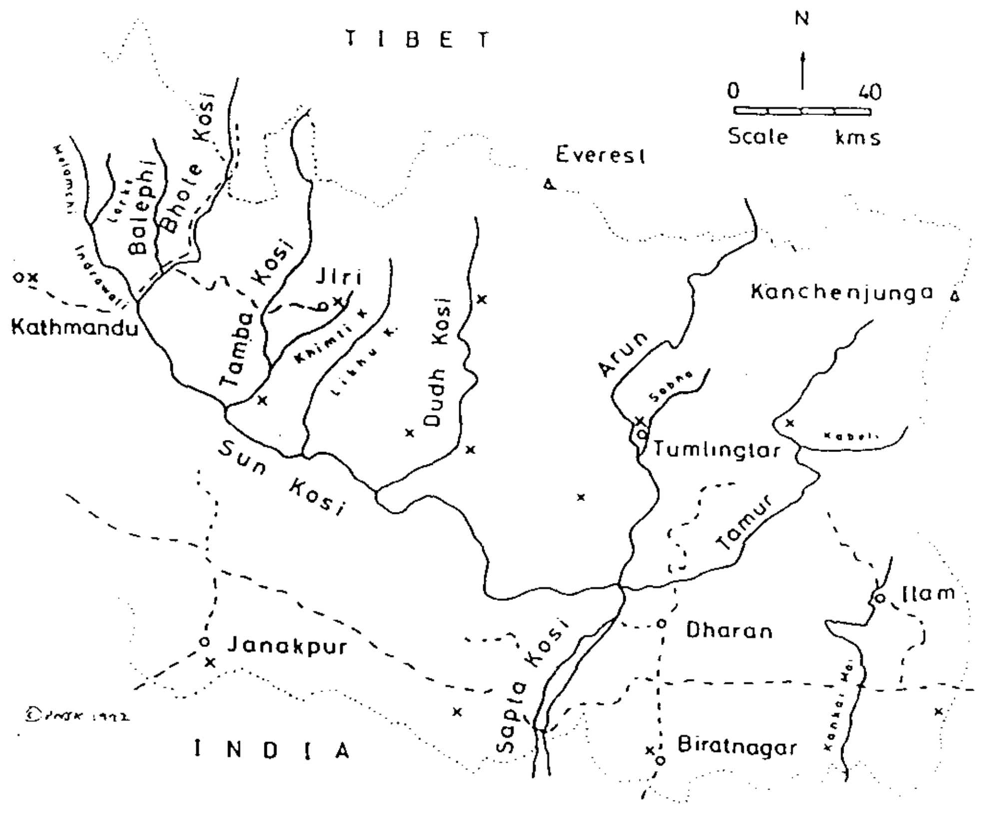


Figure 2.5 Drainage Pattern of the Kosi Basin



3 HYDROLOGY AND THE AQUATIC ENVIRONMENT

3.1 UPLANDS TO DELTA

3.1.1 Appearance and Classification of the River

Physically the river course and river bed vary considerably between the upland and lowland areas. The main surveys took place between altitudes of 900 m amsl in the mountains of the Himalayas, to a few metres above sea level in the freshwater areas just above the delta in Bangladesh. The headwater streams of the upper Ganges Basin extend above 3000 m amsl but the torrential nature of the water and cold temperatures make them biologically less significant.

The upper regions of the Ganges Basin are typified by steeper gradients and rocky channels interspersed with more meandering conditions in the valleys between the Maharabat and Siwalik ranges. Profiles are typically very steep as the tributaries fall from the heights of the Himalayas to around 1000 m amsl with something of a relative reduction below this altitude (Knowles and Allardice 1992; Temple and Payne 1995). These conditions are typical of the "erosion zone" found in most river systems (Payne 1986).

The main stem of the Ganges tumbles out onto the plain at Haridwar (Figure 3.1). At this point, the river is still fast-flowing with a bed of rounded cobbles and boulders, with some sand. The river flow is actually interrupted here by the upper Ganga Barrage, which directs most of the flow into the upper Ganga Canal. This is used to irrigate the "doab" region in the wedge between the Ganga and the Yamuna, which was renowned a century ago for its droughts and famines. The residual flow below the barrage is small.

The presence of boulders and stones at Haridwar indicates that this still lies in the "erosional zone" where turbulence tends to keep most material in suspension. Some way downstream the river becomes wider and shallower, with braided channels flowing between broad sand banks or over a bed of fine sediment. This is the "depositional zone" where conditions allow particles to sediment out to produce the typical lowland river forms. Haridwar lies at 310 m amsl, and from here the river flows through almost 2000 km to reach the Bay of Bengal below Calcutta or Dhaka, depending upon which area is followed into the delta. The tributaries follow a similar pattern. Thus, where the Narayani or the Gandak flows past Naryanghat at 80 m amsl there are still some boulders and stones, but with a greater admixture of sediment. This similarly marks the transitional area between the erosional and depositional zones.

Typically, the main stem of the Ganges carries a lot of sediment, giving it an opaque or turbid appearance. In the upland regions, however, some of the inflowing streams and tributaries are exceptionally clear. This gives rise to a most significant distinction between inflowing streams. Those which are clear are *spring fed*, whilst those which are turbid with a high sediment load are *snow fed*. Spring fed streams come from clean underground sources, usually at moderate or lower altitudes. The snow fed streams result from the melting of snow and glaciers from the heights of the Himalayas, which wash down heavy loads of sediment from the underlying moraines. This sediment is generally pale grey in colour and can be very heavy. In this respect, the waters of the upper Ganges bear a close resemblance to those of the Salimoes, the main stem of the

Amazon. The water of the Salimoes has been classified as a "white water" according to the scheme of Sioli, typified by a heavy pale sediment load, an alkaline pH and relatively high conductivity or total dissolved solids. This has been attributed to the effects of erosion by snow-melt on young, relatively unweathered mountains which in the case of the Amazon, derives from the Andes. Although the classification of Sioli was only applied to the Amazon basin, it is clear that the Ganges is similarly a "white water" derived from the Himalayas, which are themselves geologically young and unweathered.

The colour and sediment load of the upper Ganges, however, changes radically during a year. For much of the dry season from December to April, when flow is at a minimum, the colour is bright turquoise and the sediment load is lower and characterised by flakes of a reflective mica. As the temperatures become higher and the dry season progresses, the glaciers and snow cover of the Himalayas start to melt, and at Srinagar, for example, the river starts to become more opaque and greyish in the later half of April. After about a month, light penetration is cut down to a centimetre or two and, with the beginning of the monsoons, the colour may temporarily become brown as silt is washed from the land by rainfall. These changes are likely to be of considerable importance to the fish of the river, since they carry information and environmental cues for the migration and spawning activities of the communities.

There is considerable concern in the upland regions, particularly in Nepal, that deforestation and degraded land practices are leading to increased erosion and higher sediment loads in the rivers. Given the natural cycle and the lack of quantitative data, this is difficult to prove, but is was observed in one tributary of the Sun Kosi, the Chakhala, where much of the steep valley land had been taken over for terraced farming, that many exposed areas on the hillsides revealed red lateritic soil. In the middle of the monsoon in July, the Cha Khola ran blood-red with an exceptionally high sediment load which emerged as a great red plume into the Indrawati before joining the Sun Kosi. Transparency was not more than a millimetre or two. The effect was so dramatic that it was hard to escape the probable association with the barren hills and the erosional scars existing along the steep valley sides.

In the lowland depositional zone, the waters remain sediment-rich and are rather less changeable. The sediment tends to be known as cafe-au-lait, but the density does vary (see Section 3.2).

3.1.2 Physico-chemical Conditions

A series of measurements were taken at different altitudes in the Basin over the two year period of the study (Table 3.1).

In general terms, the Ganges is alkaline with a pH above 8 and with a conductivity of 160-410 µs. The alkaline pH reflects underlying soluble calcareous rocks in parts of the catchment area and is associated with a relatively high calcium level and alkalinity (Temple and Payne 1995). This gives the water a high buffering capacity and an ability to resist acidification to some degree.

The conductivity, as a measure of total dissolved solids, is also relatively high. Most tropical rivers have a conductivity less than 400 µs but many in tropical Africa and South America, including the Amazon and the Zaire, for example, have conductivities less than

150 µs (Welcomme 1988). Again, this is a function of the relative youth of the mountains in the catchment area and the sedimentary nature of much of the underlying parent material.

Figure 3.1 Map of the Ganges Basin

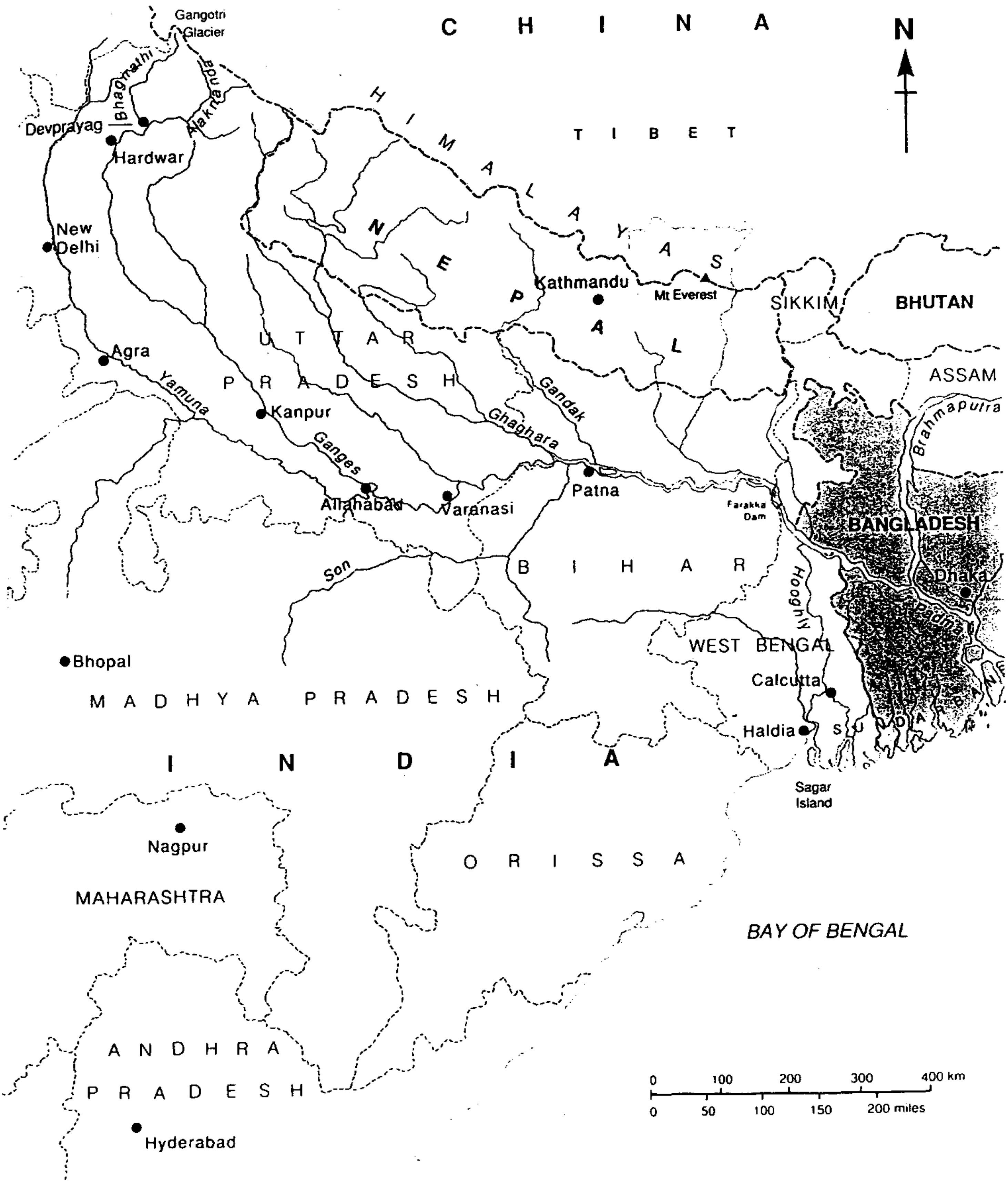


Table 3.1 Hydrological data for various sites along the Ganges basin by altitude

RIVER	SITE	ALTITUDE (m amsl)	WATER TEMPERATURE (°C)	pH	CONDUCTIVITY
Aleknanda (10/93)	Srinagar	580	16.6	8.08	159.8
	Bagwan	510	17.1	8.30	194.3
Ganga (10/93)	Kandiyada	440	17.5	8.20	168.9
	Rishikesh	360	21.3	8.13	241.0
	Haridwar	310	20.8	8.49	263.0
	Patna	48	25.1	---	293.0
Upper Padma (10.94)	Rajshahi	38	17.8	8.14	410.0
Lower Padma (10/94)	Mowra	22	19.4	8.46	309.0
Gorai (10/94)	Khulna	20	20.6	8.10-8.50	377-785

As within most river systems there is a tendency for the concentration of dissolved ions to increase downstream. This is apparent in the Ganges with a progressive increase from around 160 µs in the Garhwal Himalayas at Srinagar to 410 µs at the Upper Padma, i.e. the Bangladesh sector of the Ganges, at Rajshahi. The slight dip recorded between the Aleknanda site at Bagwan, compared to the downstream site at Kandiyada, is due to the union of the Aleknanda with the Baghirathi at Devpryag, where the Baghirathi has a rather lower conductivity of 146 µs (Table 3.1). The confluence therefore gives a dilution of the Aleknanda water detectable at the first main stem site below the confluence of Kandiyada. Similarly, below Rajshahi, the Lower Padma also shows a rather lower conductivity. At this point, however, the Ganges has been joined by the Bramhaputra, giving something of a dilution of the lower Padma. The Gorai is the only distributary of the Upper Padma to the whole south west region of Bangladesh and Khulna lies at the edge of the intertidal region, and consequently shows daily variation of the dimensions indicated above. Given that the conductivity of sea water is 46,000 µs, the effect remains marginal at this point.

The main tributaries are similarly a function of their catchment areas and the net influence of their own tributaries. Thus the Narayani / Gandaki at Naryanghat has a conductivity of some 354 µs and the Sun Kosi at Dolalghat one of 154 µs (Table 3.1). Generally, headwater or lower order streams have the lowest dissolved solid content and pH. Thus the Jhikau Khola, a first order stream in the Kosi system, has a conductivity of 122.8 µs with a pH of 7.77 and the inflowing stream to Phokara Lake at the headwaters of the Seti has a conductivity of only 67.5 µs, and a pH of 6.45 (Table 3.1) as a result of the heavy surrounding swampy vegetation which tends to create more acidic conditions. Naturally, all of these factors will show some seasonal variation.

Temperature also shows considerable downstream variation and is probably a major environmental factor influencing the distribution of fish communities in the river, so that in October, as indicated in the list above, the temperature rose from 16.6°C in the upland areas at Srinagar to 25.1°C at Patna, which is a difference of 8.5°C over an altitudinal range of some 530 m or around 1.6°C per 100 m change in altitude.

In the particular sequence shown above, the readings at Rajshahi were taken the following January in the winter, when temperatures even of these lowest regions had fallen considerably to around 18-20°C.

The seasonal range of temperatures in the lowland sectors of the river have been recorded in detail at Patna and Allahabad (see below). In the upstream sectors, the recorded water temperature range at Srinagar is 16.5-18.7°C (Table 3.1) for October (cool) to May (close to the hottest). At the major transitional zone of Rishikesh / Haridwar, the recorded range is 20.8-20.4°C, again from October to May. The influence of snow-melt during the hot season may mitigate against more extreme fluctuations in these areas. In the transitional zone on the Gandaki tributary system, the temperature in October was of a similar order, around 20.4-20.9°C (Table 3.1), although with no indication of seasonal variation. On the Sun Kosi at Dolalghat, which is in the distinct upland region, the recorded temperature range was 15.0-29.6°C between November (cool) and July (hottest).

In none of these main stem or snow-fed tributaries have temperatures above 21°C been recorded. Temperatures of this order have been recorded in some of the non snow-fed, lower altitude rivers, such as the Seti at 21.05°C in November, and the Rapti at 21.8°C during the same month (Table 3.1). Morning and evening temperatures at Srinagar on the Aleknanda in October varied between 16.1 and 16.6°C, a daily variation of around half a degree (Table 3.1).

Once on the plains, the rivers rapidly warm up. For example, the temperature of the Narayani / Gandaki, only 30 km below Naryanghat was 24.5°C, more than 4°C higher than at the transitional point. A reading taken in October of the same river after it had traversed 230 km across the plains, just before it joins the main Ganges at Patna, showed a temperature of 25.1°C (Table 3.1), very similar to that just below Naryanghat. The transitional zones evidently do show rapid changes in both river morphology, bed structure and water temperature, which reflects the relatively abrupt changes from hills to plain.

Downstream, in the lower sectors of the main stem of the Ganges, water temperatures can reach 33°C in July (Section 3.2) and are regularly over 30°C on the floodplains in Bangladesh at this time.

There does, therefore, appear to be two rather different temperature regimes between upland and lowland sectors with a relatively well marked transitional point between them. The significant transitional temperature appears to be around 21°C.

3.2 SEASONAL VARIATION IN THE LOWLAND SECTOR

3.2.1 Hydrology

Regular readings of water level as well as a variety of other physico-chemical factors, were taken at Patna (Table 3.2) and at a number of sites around Allahabad (Appendix 3).

At Allahabad, water level readings were taken specifically at Shivkuti on the main channel of the Ganga (Table 3.3) and at Gaughat (Table 3.4) on the Yamuna River before its confluence with the Ganga. Physico-chemical data has also been summarised for Sangam (Table 3.5) which is the precise point of confluence of these two major river branches and is also one of the holiest places on the Ganges.

Water level readings were all taken at official gauging staffs permanently established on the river. The most continuous records were taken at Patna (Figure 3.2).

From this it can be seen that the low point in the hydrological cycle occurs in March to April at the end of the hot dry season, which also extends into May. In late May and early June the river begins to rise. The traditional time for the beginning of the monsoon in this area is 5-10 June (Frater 1990). River levels rise sharply after that into mid to late August. At its peak the river rose an average 6.1 m, whilst the extreme variation from daily minimum to daily recorded maximum, was 9.7 m. During periods of rapid rise or fall, daily variation around the mean is also great, presumably related to rainfall events. Degree of change, rate of change and variability will all provide information for migrating fish.

At Patna, after August the river levels fall rapidly towards November, and then move gradually towards the trough the following March to April (Figure 3.2). This declining phase is essentially similar to that recorded upstream at Shivkuti, Allahabad (Figure 3.3) and on the Yamuna at Gaughat, Allahabad (Figure (3.2). There, one exceptional feature was the apparent upsurge in water level in the Ganga branch in November 1994 (Figure (3.3). This remains anomalous and was not found elsewhere in the system.

No direct concurrent measurements of changes in water level downstream of Patna in the Bangladesh sector were made, but a database has been obtained from the Hydrology Research Institute in Bangladesh, with records over a twelve year period. The most recent of these, those for 1989, is shown in Figure 3.5, which also appears relatively typical. The rising phase of the hydrograph is quite similar to that for Patna, with the low point being in March-April and the major rise occurring in May-June. The monsoon may typically begin a few days earlier over Bangladesh. The sharp rise continues until August, but the high water level persists for a much longer period and, in fact, the peak is in September -October (Figure 3.5). Direct observation by the FAP 17 project on open floodplains alongside the Upper Padma in 1993, the same period covered by part of the present observations, also showed the high water period lasting until 20 October, although the peak was actually on 3 September. Over that same period in Patna (Figure 3.2), a rapid fall in the hydrograph was observed between September and October.

The reason for the more prolonged high water period in the Upper Padma in Bangladesh is unclear. It could be a feature of the regulatory effect of the Farakka Barrage, or it could be due to the fact that between the observation point in Patna and that at Pabna on the Upper Padma, at least two major northern tributaries for the Himalayas, the Bhure Gandaki and the Kosi, as well as a number of southern tributaries, join the main Ganga. They could combine to prolong the flood period in Bangladesh. In terms of production, however, this will be a highly significant factor, since those fish using the floodplains as feeding grounds will have a longer growing season.

3.2.2 Physico-Chemical Factors

■ Temperature

Many of the major physico-chemical parameters show considerable seasonal variation which is also linked to the hydrological cycle. Much of the Ganges Basin lies in the sub-tropics and therefore does have a distinct northern hemisphere summer and winter. Consequently, water temperatures tend to reach a minimum in January and a peak in the summer. In Patna these range from an average of 18.9°C in January to 31.9°C in June (Table 3.2; Figure 3.6).

The daily recorded extremes here are 18.6-33°C (Table 3.2) which are the temperatures that resident fish species will have to contend with. From the winter point in January, the water rapidly warms up through the hot dry season and reaches its highest temperature in the pre- or early monsoon in June. They also fall again rapidly as the floodwaters recede and winter approaches in November / December (Figure 3.6).

In the Ganga at Allahabad, the seasonal temperature range was 15.1-29.1°C with daily extremes of 14.8-29.2°C (Table 3.3). These are slightly lower in all aspects than the temperatures further downstream at Patna, by about 4°C at the lower end of the spectrum. A very similar mean monthly range of 14.4-29.1°C with daily extremes of 14.2-29.6°C were observed on the Yamuna River (Table 3.4). A rapid decline from the summer peak to the winter low point in January was also seen at both sites at Allahabad, similar to the pattern shown at Patna (Figures 3.3 and 3.4).

Table 3.2 Summary of hydrological and physico-chemical observations on the Ganges River at Patna

Mean Values

Month	Air °C	Water °C	pH	Conductivity µS/m	TDS mg / l	Turbidity NTU	DO mg / l	BOD mg /l	Depth m	Level AMSL m
SEP		30.5	8.24	164	87	505.4	6.2	1.46	7.49	48.33
OCT	27	29.93	8.55	211	110	497	6.43	1.11	5.73	43.76
NOV	23.6	25.7	8.7	266	132	242	7.5	1.5		43.05
DEC	20.6	20.4	8.3	280	140	79.2	8.2	1.8	1.185	41.96
JAN	16.5	18.9	8.43	298	148	53.1	8.6	1	0.64	41.39
FEB	18	21	8.5	310	154	73		1.8	0.59	41.3
MAR	25.1	25.2	8.3	361.5	179	48.5	7.8	2.6	0.19	40.7
APR	30.4	28.2	8.3	342	170	36	7.2	1.4	0.064	40.8
MAY	32.4	30.5	8.3	318	167	56.9	6.7	1.1	0.136	40.91
JUN	33.2	31.9	8.22	220	110	186	6.4	0.8	1.72	42.5

Minimum Values

Month	Air °C	Water °C	pH	Conductivity µS/m	TDS mg / l	Turbidity NTU	DO mg / l	BOD mg /l	Depth m	Level AMSL m
SEP		29	7.8	111	55	118	5.2	1	5.45	47.01
OCT	24	27	7.9	141	69	233	4.4	0.4	4.08	43.12
NOV	21	22.5	8.3	242	120	169	6.7	0.6		42.45
DEC	17	19	7.8	254	126	28	7.5	0.8	0.82	41.59
JAN	13.5	18	8.2	274	136	13	7.6	1.8	0.5	40.85
FEB	16	20	8.3	297	147	21		0.8	0.34	41.1
MAR	19	22.5	8.1	326	162	14	6.4	1.6	0.01	40.5
APR	26.5	26.5	8.1	312	155	19	6.8	0.4	-0.26	40.5
MAY	28	29	8.1	273	136	26	6.3	0.4	0.01	40.78
JUN	31	29	8	124	60	33	5.6	0.2	0.58	41.4

Maximum Values

Month	Air °C	Water °C	pH	Conductivity µS/m	TDS mg / l	Turbidity NTU	DO mg / l	BOD mg /l	Depth m	Level AMSL m
SEP		31.8		219	109	830	7.9	2.3	8.65	49.42
OCT	30	32	8.9	270	134	680	7.7	2.6	9.08	47.92
NOV	28	27	9	285	150	410	8.1	2.3		43.96
DEC	23	22.5	8.4	311	165	218	8.9	3.2	1.67	42.44
JAN	21	20	8.6	317	157	168	9.2	3.6	0.78	41.53
FEB	20	22.5	8.6	322	160	197		3.3	0.69	41.49
MAR	30	28	8.5	388	193	128	8.7	3.8	0.32	41.09
APR	34	30	8.7	382	190	48	7.5	2.1	0.069	41
MAY	35.5	33	8.5	318	184	178	7.1	2.5	0.58	41.35
JUN	35	33	8.4	262	130	582	6.9	1.5	3.75	44.5

Table 3.3 Summary of hydrological and physico-chemical observations on the Ganges River at Shivkuti, Allahabad

Mean	Air °C	Water °C	pH	Conductivity µS	DO ppm	Water Level
Aug	27.0	29.1	7.8	205.0	5.6	272.5
Sep	27.5	28.5	7.9	228.5	7.6	261.0
Oct	26.2	26.4	8.1	341.5	7.4	247.0
Nov	21.0	21.9	8.6	293.0	12.5	257.5
Dec	15.6	17.7	8.3	436.0	11.4	256.5
Jan	13.5	15.1	8.2	462.0	11.4	255.0
Feb	15.0	17.5	8.3	461.5	10.6	254.0
Mar	20.0	21.7	8.1	492.0	7.2	252.5

Minimum	Air °C	Water °C	pH	Conductivity µS	DO ppm	Water Level
Aug	26.6	29.1	7.7	202.0	5.6	266.0
Sep	26.8	28.5	7.7	203.0	7.3	258.0
Oct	24.3	25.1	8.0	310.0	6.6	245.0
Nov	19.9	20.7	8.4	284.0	12.6	257.0
Dec	10.7	15.5	8.1	419.0	10.0	256.0
Jan	12.0	14.8	8.1	445.0	10.0	255.0
Feb	14.8	17.2	8.3	430.0	9.5	254.0
Mar	18.1	18.9	7.9	476.0	4.8	253.0

Maximum	Air °C	Water °C	pH	Conductivity µS	DO ppm	Water Level
Aug	27.5	29.2	7.8	208.0	5.6	279.0
Sep	28.1	28.5	8.0	254.0	8.0	264.0
Oct	28.2	27.7	8.2	373.0	8.2	249.0
Nov	22.2	23.1	8.8	302.0	12.4	258.0
Dec	20.5	20.0	8.4	453.0	12.8	257.0
Jan	15.0	15.4	8.4	479.0	12.8	255.0
Feb	15.3	17.8	8.4	493.0	11.8	254.0
Mar	22.0	24.5	8.4	508.0	9.7	252.0

Table 3.4 Summary of hydrological and physico-chemical observations on the Yamuna River at Gaughat, Allahabad

Mean	Air °C	Water °C	pH	Conductivity µS	DO ppm	Water Level
Aug	29.3	29.1	7.7	213.6	6.0	268.5
Sep	27.1	28.6	7.6	315.5	9.3	253.0
Oct	24.1	25.1	8.1	421.0	9.2	237.0
Nov	18.8	21.7	8.1	479.0	12.9	234.0
Dec	12.9	17.5	8.1	583.5	12.2	229.0
Jan	13.9	14.4	8.1	603.0	11.0	226.0
Feb	20.1	21.6	8.1	530.5	9.7	226.0
Mar	22.7	21.8	7.7	503.5	6.5	224.5

Minimum	Air °C	Water °C	pH	Conductivity µS	DO ppm	Water Level
Aug	29.3	28.6	7.6	171.3	6.0	267.0
Sep	26.4	28.1	7.6	261.0	8.7	247.0
Oct	23.7	23.5	8.0	385.0	9.2	237.0
Nov	18.4	21.1	8.0	469.0	12.3	234.0
Dec	11.4	16.5	8.1	543.0	11.0	228.0
Jan	13.8	14.2	8.0	596.0	10.9	226.0
Feb	19.7	21.0	8.0	527.0	9.7	226.0
Mar	20.5	21.6	7.5	501.0	4.5	224.0

Maximu	Air °C	Water °C	pH	Conductivity µS	DO ppm	Water Level
Aug	29.4	29.6	7.8	256.0	6.1	270.0
Sep	27.8	29.1	7.7	370.0	10.0	259.0
Oct	24.5	26.7	8.2	457.0	9.3	237.0
Nov	19.3	22.4	8.1	489.0	13.6	234.0
Dec	14.5	18.5	8.1	624.0	13.4	230.0
Jan	14.1	14.6	8.1	610.0	11.2	226.0
Feb	20.6	22.2	8.2	534.0	9.7	226.0
Mar	25.0	22.0	8.0	506.0	8.6	225.0

Table 3.5 Summary of hydrological and physico-chemical observations at the confluence of the Rivers Ganges and Yamuna, Sangam, Allahabad

Mean	Air °C	Water °C	pH	Conductivity µS	DO ppm	Water Level
Aug	32.6	29.8	7.7	235.0	4.4	
Sep	28.8	29.3	7.6	214.0	4.5	
Oct	25.1	24.9	7.6	229.0	5.3	
Nov	22.6	23.8	8.1	369.0	10.6	
Dec	15.4	18.5	8.0	466.0	11.2	
Jan	16.2	14.7	8.0	517.0	7.6	
Feb	21.4	21.5	7.7	518.0	4.4	
Mar	18.0	21.5	7.7	462.0	6.4	

Minimum	Air °C	Water °C	pH	Conductivity µS	DO ppm	Water Level
Aug	30.6	29.7	7.9	245.0	4.0	
Sep	27.1	27.6	7.6	223.0	4.9	
Oct	26.0	26.4	8.1	437.0	5.7	
Nov	21.3	21.5	8.1	465.0	9.6	
Dec	20.2	18.1	8.3	466.0	10.0	
Jan	24.3	18.6	8.0	522.0	5.6	
Feb	21.7	20.3	8.2	487.0	4.7	
Mar	17.0	20.4	7.9	452.0	6.0	

Maximum	Air °C	Water °C	pH	Conductivity µS	DO ppm	Water Level
Aug	31.6	29.7	7.8	240.0	4.2	
Sep	27.9	28.5	7.6	218.5	4.7	
Oct	25.5	25.6	7.8	333.0	5.5	
Nov	21.9	22.6	8.1	417.0	10.1	
Dec	17.8	18.3	8.1	466.0	10.6	
Jan	20.3	16.6	8.0	519.5	6.6	
Feb	21.5	20.9	7.8	502.5	4.5	
Mar	17.5	20.9	7.8	457.0	6.2	

Figure 3.2 Changes in water level in the Ganga River, 1994-95, at Patna

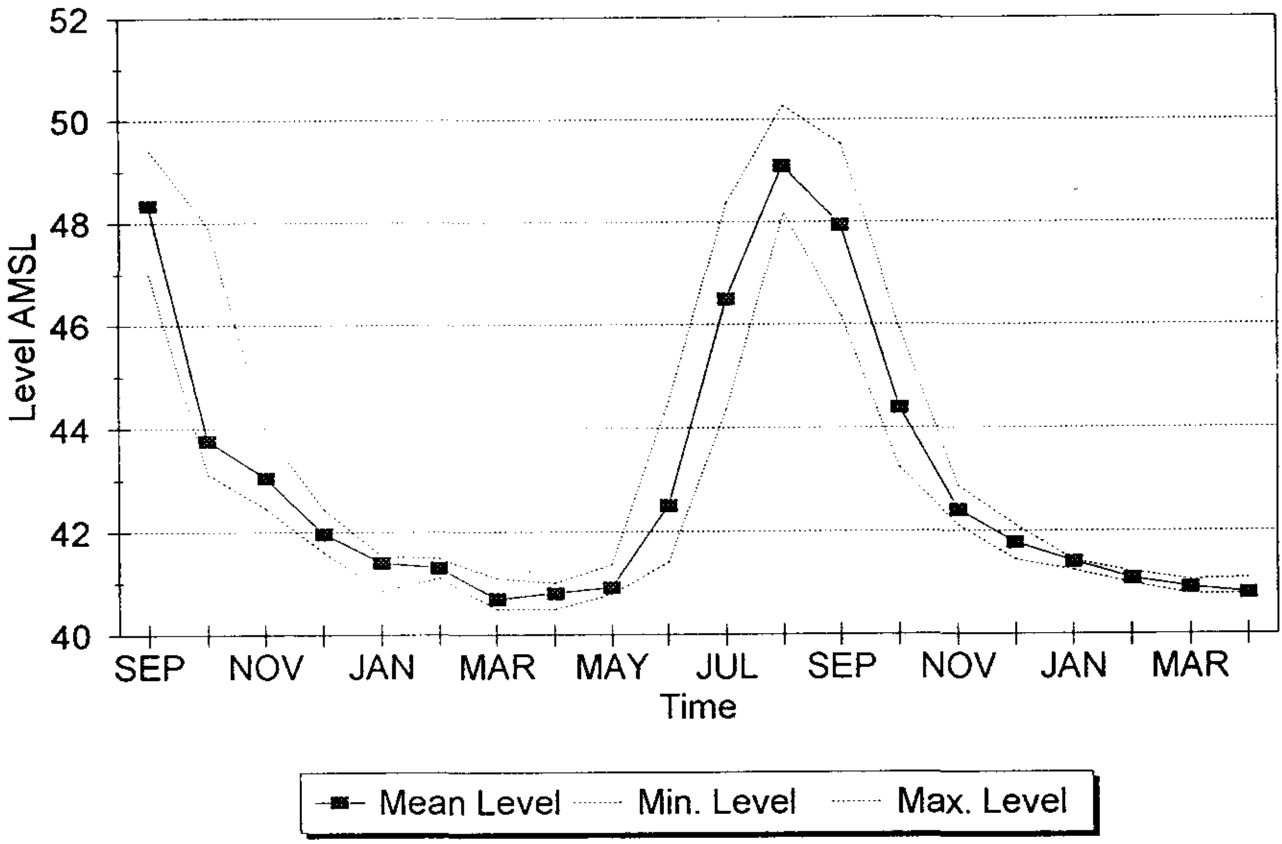


Figure 3.3 Changes in water level of the Ganga River, 1994-95 at Shivkuti, Allahabad

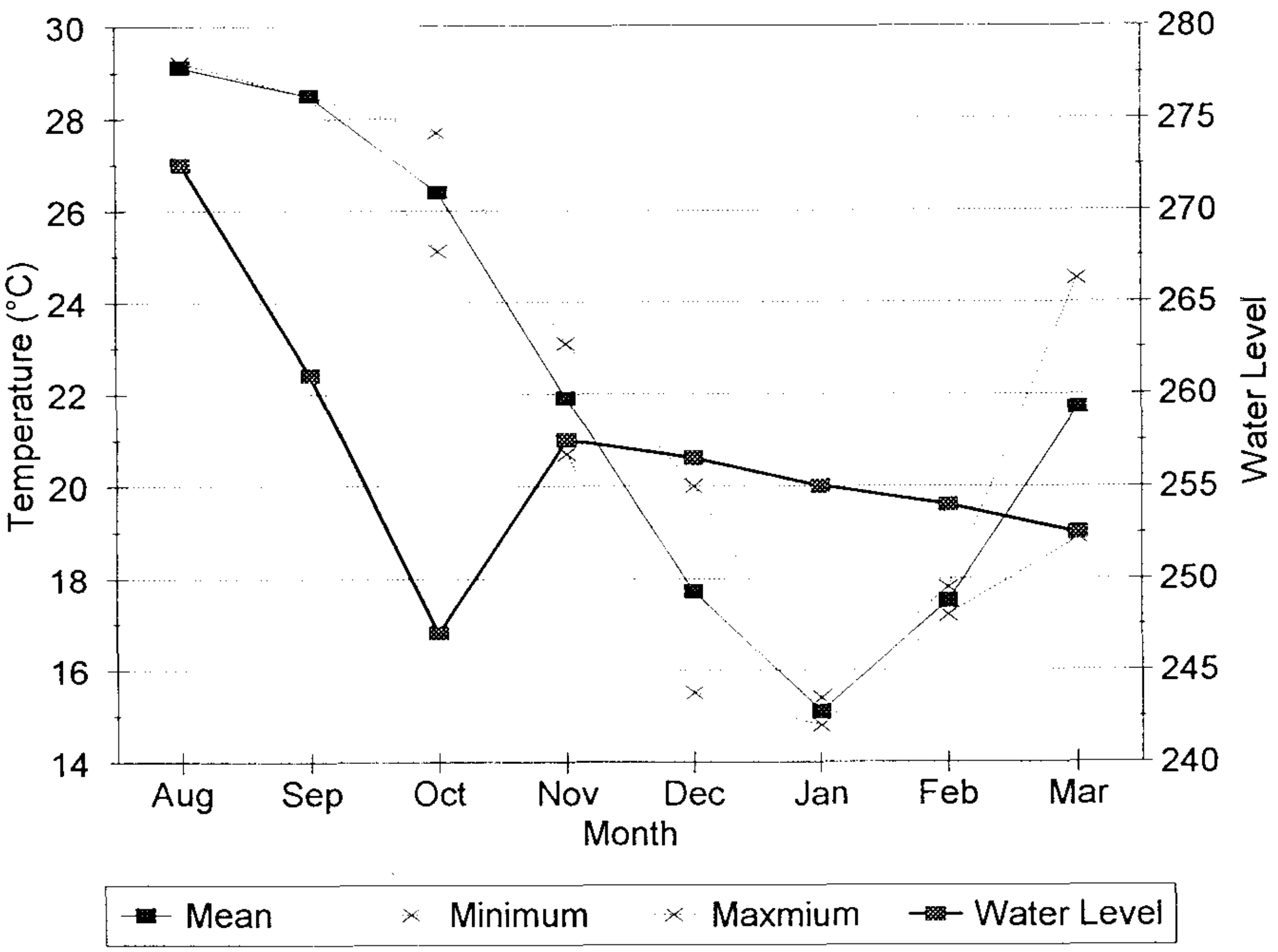


Figure 3.4 Changes in water level of the Yamuna River, 1994-95 at Gaughat, Allahabad

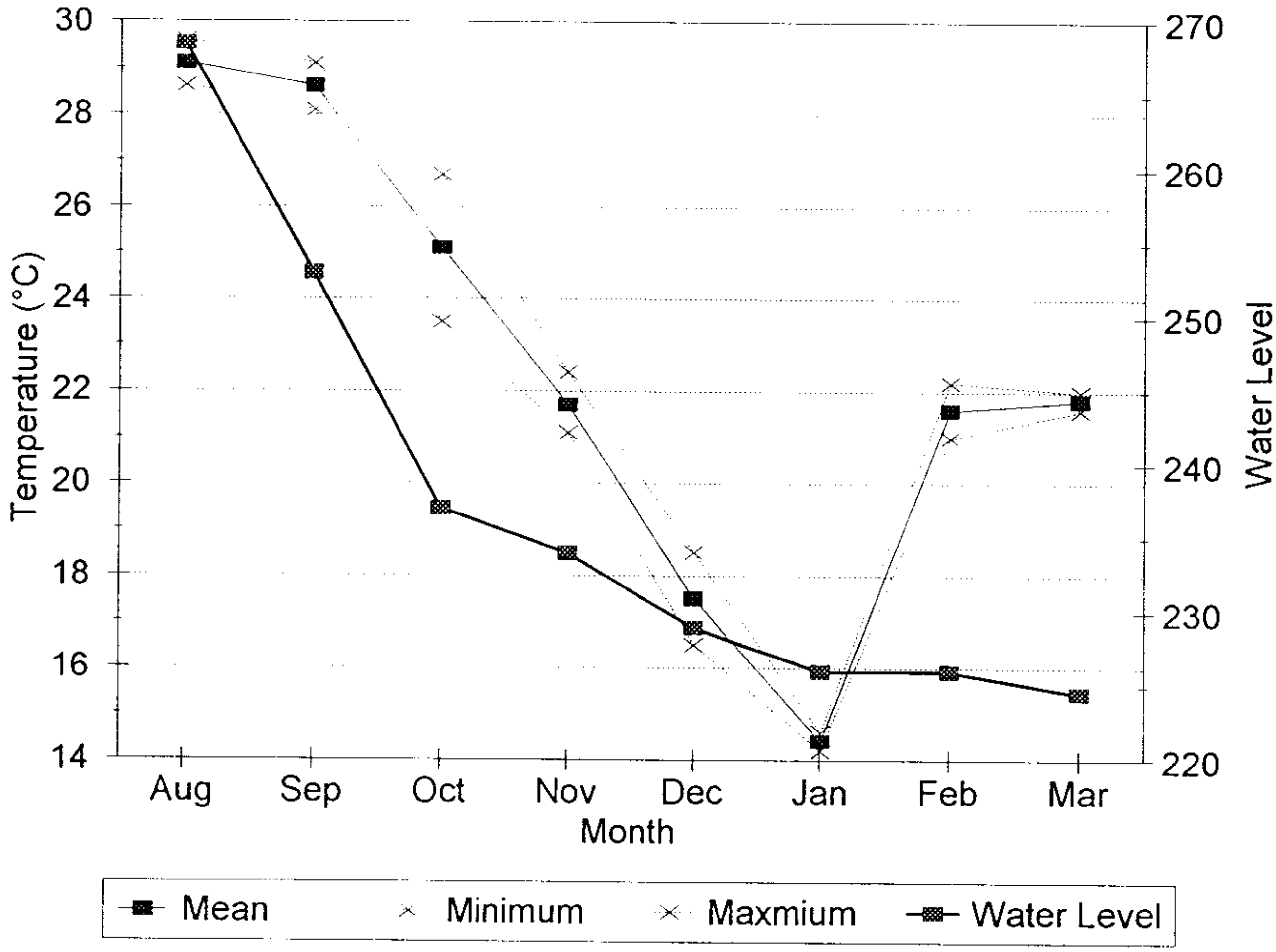
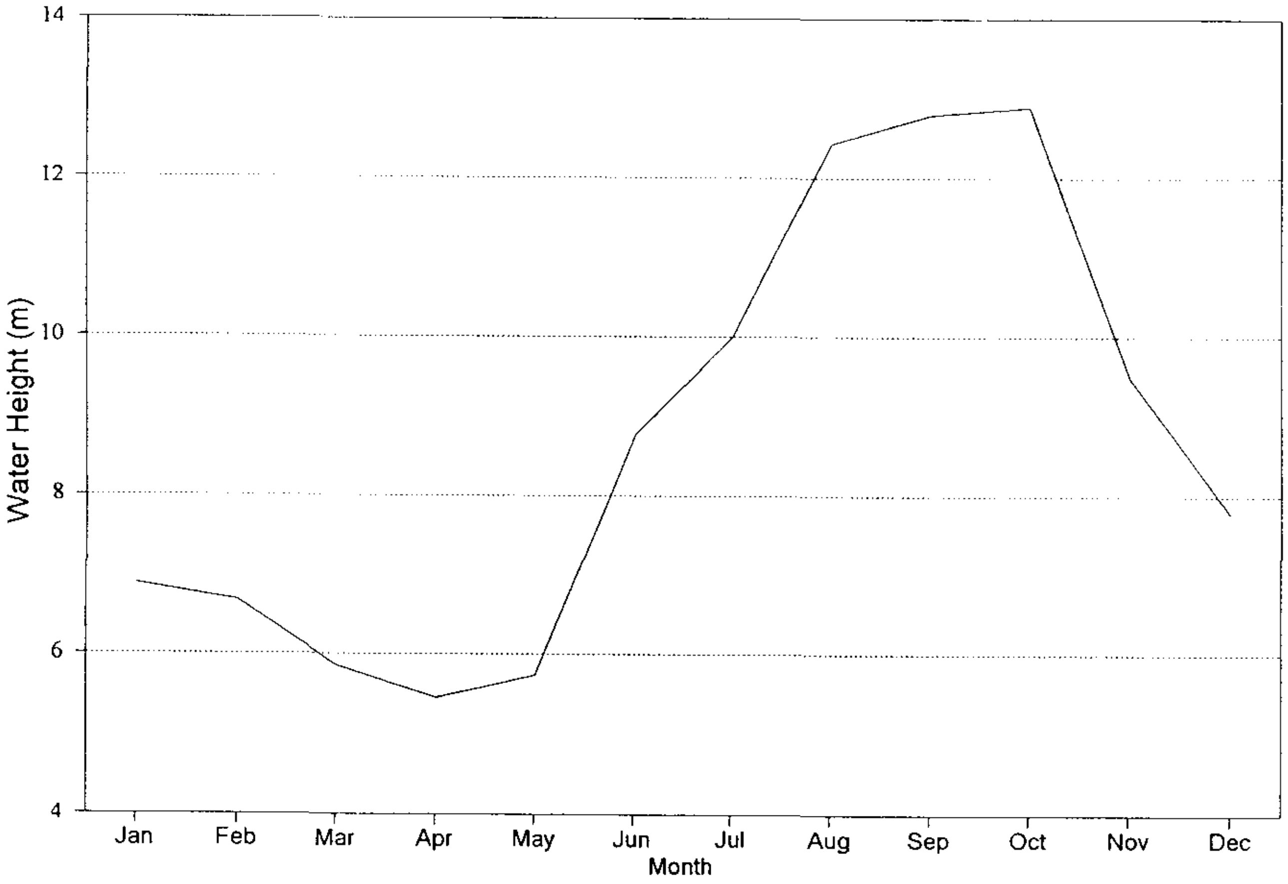


Figure 3.5 **Changes in water level of the Ganges (upper Padma) River in 1989 at Pabna, Bangladesh**



■ Conductivity and Total Dissolved Solids

Conductivity is an indirect measure of total dissolved solids (TDS) or ionic concentration. It is, however, much more rapid and convenient to use. A series of dual determinations of both were carried out at Patna, which provided a significant positive relationship that should be applicable to most waters of the Ganges Basin (Figure 3.7). If required the two may be inter connected according to this relationship. The range for these parameters is 164-361 μs which is equivalent to 80-186 mg l^{-1} TDS.

Conductivity will obviously be a function of the water in the system and the degree of evaporation taking place. Consequently, the conductivity is at a minimum when water level is at a maximum in August in the monsoons, and begins to rise as the waters fall and the dry season proceeds (Figure 3.9).

However this rise is not necessarily a simple pattern. For example, in 1994 at Patna, the peak in conductivity occurred in March even though the dry season continued throughout May. Within this period there was a measurable decline in conductivity (Figure 3.8). This could only come about if fresh water were being added to the system in the form of unseasonal showers or water upstream ultimately from snow-melt. The main decline comes with the monsoon in June.

This early peak or changes in conductivity, which almost certainly will produce detectable changes in the quality or "taste" of the water to the fishes, could provide early cues for migratory species. This may be particularly in combination with the rapid rise in temperature over the same pre-monsoon period. It is known, for example, that major carps need temperatures in excess of 22°C to spawn (Jhingran 1991), a threshold which is crossed in terms of mean temperature in March at Patna (Figure 3.6). Such features may be the early proximate stimuli needed to initiate gonad maturation and early upstream movement, bearing in mind that most of the migratory species show apparent movement before the onset of the monsoons (Section 5.2).

The same pattern for conductivity can be seen on the Yamuna at Gaughat (Figure 3.9), except that the conductivity peaks even earlier, in January, whilst in the Ganges proper at Shivkuti, it continues to rise until March (Figure 3.10).

■ Turbidity

A further factor which may provide information for fish is turbidity. Turbidity is largely caused by sediment suspended in the water. At Patna there is a clear seasonal cycle between water level and turbidity. With the early monsoons turbidity increases dramatically as the rains scour and erode sediment from the land into the rivers (Figure 3.11).

At this time also there is tremendous variation in turbidity, presumably in connection with rainfall events and their severity. Turbidity, however, peaks early in July when the river begins to flood beyond the main channel to produce more extensive, but less turbulent areas of water, from which the sediment can settle out. The turbidity then declines progressively through the high water period to reach its lowest levels between November and May. There is no sign of the increase in turbidity of the water during later April and May, which is so much a feature of the upland catchments where snow-melt has such a direct effect (Section 3.1.1).

Figure 3.6 **Seasonal changes in temperature and water level in the Ganga River at Patna, 1993-95**

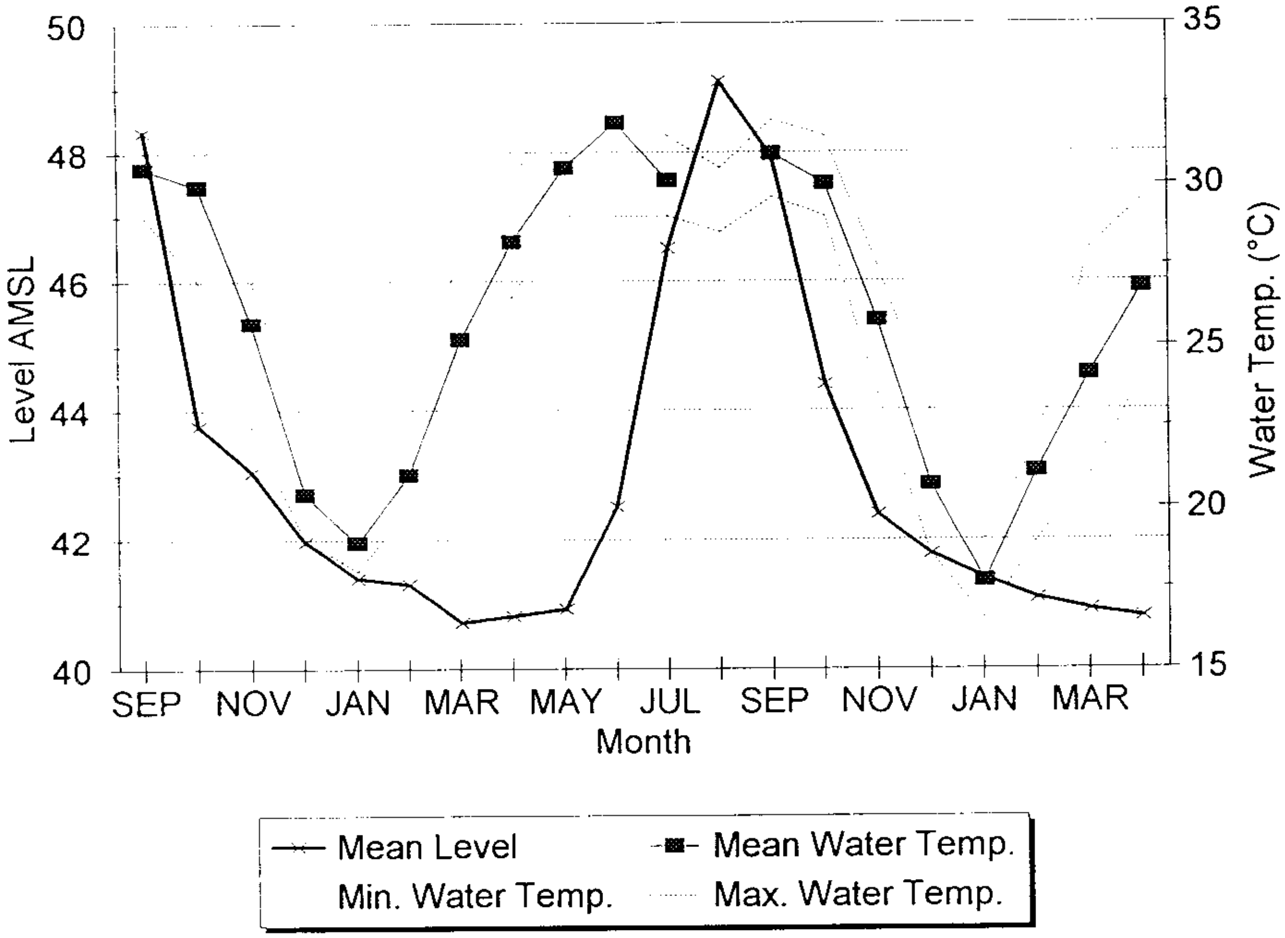


Figure 3.7 **Relationship between Conductivity (μs) to total dissolved solids (TDS) mg l^{-1} for Ganges River water**

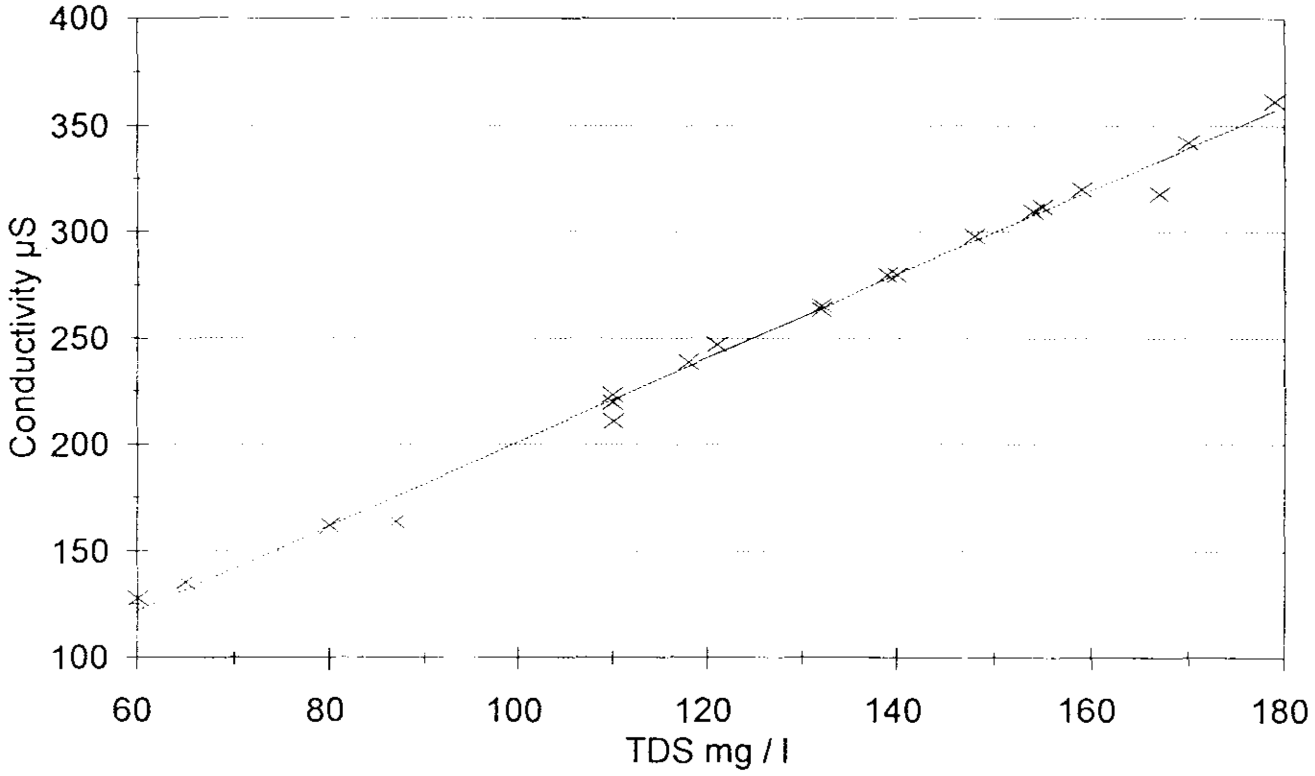


Figure 3.8 Changes in conductivity with water level on the Ganga River at Patna 1994-95

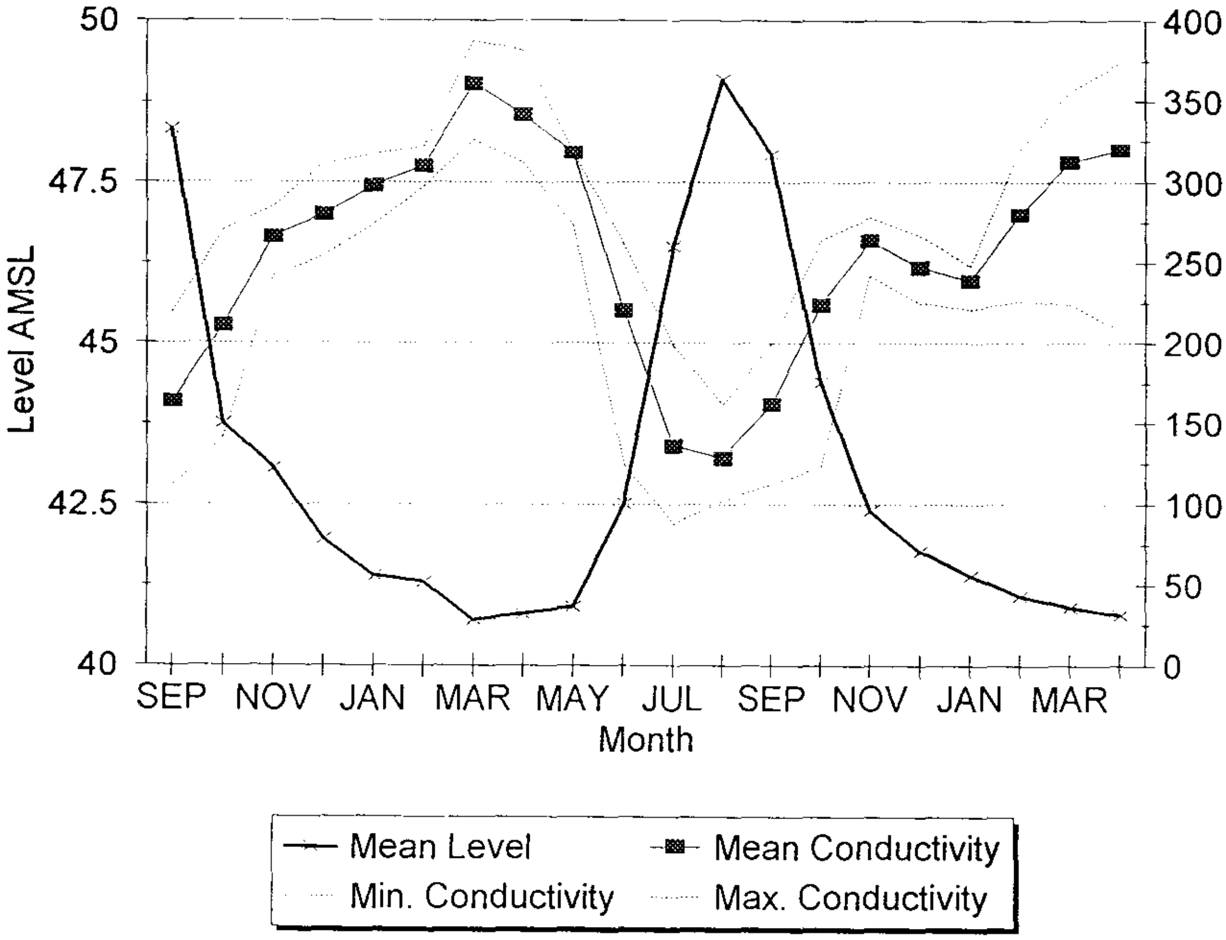


Figure 3.9 Changes in conductivity with water level on the Yamuna River at Gaughat, Allahabad, 1994-95

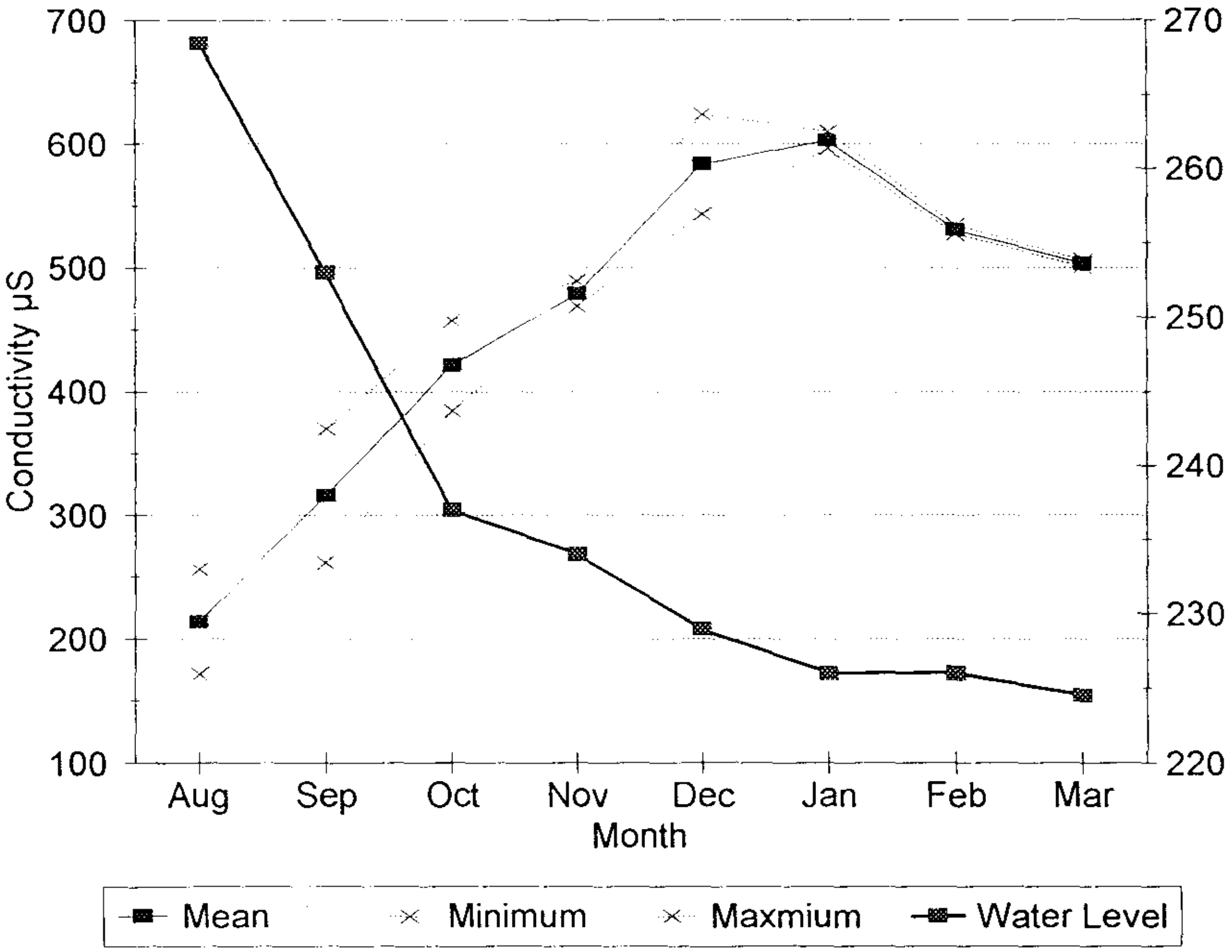
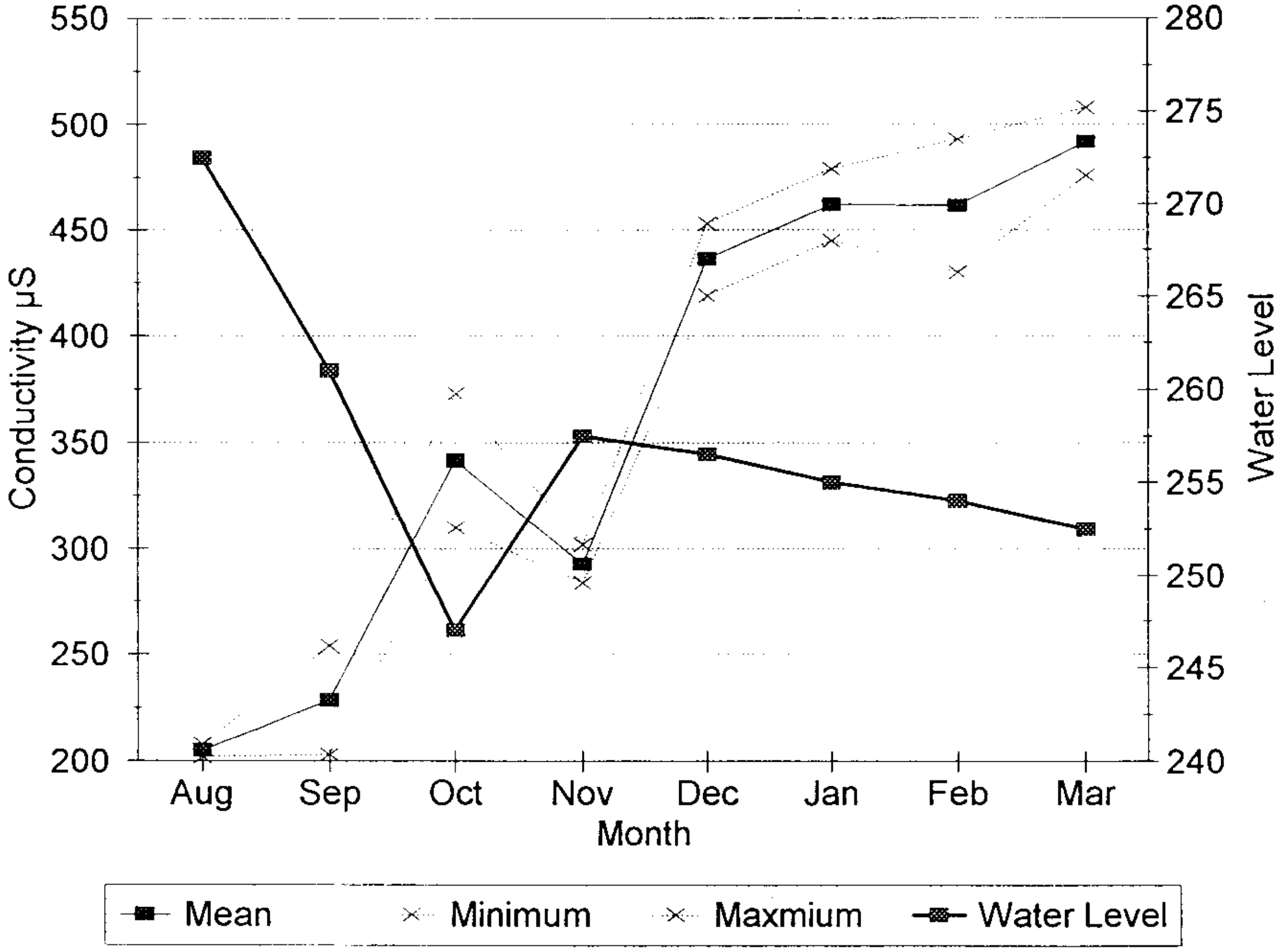


Figure 3.10 Changes in conductivity with water level on the Ganga River, Shivkuti, Allahabad, 1994-95



■ **General Relationships with Water Level**

All of the factors described above show regular seasonal changes which relate to the hydrological cycle. Applying regression analysis showed that very significant correlations existed between water level, conductivity and turbidity, and that predictive relationships could be derived (Table 3.6). This was not the case for water temperature which is overlain by the seasonal temperature cycle.

■ **Other Parameters**

Both pH and dissolved oxygen show some variation with season. The monthly average pH at Patna varies between 8.22 and 8.7 (Table 3.2), whilst in the Ganges at Allahabad, the range is 7.8 to 8.6 (Table 3.3) and in the Yamuna 7.7 to 6.4 (Table 3.4). All values are alkaline and unlikely to create problems for the fish community.

Mean monthly dissolved oxygen levels are always in excess of 6.2 mg l^{-1} at Patna (Table 3.2), 5.4 mg l^{-1} in the Ganges at Shivkuti (Table 3.3) and 6.0 mg l^{-1} in the Yamuna (Table 3.4). The absolute daily minimum value from all sites is 4.4 mg l^{-1}. These are not oxygen concentrations which are going to interfere with the metabolism or appetite of fishes.

The levels of biochemical oxygen demand (BOD) are all very low, suggesting relatively low suspended organic load. This, however, is discussed further in Section 6.2.

3.2.3 Flood Areas

In Bangladesh, up to 9 million ha will go under water during the flood season. Above the delta, however, much of the flooding is of char land, i.e. islands and sandbanks within clearly demarcated banks. A sketch map of the river at Patna at the height of the floods (Figure 3.12) shows that most of the areas to go under water are essentially those within the main channel of the river during the low water season (Figure 3.13).

The same is generally the case for both the Ganga and the Yamuna at Allahabad. This constitutes the major difference between the flood areas of the main stem of the Ganges and those of the delta regions in Bangladesh, and it has considerable implications for access to the fishery (Section 4.1) by people who essentially live around the floodplain rather than on it.

The wetlands of North Bihar constitute the floodplains of the northern Himalayan tributaries, particularly the Gandaki and the Kosi. They appear to be extensive floodplains like those of Bangladesh. They are poorly documented but it is clear that they absorb much of the flood impact of the Himalayan tributaries. For example, during the field visit in July 1993 there was catastrophic flooding of the north Bihar wetlands, largely due to the Gandaki bursting its banks, whilst the main stem of the Ganges at Pabna was at a very low level and there were almost drought conditions. The hydraulics of this system urgently require investigation.

Figure 3.11 Changes in turbidity with water level on the Ganges River at Patna, 1994-95

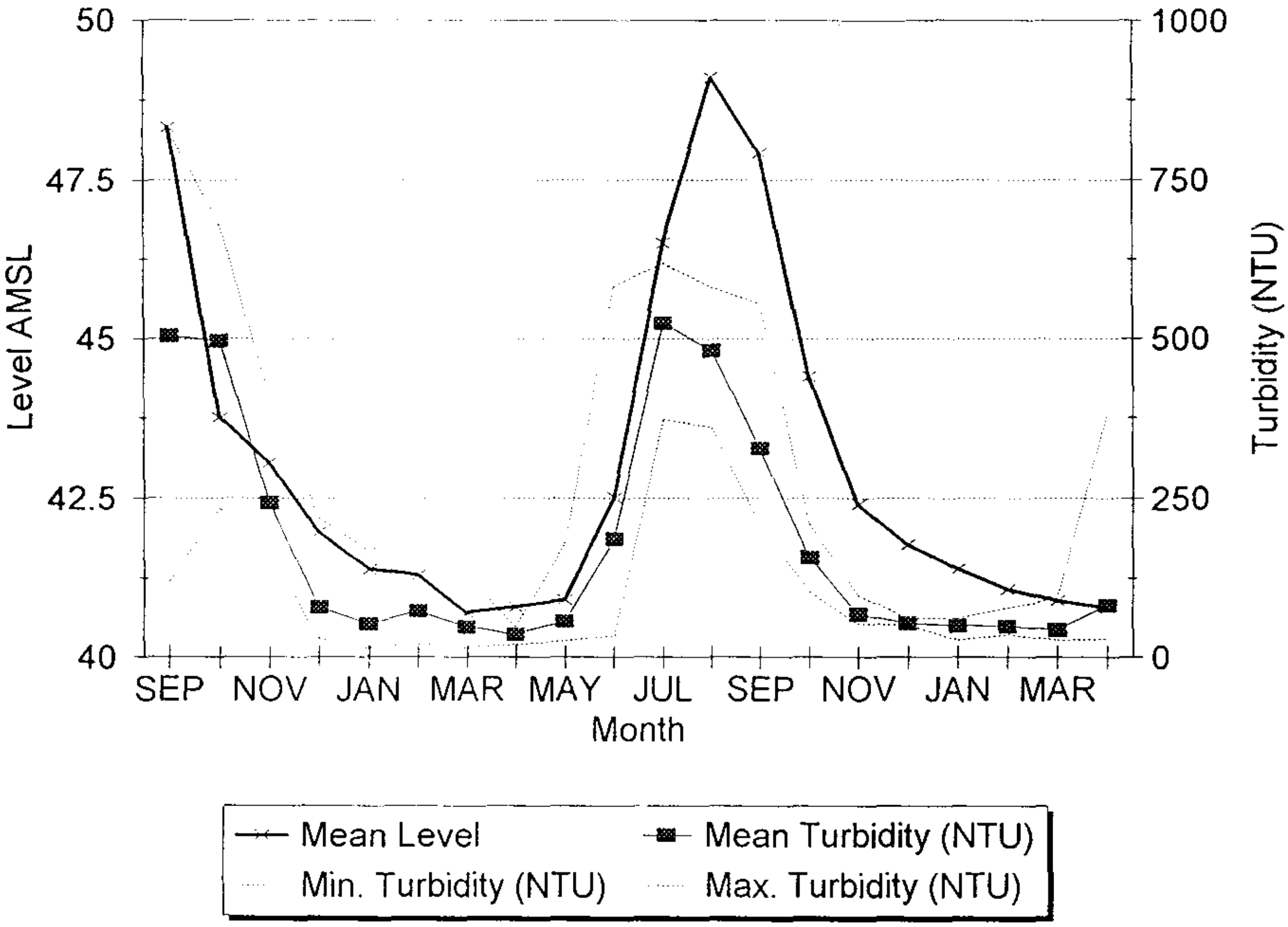


Table 3.6 Correlation and regression relationships between three parameters and water level on the River Ganges at Patna

Mean Values

Month	Air °C	Water °C	pH	Conductivity µS/m	TDS mg / l	Turbidity NTU	DO mg / l	BOD mg /l	Depth m	Level AMSL m	Water (Regr)	Conductivity (Regr)	Turbidity (Regr)
SEP		30.5	8.24	164	87	505.4	6.2	1.46	7.49	48.33	30.98	136.35	588.70
OCT	27	29.93	8.55	211	110	497	6.43	1.11	5.73	43.76	27.27	246.08	268.18
NOV	23.6	25.7	8.7	266	132	242	7.5	1.5		43.05	26.69	263.12	218.39
DEC	20.6	20.4	8.3	280	140	79.2	8.2	1.8	1.185	41.96	25.81	289.30	141.94
JAN	16.5	18.9	8.43	298	148	53.1	8.6	1	0.64	41.39	25.35	302.98	101.96
FEB	18	21	8.5	310	154	73		1.8	0.59	41.3	25.27	305.14	95.65
MAR	25.1	25.2	8.3	361.5	179	48.5	7.8	2.6	0.19	40.7	24.79	319.55	53.57
APR	30.4	28.2	8.3	342	170	36	7.2	1.4	0.064	40.8	24.87	317.15	60.58
MAY	32.4	30.5	8.3	318	167	56.9	6.7	1.1	0.136	40.91	24.96	314.51	68.30
JUN	33.2	31.9	8.22	220	110	186	6.4	0.8	1.72	42.5	26.25	276.33	179.81

Regressions

AMSL vs. Water Temperature (°C)

Regression Output:		
Constant		-8.24
Std Err of Y Est		4.63
R Squared		0.15
No. of Observations		10
Degrees of Freedom		8
X Coefficient(s)	0.81	
Std Err of Coef.	0.67	

AMSL vs. Conductivity (µS/m)

Regression Output:		
Constant		1296.78
Std Err of Y Est		31.03
R Squared		0.78
No. of Observations		10
Degrees of Freedom		8
X Coefficient(s)	-24.01	
Std Err of Coef.	4.50	

AMSL vs. Turbidity (NTU)

Regression Output:		
Constant		-2800.92
Std Err of Y Est		91.85
R Squared		0.78
No. of Observations		10
Degrees of Freedom		8
X Coefficient(s)	70.13	
Std Err of Coef.	13.33	

Figure 3.12 Sketch map of the River Ganges at Patna at peak of floods

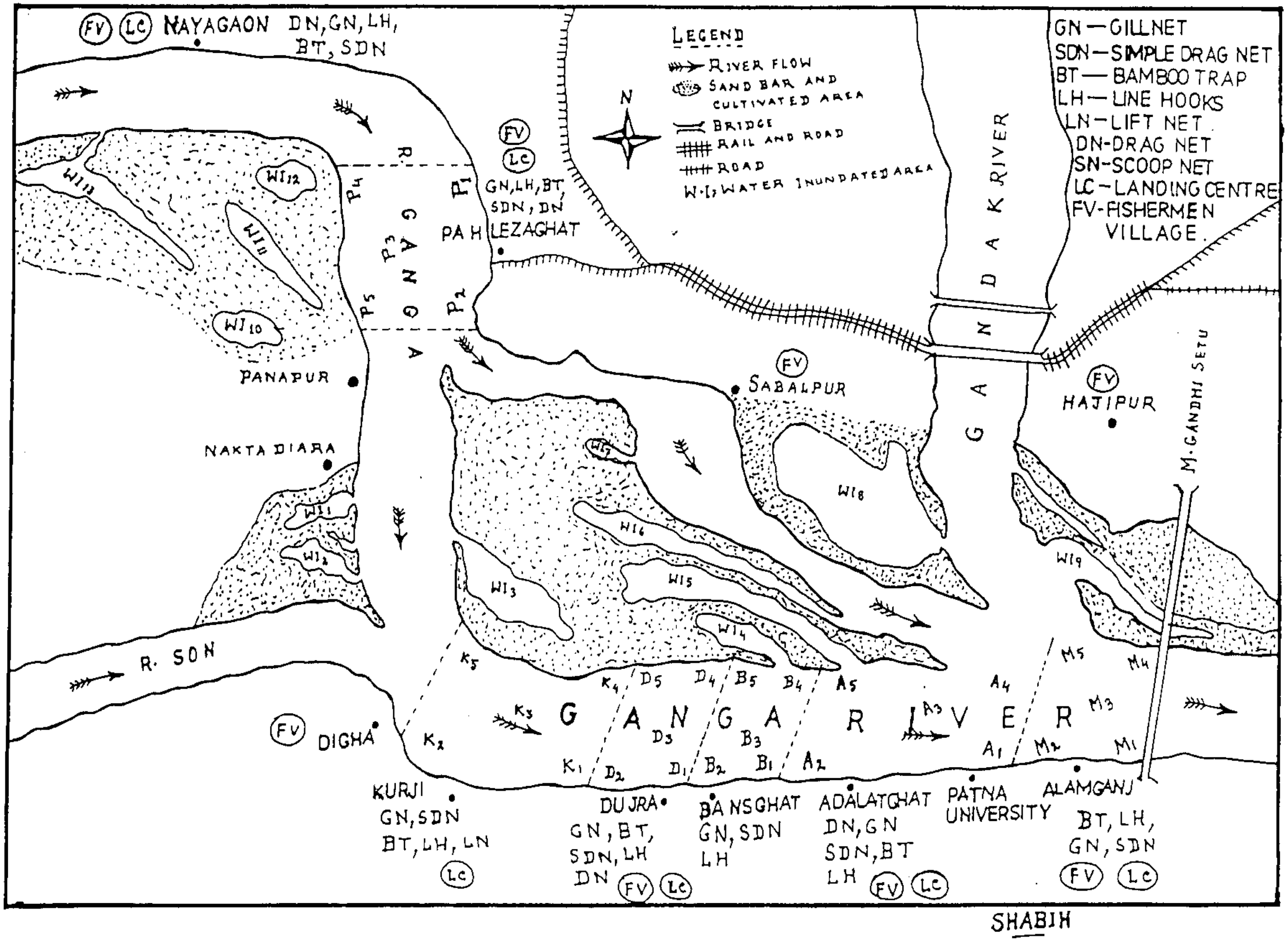
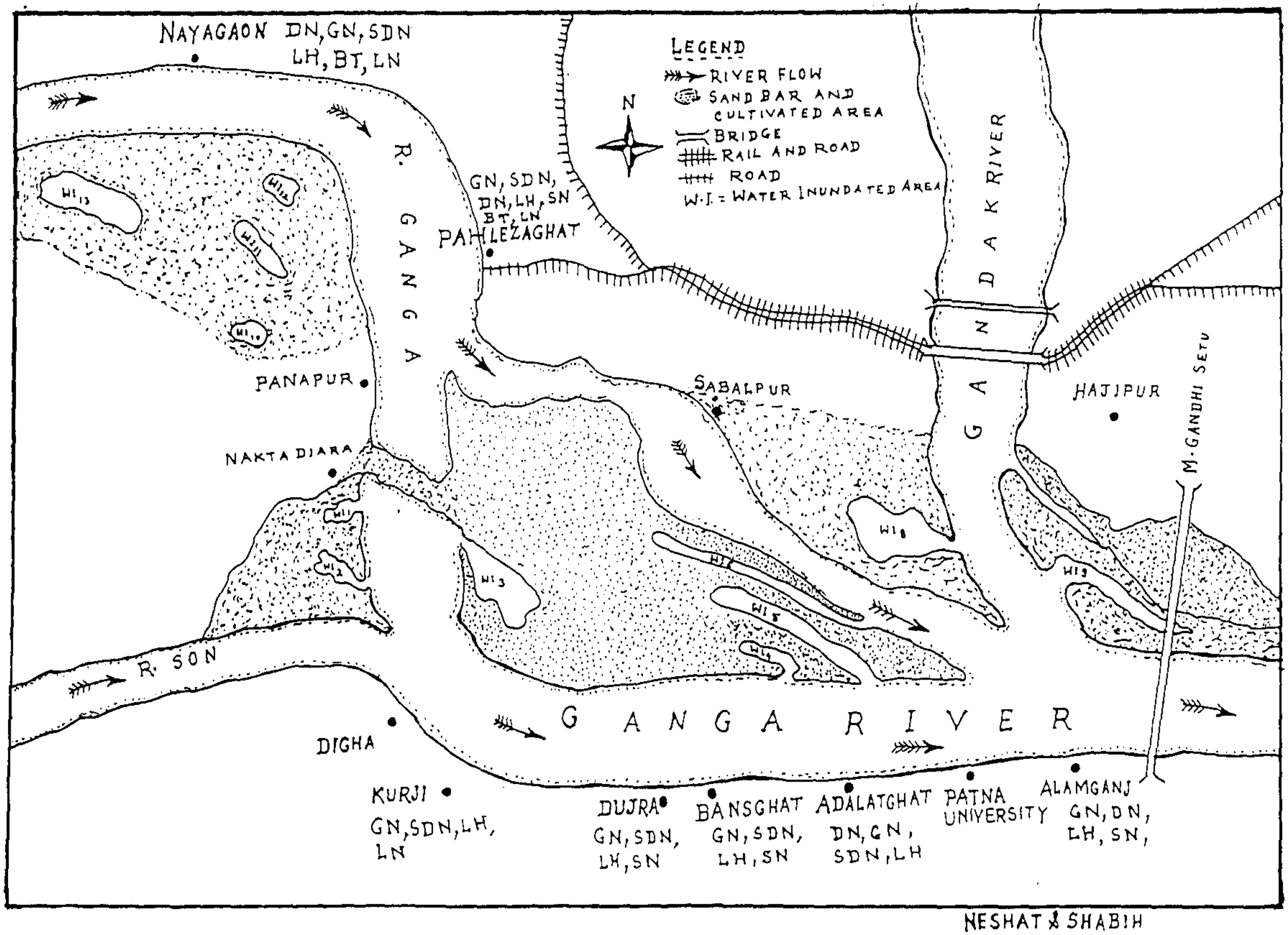


Figure 3.13 Sketch map of the River Ganges at Patna during low water season



4 ELEMENTS OF THE GANGETIC RESOURCES

4.1 SOCIO-ECONOMIC AND CULTURAL FRAMEWORK OF THE FISHERY

4.1.1 General features

The social and cultural constraints to the fisheries are perhaps one of the most unique features of the fisheries sector of the Ganges basin. This applies equally to marketing as well as production. Who catches fish and who buys fish is a function of social position, religious faith and geographical region.

The predominant faith of the people of the Ganges basin in India and Nepal is Hinduism. In Bangladesh, essentially an Islamic country, the majority of the professional fishermen are also Hindu, although this is changing (Temple and Payne 1995). There is a strong element of vegetarianism running through Hindu culture and the flesh of fish, fowl or domestic animals may be regarded as impure. For the priestly caste of the Brahmins it is completely forbidden and vegetarianism is also common in the other castes. This means that, away from the more cosmopolitan urban centres, there may not be an insatiable market for fish; the local markets may, in fact, be quite limited.

4.1.2 Limitations to Demand

In certain holy localities along the Ganges, the sale and consumption of fish and other flesh is strictly prohibited. This is particularly the case throughout the towns of Haridwar and Rishikesh, where the holy River Ganges first spills out onto the plains. Here no fish can be offered for sale. Similarly, along the two major pilgrimage routes from Rishikesh to the sacred head waters of the Ganges, one through Srinagar to Badrinath at the top of the Aleknanda River, and the second through Terai to the official source of the river at the Gangotri glacier, the sale of animal food, whilst not prohibited, is certainly not encouraged.

The market demand for fish throughout much of the Indian lowland sector of the basin is therefore very patchy. In the mountain regions of both Garhwal and Nepal, however, dietary proscriptions tend to be less marked and fish is more widely acceptable, when available, away from the pilgrimage routes.

The greatest exception to the limited demand for fish within the basin, however, is the region of Bengal. In this context, Bengal includes the Indian state of West Bengal as well as Bangladesh, an area which covers the whole of the Ganges / Bramhaputra delta. Bengalis are renowned throughout India as "the fish eaters". Unlike elsewhere in the basin, fish is often the preferred item of diet for the people of Bengal, for both Hindu and Muslim. At the heart of Bengal is Calcutta, a city of 12 million people, and it is Calcutta which creates the biggest demand for fish within the basin. It attracts fish imports from a wide area. Certainly fish from both Patna and Allahabad are despatched to Calcutta by rail. Interviews with fisheries officers at Udaipur in Rajasthan on the southern perimeter of the basin have indicated that even contractors there will put fish on ice and send it the 1500 km by rail to Calcutta, because of the limited demand in their own very traditional Hindu state.

The existence of Calcutta and the other few urban centres, combined with the relative lack of local and peripheral demand, serves to centralise the fish landing and distribution systems, at least in India. In Bangladesh, with its much more widespread demand and much higher participation amongst the rural people, the market is much more diffuse and difficult to assess.

4.1.3 Limitations to Fishing Activity

The social stratification which goes with Hinduism has a considerable influence upon potential fishing effort since it determines that only a very specific section of society can fish. The potential fishing effort or access to the fishery is, therefore, limited culturally. Within the traditional caste system there are four categories:

- Brahmin priests/teachers
- Chatryah warriors
- Vaishya traders
- Shudraothers

Fishing families inevitably find themselves in the fourth category and in fact comprise a particular sub-caste termed the "Nishad".

More recently, in India society has been re-divided into four categories:

- General category (GC)
- Scheduled castes (SC)
- Backward castes (BC)
- Other backward castes (OBC)

Once again the fishermen are included in the lowest, BC group. The clearly defined, but low, status of fishermen is a feature throughout India and Nepal. It is apparently unthinkable that members of any other caste would take up fishing. At present the demarcations of the caste system still have a strong hold, particularly in the lower orders, although occupational distinctions are breaking down to some degree amongst the upper castes.

There is no question that fishing in common property waters could ever become the virtual free-for-all as may be found in open access fisheries in Africa, for example.

In Bangladesh, the traditional fishermen are Hindu and almost all probably belong to the same category 4 sub-caste as those in India and Nepal. In recent years, however, Muslims have increasingly joined the profession (Temple and Payne 1995; FAP 17 1994). This has generally been due to the increasing pressure on the land as populations have expanded, with the consequent increase in those who become landless. The definition of landless generally used by NGOs and funding agencies are those owning 0.5 ha of land or less. One of the options of those who are landless is to become a fisherman and it is almost certainly this inexorable social and economic pressure which is driving Muslims into fishing. The participatory distinctions within Bangladesh are, therefore, breaking down under these pressures.

On the wider basis, the main distinguishing feature of the fishery in Bangladesh is the high degree of participation generally. In floodland areas it has been estimated that 75-85% of households fish at some time of the year (BCAS 1991). There may be 13 million people fishing on the floodplain. A factor in this is the traditional Bengali demand for fish, but the other contributory feature is the extensive and shallow nature of the floodplain which enables people to fish with low investment gears, such as traps, and without necessarily owning a boat.

Above the delta, i.e. above Farakka, the flooded river channel may be broad but it still remains within identifiable banks and does not give rise to extensive sheet flooding which regularly surrounds villages of the type seen in the delta. This generally means that an investment in a boat and / or specialist gear is required for significant participation in the river fishery. Both lack of accessibility and social distinction mitigate against casual participation with low cost gears in the main lowland region of the basin. The prevalence of boat ownership or need for access to a boat is demonstrated by the fact that more than 86% use boats, as shown by the Allahabad questionnaire survey (Table 4.1).

During the dry season, the exposed lands within the river channel are typically farmed to produce a "rabi" crop of horticultural produce such as tomatoes, cucumber and squashes. Around Patna these lands are owned by farmers and in fact fishermen have to pay a share of their income to the farmers when they fish over these lands during the flood season. As a group, the fishermen around Patna are essentially landless (Sinha: pers. comm.). Nevertheless, although technically professional fishermen by caste and inclination, many of the fishermen at Patna cannot derive their whole livelihood from fishing and also take part-time jobs, such as labouring at certain times of the year.

Around Allahabad, it is reported that many fishermen have received a small allocation of land, particularly from the floodlands within the river channel (H R Singh: pers. comm.). They again, therefore, are often not entirely reliant on fishing alone for their income.

In the hills and mountains of Garhwal and Nepal, there is a common pattern of participation. Wherever there is a settlement to create a demand and there are sufficient stretches of non-torrential water, there will be a few part-time fishermen. At Srinagar, for example, which is a substantial town, although also on one of the main pilgrimage routes, there are some 15 part-time fishermen fishing for themselves and to supply the local market.

At Sadiapur in Garhwal, a town noted for its mahseer fishery, there some are 17 fishing settlements downstream over the 25 km of the River Nayar. Over 5 km of the River Seti, around the village of Keshabatar in Nepal, 150 people may fish, particularly during the peak season of June-July. In all cases, however, the people who fish are essentially farmers who possess some land, but supplement their income to varying degrees. In the foothills and plains of the Terai, fishing in the rivers and streams is widespread with high demand and high participation.

The overall effect in the upland and mountain regions is of a perennial and significant fishery, carried on by a discrete body of people for their own consumption and for a rather patchy market. This fishery has certainly been underassessed and undervalued in the past and, although difficult, it is not unproductive (see Section 5.1).

One further feature which has emerged from interviews in the upland areas is the significant immigration of fishermen from the lowlands in recent years. In Srinagar, for example, it is reported that one of the fishing families supplying the local market, regularly migrates up from the coast near Bombay for five months of the year. In the town of Damali on the Seti River in Nepal, there are not only a large number of part-time local fishermen, but also some 25 Indian fishermen with larger cast nets from the lowlands, who dominate the local fishery.

Table 4.1 Distribution of access to boats amongst fishermen in villages from Allahabad Survey

Category	Respondent Frequency	Percentage of Total
1. Owned boat	158	69.40
2. Hired boat	43	18.18
3. No boat	5	2.16
4. Other	26	11.26
Total	**231**	**100.00**

Similarly, at the village of Malkau by the Trisuli River on the main Kathmandu / Indo-Nepal border road, where fish is always on offer for sale, there is a group of immigrant fishermen from the Terai / Bihar in permanent residence. Their reasons for leaving their homes in the lowlands where their families still reside, were given as too many fishermen and too low catches to provide a livelihood.

4.1.4 Limitations of Access

Access to the fisheries varies considerably within the basin, notwithstanding the role of social status. In the mountain areas, access is generally open, although practicable fishing sites may be limited.

Once again, religious practices also play a part in some instances. Major confluences within the Ganges tend to be particularly sacrosanct; fishing is forbidden and prohibition is respected. This is particularly the case at Devpryag, where the union of the Bhagirathi and Aleknanda first forms the Ganga (Ganges) main channel, and the Sangam at Allahabad, where the Yamuna meets the Ganga, the location of mass communal rites involving more than a million people every ten years. In addition, certain other holy places, such as the towns of Rishikesh and Haridwar also have complete religious bans on fishing.

Generally in the lowland areas of India and Bangladesh, until relatively recently, the allocation of fishing rights was through auction by government departments to contractors, or they were in private ownership. Contractors would then have the right to extract as much fish as possible during the year, and to do this they would generally sub-let the rights to active fishermen. This is a relict of the previous colonial system which was entirely revenue driven, with no question as to management of the resource. There was, in fact, a curious difference in attitude between the colonial services in Asia and Africa. In Africa there was always a science base to fisheries departments which tended to lead to the collection of statistics. The revenue-based approach of the colonial service in the sub continent merely awarded the fishery rights to the highest bidder and, apart from the sums received, no records of catches were kept. Consequently records have only become available following independence, from around the mid 1950s in the case of India, and systematically in Bangladesh from 1983. Much valuable information on the early status of the Gangetic fish stocks has therefore been lost.

The auction system still persists in many parts of the lowland basin. In India, all water and land resource rights tend to have been taken into public ownership, but private ownership still exists in Bangladesh. The situation varies from state to state. In Rajasthan the state Department of Fisheries still auctions river lots, whilst in Allahabad, Uttar Pradesh, auctioning does not take place. In Bihar, the state government discontinued the auction system five years ago with unforeseen consequences.

In Bangladesh, the fishing rights to the majority of water bodies are in the hands of the Revenue Department of the Ministry of Lands, which auctions these rights to middlemen. In 1988, there was a shift to a New Fisheries Management Policy (NFMP), which was to transfer the fishing rights from the Ministry of Lands to the Ministry of Fisheries and Livestock. Under the NFMP, the Department of Fisheries within the MOFL was to auction the rights but to give preference to active fishing groups rather than to middlemen. This policy has proceeded, although at present the majority of water bodies still come within the jurisdiction of the Ministry of Lands. There have been instances where the leases have been cancelled as an act of philanthropy, as was seen in BSKB beel in the south west region of the country in 1991. It was clear that those groups who were organised benefited from this, but those who were not easily fell under the influence of the middlemen who had legally been dispossessed. This seems to be a parallel to the experience at Patna where cancellation of the auction system without first assisting the fishermen to adjust and organise for new conditions, has left them prey to diverse illicit practices.

The upland regions appear to be divorced from such systems. In colonial times the upland rivers were considered only in terms of sport fisheries, particularly for the mahseers (*Tor* spp) and the introduced brown and rainbow trout. This still colours the approach to the upland river fisheries and has rather masked the significance of the robust subsistence and commercial fisheries that exist there.

4.2 FISH RESOURCES

The Ganges Basin encompasses some of the world's highest mountains within its catchment area and descends into one of the world's largest deltas. Within this range lies a considerable variation in habitats and environment (Section 3). Such a range should also be reflected in the diversity of fish communities. Ultimately, however, it is the nature and behaviour of the fish species in those communities which dictate the form and structure of the fishery. The fishermen must always follow the fish, both temporally and spatially. It has already been indicated that the rapid transition of the river from mountains to plain creates a marked change in the nature of the river and its temperature regime (Section 3.1).

To appraise the resources available throughout the Basin, representative species lists from different points in the Basin have been brought together (Table 4.2) to allow a full description and comparison to be made.

The Aleknanda (list 1) is the uppermost tributary of the main stem of the Ganges extending from 460 m amsl to 1600 m amsl where the fish zone probably ends. Surveys in Nepal have shown no fish records beyond 1650 m amsl in rivers (Shrestha 1978) and fisheries are generally not regarded as occurring beyond 1800 m amsl (Jha 1992).

Below this is the Upper Ganga with the sample in Table 4.2 being confined to Garhwal, i.e. 460-310 m amsl. The sample for the Kosi takes into account both lowland and upland species for the river as a whole. For comparison, the species actually found contributing to the lowland fisheries at Allahabad and Patna are also included, along with the carefully compiled species list for the lowest sector of the Basin, the Padma River in Bangladesh, where such extensive floodplains are found (FAP 17, 1994).

Thus in the freshwater sector of the whole, 161 species can be listed. Other species counts have included estuarine species or have been confined to one country of the Basin (e.g. Talwar, 1991). Of course not all rivers will contain all these species, since there is likely to be some geographic variation over such an extensive basin as this. Thus the number recorded for the Kosi (Table 4.2) is 103, that is 63% of the total.

The Aleknanda has the lowest number of species for any sector of the river. A total of 41, however, is still appreciable for a single, cold, upland river and gives an indication as to how relatively rich the cold upland faunas are.

An appraisal of the composition of this community in the Aleknanda shows it to be characterised by a few specialised cyprinid types, specifically the snow trouts, *Schizothorax / Schizothoraichthys* spp, and the small *Garra* spp, some of the mountain loaches *Noemacheilus* spp and the highly specialised sisorid torrent catfishes, *Glyptothorax* spp (Table 4.2). The torrent catfishes, *Glyptothorax*, are sufficiently specialised as to possess adhesive organs between the pectoral fins to allow them to stick to stones in the turbulent conditions. A typical day's fishing is likely to produce representatives of each of these groups, although the emphasis would always be upon the snow trouts and mahseers with regard to numbers.

The fish community of the Upper Ganga is very similar to that of the Aleknanda, although a few lowland species begin to appear, such as *Mastacembelus* and *Channa* (Table 4.2), so that the final species total is a little higher. Again, numerically the snow trout and mahseer would tend to dominate the fishery (Section 5.2).

The snow trouts and the mahseers are both migratory and it is essential to understand their movements in order to interpret the fishery. The snow trout *Schizothorax* migrates upstream and is reported to spawn in March to June at water temperatures ranging from 14°C to 21°C in the Himachal Pradesh (Negi 1994). It is generally regarded as tolerating waters from 8°C to 22°C. It lays its eggs in the gravel along the banks of streams in clear water of moderate current between a depth of 30-60 cm (Negi 1994). At Srinagar, in Garhwal Himalaya, spent individuals were found in mid-October, which may suggest a rather later or more protracted breeding season. At this time many tiny fry can be seen amongst the stones of the river bed. The stones themselves are covered with a film of algae and investigation of gut contents of the snow trouts shows them to consist entirely of green algal material. The fish evidently browse over the stones, scraping off the algae with their suctorial mouths. In this they resemble their con-familial *Labeo* species rather than the true salmonid, insect-eating trouts.

The mahseers have a not dissimilar migratory and spawning cycle, although the two major species do differ somewhat. The *Tor* mahseer, *Tor tor*, begins to migrate upstream towards the headwaters at the beginning of the monsoon and may spawn during a protracted period between July and September (Negi 1994). The general outline of the life history of the mahseer is shown in Figure 4.1.

The commonest mahseer tends, however, to be *Tor putitora* and there is considerable uncertainty as to the spawning cycle of this species. It is reported that there can be up to three spawning peaks per year, which can be January / February, May / June and August / September. In Garhwal Himalaya there is some dispute over the number of spawning seasons. The clear Narayani River acts as a spawning and nursery stream for *T. putitora*, with juveniles being present throughout the year.

However, length frequency analysis, using ELEFAN, of samples of migrating adults gave population growth parameters of K = 0.65 and $L\infty$ = 36.5 cm which produced the size at age matrix shown in Table 4.3. This indicates that size at age is approximately:

Year 1 17.8 cm
Year 2 26.8 cm
Year 3 31.4 cm
Year 4 33.8 cm
Year 5 35.1 cm
Year 6 35.8 cm

The longevity is approximately 6.5 years. If these characteristics are projected back to t^0 for the population, then the recruitment pattern is estimated, i.e. the point just after spawning when young fish become detectable. This shows two peaks, one in April and one in September, which would be consistent with two spawning periods, January / February and August / September (Figure 4.2) as reported by Negi (1992).

Curious absentees from the fauna of the Aleknanda and Upper Ganga are the brown and rainbow trouts. They have been introduced since 1910 (Negri 1992), but have failed to sustain any type of fishery. In the high altitude Himalayan rivers of Kashmir and Himachal Pradesh they have become sufficiently established to support fisheries as in the Beas River of the Kulu Valley. These, however, belong to the Indus Basin and it seems probable that the natural community of the upper Indus is less diverse than that of the Ganges. Consequently it may have been easier for the exotic trouts to become established within the upper Indus.

The snow trouts and mahseers also appear in the Kosi River list (Table 4.2), although in the upland sectors (Kahn and Kamal 1980). The list, however, becomes expanded by the inclusion of types typical of the lowland regions, such as the clupeid, schilbeid and bagrid catfishes, snakeheads and anabantids.

The fisheries of Allahabad and Patna comprise almost entirely lowland species, although *Tor* does appear at Allahabad. Even though all fish present may not appear in the fishery the number of species contributing is still very diverse. In these lowland areas species principally derived from estuarine types become significant, such as the sciaenid *Scieana coitor*, the mullets, *Rhinomugil corsula* and *Sicomugil cascasia*, and gobies such as *Glossogobius giurus*.

Within the river and floodplains it is possible to discern five different habitats in these lowland areas:

(i) The main channel of the river;

(ii) Those areas in the main channel which become flooded at high water, the Chaur land;

(iii) Those areas beyond the banks which constitute the extended floodplain, the dhab;

(iv) The channels which connect these to the main river, the kols; and

(v) The oxbow lakes or "maun" which are flooded only intermittently. The extent to which the species depend upon the river and the varying degrees of floodland can greatly influence potential composition of the catch.

Observations at Patna showed the associations demonstrated in Table 4.4. The most diverse single sector is the lowest portion of the basin in Bangladesh where 89 species were found to occur (Table 4.2.) No doubt, the spatial diversity offered by the river channels and extensive floodplains is a contributory factor but also the more tolerant of the estuarine fauna start to appear, such as the sales, *Cynoglossidae* and *Tetraodon.*

Table 4.2 Component fish species at various sites down the Ganges Basin

FAMILY NAME	SCIENTIFIC NAME	1	2	3	4	5	6
CYPRINIDS							
CYPRIDIDAE	*Schizothorax richardsonii*	✓	✓	✓			
	Schizothorax siniatus	✓	✓				
	Schizothorax plagiostomus	✓	✓				
	Schizothorax curvifrons	✓	✓				
	Schizothorax niger	✓	✓				
	Schizothorax intermedius	✓	✓				
	Schizothorax migropogon	✓	✓				
	Schizothoraichthys esocimus	✓	✓				
	Schizothorax annandalei			✓			
	Tor tor	✓	✓		✓		
	Tor putitora	✓	✓	✓			
	Tor chilinoides	✓	✓				
	Crossocheilus latius	✓	✓	✓		✓	✓
	Lissocheilus hexagonalepis			✓			
	Raiamas (Barilius) bola	✓	✓				✓
	Barilius everzardi						✓
	Barilius bardelensis	✓	✓				
	Barilius barna	✓	✓	✓			
	Barilius barilia	✓	✓	✓			
	Barilius vagra	✓	✓	✓			
	Barilius shacra		✓	✓			
	Garra prashadi	✓	✓				
	Garra lamta	✓	✓	✓			
	Garra annandalei			✓			
	Chagurius chaguri	✓	✓	✓		✓	
	Danio aequipinnatus		✓	✓			
	Danio vangila			✓			
	Danio devario	✓	✓	✓			✓
	Brachydanio rerio		✓				✓
	Rasbara daniconius		✓	✓			
	Labeo dero	✓	✓	✓			
	Labeo dynocheilus	✓	✓				
	Labeo boga		✓	✓			✓
	Labeo bata			✓	✓	✓	✓
	Labeo calbasu			✓	✓	✓	✓
	Labeo angra			✓			
	Labeo pangusia			✓			
	Labeo gonius			✓	✓	✓	✓
	Labeo sindensis			✓			
	Labeo rohita			✓		✓	✓
	Catla catla			✓		✓	✓
	Cirrhinus mrigala			✓		✓	✓
	Cirrhinus reba			✓		✓	✓
	Aspidoparia jaya			✓		✓	
	Aspidoparia morar			✓	✓	✓	✓
	Puntius chilinoides			✓			
	Puntius chola		✓	✓			✓
	Puntius chavatus			✓			
	Puntius conchonius		✓	✓			✓
	Puntius guganio						✓
	Puntius gelius			✓			✓
	Puntius sarana		✓	✓		✓	✓
	Puntius sophore		✓	✓		✓	✓
	Puntius ticto		✓	✓		✓	✓
	Puntius phuntunio		✓				✓
	Puntius terio						✓
	Puntius spp.				✓		
	Hinblypharygodon mola			✓		✓	✓

Table 4.2 continued

FAMILY NAME	SCIENTIFIC NAME	1	2	3	4	5	6
	Chela lanbuca			✓		✓	✓
	Chela cochius						✓
	Oxygaster argentea			✓			
	Oxygaster bacoila			✓	✓	✓	✓
	Oxygaster gora			✓			
	Oxygaster phulo			✓			✓
	Esomus danricus		✓				✓
	Osteobrama cotio			✓	✓	✓	✓
PSILORHYNCHIDAE	*Psilorhynchus pseudochensis*			✓			
	Psilorhynchus balitora						✓
HOMALOPTERIDAE	*Balitora brucei*			✓			
COBITIDAE	*Botia dayi*			✓			
	Botia dario	✓	✓			✓	✓
	Botia histrionica			✓			
	Botia cohachata			✓			
	Botia geto	✓					
	Noemacheilus botia		✓	✓			✓
	Noemacheilus montanus	✓	✓				
	Noemacheilus repicola	✓	✓	✓			
	Noemacheilus bevani	✓	✓				
	Noemacheilus savona	✓	✓	✓			
	Noemacheilus multifasciatus	✓	✓				
	Noemacheilus scaturigina		✓	✓			
	Noemacheilus zonatus	✓					
	Noemacheilus corica						
	Lepidocephalus guntea	✓	✓	✓		✓	✓
	Acanthophthalmus pangia			✓			
	Lepidocephalus annadalei			✓			
AMPHIPUOIDAE	*Amphipuous cuchia*			✓			✓
CATFISHES							
AMBLYCEPTIDAE	*Amblyceps mangois*	✓	✓	✓			
SISORIDAE	*Glyptothorax cavia*	✓	✓	✓			
	Glyptothorax pectinopterus	✓	✓				
	Glyptothorax madraspatanium	✓					
	Glytothorax annandalei			✓			
	Glyptothorax horai			✓			
	Glyptothorax telchitta			✓		✓	✓
	Glyptothorax trilineatus	✓					
	Glyptothorax brevipinnis	✓	✓				
	Glyptothorax conirostris	✓	✓				
	Pseudecheneis sulcatus	✓	✓	✓			
	Hara jendani						
	Hara hara						
	Bagarius bagarius			✓	✓	✓	✓
	Gogata cenia			✓	✓	✓	✓
	Gotata nangra			✓			✓
	Gogata viridescens			✓			✓
	Gogata youssouli						✓
SCHILBEIDAE	*Clupisoma montana*			✓			
	Clupisoma garua	✓	✓	✓	✓	✓	✓
	Clupisoma naziri						✓
	Eutropichthys vacha			✓	✓	✓	✓
	Ailia coila			✓	✓	✓	✓

Table 4.2 continued

FAMILY NAME	SCIENTIFIC NAME	1	2	3	4	5	6
	Pseudeutropius atherinoides			✓		✓	✓
	Silonia silondia			✓	✓	✓	✓
	Pangasius pangasius				✓		✓
BAGRIDAE	*Aorichthys aor*			✓	✓	✓	✓
	Aorichthys seenghala			✓		✓	✓
	Mystus bleekeri			✓			✓
	Mystus cavasius					✓	✓
	Mystus vittatus		✓	✓		✓	✓
	Mystus tengra				✓	✓	✓
	Rita rita			✓		✓	✓
	Leiocassis rama			✓	✓		
SILURIDAE	*Wallago attu*			✓	✓	✓	✓
	Ompok bimaculatus						✓
	Ompok pabda					✓	✓
HETEROPNEUSTIDAE	*Heteropneustes fossilis*			✓		✓	✓
CLARIIDAE	*Clarias batrachus*			✓		✓	✓
CLUPEIFORMES (Herrings)							
NOTOPTERIDAE	*Notopterus notopterus*			✓	✓	✓	
	Notopterus chitala				✓	✓	✓
EUGRAULIDAE	*Setipinnia phasa*			✓	✓	✓	✓
CLUPEIDAE	*Gudusia chapra*			✓	✓	✓	✓
	Hilsa ilisha				✓	✓	✓
	Corica soborna						✓
MASTACEMBELIDAE	*Mastacembelus armatus*		✓	✓	✓	✓	✓
	Magrogrognathus aculeatus			✓		✓	✓
CHANNIDAE	*Channa punctatus*			✓	✓	✓	✓
	Channa striatus			✓		✓	✓
	Channa marulius			✓		✓	✓
	Channa orientalis			✓			✓
	Channa gachua		✓				
MUGILIDAE	*Rhinomugil corsula*			✓	✓	✓	✓
	Sicamugil cascasia					✓	✓
	Liza parsia						✓
BELIDONIDAE	*Xenentrodon cancila*			✓	✓	✓	✓
CYPRINODONTIDAE	*Apolcheilus panchax*			✓			✓
GOBIIDAE	*Glossogobius giurus*			✓		✓	✓
	Brachygobius nunus						✓
	Awaous stamineus						✓
	Apocryptes bato						
ANABANTIDAE	*Colisa fasciatus*			✓	✓		✓
	Colisa lalia			✓			✓
	Colisa sota						✓
	Colisa labiosus						✓
	Anabas testudineus					✓	✓

Table 4.2 continued

FAMILY NAME	SCIENTIFIC NAME	1	2	3	4	5	6
CENTROPOIMIDAE	*Chanda nama*			✓		✓	✓
	Chanda ranga			✓			✓
	Chanda baculis						✓
NANDIDAE	*Nandus nandus*			✓			
PRISTOLEPIDAE	*Badis badis*						✓
SCIAENDIDAE	*Sciaena coitor*			✓	✓	✓	✓
	Pama pama						✓
CYNOGLOSSIDAE	*Cynoglossus*						✓
	Euryglossapan						✓
TETRODONTIODE	*Tetraodon cutcutia*			✓		✓	✓
TOTAL NUMBER OF SPECIES	**161**	41	54	103	30	56	93

Key:

1. Aleknanda River	altitude, 460-1500 m	(Singh et al 1987)
2. Upper Ganga River, Garhwal	altitude 70-600 m	(Singh et al 1987)
3. Kosi River	altitude 70-600 m	(Khan and Kamal 1980)
4. Allahabad fishery	altitude 82 m	
5. Patna fishery	altitude 37 m	
6. Padma River Bangladesh (Ganges)	altitude 30 m	(FAP 17 1994)

Figure 4.1 Life Cycle of the mahseer, *Tor putitora*

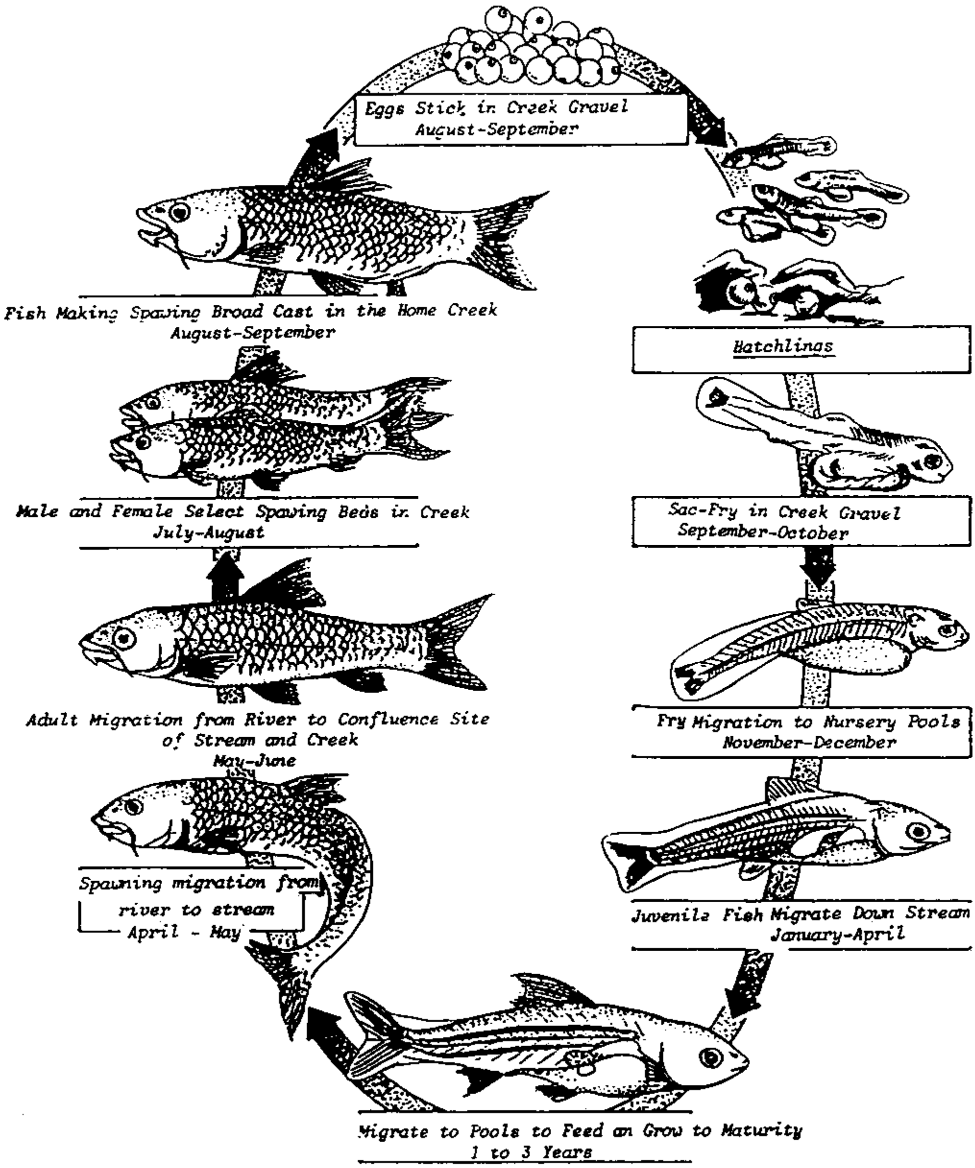


Table 4.3 Growth characteristics as total length (cm) for each month, from length frequency analysis of the adult mahseer, *Tor putitora*, in the Narayani tributary of the Upper Ganges River

Bertalanaffy growth curve fitted to the data

Growth Parameters: K = 0.65
Loo = 36.5
C = 0
WP = 0

Starting point: Sample 1, Length 12

Growth curve points (Length) for the 15th of each month

Month	1	2	3	4	5	6	7	8	9	10	11	12
Year											0.8	2.6
	4.4	6.2	7.6	9.2	10.6	12.0	13.3	14.5	15.7	16.8	17.8	18.8
	19.8	20.7	21.4	22.2	23.0	23.7	24.4	25.0	25.6	26.2	26.8	27.3
	27.8	28.2	28.6	29.1	29.4	29.8	30.2	30.5	30.8	31.1	31.4	31.7
	31.9	32.2	32.4	32.6	32.8	33.0	33.2	33.4	33.5	33.7	33.8	34.0
	34.1	34.2	34.4	34.5	34.6	34.7	34.8	34.9	35.0	35.0	35.1	35.2
	35.3	35.3	35.4	35.4	35.5	35.6	35.6	35.6	35.7	35.7	35.8	35.8
	35.9	35.9	35.9	35.9	36.0	36.0	36.0	36.1	36.1	36.1	36.1	

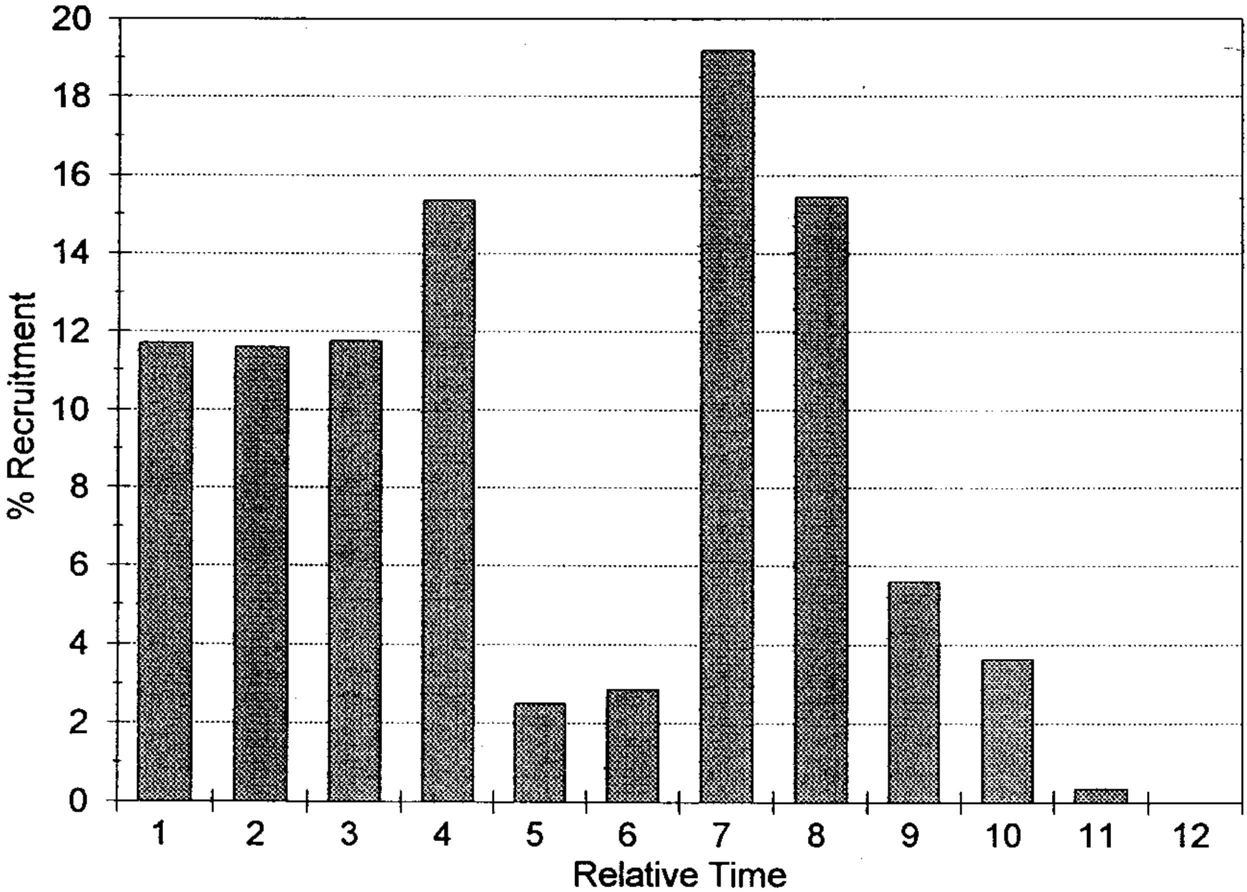
Table 4.4 List of fishes which can survive in different ecological conditions observed at Patna 1994-95

SPECIES	RIVER	FLOOD PLAIN (CHAUR LAND)	WATER INUNDATED AREA ALONG THE RIVER BED		
			KOL	DHAB	MAUN
Hypolophus sephen (Fors)	+	—	—	—	—
* *Notopterus chitala (Harm.)*	+	+	+	—	—
N. notopterus (Pallas)	+	+	+	—	—
* *Gudusia chapra (Ham.)*	+	+	+	—	—
* *Hilsa ilisha (Ham.)*	+	—	+	—	—
* *Gonialosa manmina (Ham.)*	+	+	+	—	—
G. modestus (Day)	+	—	—	+	—
* *Setipinna phasa (Ham.)*	+	+	+	—	—
* *Setipinina brevifilis (Vab.)*	+	—	+	—	—
* *Catla catla (Ham.)*	+	+	+	+	+
Chagunius chagunio (Ham.)	+	—	+	+	—
* *Cirrhinus mrigala (Ham.)*	+	+	+	—	+
* *C. reba (Ham.)*	+	+	+	+	+
* *Labeo bata (Ham.)*	+	+	+	+	+
* *L. calbasu (Ham.)*	+	+	+	+	+
* *L. gonius (Ham.)*	+	+	+	—	+
L. pangusia (Ham.)	+	—	+	+	—
* *L. rohita (Ham.)*	+	+	+	+	+
Osteobrama cotio cotio (Ham.)	+	+	+	—	—
Puntius chola (Ham.)	+	—	+	—	—
P. conchonius (Ham.)	+	—	+	—	—
P. phutunio (Ham.)	+	—	+	—	—
P. sarana sarana (Ham.)	+	+	+	+	+
* *P. sophore (Ham.)*	+	+	+	+	+
* *P. ticto (Ham.)*	+	+	+	+	+
Tor tor (Ham.)	+	—	—	—	—
Chela cachius (Ham.)	+	+	+	—	—
Chela laubuca (Ham.)	+	+	+	+	+
* *Salmostoma bacaila (Ham.)*	+	+	+	—	—
Securicula gora (Ham.)	+	+	+	—	—
* *Amblypharyngodon mola (Ham.)*	+	+	+	—	—
* *A. microlepis (Bleeker)*	+	+	+	—	—
* *Aspidoparia jaya (Ham.)*	+	+	+	+	—
* *A. morar (Ham.)*	+	+	+	+	+
Danio dangila (Ham.)	+	+	+	—	—
D. devario (Ham.)	+	+	+	—	—

Table 4.4 continued

SPECIES	RIVER	FLOOD PLAIN (CHAUR LAND)	WATER INUNDATED AREA ALONG THE RIVER BED		
			KOL	DHAB	MAUN
Esomus danricus (Ham.)	+	—	+	—	—
Parluciosoma daniconius (Ham.)	+	+	+	—	—
Raiamas bola (Ham.)	+	—	+	—	—
Rasbora rasbora (Ham.)	+	+	+	—	—
* *Crossocheilus latius latius*	+	+	+	—	—
Garra gotyla gotyla (Gray)	+	—	+	—	—
G. annandalei (Hora)	+	—	—	—	—
Nemacheilus botia (Ham.)	+	+	+	+	—
* *Lepidocephalus guntea (Ham.)*	+	+	+	—	—
* *Botia dario (Ham.)*	+	+	+	—	—
B. lohachata chaudhury	+	+	+	—	—
* *Aorichthys aor(Ham.)*	+	+	+	+	—
* *A. seenghala (Sykes)*	+	+	+	+	—
Mystus bleekeri (Day)	+	—	—	—	—
* *M. cavasius (Ham.)*	+	—	+	+	—
M. menoda (Ham.)	+	—	—	—	—
* *M. tengara (Ham.)*	+	+	+	+	+
* *M. vittatus (Bloch)*	+	+	+	+	+
* *Rita rita (Ham.)*	+	—	—	—	—
Ompok bimaculatus (Bloch)	+	—	—	—	—
* *O. pabda (Ham.)*	+	—	—	—	—
* *Wallago attu (Schneider)*	+	+	+	+	+
* *Ailia coila (Ham.)*	+	—	—	—	—
* *Clupisoma garua (Ham.)*	+	—	—	—	—
Eutropichthys murius (Ham.)	+	—	—	—	—
* *E. vacha (Ham.)*	+	—	—	—	—
* *Pseudeutropius atherinoides (Block)*	+	+	+	+	—
* *Silonia silondia (Ham.)*	+	—	—	+	—
Pangasius pangasius (Ham.)	+	—	—	—	—
* *Bagarius bagarius (Ham.)*	+	—	—	—	—
* *Gagata cenia (Ham.)*	+	+	+	—	—
Erethistes pussilus (Mull & Tres.)	+	+	+	+	—
Glyptothorax telchitta (Ham.)	+	—	+	—	—
Hara hara (Ham.)	+	—	—	+	—
Hara jerdoni (Day)	+	+	+	—	—
Nangra nangra (Ham.)	+	+	+	—	—
* *N. viridescens (Ham.)*	+	+	+	+	—
Sisor rhabdophorus (Ham.)	+	—	+	+	—
Clarias batrachus (Linnaeus)	+	+	—	+	+
* *Heteropneustes fossilis (Bloch)*	+	+	+	+	+
Chaca chaca (Ham.)	+	—	+	—	—
Hyporhamphus limbatus (Valon)	+	+	—	+	—

Figure 4.2 Recruitment pattern of the mahseer, *Tor putitora*



5 FISHERIES

5.1 UPLAND FISHERIES

5.1.1 General characteristics

The hill and montane fisheries of Garhwal and Nepal all basically exploit the cold water fish communities defined in Section 4.2. These may extend a little way out into the plains so that, for example, snow trout were seen caught by fishermen at Naryanghar (altitude 180 m amsl), where the Narayani / Gandaki river has issued into the plains. Similarly they are known to occur at Haridwar (altitude 310 m amsl). In the snow-fed, turbid, colder tributaries, such as the Trisuli, Son Kosi and Aleknanda, the predominant species are snow trout, most commonly *Schizothorax richardsonii*, augmented seasonally by mahseer (*Tor* spp.). Those clearer, spring-fed tributaries arising at somewhat lower altitudes tend to possess a more varied community as well as being important spawning grounds for such of the colder water species, particularly the mahseers.

5.1.2 Fishing methods

The fast flowing and torrential waters of the upland regions create specific problems for fishermen. Even the main stem of the Ganges, from Devpryag to Rishikesh moves through deep rocky ravines and valleys with difficult access. In their passage through the Siwalik and Maharabat Hills, however, there are meandering regions. At Srinagar itself, for example, the valley floor is relatively flat, giving a braided and meandering channel with a stony bed for over 15 km. A number of fishing techniques have been devised to deal with these varied physical conditions.

- **Cast net**

This is perhaps the single most widely employed gear, although its use is confined to the flatter meanders and the lower altitude tributaries. It has been observed in use in rivers to an altitude of 900 m, where water flow can be quite rapid. It is difficult or impossible to use during the high water period from July to September.

- **The Fase, Paso or mountain "gill net"**

This is one of the most ingenious devices for fishing in waters of fast-flowing, hilly conditions. It consists of a cord long line of 30-50 m with a monofilament nylon trace about 50 cm, each of which terminates in a noose tied with a slip knot. The line with its series of nooses is weighted to the bottom by rocks tied at each end. Fish regularly seem to put their heads into these nooses which slide and tighten behind the gills. Snow trout are particularly susceptible to this method and most offered for sale show the tell-tale constriction around the head or thorax. Whether the snaring of the fish is accidental and random or whether the movement of the trace and loop in the current actually attracts the fish remains to be seen.

It does, however, work very well under the conditions as well as being cheap and capable of being used in more difficult conditions than those suitable for a cast net.

Whilst this method is used extensively in the upper basin of Garhwal, where it is termed the "fase", in the uplands of Nepal where it is called the "paso", its use seems to be restricted to certain rivers. It has only been seen in action in the Sun Kosi in the east of the country and the fishermen say that it is also used in the main Kosi River as well as in the Tamur. In general, it may be described as a loop long-line.

On the Trisuli River a related technique is in use. Here, fishermen will use rod and line with a pair of nooses, rather than hooks, on the end of the line. Again, snow trout are the commonest species caught. Fishermen on the Sun Kosi River list the following species as the most common taken by the paso method.

asala	*Schizothorax* (snow trout)
kabreh	*Glyptothorax horai*
hileh	*Channa* (snakehead)
catleh	*Acrossocheilus hexagonolepis* (copper mahseer)

Catfishes with longer, sensitive "whiskers" are said to be less susceptible.

- **Dynamite**

The use of dynamite is common in the upland fisheries. It is perhaps more prevalent in India than in Nepal, where dynamite seems to be more widely available, but it is difficult to obtain quantified estimates. The attraction of dynamite in these upland river conditions is that, amongst other things, it can be used even in deep, fast flowing waters which are unsuitable for other methods. Typically, a stick is broken in half with one section being tied to a medium sized stone with strips of cloth. The percussion cap and fuse are inserted into a hole made in the stick with a twig. After the fuse is lit with a cigarette, the weighted dynamite is tossed into the water.

Sometimes apparently, stop nets may be used downstream to catch the fish. This, however, is often impossible because of the current and in all cases observed, the fishermen merely dive into the water to catch the dead and stunned fish by hand. Under these conditions it is a very hazardous operation. It is also very wasteful, since the fishermen need to locate and catch the fish in very turbid water, whilst both man and fish are being carried downstream extremely rapidly. The usual indiscriminate damage, both physical and biological, done by the dynamite is apparent. In shallower pools the effect can be devastating.

The use of dynamite is illegal in both India and Nepal, but is widely carried out.

- **Electricity**

Perhaps the most bizarre method of coming to terms with the turbulent, fast flowing conditions is the use of high tension cables for electro-fishing. It is commonly reported that insulated wires are clipped into overhead cables and the bare ends put in the water. The mortality rates within fish populations or amongst fishermen employing the method is unknown. The use of electricity for fishing must be a relatively common phenomenon, since the sign for the fishermen's cooperative at Begnas Lake near Pohkara in Nepal specifically bans it. At Dolalghat on the Indrawati the use of car batteries for electro-fishing was mentioned, although this must presumably be for shallow pools or isolated shallow regions.

- **Traps**

A variety of basket traps are used, largely in the flatter, shallower areas of rivers. Sometimes they may be employed in series, as they are across the junction of the Seti and the Trisuli in Nepal, but are otherwise used singly. They may also be used in combination with diversion of a water channel, particularly where the river bed and bands are sandy, or where water is being drained from rice fields. The use of traps is particularly common in the Terai. Amongst the fishermen of Garhwal the "goda", a conical basket trap of about 1 m in length, is commonly used. Refuge traps, consisting of bundles of sticks tied together and sunk in the bottom of a pool have also been seen in Garhwal.

■ **By hand and physical stunning**

Searching for fish in pools amongst rocks is casually practised, and the technique used appears to be similar to the "tickling" of trout. This can be augmented by first hitting the rock hard with a hammer so that the resulting shock waves stun the fish sheltering under the rock.

5.1.3 Garhwal Himal

■ **Aleknanda-Srinagar-Devpryag**

This comprises a stretch of the river Aleknanda up to the point where it meets the Bagirathi to form the main channel of the Ganga. Fishing is prohibited at the confluence of Devpryag itself owing to the sacred nature of this point. Over this region the river falls from 600 m amsl to around 460 m amsl in altitude and the river alternates between flowing through deep gorges and a few flatter areas, the most narrow of which is around Srinagar itself. Access is physically difficult in many places and most fishing activity is centred around the few small villages and settlements along the banks over a 30 km stretch. The larger of these settlements were surveyed. The village of Meleta lies some 5 km downstream of Srinagar. The village contains 150 families of which 10-15 families carry out fishing at some time of the year. This includes some of the schedule castes (SC). Fishing is centred around a 0.5 km stretch of river and takes place only from October to March/April, that is, during the low water season. It is largely carried out by cast net and no dynamiting has been observed along this stretch. Mainly snow trout and mahseer of weights between 0.5 and 1.5 kg are taken. A fisherman can catch 2-3 kg per day whilst, on average, 10-12 kg of fish may be taken in total from this stretch of river during the major season of October to March. The fishermen say that fish lay their eggs in pools along the river in February and March. This presumably refers to the snow trout, since these have been generally found to spawn from March to May elsewhere in the Himalayas (Negi 1994), rather than the mahseers which spawn in the autumn.

From the village of Juyalgarh fishing is carried out over a 2 km reach of the river. The village contains 35-40 families of which 15 carry out some fishing. The commonest gear is the cast net, catching largely mahseer and snow trout up to around 1.5 kg. In addition, *Glyptothorax* and *Labeo* may also feature in the catches. A daily catch per fisherman can be typically 2 kg with a total for any one village being of the order of 15 kg. Most of the fish is consumed within the village. Fishing is often an activity adopted by men otherwise unemployed. It is generally observed that the fish lay their eggs in the quieter stretches of water.

Lachmoli village lies 17 km downstream of Srinagar. There are 50 families living there with a total 214 people, of which only 7-8 families do any fishing. Catches are predominantly of mahseer and snow trout taken largely over the winter from September to April. The main fishing area extends over a 2-3 km stretch of river and the daily catch for the village would be 10-12 kg per day. Again, the typical size of mahseer caught was around 1.5 kg, with a length of around 30 cm. Some fish may be taken for sale to Srinagar or Bagwan markets. All the fishermen here also have farms with buffaloes or cows, and fishing is therefore basically a supplement to their existence.

■ **Tilwara - Rudapryag**

A stretch of the Mandakini River above its junction with the Aleknanda some 18 km above Srinagar were examined, although a long period of political unrest in the region prevented more extensive enquiries. The altitudinal range is 600-840 m amsl. The river is smaller than the Aleknanda and very turbid from snowmelt. Many of its tributaries are shallow, clear, spring-fed streams of the type favoured by mahseer and snow trout for spawning. These clear streams have a rich benthic fauna of mayfly nymphs, such as *Ecdyonurus* which will supply rich feeding as nursery grounds.

A preliminary survey in a river with a cast net produced six species of fish weighing perhaps 3 kg in total, over half an hour. The species included the mahseer (*Tor*), two species of *Schizothorax* including *S. richardsonii*, a species of *Schizothoraichthys* (*S. progastus*), one species of *Labeo* and one of *Garra*.

Gears used here are cast net, fase, the loop long-line, basket traps (goda) and dynamiting. During the monsoon when fishing is most difficult, methods are restricted to use of the basket trap and the loop long-line.

- **Eastern/Western Nayar to Aleknanda/Ganga**

At the confluence of the Eastern and Western Nayar rivers lies the town of Satpuli, which is a major crossroads in these hill regions. Below the confluence the resulting Nayar River runs 28 km to join the Ganga/Aleknanda River below Devpryag at the small town of Byasghat. It is known from previous work by the University of Garhwal that the mahseer, *Tor putitora* ascends the Nayar to spawn and the Nayar appears to be a major spawning and nursery site. The altitudinal range is around 480-450 m amsl.

Fishing on the river is relatively intensive. One of the reasons for this is that Satpuli provides a ready market for the fish. Unlike Srinagar, it is not on a pilgrimage route and therefore there are fewer impediments to the consumption and sale of fish.

There are 17 villages along the 28 km stretch of river, but the village of Bhoagi has the highest number of people involved in fishing, followed by Sanoda, Bilikhut and Budakoli. In this region, most of the fish are sold to provide a cash income, with an average of 40-50 kg from the villages appearing for sale at Satpuli daily.

The most favoured methods are cast netting and dynamiting, with loop long-lines, hook and lines and basket traps also being employed. Observed fishing with dynamite in May 1994 showed catches ranging between 5-13 kg per blast, with an average of 8.5 kg. These were predominantly of mahseer in the 9-18 cm length categories, i.e. juveniles.

Trial fishing with cast nets in May/June 1994 indicated daily catches of 0.25-2.1 kg, with an average of 0.9 kg. The predominant species in all catches was the mahseer *Tor putitora*, followed by snow trout, *Schizothorax*, with some *Puntius, Labeo, Barilius* and *Crossocheilus.* Again the size of mahseer was generally quite small, averaging 13.9 cm, 17.6 cm, 3.9 cm and 11.8 cm on different occasions, with a weight of some 80-100 g. A provisional growth curve suggests that the mahseer, *Tor putitora* achieves a length of 17.8 cm after its first year's growth. These fishes are presumably still on the nursery ground of their first year.

The Balganga River is a tributary of the Bhilganga, which flows into the Bhagirathi near

Tehri close to the projected dam site which is currently under dispute. This is some way above Devpryag. A stretch of the Balganga was surveyed around the village of Budakedar. Here there are 15-20 fishermen, as well as children who fish at some time of the year.

The peak fishing season is through March to June in the pre-monsoon, rather later than the other localities examined. The cast net is the commonest method used and during the monsoon (June-August) it may be the only available method. During the winter and spring (October-March), the goda or basket trap is frequently employed. This may be fixed for 2-3 days and yield 4-5 kg of fish. Dynamiting is used sometimes, but not as frequently as in other places.

Fishermen tend not to fish daily, but typically perhaps between 2 to 4 times per week. Much of their catch is sold locally, often to small restaurants and hotels, which prefer to take snow trout. Children generally catch fish for family consumption but will sell them if catches are good. The fishermen in the village all belong to a particular caste known as Machuwale. They are not entirely dependent upon fishing since most have their own land or may work as daily labourers for contractors.

During the peak season of March to June, individual fishermen may catch 7-8 kg per day, whilst at the worst times of year, during the rains, this is reduced to 3-4 kg per day. On average, the total weight of fish produced daily by all fishermen in the village over the 3 km stretch of river is 40-50 kg. The range during the peak season is 50-55 kg, but in the rains this falls to 25 kg per day.

The predominant species in the catches are the snow trouts and to a lesser extent *Crossocheilus*. The mahseers do not occur here, which is a curious feature and goes some way to explaining the later peak in the fishing here as opposed to other localities lower down and on the Aleknanda. The peak here coincides with the upstream spawning migrations of the snow trouts into the more elevated rivers.

5.1.4 Gandaki Basin

Seti, Trisuli, Narayani, Rapti Rivers

- **Trisuli River**

These rivers belong to the major river basin of Central Nepal. The Trisuli comes down from over 2,000 m in the Himalayas. It receives the Seti at around 320m and below that, the Kali Gandaki, to form the Narayani. This flows past Naryanghat (180 m amsl), a major town and staging post for border traffic to India, below which it receives the Rapti River, thereby encompassing the northern and western borders of the Royal Chitwan National Park.

The Narayani itself continues as a major river across the border with India, where it is controlled by a barrage, to be called the Gandak. The Trisuli, in its transition of the Gangetic Plain, like the other great tributaries of the Ganges coming from Nepal - the Karnali/Ghagra, the Bagmati/Buhri Gandak and the Kosi - feeds into the floodplains of the North Bihar wetlands with their own extensive fisheries. The Narayani/Gandak then enters the Ganges itself at Patna at 40 m amsl.

The Trisuli River is a turbid, fast flowing, snow-melt river with recorded temperatures of 15.8-21°C over its lower section, where the presence of the main Kathmandu-India road opens up a market for its fish. The river, whilst being essentially a fast flowing river, alternates between passing through steep gorges and flowing through wider valleys. The first point where the road touches the river is at the small town of Maleku, some 70 km south west of Kathmandu. Here there is a multitude of roadside restaurants all offering fish for sale. Sticks of dried cooked fish hang out over the street. These are commonly *Labeo* and *Garra* around 20 cm long and in a highly transportable form. Strings of fresh fish are also available but these appear to be small silver carp, most probably transported by lorry from the fish farms of the Terai. The restaurants all prepare fish for immediate consumption and on enquiry will generally produce "jalkapoor" from a freezer at the back of the restaurant. These fish, *Barilius jalkapoori*, together with the snow trouts "asala" (*Schizothorax* spp.) are generally regarded as the favourite fish in Nepal. It does not appear on Indian lists of Gangetic species and is therefore particularly characteristic of the Nepal rivers. It has, however, been regarded as synonymous with *Raiamus guttatus* which does have a wider distribution in the uplands of South East Asia (Talwar and Jhingran 1991).

The interaction of the road, the town and the river has acted here as a focal stimulus for fishing around Malaku. When enquiries were made of local fishermen in town in November 1993, it was estimated that there were 20-25 fishermen operating. Similar enquiries of a group of immigrant fishermen one year later indicated that the number could be 75-85.

Principal gear is the cast net and there is observable gear fabrication and maintenance in the town. The best period for fishing is October followed by April/May. In December it is said to be too cold whilst in June/July the water is too high for fishing. During the best season the fishermen would expect to catch 2-5 kg per man and to earn RsN 3000 per month (£38 per month). Most of the fish caught are sold in the town and fishermen may travel up to 25 km in each direction to fish, using bus as transport.

During the second visit in November 1994, most of the fishermen interviewed were immigrant fishermen from the Terai and Bihar lowlands. They had farms in the Terai, but these were generally too small and they had no other jobs. Their main problem was that in the Terai it was not possible to make a living from solely farming or from fishing because there were too many people. Even in the upland regions where, ten years ago, it was possible to fish profitably there were perceived to be too many people fishing and much less money to be made. They did not, however, pay any licence fees. (Technically licence fees should be payable and consequently most river fishermen are perceived to be fishing illegally.)

The commonest fishes caught from the Trisuli at this point include:

- asala snowtrout *Schizothorax* / *Schizothoraichthys*
- sahar mahseer, *Tor tor*
- gurdi *Labeo gonius*
- gaunch *Bagarius bagarius*
- thed *Labeo angra*
- katre *Glyptothorax*
- chepti *Semiplotus semiplotus*
- lori *Garra annandalei*

- budina Garra spp.
- paketa *Barilius* spp.
- sile *Channa* spp.

This list is typical of the coldwater fauna described in Section 3. Snow trout tend to dominate in this sector of the Trisuli.

Fish sell here for around RsN 220 per kg either as whole larger fish or as a number of smaller fish mounted on skewers.

The Seti River was surveyed in its entirety from just above its confluence with the Mardi River at Manauli to its junction with the Trisuli at Gaighat during November 1994. The altitude range is 365 m to 225 m amsl and recorded temperature range at this time was 20°C-22°C. In the Seti below the medium sized town of Damauli, a lot of people fish casually. In a typical instance an occasional/part-time fisherman was able to catch around 150 g of small fish for domestic consumption in 2 hours. Such a catch included:

- bhitti *Puntius (chola)*
- buduna *Garra* spp
- paketa *Barilius* spp
- bhote *Channa*, snakehead
- Tunga *Xenentodon cancila*

At other times of the year other species are available including:

- thed *Labeo angra*
- sahar *Tor tor*
- gaunch *Bagarius bagarius*
- asala snow trout
- bam *Amphipnous cuchia*

The floodplain resident species, such as *Channa* and *Xenentodon* originate in the flooded paddy fields and their inflows into the river at this point. Such inflows are typically fed through basket traps as an additional method.

Most of the fishing at this point is by cast net, although the size may vary. Within Damauli, there are 20-25 visiting Indian professional fishermen who use much larger cast nets than the locals. They tend to sell their fish in town with any surplus being exported to Pohkara, 2-3 hours up the road by bus.

The best fishing season is June/July when the water colour becomes brown with sediment at the start of the monsoon. This will coincide with the upstream migration of many of the species mentioned above (See Section 3).

The favourite fish here is "thed", *Labeo angra* which grow up to 35 cm. This is clearly an important fish in this system and sells here for some RsN 60 per kg.

The Seti passes down through steep gorges many of which are forested. The population density along much of its length appears low. It is deep, fast moving, having a mainly rock bed with some sandbanks, and is broken periodically by rapids and cataracts. Occasionally small basket traps could be seen in shallow water near habitation.

One substantial village to be found about half way down the surveyed stretch was Keshabtar. The people are basically farmers with land, but many do fishing at certain times of year. Some 150 people may fish on an occasional basis. The fish are basically caught to be sold at Gaighat, at the junction with the Trisuli, which is on the main Kathmandu/India road. As further upstream, the best time for fishing is regarded as June/July when participation is greatest. Their fishing area tends to be within one hour's walk (circa 3 km) upstream and downstream of the village. At the extremities of their range they came up to the "territories" of other settlements. There are similar fishing groups all along the river.

The fish most commonly caught here include:

- sahar *Tor tor*
- bam *Amphipious cuchia*
- thed *Labeo angra*
- katleh *Acrossocheilus hexagonolepis* (copper mahseer)
- fageta *Barilius* spp.
- budina *Garra* spp.
- gaunch *Bagarius bagarius*
- hareta large fish with prominent spine (large spine of 5 kg specimen shown)
- bata *Labeo bata*
- gurdie *Labeo gonius*

Very large specimens of the gaunch, *B. bagarius* can be caught, particularly in June, presumably during their upstream migration. A very large jaw bone was displayed which had been taken from a 45 kg specimen. Very large individuals caught locally on hook and line have been recorded from this system (Knowles and Allardice 1992), and it is known to be caught up to 1.5 m in length in the rivers of Nepal (Shreshta 1994). The species referred to as "hareta" is apparently a curious shape and posses a large spine, one of which was displayed, which has a large groove along its length. It has the appearance of the spine of a dasyatid sting ray, of which some freshwater species are known to exist in the region, although not in Nepal. The snow trout, asala, are not found in the main river here (recorded temperature in mid November, 20.5°C), but only in the colder inflowing streams where they remain all through the year.

The fishermen use largely cast nets of 2 cm mesh, although some gill nets of 3-4 cm mesh size were seen. During the good season 20-25 kg per person per day is possible, whilst a bad catch may be 0-5 kg. Considerable year to year variation is noted, but generally good rains bring good catches. The fishermen also generally consider that there has been a general decline in catches over 10 to 20 years which they attribute to increased use of dynamite and increased pollution (the Seti receives water from Phewa Lake) upstream.

Small basket traps may also be used but mainly across the outflows from paddy fields. Downstream of Keshabatar the frequency of traps increases until at the junction with the Trisuli, where there is an extensive series of rapids, there are a large number of basket traps across much of the river. This presumably also reflects the ready market at Gaighat.

There is a considerable contrast between the Seti and the Trisuli. At this time of year, in November, the Seti is a relatively transparent blue-green in colour, whilst the Trisuli is an opaque grey from the heavy silt loads derived from glacial melting. The Seti rises at much lower altitudes than the Trisuli and has a much less direct reliance on glacial melt-water. As a result, it tends to be clearer and warmer with the temperature above the confluence being 20.5°C compared to 15.8°C for the Trisuli. The fishery of the Trisuli is dominated by the characteristic snow trout, whilst that of the Seti is characterised by *Labeo angra* and other *Labeo* species. The mahseer *T. tor* is apparent in both rivers, whilst in the Seti the copper mahseer *A. hexagonolepis* is also found. This species does not occur further west in the Garhwal Himalayas. The rather warmer conditions in the Seti probably mitigate against the presence of snow trout which appear confined to the colder inflows. This is probably typical of the middle altitude rivers of the Himalayas.

- **Narayani River, Naryanghat**

The river at this point is below the confluence of the Trisuli and Seti and has also received the Kali Gandaki. It lies at an altitude of 180 m amsl and has a more lowland meandering form with a silty bed. There range between 20-60 fishermen operating in the area, all licensed to one contractor to whom the rights have been allocated. Many appear to be professional fishermen. Whilst the river is still quite fast flowing, the fishermen can use boats and gill nets unlike further upstream. Those in use were monofilament with a 2 inch mesh. The boats are of the dug-out pattern.

Snow trout, both *Schizothorax* and *Schizothoraichthys* were seen caught here for which the fishermen can obtain RsN 70-80 per kg. The recorded water temperature was 20.4-20.9°C. Fishing is typically at night with landing taking place in the early morning. Further down the river opposite the Tiger Tops ferry, the water becomes warmer still, 24.5°C in November, and by now is quite wide, around 300 m, having also received the Rapti River. There are fishermen here and they are able to fish all the year round. From this point the river flows on down through India as the Gandak, to Patna.

Naryanghat has a fish market which receives fish both from the Narayani and Rapti Rivers as well as from government fish farms or the Terai. Fish species recorded here included:

- Sahar *Tor tor* mahseer
- Katleh *Acrossocheilus hexagonolepis* copper mahseer
- Asala Snow trout
- Buchune Eutropichthys vacha
- Hileh *Channa*
- Fogoteh *Barilius* (*vagra* or *shaera*)
- Tenga *Mystus*
- Singi *Hetropneustes fossilis*
- Bam *Amphipnous cuchia*
- Jungi *Mystus cavasius*
- Moteh *Notopterus chitala*

There is a definite mixture of cold water upland species (*Tor tor*, *A. hexagonolepis* and snow trout), and lowland river and floodplain species recorded in this market. The former will come from the colder Trisuli and Narayani and the rest from the more lowland areas of the nearby Terai.

The Rapti River is a tributary of the Narayani and is rather different to the other rivers examined. It is relatively shallow, braided and with very clear water; the November temperature is around 21.5°C. It rises at relatively low altitude and is effectively spring fed. The bed is stony and gravelly, with a rich benthic fauna of insect nymphs and larvae. The valley is farmed on the north bank, with the Royal Bardia National Park forming the southern bank. The area is well populated with a number of villages.

At one such village called Manuhari there were said to be around 50 fishermen, but the general impression was that everybody, particularly the men, fishes at some time during the year. Typically cast nets and basket traps would be used. Fishing was generally regarded as "big business" and many of the fish caught were exported to Naryanghat or even Kathmandu.

Typical catches with cast nets and traps landed in the morning included:

- Tungi *Xenentrodon concila*
- Chuchia *Mastacembelus*
- Hileh *Channa*
- Budana *Garra*
- Fageta *Barilius*
- Puti *Puntius*
- Telchaba
- Guide *Nematocheilus*
- Rota
- Chabre

This list is largely composed of lowland floodplain species with the exception of *Garra* and possibly *Barilius* and *Nematocheilus*.

5.1.5 The Kosi Drainage Area

- **Dolalghat - Indrawati River**

Dolalghat is one of the major centres on the Indrawati and it is also close to the confluence with the main Sun Kosi. In Dolalghat itself there are some 25 people who fish, at least one of whom comes from India. The principal method is cast net, but the loop long line is also employed. Electric fishing with car batteries and the use of poisons are also reported. Generally the best time for fishing is October-December, when the water is cold and clear. June-July, however, when the water is very turbid, is the best time for mahseer (sahar). They are full of eggs at this time and obviously on their spawning migration (see Section 3). Recorded temperature range was from 16.4-25.6°C. The snow trout also have eggs at this time. The commonest species are:

- asala snow trout
- sahar *Tor tor*, mahseer
- paketa Barilius
- Buduna *Garra*
- Gadera *Noemacheilus*
- jalkapur *Clupisoma*

Mahseer up to 50 kg can be caught, mainly on hook and line.Fish caught in the vicinity are eaten or sold locally. Sticks of fish, largely *Labeo* and *Garra gotyla* are for sale on the roadside. Snow trout retail at RsN 75-80 kg^{-1} whilst smaller species bring around RsN 60 kg^{-1}. In comparison, meat is generally RsN 90 kg^{-1}, mutton RsN 125 kg^{-1} and buffalo RsN 45 kg^{-1}.

Flowing into the Indrawati above Dolalghat is Cha Khola. Some houses along the banks of this stream have long handled dip-nets termed "golan" (or "ghorlong", see Shreshta, 1994). These are used only over two months of the monsoon season, in June-July, when the waters are high. At this time they catch the following:

- sahar *Tor tor*, mahseer up to 7 kg
- katleh *Acrossocheilus hexagonolepis*
- asala snow trout
- sitreh *Puntius* spp.

The mahseers, sahar, katleh and snow trouts are presumably ascending this tributary to spawn at this time. At all other times only small fishes, such as *Puntius*, are present. These occasional fishermen are fishing only for their own consumption.

- **Sun Kosi River**

Just above the confluence with the Indrawati, near Dolalghat at an altitude of 570 m amsl, the Sun Kosi had a recorded range of temperature of 15-20.6°C. The river is broad and fast flowing during the monsoons when there is little apparent fishing activity. In November there is appreciable fishing activity as the waters recede. The gear most commonly used here is the loop long-line, termed the "paso" or laharch in the vicinity. Typically each line has around 300 loops each with a 30-40cm trace. These loop-lines are said by the fishermen to be in use generally on the Kosi, Tamur and in the Garhwal region. The lines are fixed across the river and there are reported to be 125 fishermen over a 2.43 km stretch of river, which is quite intensive. The gradient on the river at this point is slight and many of the fishermen use boats of the dug-out variety for setting their lines. Main catches include:

- asala snow trout
- katleh *Acrosscheilus hexagonolepis*, the copper mahseer
- kareh *Garra horai*
- hileh *Channa*, snakeheads

Fish up to 1 kg in weight are normally taken.

The small villages on the banks here offer sticks of fish for sale, including asala (both *Schizothorax* and *Schizothoraichthys*), *Labeo* and *Garra gotyla*. The commonest price for snow trout here is RsN 85-95 kg^{-1}, whereas in the Kathmandu Valley it reaches RsN 125 kg^{-1}. There is generally perceived to be an increase in pollution and in the use of dynamite in recent years.

The fact that the loop long-lines catch fish up to 1 kg whilst the occasional fishermen with dip nets in the Cha Khola may catch copper mahseer (*A. hexagonolepis*) which does grow to a large size, up to 7 kg, suggests that a greater differential effort is being exerted on the juveniles. The fishermen on the Kosi do have land, but they do not regard it as sufficient to live on.

5.1.6 Rates of Fish Production

The assessment of fish yields from these upland rivers is extremely difficult, owing to the diffuse nature of the fisheries and difficulties of access to sites. In some of the instances examined above it is possible, with certain broad assumptions, to make order of magnitude estimates of the quantities of fish being taken from the river. For example, on the information obtained from the village of Jayalgarh on the Aleknanda, taking 15 kg per day as the average total catch during the October to March reported best period, over 2 km of river fished is:

$$180 \text{ days at } 15 \text{ kg day}^{-1} = 1{,}350 \text{ kg km}^{-1}$$

and allowing a further 25% for the rest of the year, gives a total of 1,688 kg km^{-1}.

In some cases better estimates of catches during the low season have been provided, whilst in the case of the River Nayar at Satpuli most of the direct data referred to fish sold, and estimates of consumption needed also to be made to provide an estimate of total catch. The estimates that could be made are given in Table 5.2.

The lowest of these estimates is that on the River Nayar. This estimate was derived, however, from a long stretch of river. In these mountainous conditions accessibility for fishing is always a problem and the overall production will also reflect the frequency of feeding grounds, which is unlikely to include the steep rocky gorges and torrential sections. The Nayar may therefore represent a more integrated estimate than say the fishing over the 1 km fishable stretch at Malethon. These are more likely to indicate maximum points for short stretches.

The estimate at the Balganga reflects the genuine abundance of fishes there. Most of these, however, migrate in for a short period of the year. The Balganga, a tributary of Bagirathi may be a particularly important spawning area which could require protection.

It is probable, therefore, that the production of these upland rivers falls within the 1-2 mt km^{-1} yr^{-1} range. Welcomme (1974) summarised catch rates for African rivers and found them to fall mainly within the 1-15 mt km^{-1} yr^{-1} range. A significant positive relationship was found between catch rate and distance from source of the river, implying that higher order streams, i.e. progressively larger rivers, had higher rates per kilometre. Thus, for example, a river around 100 km from its source would produce of the order of 1 mt km^{-1} of fish annually. Many of the rivers in Table 5.1 are this order of distance from the source and their yields are comparable. Given that the African data was all from warm, lowland rivers, it seems probable that these cold upland rivers do show a simpler order of yield.

In considering the cold water upland areas of the Ganges Basin, a working estimate of some 1.5 mt km^{-1} for annual fish production is indicated. The limits of this cold water area can be defined at its lowest limit by the distribution of the snow trout, at around 180 m amsl. The upper limit is unlikely to extend much beyond 1600 m amsl since most species of commercial importance do not extend up the rivers of the Himalaya much beyond this (Shreshtha 1978). At such altitudes, also, opportunities for fishing are scarce and difficult. The upper limit for significant fishing activity may well be 1200 m or less.

These limits and potential rates of production from major rivers may be useful in evaluating potential losses from river fisheries during impact assessments of the numerous dams currently under consideration in the Himalayas.

5.2 LOWLAND FISHERIES

5.2.1 Catches and Fish Movements

The catch records from all of the four sampling sites at Patna (Appendix 1) have been compiled into monthly totals for all sites by species (Table 5.2)

Amongst the four stations, Kurji consistently landed the highest catches, since it is close to the confluence with the Son River and also to a major area of inundation on the opposite shore.

Catches have been recorded for Sadiapur, Gaughat and Daraganj at Allahabad (Tables 5.3, 5.4, 5.5) have been treated separately, because Sadiapur and Gaughat are actually landing from the Yamuna River whilst Daraganj lands from the Ganga main channel. In addition, Sadiapur and Daraganj have been used historically as sampling sites for which some earlier comparable data exists (See Section 6.1).

Of all the centres examined, Sadiapur is by far the most significant with some 240 mt being landed over the time of the survey, compared to 63 mt at Gaughat, 24 mt at Daraganj and 26 mt at Patna. This demonstrates that there are still substantial quantities of fish moving up to Yamuna, even though it is reported to be polluted from Agra and Delhi. They may, of course, be moving up to Chambal. Sadiapur seems in fact to be regaining its pre-eminence, having sunk to an annual low of 97 mt in 1976, compared to 300-400 mt in the 1950s. Catches from Patna are currently rather low compared to earlier decades, when they ranged from 40-115 mt (Jhingran 1991). Those of Daraganj have been relatively comparable over the whole time period.

The pattern of the fisheries is similar at all sites. There is a major peak in spring, in the pre-monsoon season and a second peak in the post-monsoon as the river waters go down.

There are, however, small differences in the timing. At Daraganj on the Ganga River, for example, the pre-monsoon peak is in June, whilst downstream at Patna it is in May-June. Lower down still, the FAP 17 survey was operating over this same period on the Upper Padma and found that the peak was in June-July (FAP 17, 1994). Below this, on the lower Padma, the peak occurs in September, but the rather different pattern here is probably due to the predominant role of *Hilsa* in the catches. Down the main stem of the Ganges, therefore, there does appear to be a slight delay in the earlier peak. One exceptional feature is the secondary peak which appears in the Ganga fishery at Daraganj in February. This was entirely due to immense catches of the small cyprinid *Oxygaster*.

By contrast to the events in the main channel, the pre-monsoon peak from the Yamuna at Sadiapur and Gaughat occurs rather earlier, in April, and the pattern of the catches here demonstrates quite clearly that the peak catch is primarily made up of migratory species and that it precedes any evident rise in the water level from the earliest rains (Figure 5.1). The same is also true of the other sites.

The cues for movement by the fish must come from something other than significant changes in water level. It should be borne in mind that the headwaters of the Ganges and its tributaries are snow-melt and glacial rivers, in which snow-melt occurs in advance of the monsoon, producing increases in colour and turbidity of the water, and possibly also in dilution and "taste". It may be some aspect of this snow-melt which provides the proximate factors which trigger upstream migration.

Table 5.1 Estimates of fish production in upland rivers of the Ganges Basin

River/Site	Altitude (m amsl)	Stretch examined (km)	Estimated production (kg. km^{-1} $year^{-1}$)
Aleknanda	550-440		
Meletha		1.0	2475
Juyalgarh		2.0	1688
Lachmoli		2.5	1035
Srinagar		2.0	1406
Balganga	800		
Budha-Kedar		3.0	2250
Nayar	51-460		
Satpuli-Byasghat		28.0	621
Seti	270		
Keshabatar		8.0	1489

Table 3.2 Catch by weight (kg) from Patna with all four sampling stations combined. Key: M - major carps, R - riverine species, C - catfishes; P - predators; F - floodplain species

Species	M	R	C	P	F	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Total Weight	%
	Categories					Month												Month													
L. rohita	x	x				4.40	9.10	4.30				2.50	1.10			200.00	42.15	1.40	0.00			6.00	9.85							279.80	0.39%
C. catla	x	x				143.16	48.20					36.00		9.00		800.00	59.75	117.60	70.80	105.30	35.00		24.50	14.00	12.00					1270.30	1.78%
C. mrigala	x	x				52.10	53.90		13.86	3.00		3.86		7.20	2.10	216.20	66.70	141.00	20.60	168.30	69.00	3.20	61.00	39.00	10.60					933.20	1.31%
L. calbasu	x	x				4.00	11.20		8.00	1.00	5.10	17.45	11.90	10.65	37.10	28.30	50.38	17.80	10.30	13.45	6.40	2.20	1.60	54.10	83.30					359.63	0.50%
M. seenghala		x	x	x				64.35	9.10	3.75	6.00	29.25	6.30	41.55	144.20	123.70	103.20	214.30	78.80	2.50		6.20	47.20	20.60	12.50					910.50	1.28%
M. aor		x	x	x		204.35	342.85	130.20	109.30	42.80	33.95	91.10	27.46	68.30	89.25	317.10	360.93	756.40	474.00	32.10	51.45	38.10	70.25	71.80	162.85					3473.83	4.87%
W. attu		x	x	x		43.75	56.95	8.60	4.80	0.80				2.25	6.00	64.20	78.06	157.20	390.40	44.60	25.00	3.50	14.60	0.40	0.40					900.10	1.26%
C. garua			x	x		243.45	63.30	72.20	36.15	46.50	196.55	409.65	458.20	842.10	773.40	675.00	471.75	1248.40	854.40	109.90	212.95	24.80	76.85	147.50	182.85					7219.90	10.13%
E. vacha			x	x		17.35	481.20	124.80	60.30	21.15	2.30	4.16	82.65	174.10	168.10	6.90	7.40	13.80	102.70	4.90	16.55	4.56	20.40	10.26	14.75					1338.10	1.88%
R. rita			x	x		74.10	69.00	8.70	0.20	0.50	3.85	7.50	8.85	5.15	10.60	122.59	191.90	297.20	106.00	7.00	1.50	0.60	1.50		1.00					929.64	1.30%
Oxygaster						5.65	50.56	76.85	93.90	44.60	35.60	119.35	373.80	101.20	132.20	28.00	24.30	236.20	978.00	125.30	192.75	123.60	75.25	240.90	458.80					3518.00	4.93%
N. notopterus				x	x		0.60							4.70																5.30	0.01%
N. chitala				x	x	6.10	21.00	4.50	23.00	0.30		18.50		4.23	9.10	20.50	27.50			13.00	7.20	5.00	0.76	9.00	73.20					241.88	0.34%
B. bagarius		x	x	x		2.60	35.10	4.20	16.45			11.50		3.90	5.50	1.50	10.80	82.30	37.50	5.00	8.00	9.00	58.30	22.10	68.75					371.80	0.52%
S. phasa						37.15	69.90	70.25	499.05	441.35	501.60	152.65	777.80	2284.50	1210.85	628.80	143.65	195.10	451.80	76.20	163.00	90.70	73.05	98.00	437.60					8383.00	11.76%
G. cemia																														0.00	0.00%
M. armatus					x	9.20	10.70	0.50	2.60	2.00	1.60	33.80	2.10	1.20	73.40	93.20	22.80	5.40	49.00	0.40	2.60	7.20	7.60	9.60	3.40					338.30	0.47%
Puntius					x	11.31	27.10	2.70	6.60	2.63	5.85	16.64	146.50	680.98	1123.58	302.85	19.87	6.00	3.60	17.60	16.35	27.50	29.90	2.20	1.45					2452.91	3.44%
O. cotio						2.40	3.50	0.80	2.30		0.20	37.95	20.50	2.36	12.15	1.62				0.60	0.05	1.00		13.90						99.12	0.14%
L. bata						0.60	1.90				15.70	25.15	3.70	41.30	10.60	40.05	4.73	2.50	20.30			16.00	28.05	26.30	51.90					289.58	0.41%
L. gonius													0.80	77.10	79.65	67.45							3.50	24.90	11.30					264.70	0.37%
A. coila		x	x	x		24.20	78.70	462.75	1636.60	386.50	171.85	207.50	301.20	220.15	131.95	62.00	155.60	930.20	477.50	170.35	363.85	144.20	119.85	73.85	14.20					6131.70	8.60%
S. cotior						51.25	118.05	48.05	182.80	21.65	72.80	130.50	28.30	710.63	616.95	587.80	67.95	198.10	27.50	22.70	22.55	6.30	28.40	12.15	1.70					2955.93	4.15%
R. corsula		x				3.40	14.70	26.85		0.20	57.90	84.60	16.10	46.55	6.00		5.00			11.00	6.00	6.00	6.80	9.90	25.40					325.40	0.46%
G. chapra		x				6.90	30.60	64.65	1113.15	23.75	38.45	24.15	78.50	10.60	21.00	204.75	27.60	190.30	325.00	243.15	287.20	107.20	57.80	26.35	509.90					3389.00	4.76%
X. cancila					x	0.15	0.20						4.70	1.00	6.60	13.00	1.00													26.65	0.04%
T. tor																														0.00	0.00%
M. tengra					x							8.70	0.30	18.30	79.20	19.20	9.85							2.00						138.35	0.19%
G. manimina							4.90	10.65	39.40		1.20	5.10	34.80	1006.85	901.75	328.00	41.60				15.00		2.00	8.20	88.50					2487.65	3.49%
P. pangasius		x	x	x																										0.00	0.00%
Hilsa		x					2.80	1.50	86.75	13.80	53.35	2.00	13.20	20.85						9.50	58.56	50.80	108.40	29.45	1.15					452.10	0.63%
Channa				x	x	12.10	37.75	3.20	1.50	0.50	0.06		1.40		12.60	38.23	12.70						3.60							123.63	0.17%
Others																														0.00	0.00%
A. jaya									4.00			39.00	175.65					42.80		20.00	211.00	183.25	213.05	10.00						898.75	1.26%
A. morar						20.35	266.15	179.25	503.10	405.15	489.20	1474.00	1312.63	1267.00	663.93	190.05	88.50	540.90	1005.00	232.00	192.75	123.60	75.25	441.35	1165.05					10643.21	14.94%
C. reba						0.80					6.25	2.40					1.20						11.30	3.10						24.05	0.03%
C. latius		x				0.10		1.80		36.70	9.10	7.30	1.00			2.20		3.80	467.80	104.00	115.90	43.45	116.20	30.50						938.85	1.32%
C. chagunio													0.30			1.00														1.30	0.00%
A. mola						0.10	0.30						2.50							0.30	4.00									7.20	0.01%
C. laubuca													0.10	2.00																2.10	0.00%
C. atpar																	1.50													1.50	0.00%
B. dario														2.30						0.05		3.50	7.70	6.80	35.90					56.25	0.08%
B. lohachata						0.45	0.40	0.05						0.40	0.30															1.60	0.00%
L. guntea									1.00	1.60		0.30				0.06						3.00	2.30	0.80						8.75	0.01%
O. pabda		x	x	x		0.30	0.30															6.00								6.60	0.01%
M. cavasius		x	x	x		27.25	94.45	4.20				6.25		7.80	163.35	172.60	48.20	29.80	692.00					6.80	10.60					1263.30	1.77%
M. vittatus			x	x	x			1.50				2.70	15.15	25.20			7.78	6.20	37.10	1.50	0.10	0.60	6.00	0.50						111.33	0.16%
M. menoda			x										5.25	1.00																6.25	0.01%
G. conia		x	x	x			0.20			2.60	39.80	238.95	273.80	74.30	16.60					1.00	123.50	19.50	61.50	108.00	166.00					1125.75	1.58%
G. telchitta													39.10	5.00																44.10	0.06%
N. punctata						0.03	10.50	7.70	352.85	159.15	279.80	362.15								111.70	191.85	95.25	123.65	50.25	97.30					1831.58	2.57%
E. murius														15.25								1.10	0.80							16.95	0.02%
P. atherinoides		x	x	x		12.50	38.00	0.80						0.50	1.00	3.30	4.70		93.00					19.00						172.80	0.24%
S. silondia		x	x			0.70	16.55	1.20	0.20						6.90	339.95	26.60	140.70	84.80											619.60	0.87%
H. fossilis				x	x	1.95	9.00								0.50	1.20	2.00													14.65	0.02%
C. batrachus			x	x	x		0.80				0.30				0.60		1.70													3.40	0.00%
S. cascasia						3.30	32.90	24.70	205.20	138.80	278.10	85.95	62.00	151.00	334.00	106.40	67.00	109.90	49.00	51.00	10.05	78.00	46.20	78.10	298.00					2209.40	3.10%
Chanda sp.					x						2.00		13.10							0.10	0.50									15.70	0.02%
A. testudineus					x											0.05														0.05	0.00%
G. giuris				x	x	0.95	1.80	1.25	8.90	13.95	28.27	27.10	8.70	7.70	6.20	52.40	1.90		11.90	8.50	4.20		6.85	14.20						201.77	0.28%
M. aculeatus					x								1.40	2.50			1.70													5.60	0.01%
M. pancalus					x	0.60	5.90	0.20	1.40	0.40	1.00	4.10			2.50	10.41	3.50					3.30	4.00	15.30	48.60					101.21	0.14%
T. fluviatilis																	0.70													0.70	0.00%
Macrobrachium						13.25	33.00	1.00				4.95	6.20	29.58	488.50	449.38	131.55	126.40	20.60	1.90	4.00	6.00	3.20	1.70	3.10					1320.21	1.85%
Total Weight						1041.19	2141.60	1414.05	5022.85	1817.23	2334.72	3803.59	4313.73	7991.22	7354.11	6127.63	2395.69	9781.20	6938.40	1714.70	2417.50	1247.20	1615.30	1751.15	4038.05	0.00	0.00	0.00	0.00	71261.11	100.00%
No. of Species	5	20	17	20	15	23	26	21	21	19	19	24	23	27	26	26	25	18	19	21	21	22	25	24	23	0	0	0	0		

		Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
		Month												Month											
Major Carps	Weight	203.65	119.4	4.3	21.85	5.5	5.1	58.8	13	26.85	39.2	1044.5	218.96	278.3	101.7	287.05	109.4	10.4	96.85	107.1	91.9	0	0	0	0
Catfish	Weight	650.55	1268	883.3	1871.8	505.3	455.6	1088.55	1177.85	1470.3	1526.45	1888.84	1468.61	3856.5	3427.2	378.85	802.9	256.05	486.05	488.6	633.9	0	0	0	0
Others	Weight	186.985	754.2	526.45	3129.3	1306.33	1874.02	2656.24	3122.88	6495.07	5788.46	3194.29	708.1	1646.4	3409.5	1048.8	1505.2	980.75	1033.4	1155.45	3312.25	0	0	0	0

Major Carps	Percentage	19.56%	5.58%	0.30%	0.44%	0.31%	0.22%	1.55%	0.30%	0.32%	0.53%	17.05%	9.14%	4.81%	1.47%	16.74%	4.53%	0.83%	6.00%	6.12%	2.28%	0.00%	0.00%	0.00%	0.00%
Catfish	Percentage	62.48%	59.21%	62.47%	37.27%	27.81%	19.51%	28.62%	27.30%	18.40%	20.76%	30.82%	61.30%	66.71%	49.39%	22.09%	33.21%	20.53%	30.03%	27.90%	15.70%	0.00%	0.00%	0.00%	0.00%
Others	Percentage	17.96%	35.22%	37.23%	62.30%	71.89%	80.27%	69.84%	72.39%	81.26%	78.71%	52.13%	29.56%	28.48%	49.14%	61.17%	62.26%	78.64%	63.98%	65.98%	82.03%	0.00%	0.00%	0.00%	0.00%

Around Allahabad, the bulk of the catch comes from catfishes and major carps throughout much of the year, but particularly through this monsoon peak period in the Yamuna and, to a lesser extent, in the Ganga. In fact the major carps feature particularly strongly in the Yamuna sites at Sadiapur and Gaughat (Figures 5.2, 5.3 and 5.4).

By contrast, at the point of peak catches in May-June in the Ganga at Patna, the proportion of catfishes and major carps is quite small compared to other species (Figure 5.5). Throughout much of the year, in fact, major carps are virtually absent, except for the beginning and end of the monsoons.

In many ways, the major carps are the key indicator species of the Ganges system. They are the original predominant species of the river and floodplain ecosystem (Section 6.1). They are amongst the most highly regarded of the fish species with respect to commercial value and have become virtually synonymous with fisheries in the Ganges.

The pre-monsoon peak in fish catches is characterised by pulses of different types of species, particularly those belonging to groups of major carps and catfishes (Figures 5.4, 5.5). This was particularly true at Sadiapur and Gaughat on the Yamuna where these two categories dominated the catches for much of the year (Figure 5.2, 5.3).

The major carps as a whole were generally best represented at the Yamuna sites with catches at Patna being relatively low (see Section 6). On the Ganga River main channel at both Patna and Daraganj there was a clear peak in major carps in June / July (Figures 5.6, 5.7, 5.8 and 5.9). At Sadiapur (Figures 5.10 and 5.11), the peak was rather earlier, although at Gaughat (Figures 5.12 and 5.13) also on the Yamuna, whilst the peak was not so clearly defined, it was actually in June. These peaks represent the upstream spawning migrations of the major carps. They tend to show limited upstream migration followed by lateral migration onto flooded areas, following spawning, close to the edge of floodlands. The average size of carps recorded at Sadiapur at this time is quite large, ranging from 7-10 kg, depending upon the species. These must represent the spawning stock. The predominant major carp is *L. calbasu* at all locations whilst *L. rohita* is either absent, or present in very low numbers. Indeed numbers are generally so low, bearing in mind its previous significant role in the fishery (Section 6) that specific measures for its conservation or rehabilitation would seem to be a consideration.

At sites in both rivers at Allahabad equally prominent peaks were to be seen in September (Ganga) or November (Yamuna sites). These are the returning fishes, both adults and juveniles. At Patna, however, this post-monsoon peak was only poorly marked.

It generally appears that the lower Yamuna as represented by catches at Sadiapur and Gaughat, sees the greatest concentration of adult major carps, even compared to the nearby Ganga. Although there are a number of tributaries, including the Gandak and the Son entering near Patna, which have perviously been identified as prime spawning grounds for major carps (Jhingran 1991), nevertheless the quantities taken by the fishery are relatively very low compared to those around Allahabad. At Patna major carps only account for some 4% of the total catch. Further downstream in Bangladesh, the riverine catch of major carp amounts to 7% of the catch, whilst on the Padma it is only 6% (FAP 17 1994). The confluence of the Yamuna and Ganga at Allahabad does, therefore, remain a crucial location for major carp stocks for the basin as a whole. What remains unknown is how far those fishes which pass up the Yamuna for spawning have travelled, i.e. how localised are the stocks. Major carps are generally regarded as being relatively local upstream migrants which additionally migrate laterally onto the floodplains, as a whole, after spawning. From what is known, it would seem unlikely that those individuals passing through Allahabad have come from as far downstream as Patna, for example. Naturally those existing downstream of the Farakka Barrage in the Padma sector will necessarily have had their migratory paths curtailed.

Like the major carps, the catfishes show two marked peaks, one in April at Allahabad or May at Patna, and the second in September / October (Figures 5.14, 5.15, 5.16, 5.17). The first represents the upstream migrating adults and the second peak the returning adults, together with the young of the year juveniles.

On the Ganga sites, at Patna and at Daraganj at Allahabad, the later peaks, as the flood waters recede, are three times higher than the pre-monsoon adult spawning peak. Only on the Yamuna at Sadiapur and Gaughat are the peaks both equally marked (Figures 5.18, 5.19, 5.20 and 5.21).

At Patna, in fact, the pre-monsoon peak is more of a gradual increase to a more elevated level during the high water period (Figures 5.16, 5.17). This is consistent with the catfish using the extensive flood areas downstream of Patna as feeding grounds during high season. At all sites at Allahabad the more marked peaks would indicate that the fish are in transit to and from feeding and nursery grounds further upstream. In the case of all the catfishes species concerned, the rich feeding grounds in the flood areas are provided by the larvae and young of other species with which they share the flood areas for spawning and feeding.

The principal catfishes involved in these movements are schilbeid species *Clupiosoma garua* and *Eutropius vacha* and the bagrids *Aorichthys* (= *Mystus*) *aor*, *Mystus* spp and *Rita rita*. Of these *E. vacha* only features at sites on the main Ganga at Patna and Allahabad, but not at the main site on the Yamuna at Allahabad. Conversely neither *W. attu* or *R. rita* are significant downstream at Patna.

Generally in the pre-monsoon season, pulses of these various species can be detected coming up the river, although there does not seem to be a consistent order in which the peak of each species arrives. At the Ganga sites the small pelagic *C. garua* dominates both peaks, whilst on the Yamuna *A. aor* is commonest together with *R. rita* in April and *M. seenghala* in September.

Amongst the commonest catfishes the exception appears to be the schilbeid *Aiola coila* which does not appear to show any pronounced peaks and may, therefore, be essentially a more resident species.

Of the less common species, the schilbeids *Pseudoeutropius atherinoides*, *Mystus cavasius* and *M. vittatus* all appear most strongly at the peak times or in the monsoon season and are, therefore, presumably following the same migratory cycle as their commoner relatives. These species do not, however, appear in the catches at Allahabad further upstream, although they are significant components of the fishery lower downstream still in Bangladesh (FAP 17 1994).

The same problem is also shown by some cyprinids other than the major carps. The *Oxygaster* group, largely *O. bacoila* and at Patna, *A. morar* rise to sharp peaks in March / April and again in September / October (Tables 5.3, 5.4, 5.6). At Allahabad, however, *Oxygaster* tended to increase markedly in catches from March through to the monsoons in June / July. Most spectacular were the huge quantities landed rather earlier than this, in January / February of 1994 at Daraganj, when they constituted the bulk of the catch. The following year a peak appeared at the same time, but of much lower dimensions (Table 5.6). Peaks do, therefore, appear in the first quarter of the year, but on a rather erratic basis with regard to season. They seem to represent aggregations, perhaps for feeding and/ or spawning, rather than a transitory migratory throughput. The total quantities of this small cyprinid which can be caught, however, can be considerable.

There are other species which are known to be long distance migrants which do appear in some of the catches. Low numbers of the montane migratory species, the mahseer *Tor tor* appears in lowland catches at Allahabad, almost exclusively during January / March. Although they have not appeared in the regular survey, larger individuals of *T. tor* have also been observed directly in landings at Patna. These individuals probably represent the extremity of the downstream migration of mahseer from the northern tributaries, the Gagra, Gandaki and Kosi (see Section 5.1), which enter the Himalayas through Nepal. The disappearance of the fish in March will mark the start of their upstream migration to spawn in the streams and tributaries in the mountains. This situation is probably complicated, however, by the existence of barrages in all three northern rivers at the Indo-Nepal border. These will be effectively closed during the dry season and will therefore prevent the mahseer from the lowlands reaching the spawning grounds in the upland areas. At high water, by contrast, the barrage gates are open to discharge the overflow and no doubt to cause numbers of mahseer and other fish species to be swept beyond the gates (Sinha: pers. comm.). This leakage and net loss of fish from upstream to downstream across weirs and barrages has been documented in other rivers (Linfield (1985). Those mahseer which appear in the lowlands and main channel of the Ganges could therefore be an isolated sub-population which is regularly replenished by leakage from upstream. Conversely, this will represent a further drain on the upstream sub-population which, although able to complete their life-cycle and spawn, must rely on those mature individuals remaining above the barrages to sustain the population.

Another species which features in the upland fishery is the gaunch, *B. bagarius* which, like *Tor tor*, can grow to a considerable size. The fishermen of the lower altitude montane fisheries, such as those on the Seti, record this catfish as a regular feature of their peak catches at the time of early monsoon upstream migration when the largest individuals appear (Section 5.1). At Allahabad, there are indications of peaks of their species appearing around this time in April to June in both rivers (Tables 5.5 and 5.6). At Patna, however, although the species is present all through the year, catches do not show particular peaks. There is, however, probably some confusion of species here. Many records of *B. bagarius*, which is a relatively small species rarely exceeding 19 cm, actually refer to *B. yarelli*. which does indeed grow to 2 m or more and can weigh up to 135 kg (Talwar 1991 and Jhingran 1991). This is the more upland species and the extent of its ingression into the lowland fishery is confirmed.

Another large catfish species which was renowned for moving long distances was the giant river catfish, *Pangasius pangasius*. This was known to move long distances upstream from the estuaries where the non-breeding adults tended to reside and feed. It was recorded only at the Yamuna sites between December and March with one observation in August (Tables 5.4, 5.5). Curiously, this was not caught at Patna, i.e. at sites en route for the estuary. The status of *P. pangasius* therefore remains obscure, except that it is considerably less prominent than in earlier times when significant fisheries occurred in the Gangetic estuarine areas during July and August (Talwar and Jhingran 1991). In the Mekong this species is recorded as migrating up to 1000 km upstream from the estuary (Lowe-McConnell, 1975).

Figure 5.1 Catches from the Yamuna River in relation to water level (m amsl), Allahabad 1993-1994

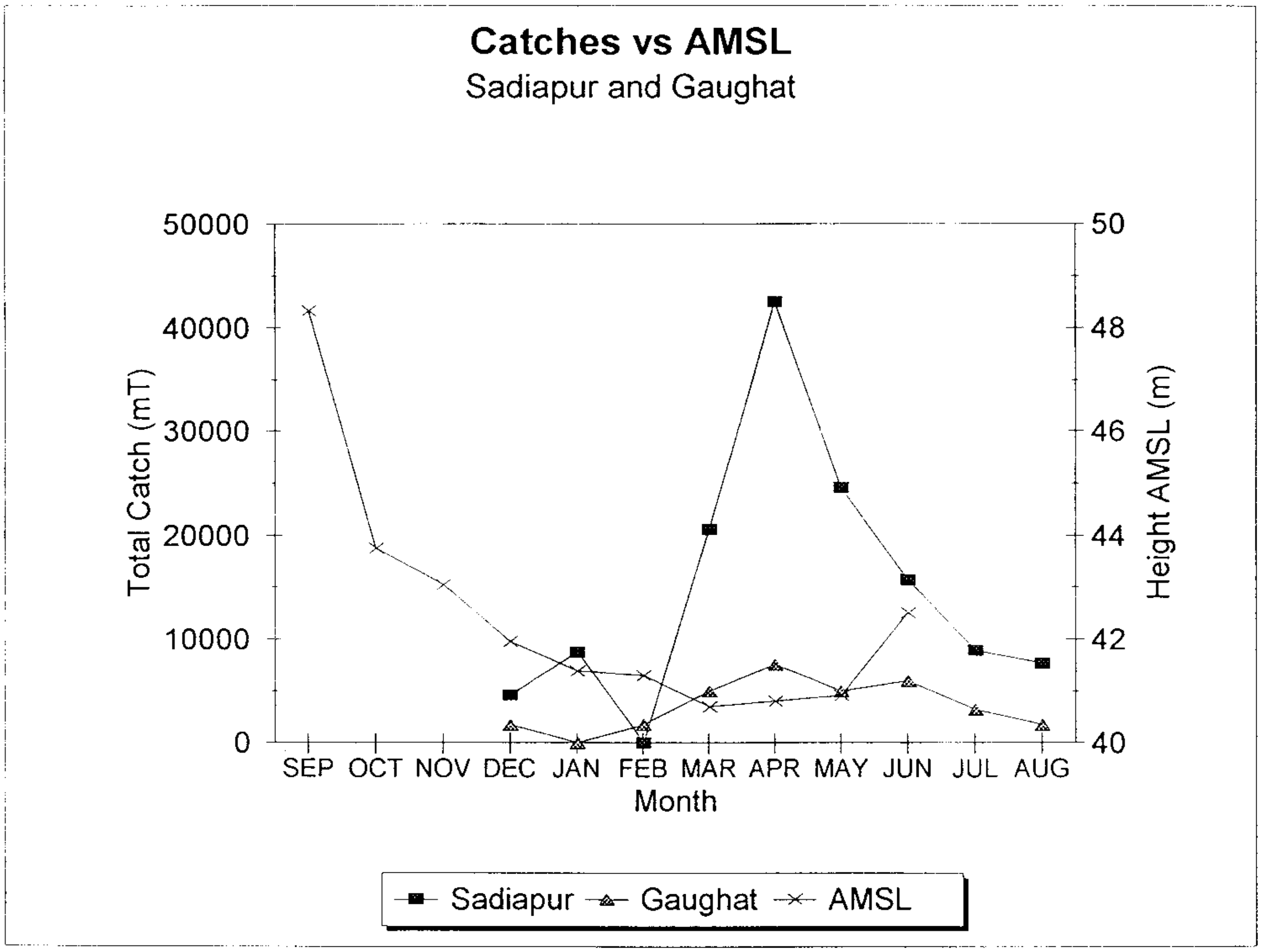


Figure 5.2 Proportions of major carps and catfishes in catches from the Yamuna River at Sadiapur, Allahabad.

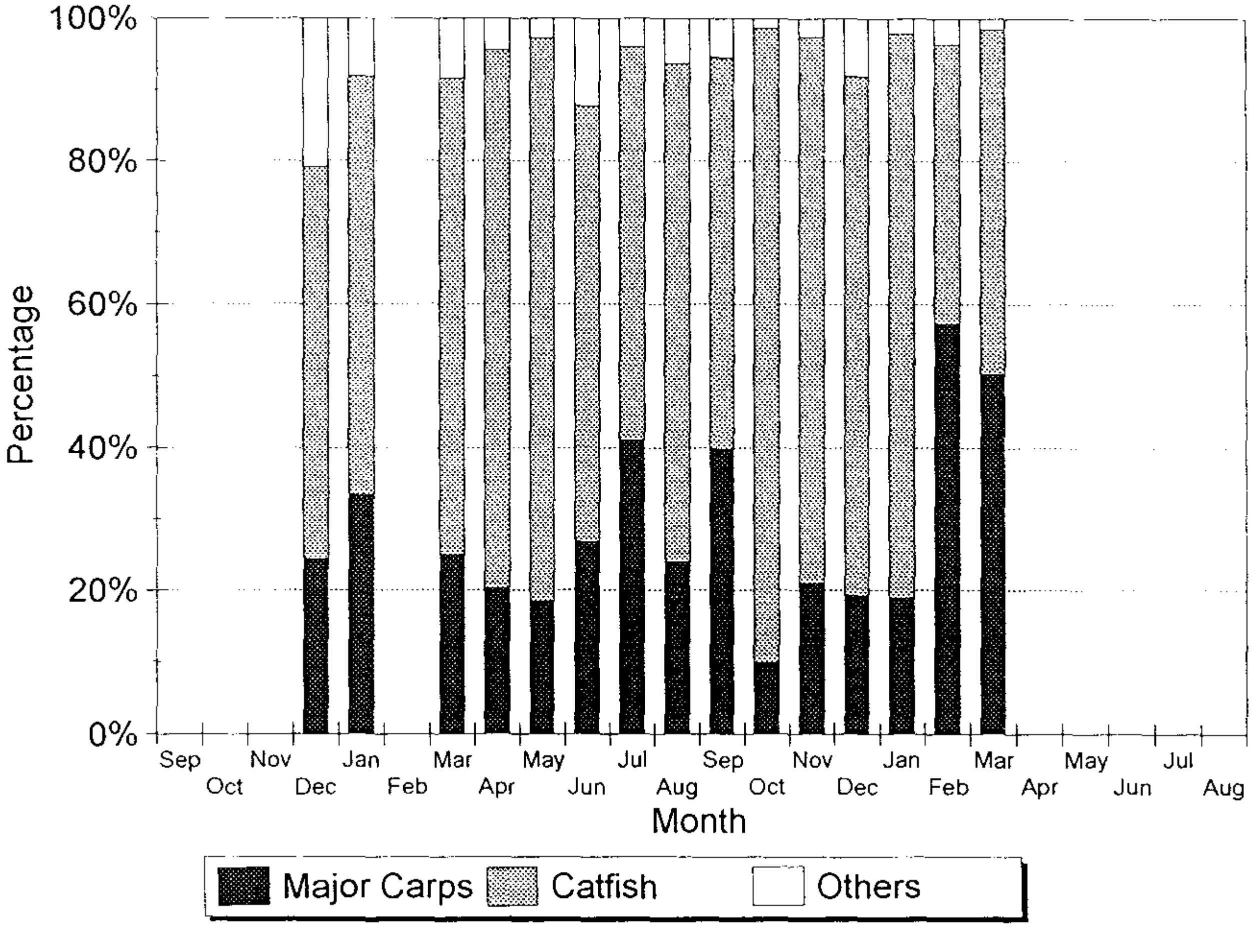


Figure 5.3 **Proportions of major carps and catfishes in catches from the Yamuna River at Gaughat, Allahabad**

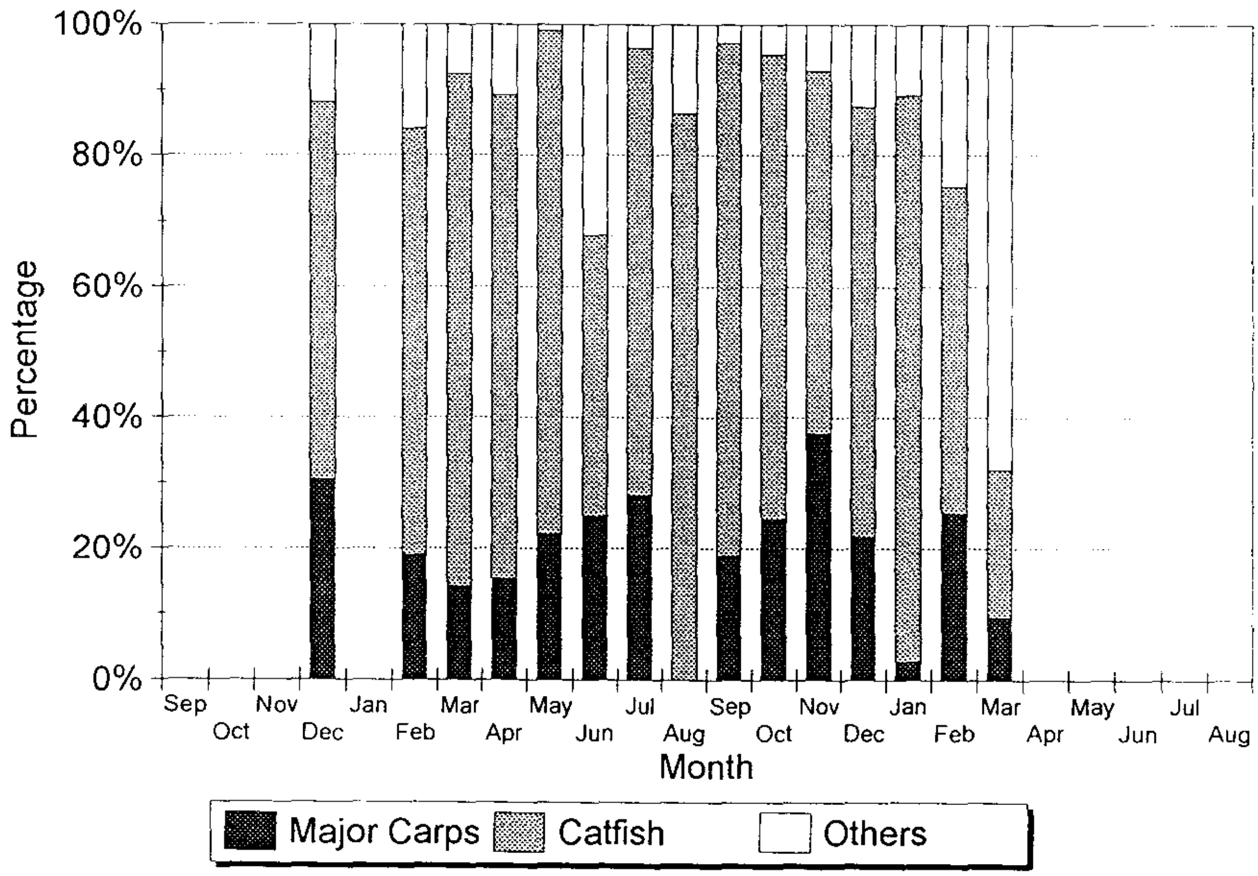


Figure 5.4 Proportions of major carps and catfishes in catches from the Ganga River at Daraganj, Allahabad

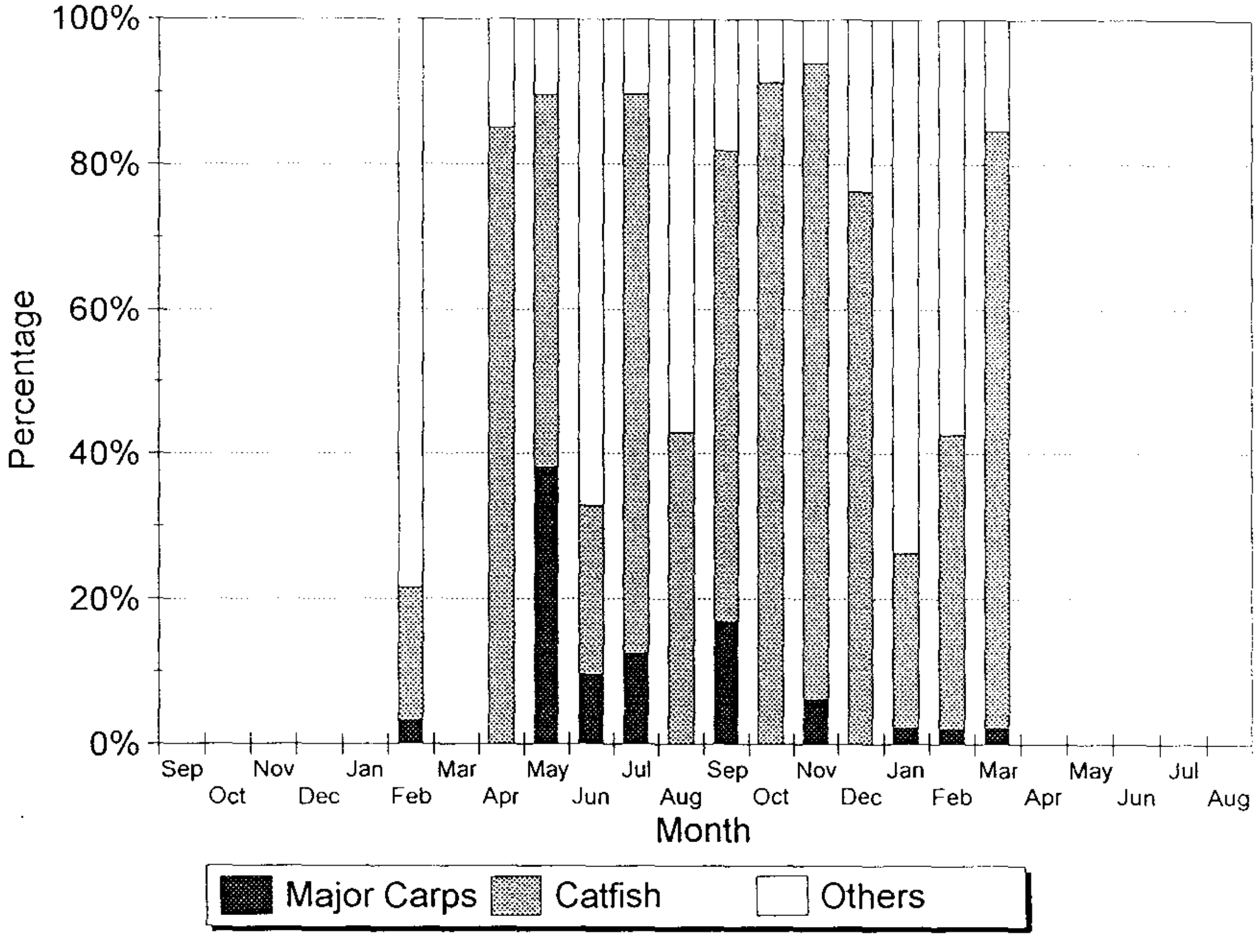


Figure 5.5 **Proportions of major carps and catfishes in catches from the Ganga River at Patna**

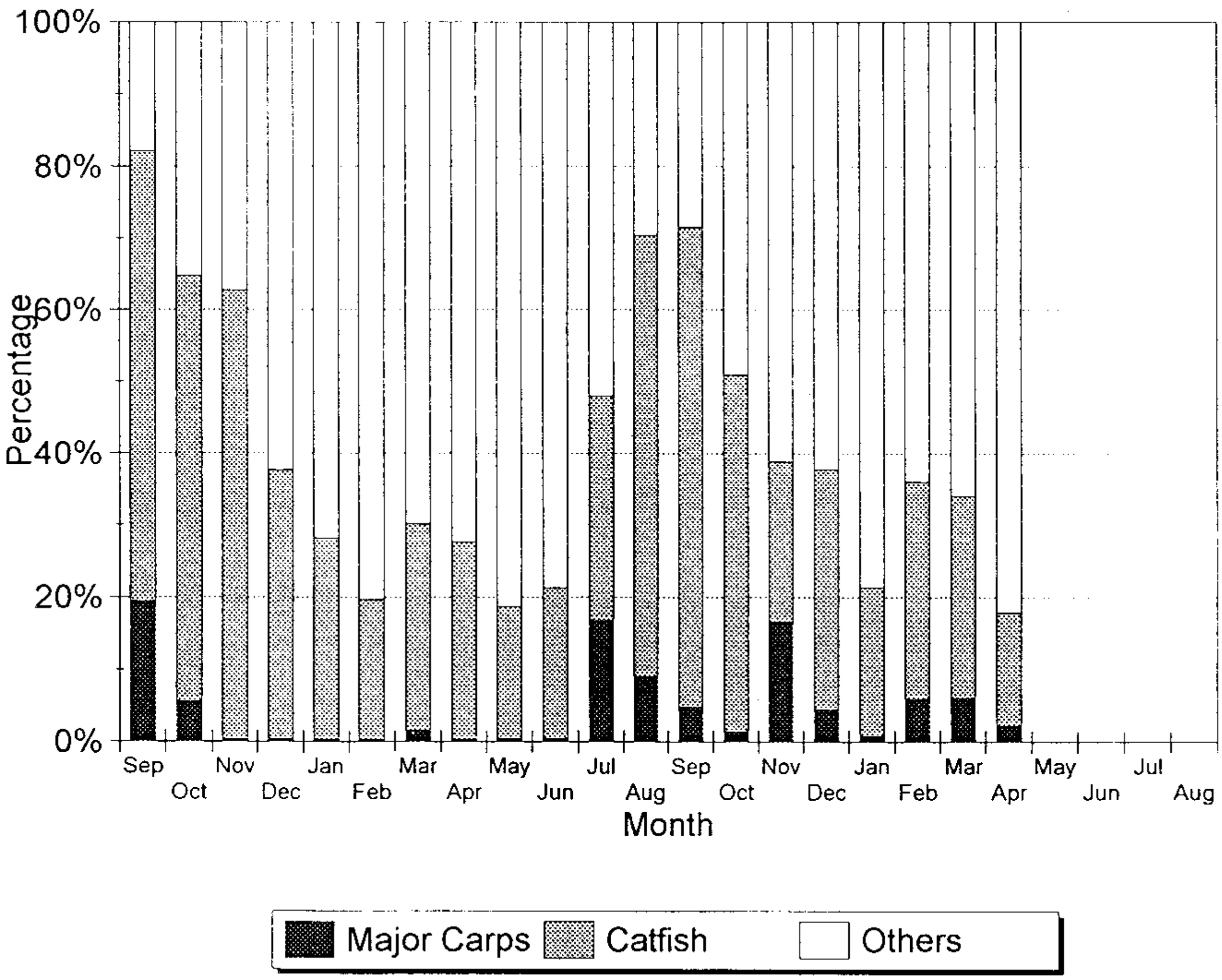


Figure 5.6 Catch composition of major carps from the Ganga River at Patna 1993-94

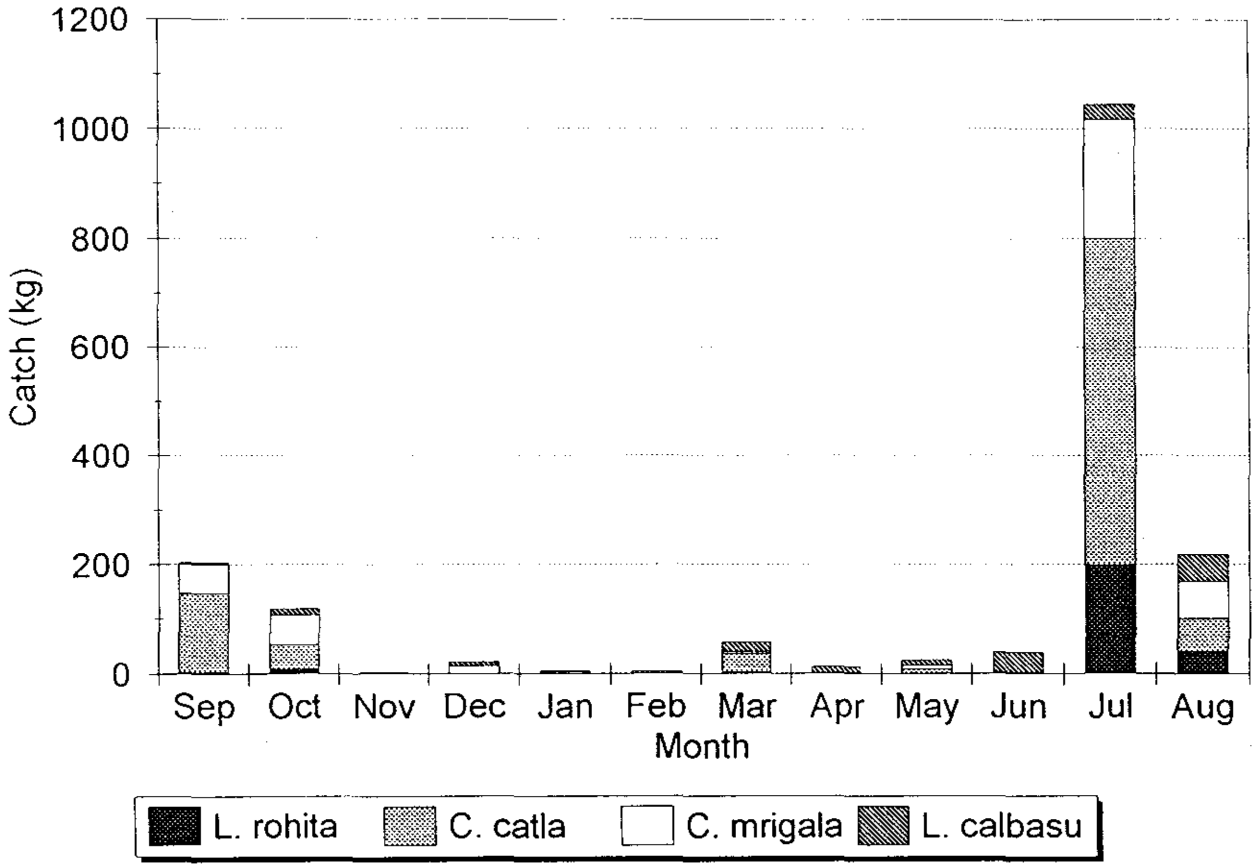


Figure 5.7 Catch composition of major carps from the Ganga River at Patna 1994-95

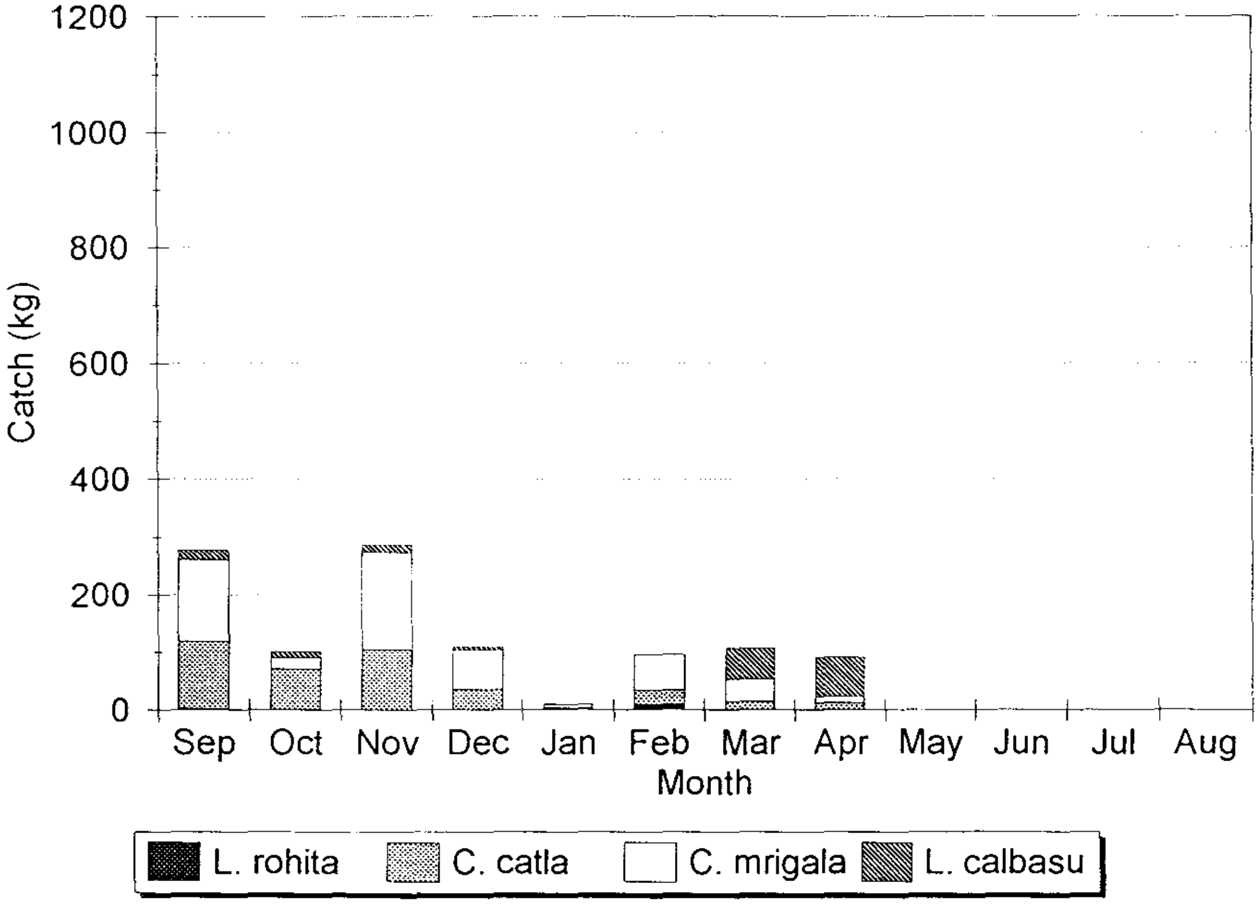


Figure 5.8 Catch composition of major carps from the Ganga River at Daraganj 1993-94

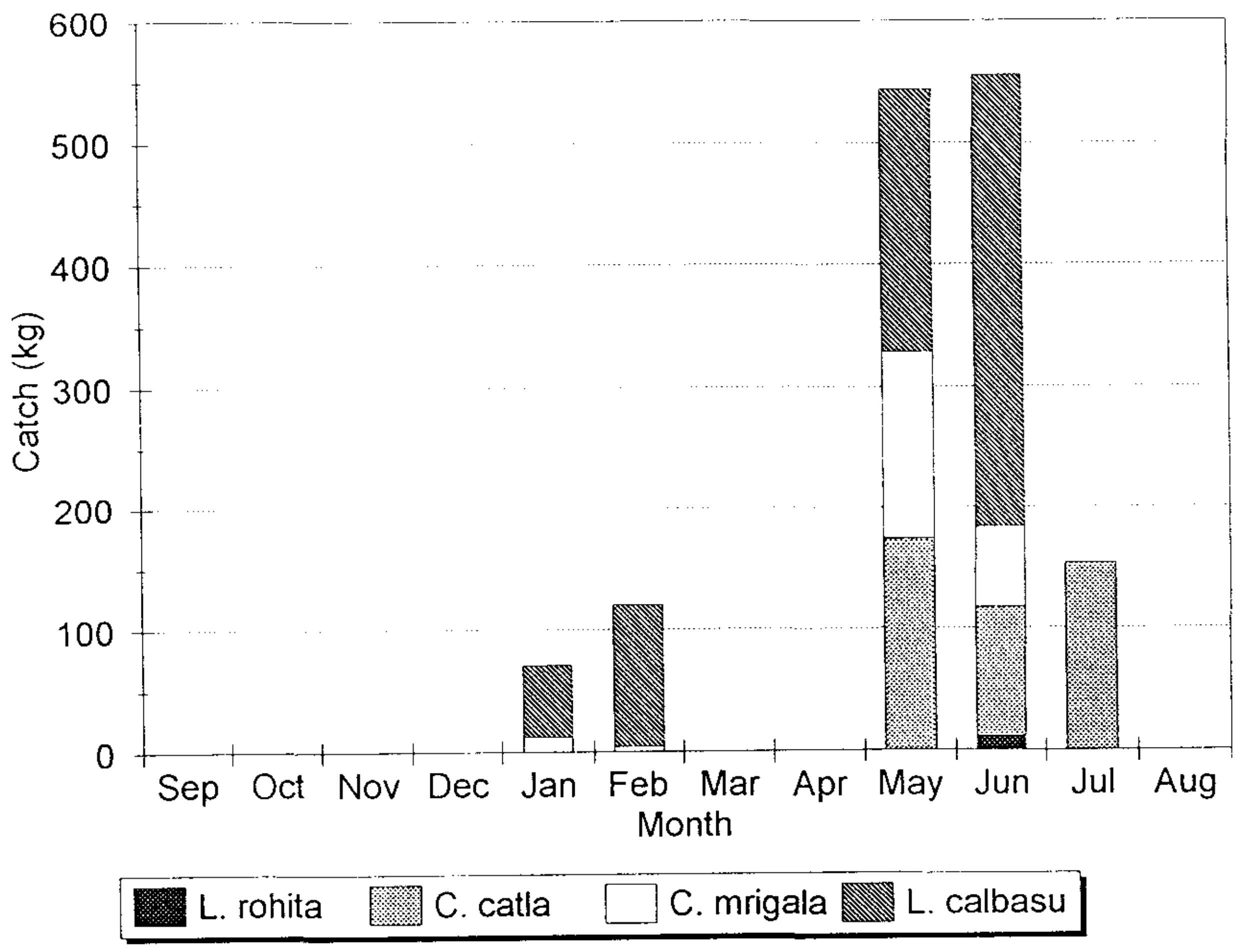


Figure 5.9 Catch composition of major carps from the Ganga River at Daraganj 1994-95

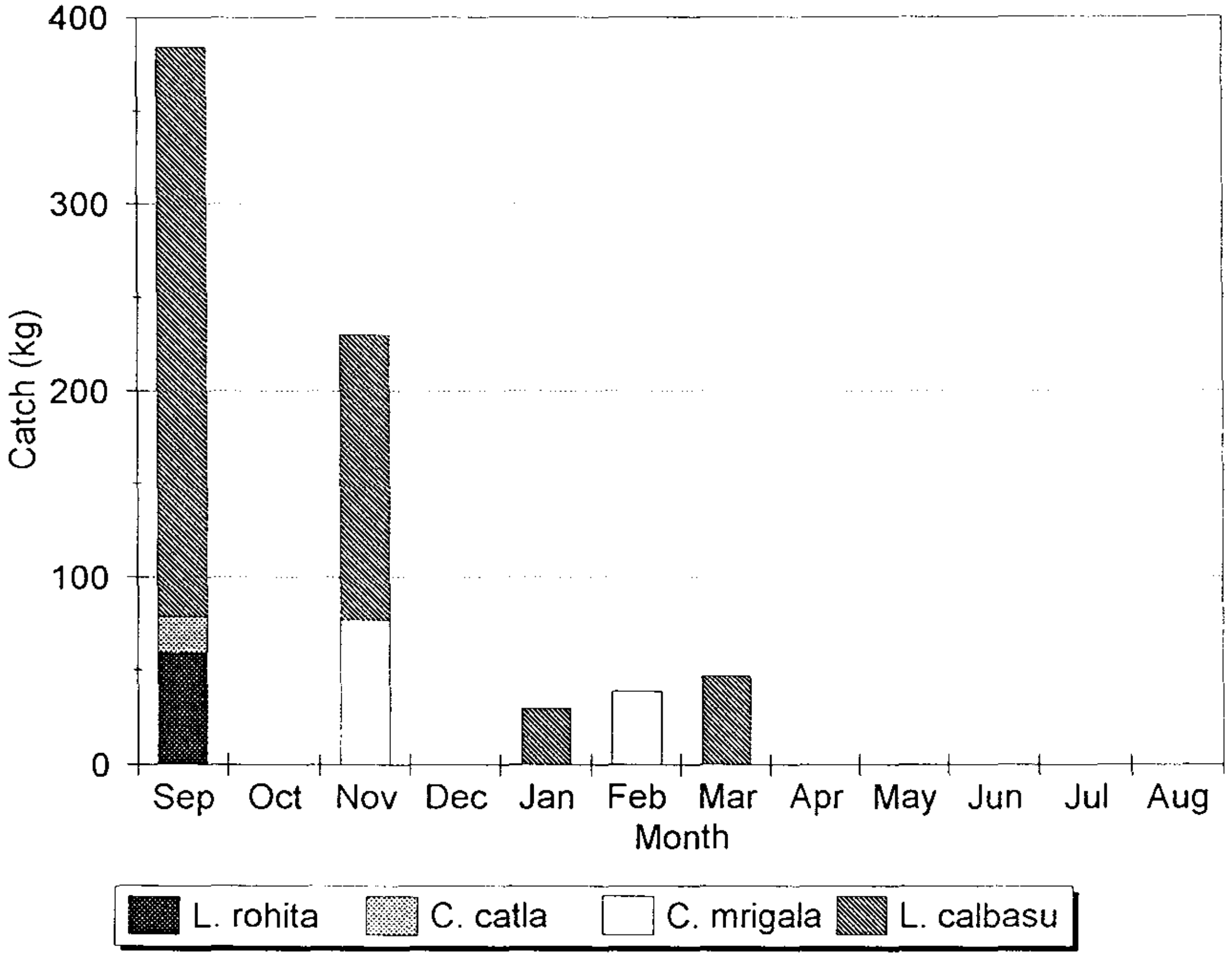


Figure 5.10 Catch composition of major carps from the Ganga River at Sadiapur 1993-94

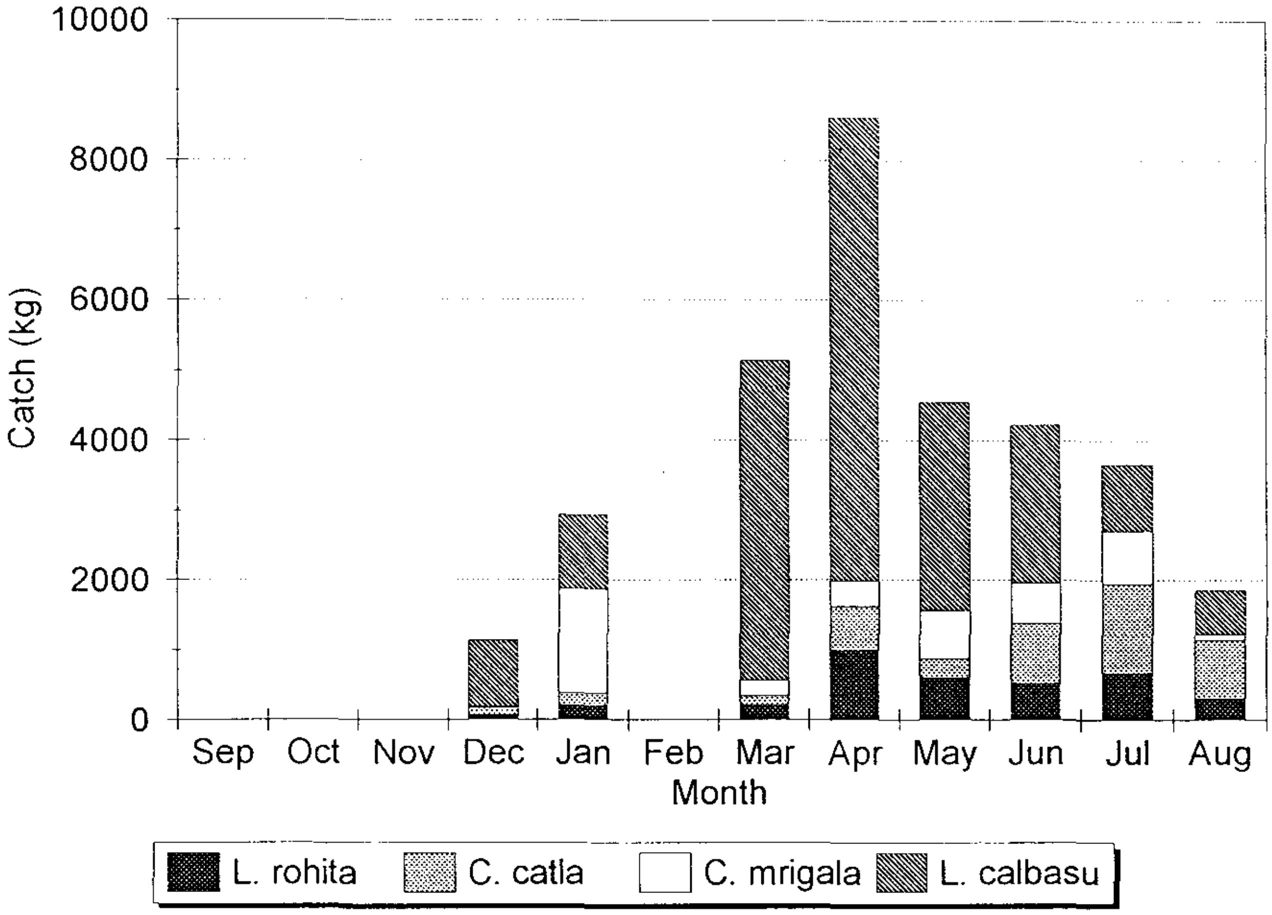


Figure 5.11 Catch composition of major carps from the Ganga River at Sadiapur 1994-95

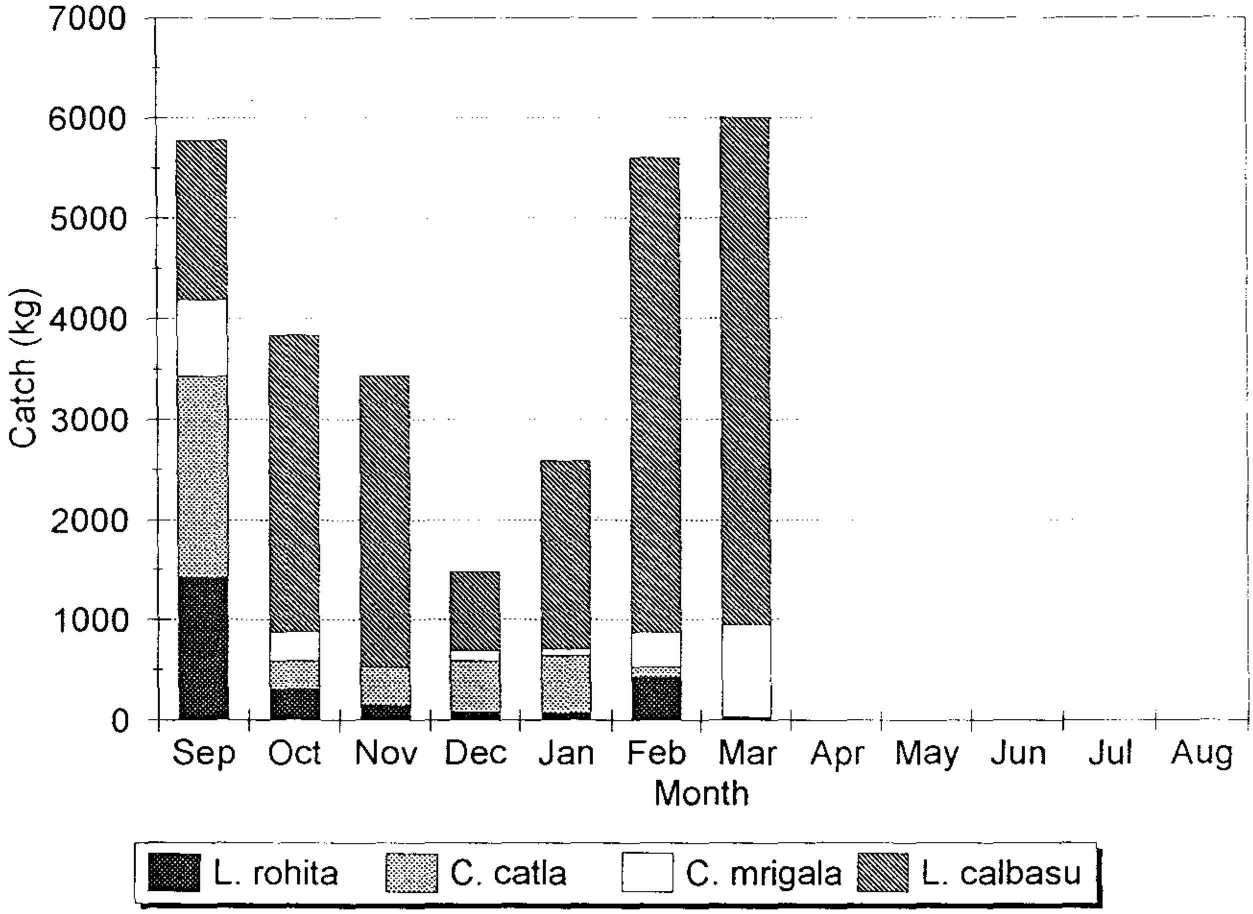


Figure 5.12 Catch composition of major carps from the Ganga River at Gaughat 1993-94

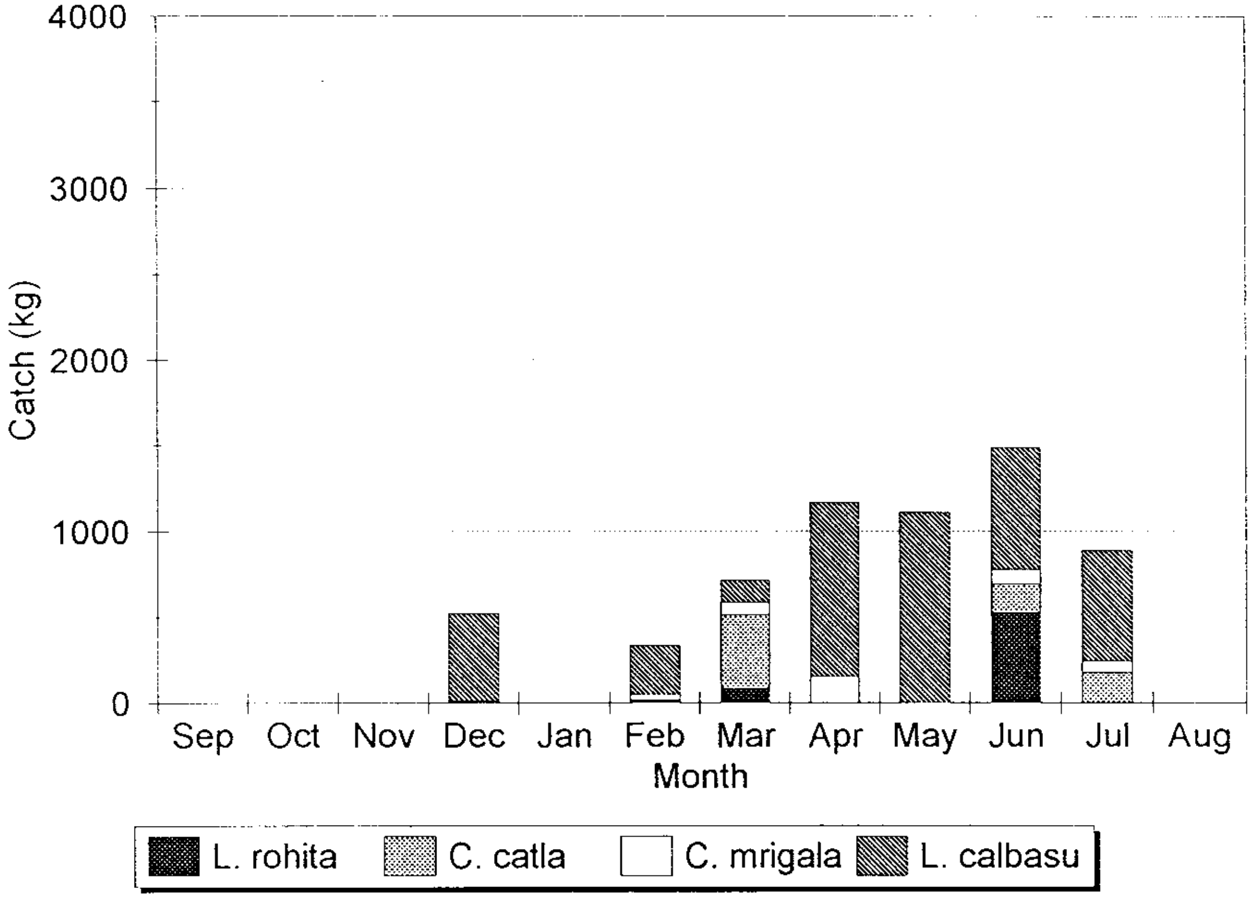


Figure 5.13 Catch composition of major carps from the Ganga River at Gaughat 1994-95

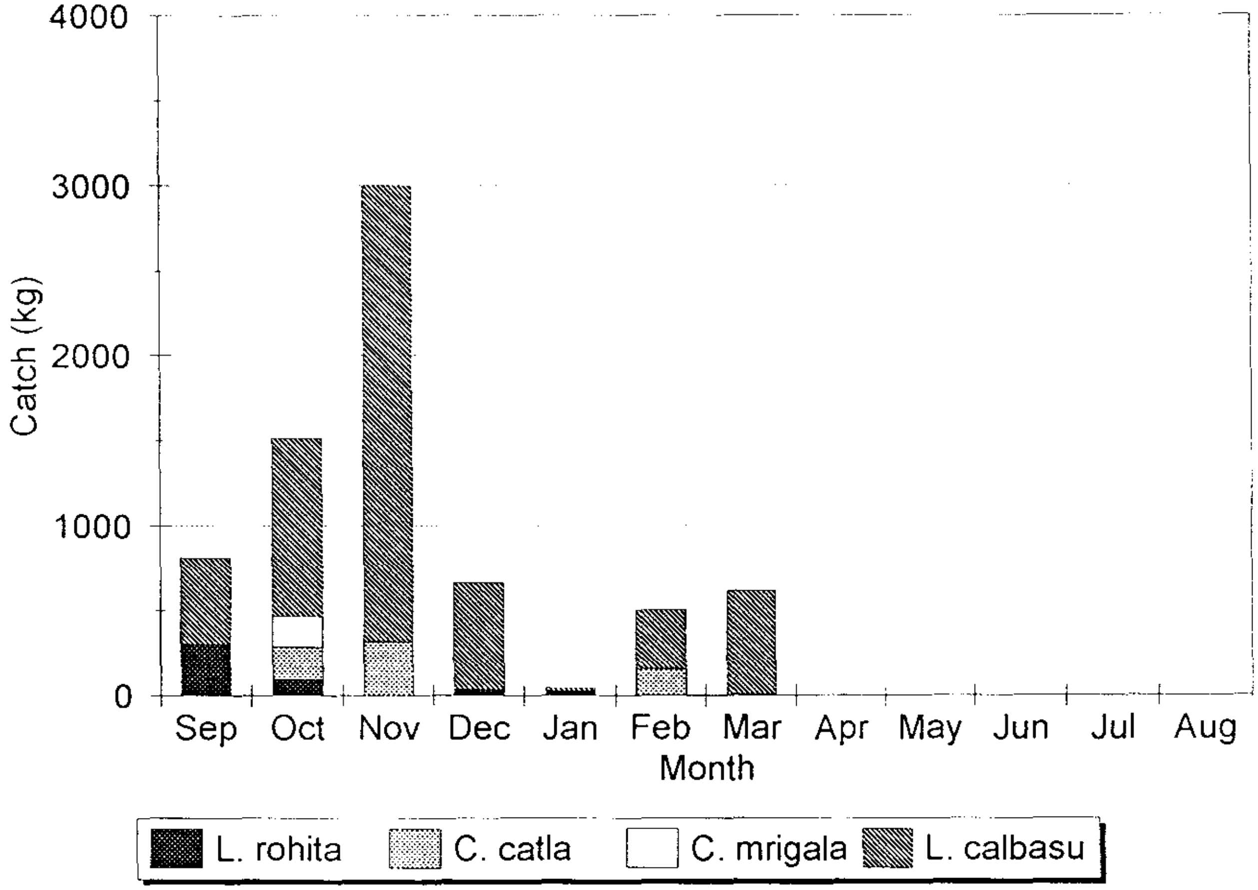


Figure 5.14 Catfish catch composition at Daraganj on the Ganga River 1993-94

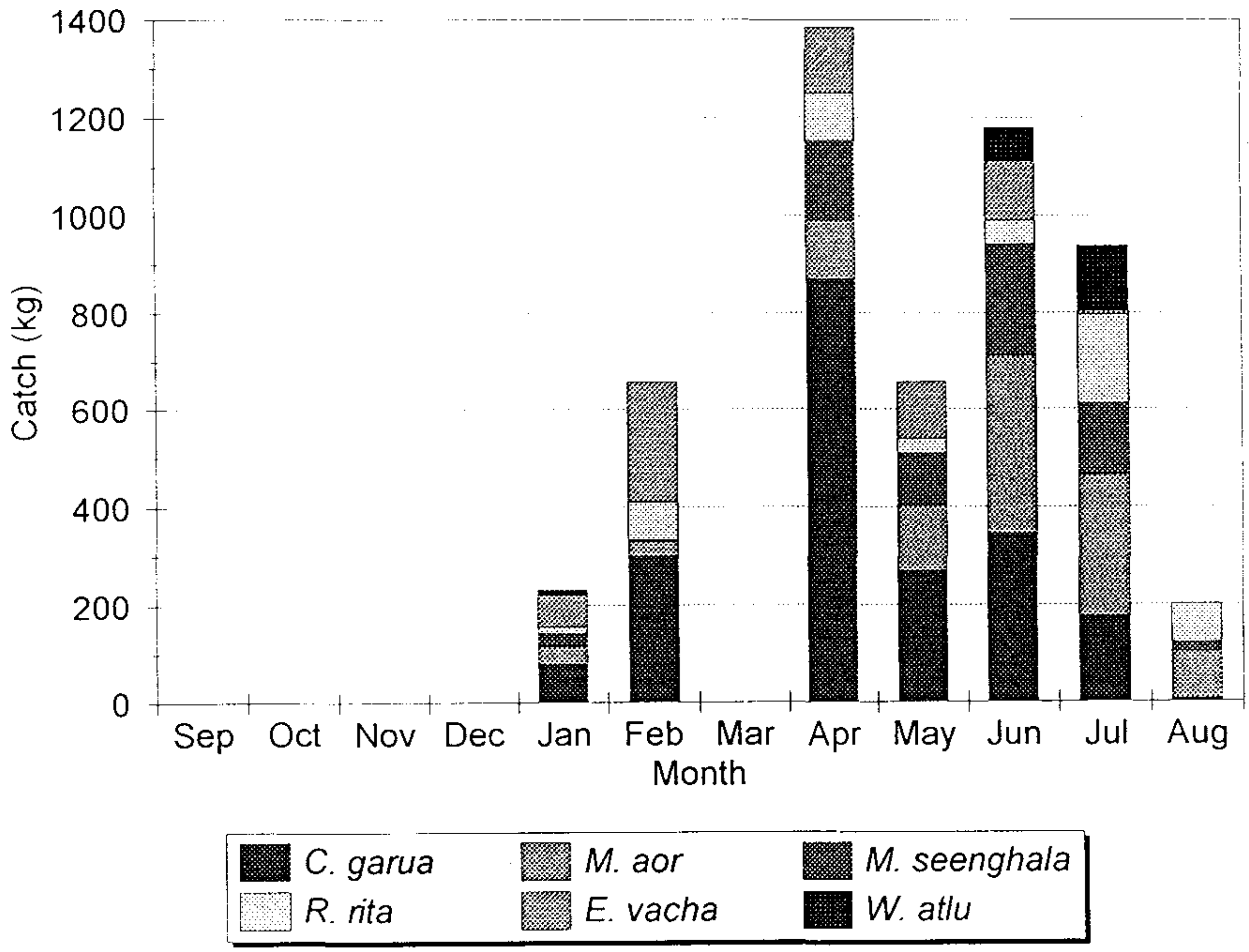


Figure 5.15 Catfish catch composition at Daraganj on the Ganga River 1994-95

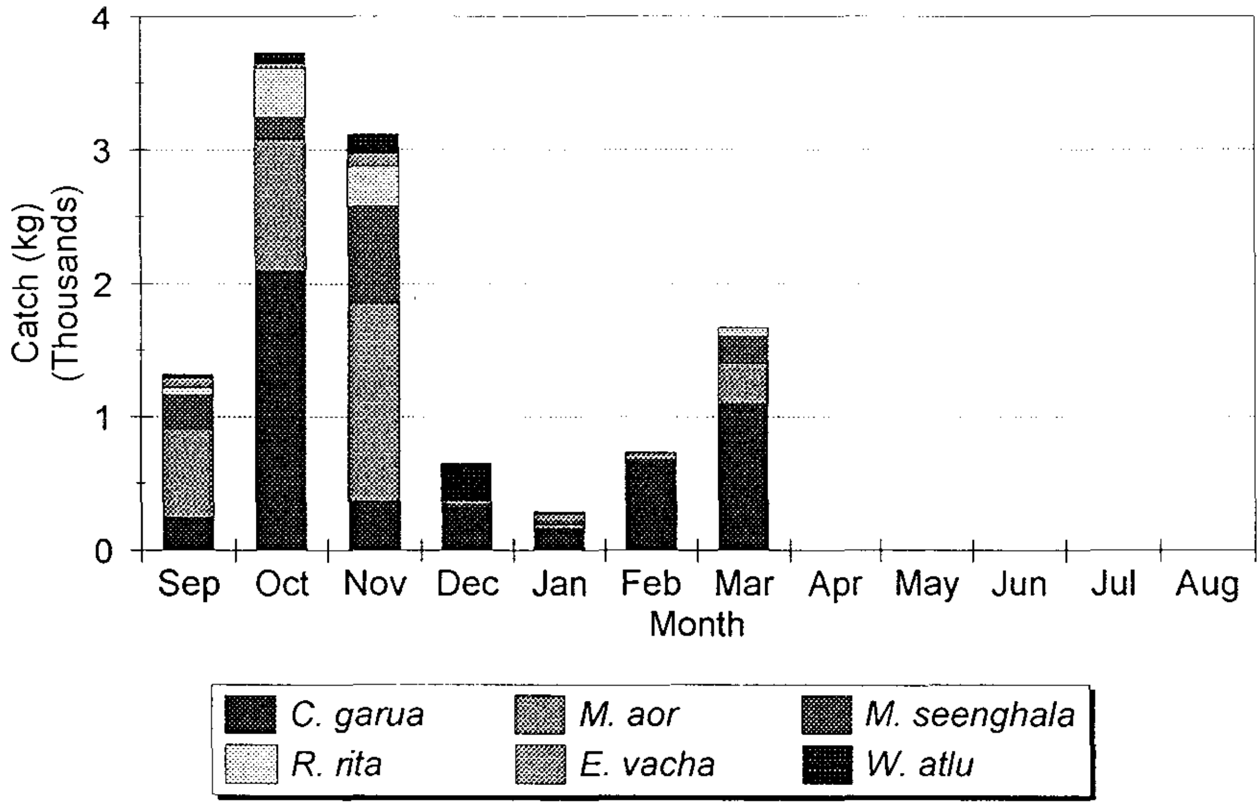


Figure 5.16 Catfish catch composition at Patna on the Ganga River 1993-94

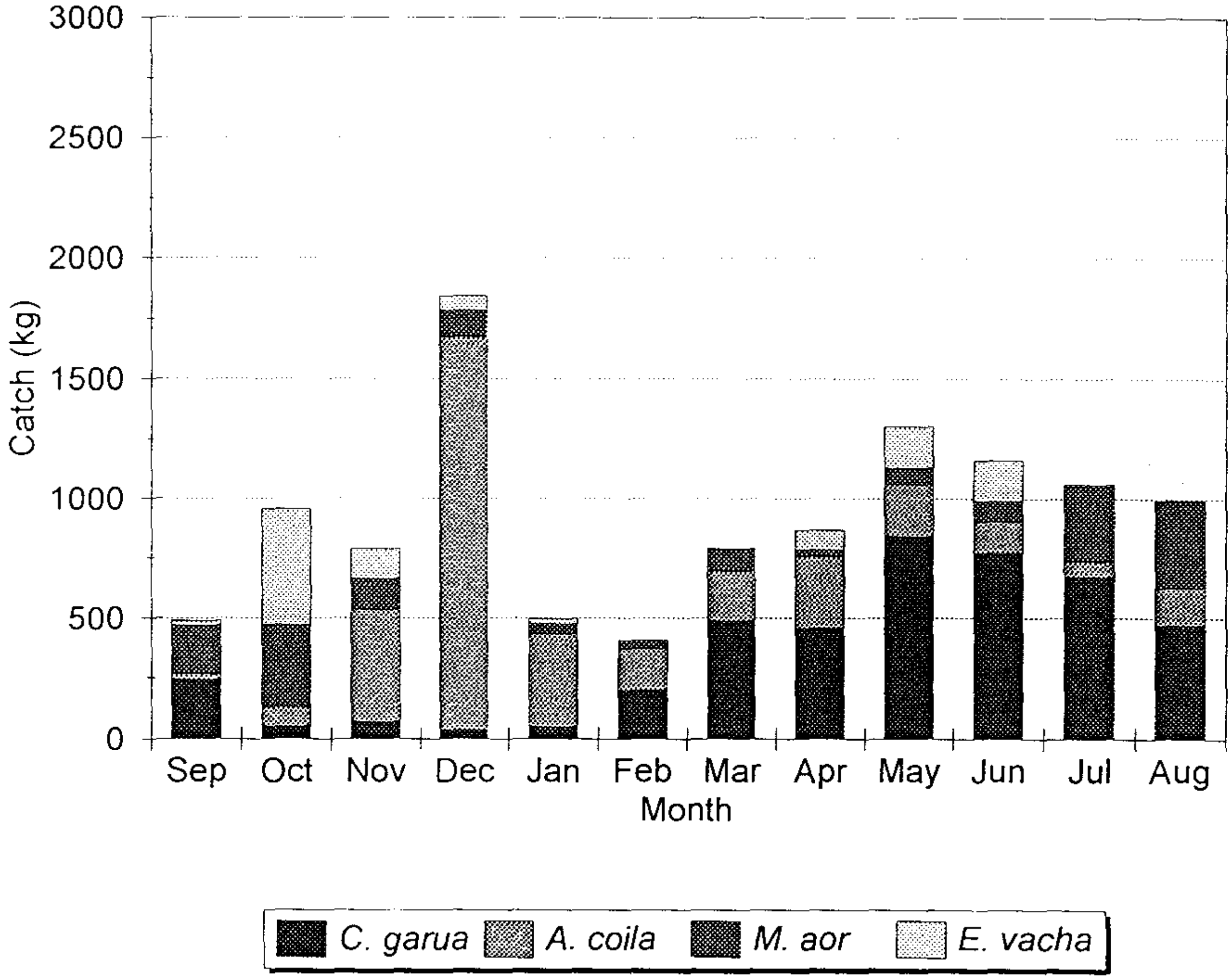


Figure 5.17 Catfish catch composition at Patna on the Ganga River 1994-95

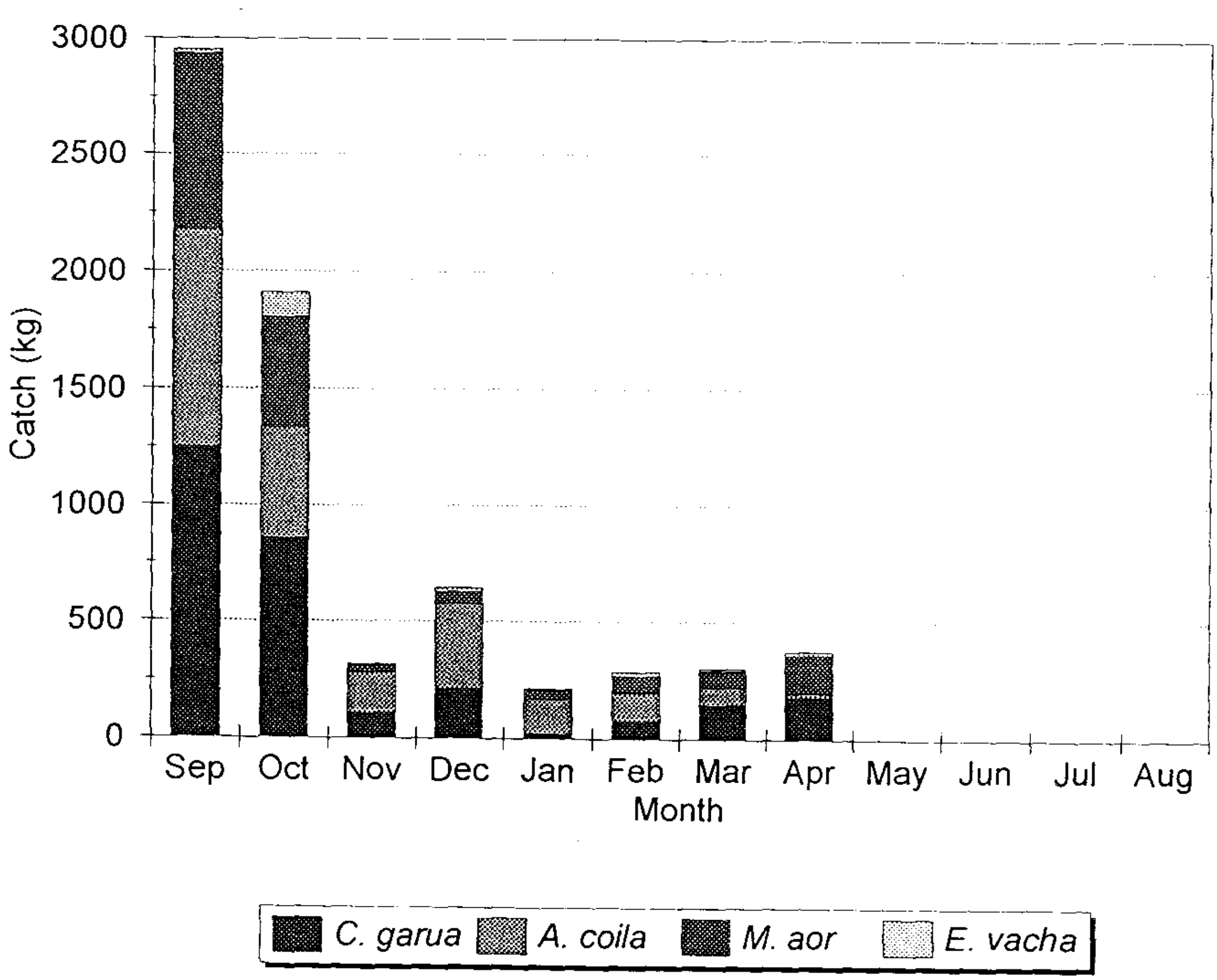


Figure 5.18 Catfish catch composition at Sadiapur on the Yamuna River 1993-94

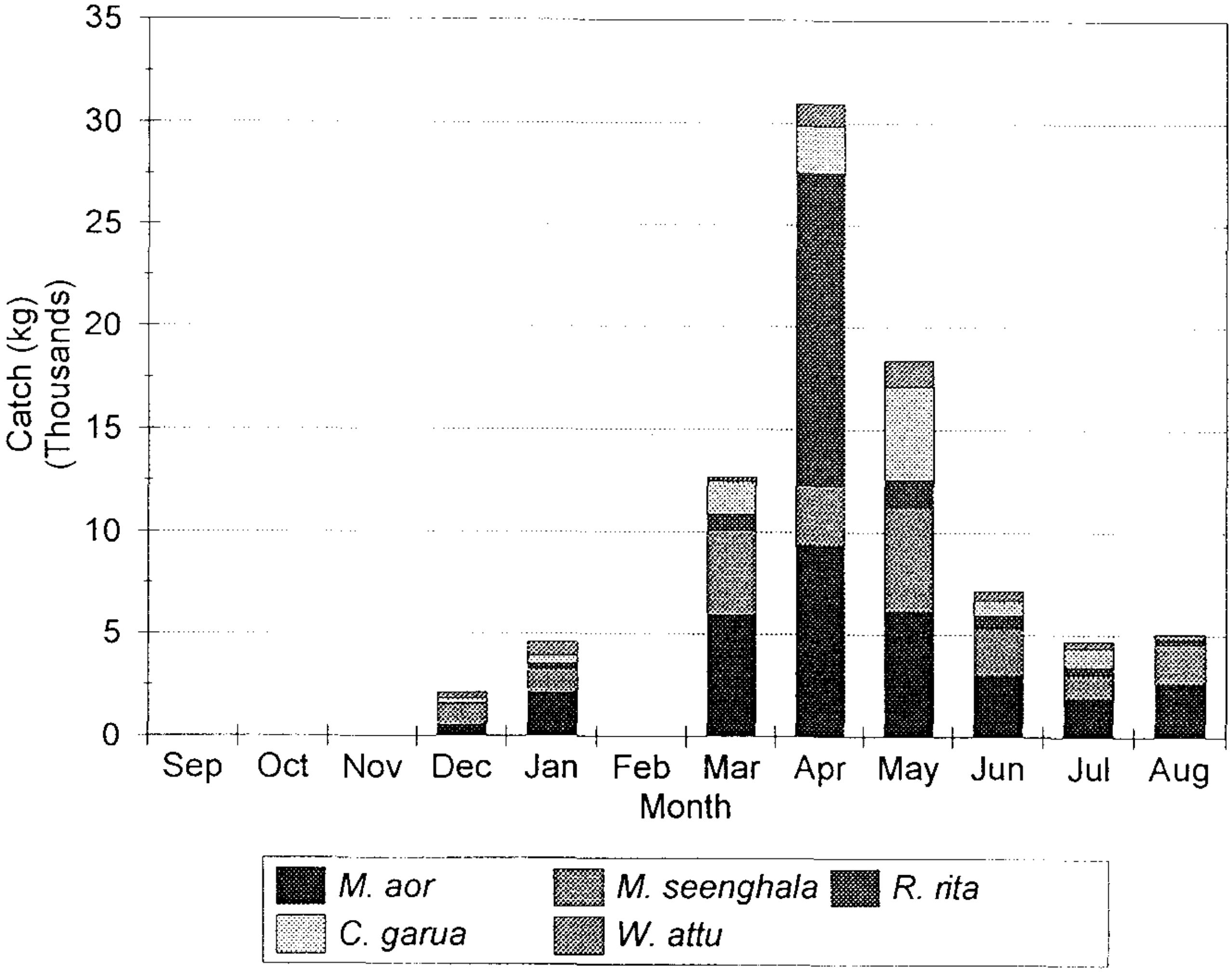


Figure 5.19 Catfish catch composition at Sadiapur on the Yamuna River 1994-95

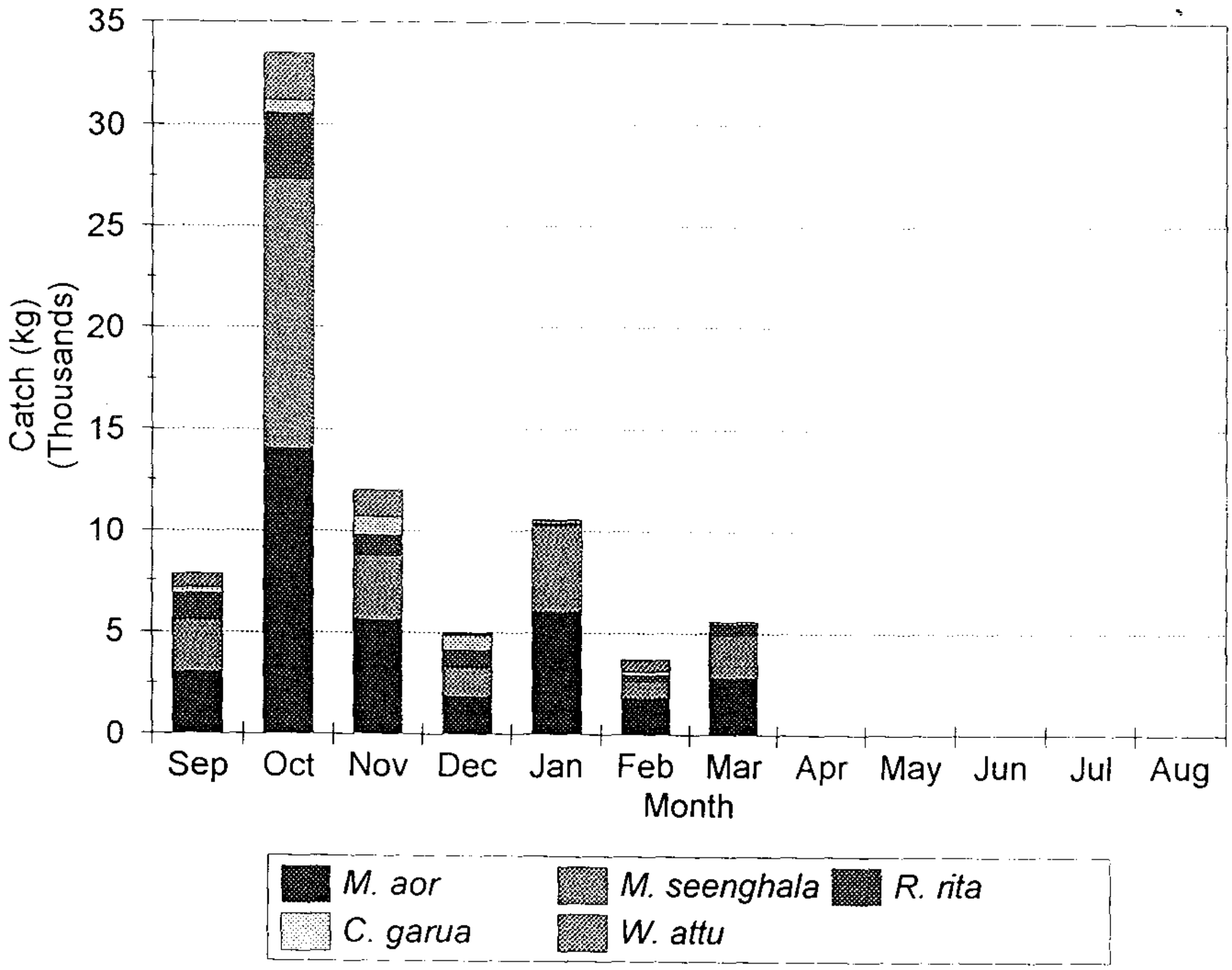


Figure 5.20 Catfish catch composition at Gaughat on the Yamuna River 1993-94

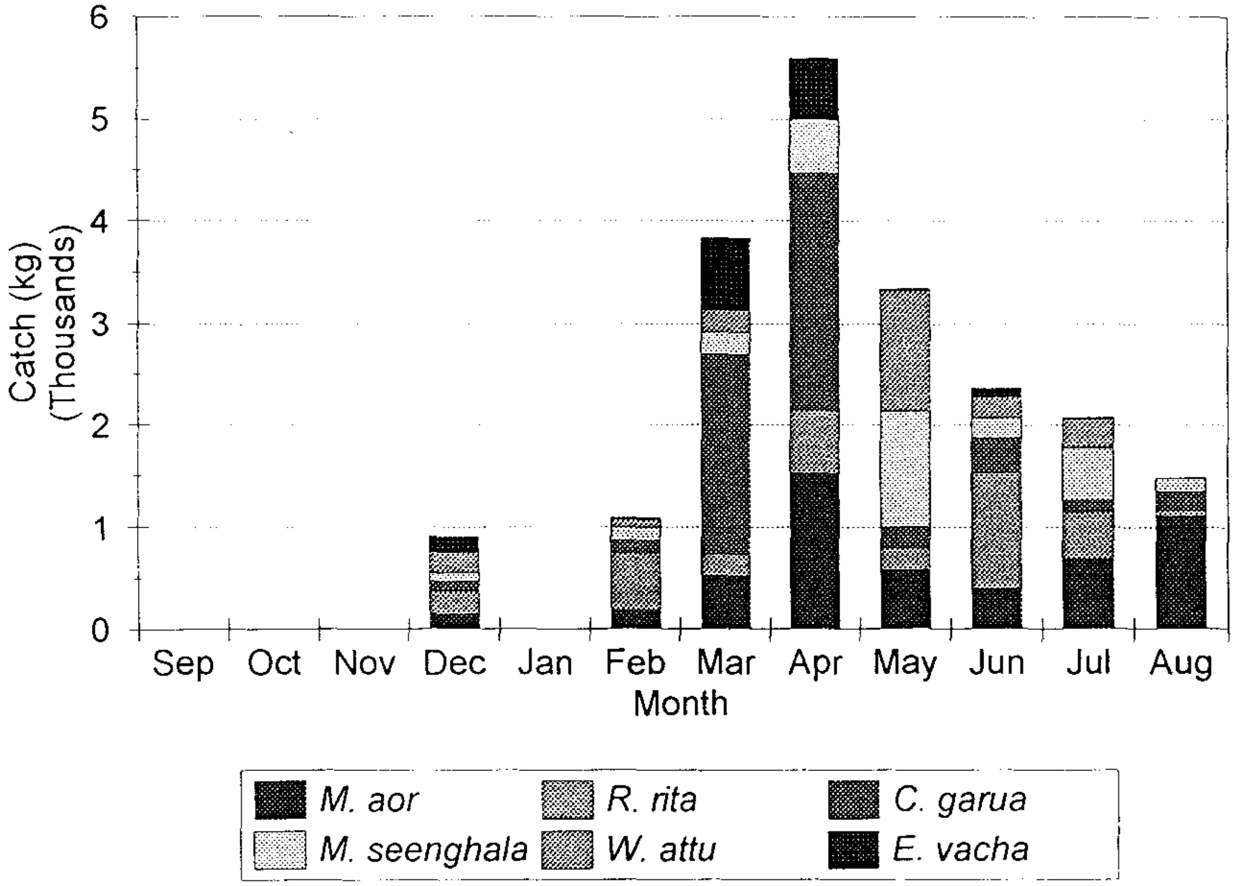
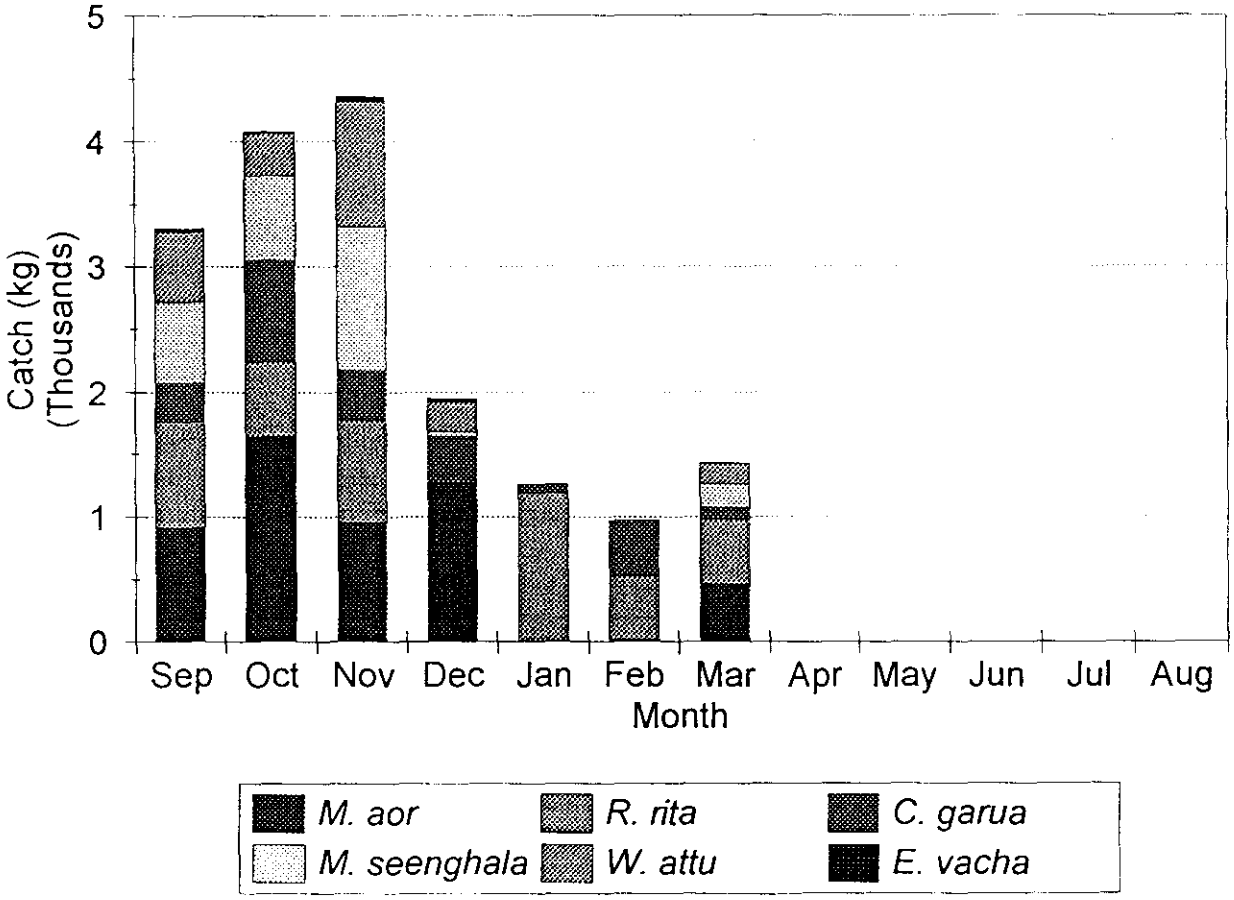


Figure 5.21 Catfish catch composition at Gaughat on the Yamuna River 1994-95



5.2.2 *Hilsa* Survey

The clupeid, *Hilsa ilisha* is also a long distance migrant between the estuaries and the upstream section of the lowland rivers, which previously was a major component of the catch, particularly in the lower regions such as Patna or Buxar (see Section 6.2). Traditionally, *Hilsa* has always been caught as far upstream as Allahabad, some 1500 km from the estuary and this continues to be the case (Tables 5.3, 5.4, 5.5). Historically *Hilsa* is rarely caught further upstream, at Kanpur, for example (Jhingran 1991). In fact, although proportionally inferior, the total weight caught at Allahabad exceeds that caught around Patna, and can be landed from catches on both the Yamuna and the Ganga. On the Yamuna, however, it appears for only a very limited time period, during September and October, whilst in the Ganga both at Daraganj and also at Patna, where it is present more or less continuously, there are peaks during both April / May and September / October or December respectively. This reflects events downstream in the estuary in Bangladesh, where the fish are present continuously but show broad peaks in March and August - October. In Bangladesh *Hilsa* still accounts for around 40% of the total inland riverine fish catch and 47% in the Padma itself (FAP 17 1994), compared to 1% at Patna, 0.6% for the Ganga at Daraganj and 0.1% on the Yamuna at Allahabad.

There is considerable seasonal variation in abundance of *Hilsa* in the lower regions of the river as indicated by the daily records made at the Swarighat landing centre in Dhaka. The peak contributions from the coastal catches appear in March and November / December (Table 5.6). By contrast there is one single protracted peak in the riverine areas, from July to November, which tends to dominate overall landings at the centre. Some of these fish in the lower Padma may then drop back into the estuary to provide the December peak there.

Further upstream, at Patna, *Hilsa* appears from October / November to May, whilst at Allahabad they only appear in April and May. This would be consistent with a possible movement of fishes upstream from the coast in March into the lower estuary during July to November, and some moving further upstream from October to May. Of course the Padma population cannot contribute directly to that at Patna because of the Farakka Barrage. This must be derived from the Hooghly population.

Examination of the mean length of *Hilsa* caught (Table 5.7) shows that as catches build up during May to October the mean size of fish also increases. This could be due to the cohort growing in size or to progressive immigration of bigger fish. However, between November and January there is a dramatic drop in both mean size from 41.8 cm to 27.5 cm. In fact examination of the daily records showed that this drop happened virtually between 22 December and 24 December. These observations are consistent with emigration of larger fishes rather than recruitment of smaller ones.

5.2.3 Other Species

One other clupeid is also to be found amongst the catches of the Ganges, the *Gadusia chapra*. Around Allahabad, however, this appears rather erratically at the Yamuna sites, but more positively between May and September on the Ganga at Daraganj. At Patna it occurs all the year round but peaks between October to December (Table 5.2).

The other remaining species with an obvious migratory pattern is the small engraulid *Setipinnia phasa*. Again, at the upstream sites around Allahabad its presence is rather erratic, although with a peak in June on the Ganga at Daraganj, it is much more strongly and continuously represented in the downstream fishery at Patna with a marked peak in April to June, which is likely to represent the upstream spawning migration. Daraganj may be close to the extremity of the migration.

Prawns can be a major element of the catch at Patna where they can comprise 25% of the weight of the fish catch. This is of a similar order to that which can be found downstream in the delta of Bangladesh (FAP 17 1994). In addition, the valuable Macrobrachium can also be found here, which could provide valuable brood stock for any inland culture centre (Table 5.2). It is clear, however, that prawns are not taken at all at Allahabad. It appears that the cut-off point for the prawn fishery lies between Varanasi, where they can still be caught in small numbers, and Allahabad where they do not appear (Singh, pers. comm.).

5.2.4 Biodiversity and Species Composition

The species appearing in the fisheries at each station can be ranked according to their contribution to the overall catch (Tables 5.8 - 5.11). General comments on biodiversity have already appeared in Section 4.2. The fishery at Patna appears to involve a greater number of species than those at all Allahabad sites, in fact almost twice as many, with 61 recorded here compared to 30-32 at Allahabad. This could reflect a more diligent searching at Patna, but this is most unlikely, particularly given the margin of difference. It suggests that there are a larger number of species available in the lower reaches of the river compared to the middle sector. This was commented upon particularly in Section 4.2.

The build up of larges fishes between March to October is also associated with increased percentage of mature individuals. This is, therefore, part of the migratory movements of *Hilsa* into freshwater to spawn.

Both sites in the main stem of the Ganges at Patna and Daraganj show cyprinids as the single largest contributors. In the case of Daraganj, *Oxygaster*, a small species, contributed an astonishing 40%, mainly due to a huge peak period in the dry season of 1994. At the Yamuna sites, catfish species were the single most common, *C. garua* and *A. aor*. Of the most common species, only *Aorichthys aor* is a larger species, sometimes attaining 1.5 m (Talwar 1991 and Jhingran 1991).

In order to focus future research requirements for assessing the future response of the fishery, it is appropriate to identify those species upon which the fisheries most widely depend. Most research up to the present time has been centred upon the major carps, but whilst they remain significant around Allahabad, they are no longer the main pillars of the fishery. Taking as a guide those species contributing more than 2% overall to the catch as being those of most significance, there are 11 around Allahabad and up to 14 at Patna (Tables 5.8-5.11).

Of all the species in this category only the pelagic catfishes *C. garua* and *A. aor* and the cyprinid *Oxygaster* and common and significant at all sites. Beyond these *Wallago attu*, another large catfish, is significant at three of the four sites and also contributes at the fourth. The engraulid, *S. phasa*, is significant at the two Ganga river sites.

A number of species are significant at the three Allahabad sites, whilst being present but at lower levels at Patna; these include the major carp species as well as the catfishes *M. seenghala*, *E. vacha* and *R. rita*.

Finally, there are a few species which play a significant role at Patna, but which just do not appear upstream at Allahabad. Most notable is the small cyprinid *A. morar* which is the single most common species: others include the congeneric *A. jaya* as well as *C. latius*, which features in some upland fisheries (Section 5.1), *S. cascasia* and *M. cavasius*. The mullet, *Sicomugil cascasia* is entirely freshwater although derived from an estuarine group, and Patna has been recorded as the lowest point at which it has been recorded (Talwar and Jhingran 1991). However, it has also been recorded from the Bangladesh sector of the Ganges (FAP 17, 1994).

In this lower sector of Bangladesh, those species contributing more than 2% include *A. aor* and *C. garua*, although *Hilsa* dominates overall. Others include *R. rita*, *S. phasa*, *C. sorborna*, *A. coila*, *R. corsula*, *P. pangasius*, *C. catla* and *G. giurus* (FAP 17, 1994).

To understand the status and prospects of the fisheries in the lowland sector of the Ganges, it will be essential to understand more of the most common species overall, i.e. *A. coila*, *C. garua* and *Oxygaster* with respect to production, population dynamics and bioeconomics. As secondary targets can be added, some of the other species such as *S. phasa*, *R. rita* and *Mystus* spp. with more local priorities such as *A. morar* and other smaller cyprinids.

Amongst the fish catches from all sites, floodplain resident species contribute only a minor fraction (Tables 5.8-5.11). The majority of the catch comes from riverine, migratory species. By contrast, it was found that with the more extensive flooding of Bangladesh, the floodplain resident species, comprising a community of around 25 species of "black fishes" comprised more than 65% of the catch (FAP 17, 1994). The more discrete river channel of the Ganges above the Farakka Barrage appears to mitigate against this predominance and the rather more vulnerable migratory river species constitute the much greater proportion.

5.2.5 The Farakka Barrage

The Farakka Barrage creates something of an impoundment. This stretches for some 50 km behind the barrage and is about 7 km wide close to the barrage itself. The cause is the relatively narrow outlet of the canal which diverts the water into the Baghirathi river and ultimately down to the Hoogly estuary. This causes the water to back up and form the impoundment.

The impoundment is reported, from a University of Patna survey, to have become quite shallow with dense growth of submerged and emergent vegetation sufficient to impede the movement of boats in places. A contributory factor to the shallow depth appears to be the high rate of silt deposition from the Ganges River behind the barrage (Sinha: pers. comm.)

The collaborative team from the University of Patna have also recently conducted a 17 day survey by dinghy along the waterways linking Farakka to the Hooghly river (Figure 5.24), noting the distribution of river dolphins, fishing and other activities. There is a flourishing fishery here which largely comprises floodplain rather than riverine species. There was evidently considerable abstraction of water along the channels for agriculture largely using low-life pumps. Moderate fishing activity was noted along the banks but the fishermen all claimed that, even here below the barrage, the fishery for *Hilsa* had declined markedly. A possible reason for this may be the "barrier" to the migrating fish of pollution, which exists in the Hooghly due to effluent from Calcutta.

5.2.6 Spawn Collection from Major Carps in the River Ganga at Patna

A spawn collection survey was conducted between 25 July and 15 August 1993 over a 20 km stretch of the River Ganga, from Digha ghat in the west to Malsalami in the east.

The collection of spawn and fry of Indian major carps such as *Catla catla*, *Cirrhinus mrigala*, *Labeo rohita* and *Labeo calbasu* from the River Ganga a few decades ago comprised 90% of the total requirement, with only 10%coming from culture fisheries. Quality fish seed is required to supplement supply from hatcheries, and in order to stock an estimated 1.6 million ha of ponds and tanks approximately 32 billion seeds are required. Spawn production from hatcheries contributes only 10% (or an estimated 5.3 billion seeds) and the remaining 90% is derived from wild stock in rivers. Carps do not breed in confined water but only in flowing water, since they require a large area to move around in. The breeding season extends from late May to August during the monsoons.

The spawn is collected with a special spawn collection or shoaling net which is conical in shape and this is connected to a "Puchhra" or Gamchha" (small cloth tied with bamboo sticks). Within 30 minutes of being caught the spawn are transferred into "Hapas", small square cotton cloths tied at each end to four bamboo poles, and stored in water. The size of the nets and the tail pieces (Gamachha or Puchhra) vary according to water level, current, turbidity and river width at collection sites. The fisherman uses a "bati" or small metallic bowl to measure the spawn. They sell small-sized bati containing approximately 10,000 fish seeds for IRs 30 per bati, whilst larger batis containing between 20,000-22,000 seeds fetch IRs 50 each.

At high water, at the height of the monsoon season when the current is at its fastest, the fishermen collect spawn 24 hours a day. Catches of spawn increase markedly when the red soil-laden waters of the River Sone flow into the Ganges and river flow increases. During this period a fisherman can catch about 100 bati of spawn (10 laks) in 24 hours. There are 29 spawn collection sites near the confluence of the River Sone and the Ganges at Patna, with an average of eight shoaling nets and one hapa in operation at each site. It has been observed that when river flow decreases and the concentration of red soil suspended in the water declines, there is a consequent 50% reduction in spawn collection. The spawn collection season lasts for two and a half months in all, with a one month peak. According to local fishermen, the spawn consists mainly of carps and there are no larvicidal fish. The spawn collection centres and number of collection nets and hapa are shown in Table 5.12.

The major carp fishery of the River Ganga in India is virtually being destroyed due to indiscriminate fishing at every stage of the life cycle of the fish. Spawn collection from the river is essentially a fishing mortality that occurs mostly at the pre-recruitment phase of the fishery. It is a matter of some controversy as to whether the practice of spawn collection from wild stock should be discontinued in the future, if it continues to gain in popularity and become more widespread.

5.2.7 Socio-Economic Surveys at Allahabad

- **Demographic Structure**

Throughout this survey categories related to boat ownership were used to represent the fundamental divisions with regard to fishing as a livelihood (See Section 4.1). Based on the interview survey of 8 villages around Allahabad, the demographic structure of the sampled families (Table 5.13) indicated low variation across the different categories of fisher families, with the overall highest group being adult males (42%) followed by adult females (34%). The children below and above 5 years were almost the same at approximately 12%. The average size of the families (Table 5.14) was highest for "others" (9.39) and lowest for "without boat" categories (4.8). For the remaining categories, family size was around 8.6. Consequently, the average number of adults and minors were maximum for "others" and minimum for families "having no boat". On average, a family comprised of 3.63 males, 2.96 females and 2.1 children. The sex ratio indicated overall 82 females per 100 males. The highest sex ration was for families without boat (1 : 0.90) and the lowest was for others (1 : 0.77). The women have no immediate role in catching fish, but plan an important role in fish marketing and in the making of fishing gear.

- **Gear in Use**

Seine nets of various types, (Chaundhi 36%, Chanta 24% and Mahajal 9%) were most common followed by gill nets (Fasla 22%). Since these need to be set or laid in the water they are common only in families who owned or hired boats. The families without boats used hook and line and other nets, e.g. cast and scoop nets and traps (Table 5.15).

- **Level and inheritance of fishing activity**

The time devoted to fishing activity revealed that more than 50% of the fisher families conducted full-time fishing, followed by around 25% of active part-time fishing (Table 5.16). The level of activity varied according to fixed assets, e.g. boat or net ownership. More than 66% of the families owning boats were full-time fishermen against 24% of families with hired boats and 40% without boat. The families of "other" category only rarely go fishing. The response to inheritance of fishing activity for future generations was very poor. Its highest positive value was for the families with owned boat (16%). The low status of this activity and the low returns may be the principal reasons for this.

- **Catch and Income**

The average fish catch per day in quantity and value was estimated at 9.28 kg and IRs 74.25 for all the families (Table 5.17), with the maximum for families with owned boat (12.05 kg and IRs 88.64), and minimum for "others" (3.30 kg and IRs 35.96). Both quantity and value of fish catch varied according to the level of fishing and ownership of fishing gear.

- **Financial Assistance**

The results presented in Table 5.18 indicated that formal institutional credit structure for fishing activities was almost missing. The major source of finance was unofficial credit from money lenders who provided over 94% of the credit. Only 32% of the families benefited from credit facilities. All the beneficiaries were the families who owned or hired boats. The weak financial provisions may be due to the nature of security assets offered, very low repaying capacity and risk bearing ability.

- **Secondary employment status**

The highest number of families for all the categories except "others" were engaged in miscellaneous activity as secondary employment (Table 5.19). Besides fishing, agriculture was the major single secondary occupation. Over one third of the families with owned boat had agriculture as their secondary occupation. Business, particularly trading was the most important secondary activity for others.

- **Perceived Problems**

Coping with the depredations of fellow fishermen and non-fishing groups through interference and the demanding of money and catch for protection, proved to be the primary concern of fishermen (Table 5.20). Economic problems (52% were also severe, together with problems of fish production and disposal. The poor financial status and the money paid at various fish production and disposal stages resulted in low investment in fisheries and curtailed returns from it.

Table 5.3 Catch by weight (kg) from Sadiapur, Yamuna River, Allahabad

Species	Categories M	R	C	P	F	Month 1993 / 94 Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
L. rohita	x	x							67	204		223	1002	816	527	678	306
C. catla	x	x							98	181		122	621	258	856	1271	840
C. mrigala	x	x							19	1475		221	365	890	573	756	78
L. calbasu	x	x							944	1075		4874	6630	2985	2273	963	620
M. seenghala		x	x	x					972	1166		4138	2895	5100	2306	1134	1920
M. aor		x	x	x					594	2126		5964	9390	6135	3021	1926	2655
W. attu		x	x	x					271	701		198	1156	1306	458	299	260
C. garua			x	x					218	368		1638	2235	4545	752	900	23
E. vacha			x	x					93	62		468	825	810	1998	30	41
R. rita			x	x					62	261		736	15285	1306	809	414	198
Oxygaster									515	80		1400	1500	300	1500	300	180
N. notopterus				x	x				59	368		32	89		102		
N. chitala				x	x				21	68		12	39	22	23	22	15
B. bagarius		x	x	x					285	350		450	188	150	375	150	225
S. phasa									34	8		48	48	83	27	11	18
G. cemia									1			1		4			
M. armatus					x				3	34		82	21	74	101	11	7.5
Puntius					x				8	5		1	2	2	3		
O. cotio										6		2	2	27	8	2	37.5
L. bata									4	61		28	147	102	98	8	38
L. gonius									33	3		2					
A. coila		x	x	x					41	94		86	28	48	24	41	30
S. cotior									155	34		36	21	6	18	6	15
R. corsula		x										10	8	12	15	4	
G. chapra		x								2		76	17	9	27		150
X. cancilata					x							1	12	69	12		
T. tor										42		30					
M. tengra					x					1		2					
G. manimina												6	6		6		60
P. pangasius		x	x	x						4		2					
Hilsa		x															
Others									128								
Total Weight						0	0	0	4626	8769	0	20569	42631	24636	15711	8924	7683
No. of Species	5	14	9	11	6	0	0	0	22	26	0	30	26	24	25	20	21

Species	Month 1994 / 95 Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Total Weight	%
L. rohita	1427	308	152	83	76	432	38						6137	2.50%
C. catla	1996	287	376	609	664	96							8073	3.28%
C. mrigala	759	283		106	66	345	906						6640	2.70%
L. calbasu	1596	2960	2907	784	1884	4721	5064						39980	16.26%
M. seenghala	2541	13277	3200	1380	4271	832	2122						47244	19.21%
M. aor	3037	13999	5604	1875	6014	1800	2601						66941	27.22%
W. attu	663	2326	1327	139	71	566							9738	3.96%
C. garua	281	601	914	724	92	165	116						13572	5.52%
E. vacha	19	41	183		6	42	42						4660	1.90%
R. rita	1308	3283	972	894	113	324	518						26282	10.69%
Oxygaster	16	15	98	345	15	83							6316	2.57%
N. notopterus	210												860	0.35%
N. chitala	8	11											241	0.10%
B. bagarius	75	780	225	480	90	45	90						3958	1.61%
S. phasa	37.5		19	30	8	11	23						382.5	0.16%
G. cemia	4.5	15											25.5	0.01%
M. armatus	45	20.5	63	8	30	15	18						501	0.20%
Puntius	15												36	0.01%
O. cotio			3			23							110.5	0.04%
L. bata		7.5	75	38	90	45	120						861.5	0.35%
L. gonius													38	0.02%
A. coila	15	3.8	45	90	53	23	53						674.8	0.27%
S. cotior	135	15	68	83	75	15	11						692	0.28%
R. corsula	15	5	2										71	0.03%
G. chapra	19	23	45	45	8								421	0.17%
X. cancilata													94	0.04%
T. tor						159							231	0.09%
M. tengra													3	0.00%
G. manimina	12	18	45	45	8								206	0.08%
P. pangasius													6	0.00%
Hilsa	180	137											317	0.13%
Others	105	231	8	38	60		3						573	0.23%
Total Weight	14518	38664.8	16320	7696	13594	9740	11926	0	0	0	0	0	245885.8	100.00%
No. of Species	24	22	20	18	19	19	14	0	0	0	0	0		

		Month 1993 / 94 Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Month 1994 / 95 Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Major Carps	Weight	0	0	0	1129	2935	0	6140	8618	4548	4228	3667	1843	5778	3838	3434	1481	2590	5593	6008	0	0	0	0	0
Catfish	Weight	0	0	0	2536	6122	0	13680	32001	19398	9543	4894	5352	7939	34310.8	12470	5582	10710	3796	5742	0	0	0	0	0
Others	Weight	0	0	0	961	712	0	1739	1912	690	1940	363	488	801	506	416	632	294	351	175	0	0	0	0	0
Major Carps	Percentage	0.00%	0.00%	0.00%	24.41%	33.47%	0.00%	25.00%	20.26%	18.46%	26.91%	41.09%	23.99%	39.80%	9.93%	21.04%	19.25%	19.05%	57.42%	50.38%	0.00%	0.00%	0.00%	0.00%	0.00%
Catfish	Percentage	0.00%	0.00%	0.00%	54.82%	68.41%	0.00%	66.54%	75.24%	78.74%	60.74%	54.84%	69.66%	54.68%	88.76%	76.41%	72.54%	78.78%	38.97%	48.15%	0.00%	0.00%	0.00%	0.00%	0.00%
Others	Percentage	0.00%	0.00%	0.00%	20.77%	8.12%	0.00%	8.46%	4.50%	2.80%	12.35%	4.07%	6.35%	5.52%	1.31%	2.55%	8.21%	2.16%	3.60%	1.47%	0.00%	0.00%	0.00%	0.00%	0.00%

Table 5.4 Catch by weight (kg) from Gaughat, Yamuna River Allahabad

Species	Categories					Month 1993 / 94												Month 1994 / 95												Total	%
	M	R	C	P	F	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Weight	
L. rohita	x	x							3		20	84			528			304	99		38	24								1100	1.74%
C. catla	x	x							7			427			181	174			185	316			153							1422	2.25%
C. mrigala	x	x							2		28	71	150		87	66			182					2						588	0.93%
L. calbasu	x	x							507		285	129	1020	1110	711	650		506	1049	2684	629	19.5	351	614						10264.5	16.24%
M. seenghala		x	x	x					83		120	213	525	1125	197	513	129	644	668	1147	35		6	180						5585	8.84%
M. aor		x	x	x					152		187	519	1530	585	398	690	1110	916	1641	962	1274		21	463						10448	16.53%
W. attu		x	x	x					199		83	222		1200	202	282		568	343	995	240		3	163						4500	7.12%
C. garua			x	x					90		123	1971	2325	210	338	119	180	307	810	401	373	68	441	97						7853	12.43%
E. vacha			x	x					156		16	699	600	15	89	18	2	29	18	43	31			5						1721	2.72%
R. rita			x	x					227		560	210	615	210	1137	454	57	847	602	811		1183	507	519						7949	12.58%
Oxygaster									116		35	180	450	15	1650				15	60	53	12	315	60						2961	4.69%
N. notopterus				x	x				12		22				20		15	30	15		4	9								126	0.20%
N. chitala				x	x				1		7						8	8	15											39	0.06%
B. bagarius		x	x	x					65		45	60		498	188	75		45	270	3	41			30						1310	2.07%
S. phasa									7		16	21	45	6	18	21	26	8			5		30	8						211	0.33%
G. cernia									1				1								8									10	0.02%
M. armatus					x				4		19	19	16						19	90	8	4		26						205	0.32%
Puntius					x				negl.		3			3	74	3	8			15			75							181	0.29%
O. cobo											7	1	2				11					4								25	0.04%
L. bata									33		43	123	171	19	122	66	23	15	23	150	48	60	53	4141						5090	8.06%
L. gonius																														0	0.00%
A. coila		x	x	x					2		3	10					4			30			8							57	0.09%
S. cotor									20		34	14	5	4	5	8	113	3			45	30	15							296	0.47%
R. corsula		x											75		8															83	0.13%
G. chapra		x									13	16	42		8	17		34	8	75				9						222	0.35%
X. cancilata					x				1			1	3								1	2								8	0.01%
T. tor											36									15		30								81	0.13%
M. tengra					x				1		3	5																		9	0.01%
G. menimina											37	1	11		3		23	20	8	45		8		6						162	0.26%
P. pangasius		x	x	x					9								15													24	0.04%
Hilsa		x																	60	15	75			23						173	0.27%
Channa				x	x												8		15	105	135			45						308	0.49%
Others									6		4			1					106					60						177	0.28%
Total Weight						0	0	0	1704	0	1749	4996	7586	4991	5944	3156	1732	4284	6151	7961	3043	1462.5	1976	6451	0	0	0	0	0	63188.5	100.00%
No. of Species	6	14	9	12	7	0	0	0	25	0	25	22	18	14	20	15	16	16	21	19	18	13	13	18	0	0	0	0	0		

		Month 1993 / 94												Month 1994 / 95											
		Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Major Carps	Weight	0	0	0	519	0	333	711	1170	1110	1487	890	0	810	1616	2999	667	43.5	504	618	0	0	0	0	0
Catfish	Weight	0	0	0	983	0	1137	3904	5596	3833	2549	2181	1497	3356	4362	4392	1994	1261	986	1457	0	0	0	0	0
Others	Weight	0	0	0	202	0	279	381	821	48	1908	115	236	118	284	570	382	158	486	4376	0	0	0	0	0

Major Carps	Percentage	0.00%	0.00%	0.00%	30.46%	0.00%	19.04%	14.23%	15.42%	22.24%	25.02%	28.20%	0.00%	18.91%	24.63%	37.67%	21.92%	2.97%	25.48%	9.56%	0.00%	0.00%	0.00%	0.00%	0.00%
Catfish	Percentage	0.00%	0.00%	0.00%	57.69%	0.00%	65.01%	78.14%	73.75%	76.80%	42.88%	69.16%	86.43%	78.34%	70.75%	55.17%	65.53%	86.22%	49.85%	22.59%	0.00%	0.00%	0.00%	0.00%	0.00%
Others	Percentage	0.00%	0.00%	0.00%	11.85%	0.00%	15.95%	7.63%	10.82%	0.96%	32.10%	3.64%	13.57%	2.75%	4.62%	7.16%	12.55%	10.80%	24.67%	67.87%	0.00%	0.00%	0.00%	0.00%	0.00%

Table 5.5 Catch by weight (kg) from Daraganj, Ganga River, Allahabad

Species	Categories					Month 1993 / 94												Month 1994 / 95												Total	%
	M	R	C	P	F	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Weight	
L. rohita	x	x													12			60												72	0.22%
C. catla	x	x												173	105	153		19												450	1.35%
C. mrigala	x	x								12	4.6			155	66					77			39							353.6	1.06%
L. calbasu	x	x								59	116			215	372			305		153		30		47						1297	3.89%
M. seenghala		x	x	x						26	5		165	109	231	147	20	256	161	732	30	25		201						2109	6.32%
M. aor		x	x	x						36	29		120	132	365	288	98	662	963	1488	5	33		303						4542	13.62%
W. attu		x	x	x						11					69	134		32	84	152	289	21								792	2.38%
C. garua			x	x						80	300		870	270	348	177	5	244	2103	363	312	161	675	1099						7005	21.01%
E. vacha			x	x						65	248		135	118	122	9		73	34	95	14	49	53							1015	3.04%
R. rita			x	x						12	76		95	29	47	163	78	64	365	293				66						1298	3.89%
Oxygaster										2400	2900		150		1500		75	15	57	18	165	750	750	75						8755	26.26%
N. notopterus				x	x						5						3	8		6										22	0.07%
N. chitala				x	x																									0	0.00%
B. bagarius		x	x	x						5	5		75	75	150		17	150	45	45	8									575	1.72%
S. phasa										22	39		54	34	2250	11	17	30	30	15	11	6	45	75						2641	7.92%
C. carnia										2	3		1				19			3			15	11						54	0.16%
M. armatus					x					1	1		2	14	11	7	16	30	17	8		3		4.5						114.5	0.34%
Puntius					x					1	7		2		15							9		30						64	0.19%
O. cotio										2	2		1	24	20	14	16						150	8						237	0.71%
L. bata										2	32		10	39	25		8		8	22	15	75	120	53						409	1.23%
L. gonius																														0	0.00%
A. coila		x	x	x						18	24		2	14						30	30	19	37.5	75						249.5	0.75%
S. cotor										8	17		3	5	3	5	30	232	15	53		83		52						506	1.52%
R. corsula		x								2			15			4				15	15									51	0.15%
G. chapra		x									13		4	9	25	84	45	45	23	23		15		5						290	0.87%
X. cancila					x															2		8								10	0.03%
T. tor											3																			3	0.01%
M. tengra					x					5	4																			9	0.03%
G. menimina											1						80	30	23	23				11						148	0.44%
P. pangasius		x	x	x																										0	0.00%
Hilsa		x											15	9				19	150											193	0.58%
Channa				x	x														15	7	8									30	0.09%
Others										13									15	23										51	0.15%
Total Weight						0	0	0	0	2784	3735	0	1719	1422	5734	1216	507	2264	4128	3646	902	1289	1985	2116	0	0	0	0	0	33346	100.00%
No. of Species	5	14	9	12	7	0	0	0	0	21	22	0	18	17	19	13	15	18	17	23	12	15	9	16	0	0	0	0	0		

		Month 1993 / 94												Month 1994 / 95											
		Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Major Carps	Weight	0	0	0	0	71	120.6	0	0	543	555	153	0	384	0	230	0	30	39	47	0	0	0	0	0
Catfish	Weight	0	0	0	0	255	687	0	1462	732	1330	938	218	1471	3775	3198	688	308	785.5	1744	0	0	0	0	0
Others	Weight	0	0	0	0	2458	2927	0	257	147	3849	125	289	409	353	218	214	951	1080	324.5	0	0	0	0	0
Major Carps	Percentage	0.00%	0.00%	0.00%	0.00%	0.00%	3.23%	0.00%	0.00%	38.19%	9.68%	12.58%	0.00%	16.96%	0.00%	6.31%	0.00%	2.33%	2.07%	2.22%	0.00%	0.00%	0.00%	0.00%	0.00%
Catfish	Percentage	0.00%	0.00%	0.00%	0.00%	0.00%	18.40%	0.00%	85.05%	51.48%	23.19%	77.14%	43.00%	64.97%	91.45%	87.71%	76.27%	23.89%	40.62%	82.44%	0.00%	0.00%	0.00%	0.00%	0.00%
Others	Percentage	0.00%	0.00%	0.00%	0.00%	0.00%	78.38%	0.00%	14.95%	10.34%	67.13%	10.28%	57.00%	18.07%	8.55%	5.98%	23.73%	73.78%	57.31%	15.34%	0.00%	0.00%	0.00%	0.00%	0.00%

Table 5.6 Coastal and riverine catches of *Hilsa* from daily surveys conducted at Swarighat landing centre, Dhaka (1994-95)

Month	Coast		Padma / Meghna Rivers		Total
	mt	%	mt	%	mt
March	1647	56	1295	44	2942
April	583	60	389	40	972
May	424	31	943	69	1367
June	770	27	2082	73	2852
July	159	5	3012	95	3171
August	452	13	3026	87	3478
September	706	20	2822	80	3528
October	731	23	2449	77	3180
November	1025	33	2080	67	3105
December	1103	44	1404	56	2507
January	611	31	1361	69	1972
February	515	41	742	59	1257
March	482	50	482	50	964
TOTAL					31,295

Table 5.7 Total landings of Hilsa in relation to mean size and maturity stage from daily surveys at Swarighat landing centre, Dhaka (1994-95)

Month		Mean Length (cm)	Total Landing (mt)	Mature Females (%)
1994	March	30.6	2942	6
	April	38.5	972	24
	May	39.7	1367	55
	June	40.9	2852	92
	July	40.7	3171	55
	August	41.0	3479	85
	September	41.2	3528	100
	October	41.8	3180	
	November	40.8	3105	
	December	37.8	2507	
1995	January	27.5	1972	
	February	36.2	1257	
	March	33.2	964	

Table 5.8 Species Composition by Weight (kg) from Patna

Species	Categories					Total Weight	%
	M	R	C	P	F		
A. morar						10643.21	14.94%
S. phasa						8383.00	11.76%
C. garua			x	x		7219.90	10.13%
A. coila		x	x	x		6131.70	8.60%
Oxygaster						3516.00	4.93%
M. aor		x	x	x		3473.83	4.87%
G. chapra		x				3389.00	4.76%
S. coitor						2955.93	4.15%
G. manimina						2487.65	3.49%
Puntius					x	2452.91	3.44%
S. cascasia						2209.40	3.10%
N. punctata						1831.58	2.57%
E. vacha			x	x		1338.10	1.88%
Macrobrachium						1320.21	1.85%
C. catla	x	x				1270.30	1.78%
M. cavaasius		x	x	x		1263.30	1.77%
G. cenia		x	x	x		1125.75	1.58%
C. latius		x				938.85	1.32%
C. mrigala	x	x				933.20	1.31%
R. rita			x	x		929.54	1.30%
M. seenghala		x	x	x		910.50	1.28%
W. attu		x	x	x		900.10	1.26%
A. jaya						898.75	1.26%
S. silonidia		x	x			619.60	0.87%
Hilsa		x				452.10	0.63%
B. bagarius		x	x	x		371.50	0.52%
L. calbasu	x	x				359.63	0.50%
M. armatus					x	338.30	0.47%
R. corsula		x				325.40	0.46%
L. bata						288.68	0.41%
L. rohita	x	x				279.80	0.39%
L. gonius						264.70	0.37%
N. chitala				x	x	241.88	0.34%
G. giurus				x	x	201.77	0.28%
P.atherinoids		x	x	x		172.80	0.24%
M. tengra					x	138.35	0.19%
Channa				x	x	123.63	0.17%
M. vittatus			x	x	x	111.33	0.16%
M. pancuius					x	101.21	0.14%
O. cotio						99.12	0.14%
B. dario						56.25	0.08%
G. telchitta						44.10	0.06%
X. cancilata					x	26.65	0.04%
C. reba						24.05	0.03%
E. munius						16.95	0.02%
Chanda sp.					x	15.70	0.02%
H. fossils				x	x	14.55	0.02%
L.guntea						8.75	0.01%
A. mola						7.20	0.01%
O. pabda		x	x	x		6.60	0.01%
M. menoda			x			6.25	0.01%
M. aculeatus					x	5.60	0.01%
N. notopterus				x	x	5.30	0.01%
C. batrachus			x	x	x	3.40	0.00%
C. laubuca						2.10	0.00%
B. lohachata						1.60	0.00%
C alpar						1.50	0.00%
C. chagunio						1.30	0.00%
T fluviatilis						0.70	0.00%
A. testudineus					x	0.05	0.00%
P. pangasius		x	x	x		0.00	0.00%
Others						0.00	0.00%
G cemia						0.00	0.00%
T tor						0.00	0.00%
Total Weight						71261 11	100 00%
No of Species	5	20	17	20	15		

Table 5.9 Species Composition by Weight (kg) from Sadiapur

Species	Categories					Total Weight	%
	M	R	C	P	F		
M. aor		x	x	x		66941	27.22%
M. seenghala		x	x	x		47244	19.21%
L. calbasu	x	x				39980	16.26%
R. rita			x	x		26282	10.69%
C. garua			x	x		13572	5.52%
W. attu		x	x	x		9738	3.96%
C. catla	x	x				8073	3.28%
C. mrigala	x	x				6640	2.70%
Oxygaster						6316	2.57%
L. rohita	x	x				6137	2.50%
E. vacha			x	x		4660	1.90%
B. bagarius		x	x	x		3958	1.61%
L. bata						861.5	0.35%
N. notopterus				x	x	860	0.35%
S. coitor						692	0.28%
A. coila		x	x	x		674.8	0.27%
Others						573	0.23%
M. armatus					x	501	0.20%
G. chapra		x				421	0.17%
S. phasa						382.5	0.16%
Hilsa		x				317	0.13%
N. chitala				x	x	241	0.10%
T. tor						231	0.09%
G. manimina						206	0.08%
O. cotio						110.5	0.04%
X. cancilata					x	94	0.04%
R. corsula		x				71	0.03%
L. gonius						38	0.02%
Puntius					x	36	0.01%
G. cemia						25.5	0.01%
P. pangasius		x	x	x		6	0.00%
M. tengra					x	3	0.00%
Total Weight						245885.8	100.00%
No. of Species	5	14	9	11	6		

Table 5.10 Species Composition by Weight (kg) from Gaughat, Yamuna River

Species	Categories					Total Weight	%
	M	R	C	P	F		
M. aor		x	x	x		10448	16.53%
L. calbasu	x	x				10264.5	16.24%
R. rita			x	x		7949	12.58%
C. garua			x	x		7853	12.43%
M. seenghala		x	x	x		5585	8.84%
L. bata						5090	8.06%
W. attu		x	x	x		4500	7.12%
Oxygaster						2961	4.69%
E. vacha			x	x		1721	2.72%
C. catla	x	x				1422	2.25%
B. bagarius		x	x	x		1310	2.07%
L. rohita	x	x				1100	1.74%
C. mrigala	x	x				588	0.93%
Channa				x	x	308	0.49%
S. coitor						296	0.47%
G. chapra		x				222	0.35%
S. phasa						211	0.33%
M. armatus					x	205	0.32%
Puntius					x	181	0.29%
Others						177	0.28%
Hilsa		x				173	0.27%
G. manimina						162	0.26%
N. notopterus				x	x	126	0.20%
R. corsula		x				83	0.13%
T. tor						81	0.13%
A. coila		x	x	x		57	0.09%
N. chitala				x	x	39	0.06%
O. cotio						25	0.04%
P. pangasius		x	x	x		24	0.04%
G. cemia						10	0.02%
M. tengra					x	9	0.01%
X. cancilata					x	8	0.01%
L. gonius						0	0.00%
Total Weight						63188.5	100.00%
No. of Species	5	14	9	12	7		

Table 5.11 Species Composition by Weight from Daraganj

Species	Categories					Total Weight	%
	M	R	C	P	F		
Oxygaster						8755	26.26%
C. garua			x	x		7005	21.01%
M. aor		x	x	x		4542	13.62%
S. phasa						2641	7.92%
M. seenghala		x	x	x		2109	6.32%
R. rita			x	x		1298	3.89%
L. calbasu	x	x				1297	3.89%
E. vacha			x	x		1015	3.04%
W. attu		x	x	x		792	2.38%
B. bagarius		x	x	x		575	1.72%
S. coitor						506	1.52%
C. catla	x	x				450	1.35%
L. bata						409	1.23%
C. mrigala	x	x				353.6	1.06%
G. chapra		x				290	0.87%
A. coila		x	x	x		249.5	0.75%
O. cotio						237	0.71%
Hilsa		x				193	0.58%
G. manimina						148	0.44%
M. armatus					x	114.5	0.34%
L. rohita	x	x				72	0.22%
Puntius					x	64	0.19%
C. cemia						54	0.16%
Others						51	0.15%
R. corsula		x				51	0.15%
Channa				x	x	30	0.09%
N. notopterus				x	x	22	0.07%
X. cancilata					x	10	0.03%
M. tengra					x	9	0.03%
T. tor						3	0.01%
L. gonius						0	0.00%
N. chitala				x	x	0	0.00%
P. pangasius		x	x	x		0	0.00%
Total Weight						33346	100.00%
No. of Species	5	14	9	12	7		

Figure 5.22 Outline of the Waterways around Farakka Barrage

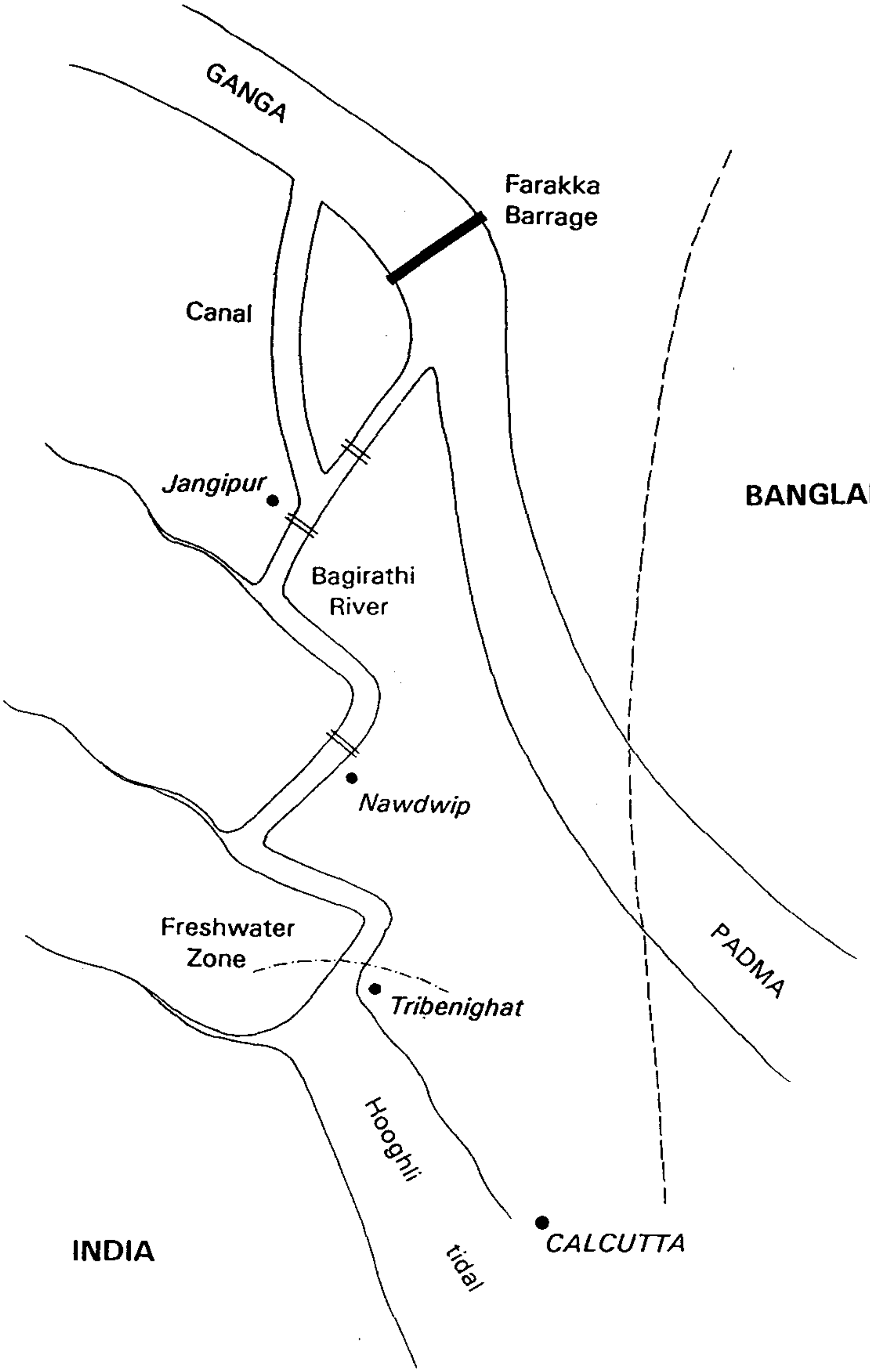


Table 5.12 List of Spawn Collecting Nets and Hapa in operation at sites along the South Bank of the Ganges, with Operator (where known)

Name of Site	No of nets	No of hapa	Name of Operator
Digha ghat	none	none	----
Rajendraghat, near Bihar			
Vidyapeeth Kurjee	5	1	Agnu Sahni and Pradeep Sahni
Indira ghat near Sadaquat Ashram	2	1	
Pahalwanghat	8	1	Dujira Singh and Shahne Pahalwan
Rajendra ghat near Buddha Colony	----	----	----
Bansghat	none	none	----
Buddha ghat	none	none	----
Collectorate ghat or Anta ghat (near Gandhi maidan)	5	2	Jagdish Sahni and Khapri Sahni
Mahendru ghat	none	none	----
Behind Darbhanga House	6	1	Rambabu and Golakhnath Sahni
Krishna ghat	4	1	----
Gandhi ghat	none	none	----
Ranighat	4	1	Rajendra Chaudhury
Gulbi ghat	4	1	Rajendra Chaudhury
Balu ghat	2	1	Relative of Rajendra Chaudhury
	3	1	Relative of Rajendra Chaudhury
Ghagha ghat	6	2	Kshatri, Mahabir and Sitwa Sahni
Masjid ghat	none	none	----
Pathri ghat of BNR Training College ghat	none	none	----
Loharwa ghat near Nooranibagh	2	1	Rajendra Sahni
Tilarwa ghat	none	none	----
Gosai ghat	none	none	----
Gaighat	2	1	----
Bhadra ghat	2	1	Harish and Lalloo Sahani and Somar Sahu
Nojar ghat	2	1	Bansi Sahni
Mahabir ghat	none	none	----
Mittan ghat	20	1	Shatrughan, Suraj, Jamai and Ramasheesh Sahni
Jankighat	none	none	----
Khajekalan ghat Rita of Roygi	30	2	Roshan, Thorkatta Maula and Ghyasuddin
Malsalami	6	1	Pradeep Sahni

Table 5.13 Category-wise demographic composition of fisher families at Allahabad, India, by number

S No.	Particular	Category of Family									
		Owned boat	% of total	Hired boat	% of total	No boat	% of total	Other	% of total	Total	% of total
A	Adult										
1	Male	583	42.19	141	39.17	10	41.67	105	43.03	839	41.74
2	Female	470	34.01	124	34.44	9	37.50	81	33.20	684	34.03
B	**Minor**										
1	Below 5 yrs	166	12.01	53	14.72	2	8.33	25	10..25	246	12.24
2	Above 5 yrs	163	11.79	42	11.67	3	12.50	33	13.52	241	11.99
Total		1382	100	360	100	24	100	244	100	2010	100

Table 5.14 Average Family Size Sex Ratio of fisher families at Allahabad, India

S. No.	Particulars	Category of Family				
		Owned boat	Hired boat	No boat	Other	Total
A	**Adult**					
1	Male	3.69	3.36	2.00	4.04	3.63
2	Female	2.97	2.95	1.80	3.12	2.96
B	**Sex ratio (Male : Female)**	**1 : 0.81**	**1 : 0.88**	**1 : 0.90**	**1 : 0.77**	**1 : 0.82**
C	**Minor**					
1	Below 5 years	1.05	1.26	0.40	0.96	1.06
2	Above 5 years	1.03	1.00	0.60	1.27	1.04
Total		**8.74**	**8.57**	**4.80**	**9.39**	**8.69**

Table 5.15 Fishing Gears in operation at Allahabad, India

S No.	Name of Gear	Category of Family									
		Owned boat	% of total	Hired boat	% of total	No boat	% of total	Other	% of total	Total	% of total
1	Drag net - Chaundhi	145	35.45	40	40.40	---	---	1	33.34	186	35.91
2	Drag net - Chhanta	102	24.94	25	25.25	---	---	---	---	127	24.51
3	Drag net - Mahajal	40	9.78	7	7.07	---	---	1	33.33	49	9.27
4	Gill net - Fasla	94	22.98	22	22.22	---	---	---	---	116	22.39
5	Hook and Line (Jor)	13	3.18	---	---	2	28.57	---	---	15	2.90
6	Other	15	3.67	5	5.06	5	71.43	1	33.33	26	5.02
TOTAL		409	100	99	100	7	100	3	100	518	100

Table 5.16 The extent of time devotion and inheritance in the fishing activity at Allahabad by number and percentage

S No	Particular	Own boat	%	Hired boat	%	No boat	%	Other	%	Total	%
A	Time devotion										
1	Full time	105	66.46	10	23.81	2	40.00	--	--	117	60.65
2	Part time	37	23.42	18	42.86	2	40.00	--	--	57	24.68
3	Rarely	16	10.13	14	33.33	1	20.00	4	15.38	35	15.15
4	Other	--	--	--	--	--	--	22	84.62	22	0.52
B	Inheritance to future generations										
1	Yes	26	16.46	1	2.38	--	--	--	--	27	11.69
2	No	132	83.54	41	97.62	5	100.00	26	100.00	204	88.31
	Total Respondents	**158**		**42**		**5**		**26**		**227**	

Table 5.17 The mean daily catch per fisherman family for the riverine stretch at Allahabad

S. No.	Category	Quantity (kg)	Value (RsI)
1	Owned boat	12.05	88.64
2	Hired boat	5.07	47.98
3	No boat	3.70	39.50
4	Other	0.33	35.96
	TOTAL	**9.28**	**74.2**

Table 5.18 The status of financial assistance received by fisher families at Allahabad by number and percentage

S. No.	Category	Source				Total	
		Money Lender		Other			
		number	%	number	%	number	%
1	Owned boat	59	37.34	2	1.27	61	38.61
2	Hired boat	11	26.19	2	4.76	13	30.95
3	No boat	--	--	--	--	--	--
4	Other	--	--	--	--	--	--
	Total	**70**	**30.30**	**4**	**1.73**	**74**	**32.03**

Table 5.19 The employment status of fishermen in activities other than fishing, Allahabad

S No	Activity	Own boat	%	Hired boat	%	No Boat	%	Other	%	Total	%
1	Agriculture	53	33.54	7	16.67	1	20.00	3	11.54	64	27.71
2	Business	23	14.56	10	23.81	1	20.00	16	61.54	43	18.61
3	Daily labour	18	11.39	8	19.05	--	--	8	30.77	30	12.99
4	Job	4	2.53	8	19.05	--	--	--	--	12	5.19
5	Other	65	41.14	11	26.19	3	60.00	2	7.69	76	32.90
	TOTAL	**163**		**44**		**5**		**29**		**225**	

Table 5.20 Intensity of problems faced by fisher families in Allahabad by number and percentage

S No	Problem	CATEGORY OF FAMILY									
		Own boat	%	Hired boat	%	No boat	%	Other	%	Total	%
1	Illegal activities	88	55.70	18	42.86	3	60.00	7	26.92	116	50.22
2	Economic	78	49.37	22	52.38	--	--	20	76.92	120	51.95
3	Climatic	7	4.13	6	14.29	--	--	--	--	13	5.63
4	Marketing	5	3.16	1	2.38	--	--	--	--	6	2.60
5	Other	11	6.93	5	11.90	2	40.00	3	11.54	21	9.09
	Total	**189**	**119.62**	**52**	**123.81**	**5**	**100.00**	**30**	**115.38**	**276**	**119.48**

6. SYNTHESIS

6.1 CHANGES IN SPECIES COMPOSITION AND BIODIVERSITY, WITH TIME

Seasonal changes in species number and composition within the fisheries of the Ganges River at Patna and Allahabad can be seen in Section 6.3. Over the long term, however, there have been increasing pressures on the fisheries through possible increases in pollution level, increased river regulation and increased population density. It is conceivable that such changes within the basin may have influenced the structure of the fish community and the composition of the fish catches. Some information has been compiled on the catch composition at Allahabad and Patna in previous years (Temple and Payne 1995), but total species number does not appear to have been recorded (Table 6.1). The "other species" category has often been regarded as "trash fish" with little economic importance. It is plain, however, that all species do have their value both economically and biologically, and should in future be taken into consideration.

The most dramatic change at Allahabad is in the proportion of major carps. In 1958-66 collectively they accounted for 43.5% of the total catch. By 1972-76 this had been reduced to 29%, whilst currently it is some 13% overall. The major carps are typically the principal component of the river and floodplain community.

6.2 SIGNIFICANCE OF CHANGES IN CATCH WITH TIME

There are strong indications of marked changes in catch composition and changes in the fish community over the last three decades, with the reduction in the previously dominant *Hilsa* and major carps in particular (Table 6.1). Whilst there has been a consequent increase in the proportion of other species contributing to the catch there is a wide perception that catches overall are declining radically due to a combination of pollution, river regulation and over-exploitation. This, however, remains a perception partly because of a scarcity of time series of catch data, and partly because such data will intrinsically show considerable variability from year to year, as a result of natural year to year variation in the hydrology and flood regime which drives the production cycle.

During the review stage two time series of catch data were identified (Temple and Payne 1995). One was based on annual monitoring of catches at various centres in India between 1956 and 1985, largely drawn from Jhingran (1991) and the other upon the national fisheries statistics of Bangladesh produced by the Department of Fisheries, which had been put on a systematic basis since 1983. The most complete data set for India is that for Allahabad between 1956 and 1982 (Table 6.2).

Simple regression analysis was applied to various components of these data sets in relation to time in years (Table 6.3).

This clearly shows that within Bangladesh there has been a significant decline in catches from all rivers taken together. This is not manifest amongst the major commercial categories but results from overall reduction of other species, sometimes categorised as "miscellaneous" in the catches.

Amongst the rivers of Bangladesh, the Ganges (Padma) itself distinctively shows the same significant negative trend of total catches from all species, but in this case all the major commercial categories, *Hilsa*, catfishes and major carps follow this negative trend in a highly significant fashion. Allahabad has also shown significant reductions in catch between 1965 and 1982, although this is less evident from the shorter data runs of some of the constituent centres.

Over this time period the regression line suggests that, on average, the loss at Allahabad was continuing at about 5 mt on a catch of around 250-300 mt. On the Ganges in Bangladesh the losses were much more drastic, amounting to an average loss of 1600 mt per year even though the 1983 catch was only 12,500 mt.

On those data sets available, therefore, significant reductions in catches with time can be detected, although the extent does seem to vary. The analysis of the underlying causes of decline might respond to the approach of Quiros (1993) in using macro-indicators of such features as pollution, river regulation and fishing intensity, but this would be a project in its own right. Some of the potential causes can be considered in a more qualitative fashion.

6.3 POLLUTION INDICATORS

It was concern that increasing levels of pollution were damaging various economic sectors within the Basin, such as fisheries and health, that stimulated the Government of India to first review the situation (Central Pollution Control Board 1984) and then to formulate the Ganga Action Plan (GOI 1986). This called for consistent monitoring of water quality at various points along the river. The University of Patna contributed to this process and have been able to make available a summary of the changes in a number of indicators of water quality since the inception of the Action Plan (Table 6.4).

Annual means are a little difficult to interpret, particularly those such as conductivity and chloride which can be a function of dilution, i.e. the amount of rainfall and river discharge in the year in question. Nevertheless there does appear to be a general reduction in the content of total dissolved solids in the water, as indicated by reductions in the conductivity values, perhaps by as much as a half to a third. This is not, however, reflected in the chloride concentrations. As a relatively inert ion, chloride can be a good indicator of dilution and this may indicate, therefore, that the changes in total dissolved solids / conductivity are not purely a dilution effect.

At the same time, chloride is also a good indicator of domestic pollution through its predominance in urine; the fact that it has not declined in the same way as total dissolved solids suggests the effect may not result predominantly from reduced domestic effluent. Chloride, however, is equally present in processed and unprocessed domestic effluent.

The most dramatic effect has been upon BOD (Table 6.4). The BOD, an indicator of organic pollution from either domestic or industrial sources, has fallen emphatically to around 20% of its earlier value. This has also probably been instrumental in the concurrent increase in dissolved oxygen (DO), since less will be used for decomposition of the organic load, and also in reversing the acidification of the river water, another general effect of rapid decomposition of organic waste. The pH has now returned to the more alkaline values typical of Ganges water (Section 2).

The determinations made during the current study show the ranges now experienced over a year by some of these key indicator parameters (Section 2). These can be considered in relation to the tolerance limits laid down for receiving waters by the Indian Standards IS:2296 (Indian Standard Institution 1982) in relation to the range determined (Table 6.5).

From this it can be seen that with regard to the parameters in question, the Ganges at both Patna and Allahabad conforms to the requirements for category 'D' waters, those consistent with its use as a fishery. On most counts they also conform with the stricter standards for category A drinking water, with the exception of BOD (Table 6.5). however, even though the upper values of BOD exceed the 2 mg l^{-1} limit for category 'A' water, the average of 1.4 mg l^{-1} in 1994 (Table 6.4).

With regard to these key chemical indicators, therefore, the river waters around Patna and Allahabad are, therefore, presumably for some distance upstream of a suitable quality to sustain a fishery. This looks to have been less so a decade previously. At that time, between 1957 and 1982 a significant negative trend has been found in the fishery (Section 6.2) with catches declining from 300-400 mt per year to 160-200 mt (Table 6.2). The annual total from Allahabad, taken from the same sites as the earlier surveys in 1993-94 was 277 mt, i.e. well towards the upper range of earlier years (see Table 6.2). This would reflect in improved water quality. This however can only be indicative and would need a longer time series of data to put a probability to it.

Table 6.1 Catch composition by major categories at Allahabad (a) and Patna (b) since 1958

	Patna		Allahabad *		Sadiapur (Yamuna)			Duraganj (Ganga)		
Species	1952-66 +	1995-95	1958-59 / 85-66 +	72-76 +	72-74 +	76-85 +	93-95	72-74	76-82	93-95
L. rohita	8.50	0.06	7.80	3.00	3.60	2.50	2.56	1.50	0.55	0.22
C. catla	5.40	1.49	7.70	3.53	3.80	3.70	3.36	2.80	1.45	1.35
C. mrigala	11.90	2.01	23.50	9.64	10.00	8.10	0.38	8.70	2.35	1.06
L. calabasu	0.70	0.68	4.50	12.94	16.20	24.30	16.65	3.30	1.61	3.89
M. seenghala	10.10	1.49	16.60	7.30	7.00	8.50	19.67	8.40	5.70	6.32
M. aor	0.00	6.50	0.00	11.20	12.40	11.70	27.87	7.70	1.30	13.62
W. attu	8.10	2.49	6.00	5.20	5.60	3.70	4.05	4.20	2.70	2.38
Hilsa	11.90	1.01	9.40	4.90	4.30	0.84	0.13	6.50	0.14	0.58
Others	43.50	84.27	25.00	42.20	37.20	58.40	25.33	56.90	20.70	70.58
Total	100.10	100.00	100.50	99.91	100.10	121.74	100.00	100.00	36.50	100.00

* Sadiapur and Durangaj together
+ Jhingran 1991

Table 6.2 Summary of available yearly catch data (mt) on the Indian Sector of the Ganges alongside mean discharge rates ($m^3\ sec^{-1}$) at the Hardinge Bridge, on the lower Ganges in Bangladesh arranged as the same Year (M3), year -1 (M2), year -2 (M1) and year -3 (M).

							MDRATE			
Year	Allahabad	Sadipur	Daraganj	Lalgola	Buxar	Bhagalpur	M	M1	M2	M3
1956	316.42						60100	60300	58600	50900
1957	485.00						46200	60100	60300	58600
1958	200.06						56300	46200	60100	60300
1959	145.35						52700	56300	46200	60100
1960	193.58						48000	52700	56300	46200
1961	200.11						73200	48000	52700	56300
1962	202.82						58700	73200	48000	52700
1963	263.08						56100	53700	73200	48000
1964	200.41						49000	56100	58700	73200
1965	256.35						36800	49000	56100	58700
1966	212.49						41900	36800	49000	56100
1976	127.83	97.30	30.53	59.90	3.67	88.00	65400	41900	36800	49000
1977	131.60	103.52	28.08	43.27	18.73	76.09	51100	65400	41900	36800
1978	160.51	128.78	31.73		8.32		67900	51100	65400	41900
1979	137.42	100.26	37.16	21.56	13.30	101.48	36900	67900	51100	65400
1980	174.21	128.35	45.86				57800	36900	67900	51100
1981	164.66	122.99	44.13	46.36	16.49	129.85	47900	57800	36900	67900
1982		126.88	37.81	37.36		110.22	61600	47900	57800	36900
1983		119.30			17.15			61600	47900	57800
1984		152.96							61600	47900
1985		132.93		56.17	26.75	62.54				61600

Table 6.3 Predictable significance of decline in catches with time at points along the Ganges River

AREA	Species category	Correlation (R)	Probability (p)	Significanc e
BANGLADESH				
All rivers 1982-89	All	0.90	0.002	S
	Hilsa	0.18	0.680	NS
	Prawn	0.10	0.800	NS
	Catfish	0.64	0.070	NS
	Carps	0.50	0.200	NS
Padma (Ganges)	All	0.93	0.001	S
	Hilsa	0.88	0.004	S
	Prawn	0.49	0.220	NS
	Catfish	0.84	0.010	S
	Carp	0.74	0.040	S
INDIA				
Allahabad (Total) 1965-82	All	0.59	0.010	S
Daraganj (Ganges) 1976-82	All	0.77	0.040	S
Sadiapur (Yamuna) 1976-85	All	0.69	0.090	NS

S - significant
NS- not significant

Table 6.4 Annual average of Water Quality of River Ganges at Patna 1984-94

Parameters	1984	1985	1986	1987	1988	1989	1991	1992	1993	1994
Water Temperature (°C)	27.6	26.7	27.9	28.2	27.5	22.8	29.9	25.4	26.0	27.7
Conductivity (mS/m)	68.7	71.3	---	---	27.0	22.5	34.3	29.5	28.1	25.4
pH	7.9	2.8	7.8	89.2	8.1	8.3	8.5	8.5	8.4	8.3
T Alkalinity (mg l^{-1})	125	139	135	155	109	125	91	149	167	136
BOD (mg l^{-1})	7.2	8.2	6.0	7.8	3.1	2.1	1.2	1.2	1.6	1.4
DO (mg l^{-1})	6.8	6.9	6.8	6.8	8.0	8.8	6.7	7.7	7.8	7.2
Chloride (mg l^{-1})	16.7	14.8	12.4	11.2	17.9	18.0	15.2	16.3	18.3	11.7

Note: The data for the year 1990 is not available

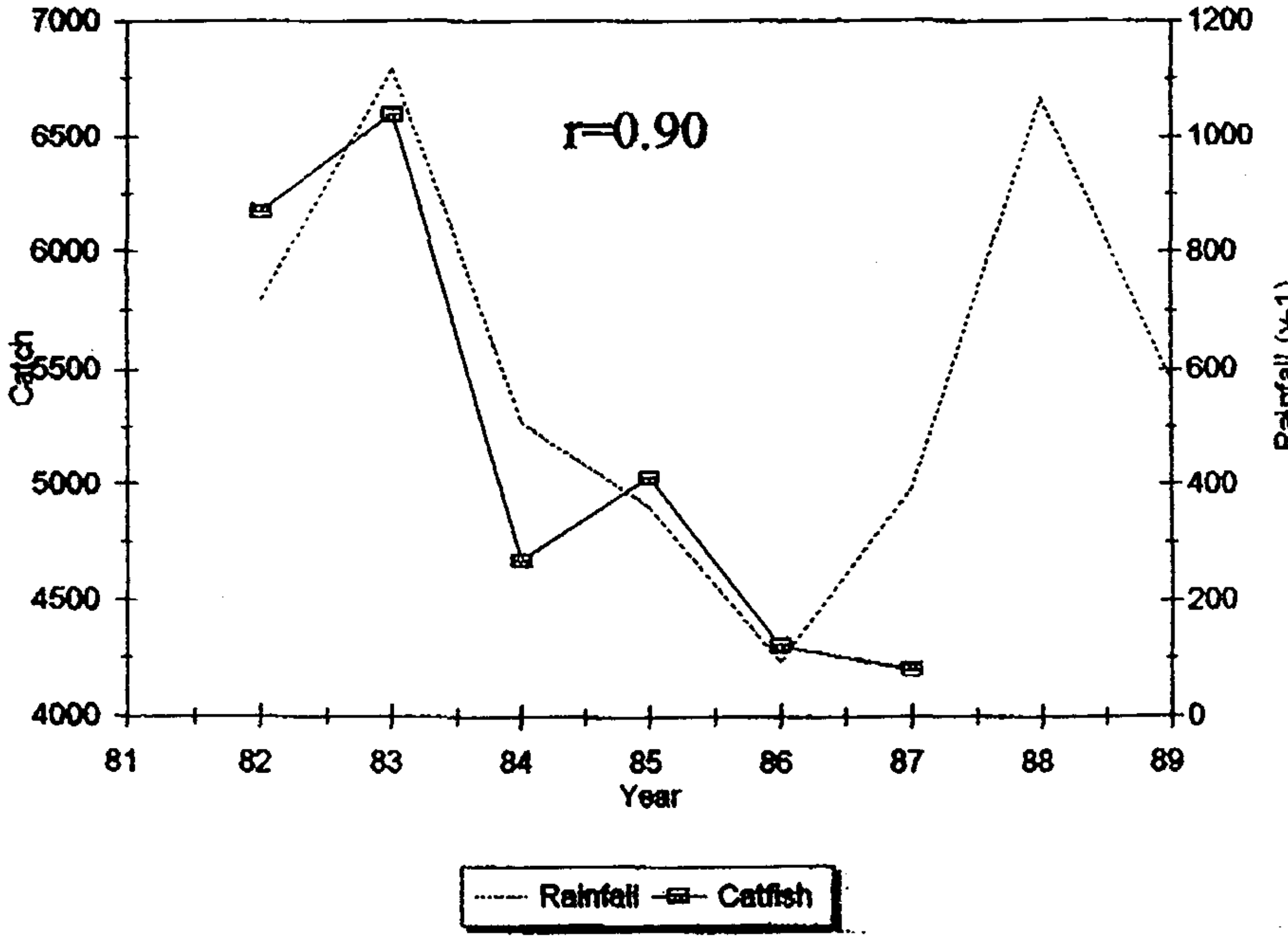
Table 6.5 Tolerance limits for selected characteristics from Indian Standards IS:2296, in relation to observed ranges at Patna and Allahabad

Characteristic	Class D Water Tolerance Limit	Class A Water Tolerance Limit	Range Patna	Range Allahabad
pH	6.5-8.5	6.5-8.5	7.8-9.0	7.8-8.8
DO (mg l^{-1}) min	4	6	4.4-9.2	4.0-12.8
BOD (mg l^{-1}) max		2	0.2-3.6	
Conductivity (µs) max	1000		111-388	171-596
TDS (mg l^{-1}) max		500	55-193	
Chloride (mg l^{-1}) max		250		

Class D Water: Inland surface waters used for fish culture and wildlife propagation

Class A Water: Inland surface waters for use as drinking water without conventional treatment, but after disinfection

Figure 6.1 Catches of catfishes at Padma, Bangladesh in relation to annual rainfall



6.4 ENVIRONMENTAL FLUCTUATIONS, ENVIRONMENTAL MODELS AND PREDICTABILITY OF CATCHES

In any river fishery there is intrinsic variability in catches from year to year. The degree of variation depends upon the year to year variability of the flood regime since this drives the production of the fishery (Welcomme and Hagborg 1977). In this way, river and floodplain fisheries are much more a product of climatic and environmental fluctuations than are lake or marine fisheries. In analysing river fisheries in South America, Quiros (1993) found that even in those severely influenced by pollution or regulation, 50-60% of all variability stemmed from environmental fluctuations. It is this high degree of variation which make significant trends through time so difficult to detect from such noisy data, and consequently why long time series of information are so valuable.

By the same token, if catches are so responsive to changes in environmental parameters, it should be possible to derive some modelling or predictive ability to enable changes in catches to be determined from measured changes in the environmental parameter. In analysing a database of fish catches and a wide range of physical and environmental dimensions of river basins throughout the tropics, Payne *et al*. (1993) found there to be significant positive relationships between mean discharge rate of the river for both South America and Asia. Mean discharge rate is really a macro indicator for a number of variables such as flood regime and throughput of resources in the river. Previously Welcomme and Hagborg (1977) had found positive relationships between flooding and growth rates, and low water area and mortality. The hydrological cycle should therefore offer considerable predictive options. The ability to predict catches and the influences of the natural environment makes it easier to manage and plan the fisheries sector, and understanding of the varying baseline makes it more possible to disentangle the influences of anthropogenic processes in the performance of the sector.

The most direct approach would be to try to correlate discharge rate with recorded catches from the two time series previously identified. Unfortunately, in India, discharge data on the Ganges is classified information and is therefore unavailable. Over the period of the Allahabad data (Table 6.2) detailed records are available for the lower Ganges at Hardinge Bridge, although at a considerable distance downstream of the site (Temple and Payne 1995). It must also be considered that the discharge and flood regime of previous years may have the greatest effect on recruitment into the fishery by affecting growth and survival of the young before they enter the fishery. For the initial analysis, therefore, the Hardinge Bridge discharge series was advanced 1, 2 and 3 years to check correlation with the catches at Allahabad (Table 6.2).

A multiple regression has been carried out to detect if there is any significant relationship of discharge as measured in the lower Ganges and the catches at Allahabad of the same year or up to three years later. No significant relationships were found. However, not only was the discharge rate measured some way below Allahabad, but in 1974, in the middle of the data set, the Farakka Barrage was closed just above the Bangladesh border, thereby disrupting the direct link between Allahabad and the recording site at Hardinge Bridge.

Given the difficulties of obtaining suitable discharge data a less direct approach can be used. The ultimate source of discharge is rainfall and the simplest model (Sharp and Sawden 1984) for a river system is as follows:

$$P = ET + Q \pm \Delta S$$

where P is precipitation, ET is evapotranspiration, Q is stream flow or discharge and Δ is change in ground water storage.

Estimates of mean annual evapo-transpiration rates for Asia, Africa and South America show a relatively constant inter-annual variation of generally less than 10% and yearly variations in ground water storage tend to be very small (Payne et al 1993). This means that discharge is likely to be largely proportional to precipitation.

Rainfall data over the appropriate catchment area are required. Regional rainfall data over Bangladesh are sparse but Bangladesh only covers around 13.5% of the basin area and this is largely the final deltaic sector. The bulk of the basin lies in Indian territory and regional rainfall data are available from the "India Weekly Weather Reports" between 1962 and 1994 inclusive. These have been entered into a database, termed "HYDROL", by their 35 sub-divisions, including those constituting the Ganges Basin.

A correlation was found between rainfall in those sectors of the upper basin, sub-divisions 8-14 of the Indian Weather Reports, and discharge at the Hardinge Bridge. Only data post-1976, after the completion of the Farakka Barrage, was included. The resulting relationship is given by:

$$MDRATE = 9223 + 6.475\ (R_y)$$

for which $r = 0.74$ and $p = 0.05$, where MDRATE is mean discharge rate and R_y is rainfall.

A significant relationship does therefore exist between rainfall and discharge which provides some confidence that rainfall may be used as a proxy indicator of discharge.

Comparing rainfall in the upper catchment (Sections 8-14) with catches recorded in the Bangladesh Sector of the Ganges (Padma) from 1982 up to 1987, as a series of single correlations by year by species or category, showed a number of significant positive relationships particularly between catches and the rainfall of the previous year. These were particularly pronounced for catfishes (Figure 6.1), major carps, *Hilsa* and other, i.e. miscellaneous species.

One feature this demonstrates specifically is that a large component of the apparent decline in catches from the Padma referred to in Section 6.2 is environmental. The declining catches are largely mirroring the declining rainfall pattern over the period in question. In other circumstances it might have been tempting to ascribe such an apparently marked decline purely to a factor such as the Farakka Barrage or to "pollution". This emphasises the need to understand the role played by natural environmental variation.

It is possible to pursue this approach in a more detailed fashion through the use of multiple regression to test sequentially the effects of the influence of rainfall for a number of years previously (Payne and Halls 1994). Such a model has the form:

where Y = yield, α = constant, β = coefficient, R = rainfall, y = year, i = steps 0..3, ε = residual.

This has been applied to data for all rivers, including the Ganges/Padma and all major catch categories for the Bangladesh data series from 1982 to 1991 using total rainfall in the Indian sector of the Basin.

Amongst these, only prawn catches in the Padma, *Hilsa* catches from the Jamuna and catches of "other species" from the Meghna show significant amounts of their variability being most probably derived from rainfall up to three years previously.

The rainfall data used in this analysis are very wide-ranging, covering the whole basin. There has always been the contention that much of the flooding in Bangladesh, particularly the early phases of the flood, is due to local rainfall rather than rising river levels. Repeating the analysis just using the neighbouring sectors of Indian rainfall data, essentially from West Bengal and Assam (sub-divisions 2-5) gave a better agreement for this local rainfall element for a wider number of categories (Table 6.7).

The same approach has been used on catches by habitat. The national statistics of Bangladesh are divided by floodplain, beel and boar, and central rivers. Applying the stepwise multiple regression to this time series, 1982-1990, indicated that 80% of the variability of floodplain catch could be explained by a combination of rainfall in the same year and in the year two years before (Payne and Halls 1994). The relationship is given by:

$$\text{Yield } (Y_y) = -73120 + 8.395\,(R_y) + 1388\,(R_{y-2})$$

where $p = 0.02$, $r = 0.89$ and $n = 8$

A significant relationship was also obtained with catches from beels and boars and rainfall, although in this case the predominant influence by far was for rainfall of the same year. The relationship is described by:

$$\text{Yield } (Y_y) = 29313 + 1.396\,(R_y)$$

where $p = 0.04$, $r = 0.72$, $n = 8$

It appears, therefore, that given the availability of appropriate data, rainfall as a macro indicator of hydrological conditions can be used to predict catches of some species categories or of some spatial or habitat divisions. Within the Ganges Basin time series of fish catches are sparse, but rainfall records are good and have now been compiled into a flexible relational database within the project.

There are, therefore, a number of categories within the catches of the major rivers where the major part of their year to year variation can be explained by the rains, particularly on a regional basis, and for which significant predictive relationships can be obtained. Particularly relevant is the finding that this is true for "other species" in some rivers and for "all rivers" taken together, since these "other species" tend to now provide the major proportion of the catches at the centres recorded here, and also as has previously been found for the floodplains of Bangladesh (FAP 17, 1994).

For the Padma itself only the prawn catch showed itself significantly correlated, although simple regressions had pointed to equally significant relationships of other categories and rainfall in specific years. The multiple regression approach is asking more complex questions of the data and this, to some extent, leads to a reduced discrimination with respect to specific questions and relationships. Nevertheless, this multiple regression model offers a powerful predictive tool. In the case of prawns in the Padma, variation in rainfall in the Padma can explain 83% of all variability (Table 6.7). The most single significant influence was for the rains 2 years previously. If rainfall data is fed into the model for prawn catches in the Padma, then the pattern of predicted catches to those observed is very close (Figure 6.2).

6.5 CATCH PREDICTION AND THE INDIAN MONSOON AND OTHER CLIMATIC MODELS

Rainfall can be used as a predictor for fish catches in the Gangetic fisheries. This needs to be refined as a method by further work on existing records, but in principal, if rainfall records one, two or three years previously are available, or if the rainfall of the same year could be predicted, then the most probable trends in fish catches could also be predicted.

Rainfall is of paramount importance in India, owing to the variability of the monsoon and the reliance of much of the agricultural sectors upon it. As a result, the Meterological Office have developed a complex model for predicting the onset and most probable precipitation of the monsoon (Das 1995).

The form of the model is not dissimilar to the multiple regression used above, but this one includes the 6 predictors which are shown in Table 6.8 (Srivastura and Singh 1994).

This IMO model is now used to provide a preliminary view of the monsoon in April or May of the year in question to enable some indication of harvests to be obtained. There is no reason whey the output of this model could not be linked with models of the type outlined in the previous section to obtain longer term implications on the likely performance of the inland fishery sector. At the moment, the IMO model is less sensitive to the prediction of regional rainfall than to total monsoon rainfall, but modifications are being introduced (Das 1995).

Climatic and rainfall models are being developed for many parts of the tropics along with a General Circulation Model (GCM) for global rainfall. The use of rainfall as a predictor of inland and river fish catches in the major continental areas offers the prospect of improved management and longer term management of these resources in future.

Table 6.6 Results of stepwise Multiple Linear Regression of catch by species by river in Bangladesh and basin-wide rainfall* in the same and preceding years

River	Hilsa		Prawn		Catfish		Carp		Other		All	
	R^2	P	R^2	P	R^2	P	R^2	P	R^2	P	R^2	P
Meghna	0.00	0.00	0.00	0.00	0.00	0.00	0.388	0.09	**0.828**	**0.01**	0.00	0.00
Padma	0.00	0.00	**0.54**	**0.04**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jamuna	**0.892**	**0.02**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other	0.361	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.346	0.125	0.00	0.00
All	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

* Rainfall data relates to sum weekly rain falling in the approximate catchment area of the Ganges / Jamuna / Meghna river system (sub-divisions 2-4 and 8-14 Indian Weekly Weather Reports).

Minimum tolerance for entry into model = 0.01

Table 6.7 Results of stepwise Multiple Linear Regression of catch by species by river in Bangladesh and more local rainfall* in the same and preceding years

River	Hilsa		Prawn		Catfish		Carp		Other		All	
	R^2	P	R^2	P	R^2	P	R^2	P	R^2	P	R^2	P
Meghna	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.004	**0.824**	**0.01**	0.00	0.00
Padma	0.00	0.00	**0.832**	**0.01**	0.00	0.028	0.367	0.111	0.00	0.012	0.335	0.133
Jamuna	**0.66**	**0.013**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other	0.00	0.00	0.359	0.117	0.00	0.00	0.00	0.00	**0.736**	**0.006**	**0.46**	**0.06**
All	0.00	0.00	**0.486**	**0.05**	0.00	0.00	0.00	0.00	**0.687**	**0.011**	03570	0.118

* Rainfall data relates to sum weekly rain falling in the approximate catchment area of the Ganges / Jamuna / Meghna river system (sub-divisions 2-4 and 8-14 Indian Weekly Weather Reports).

Minimum tolerance for entry into model = 0.01

Figure 6.2 Observed and Predicted catches of prawn at Padma, Bangladesh 1983-84 to 1990-91

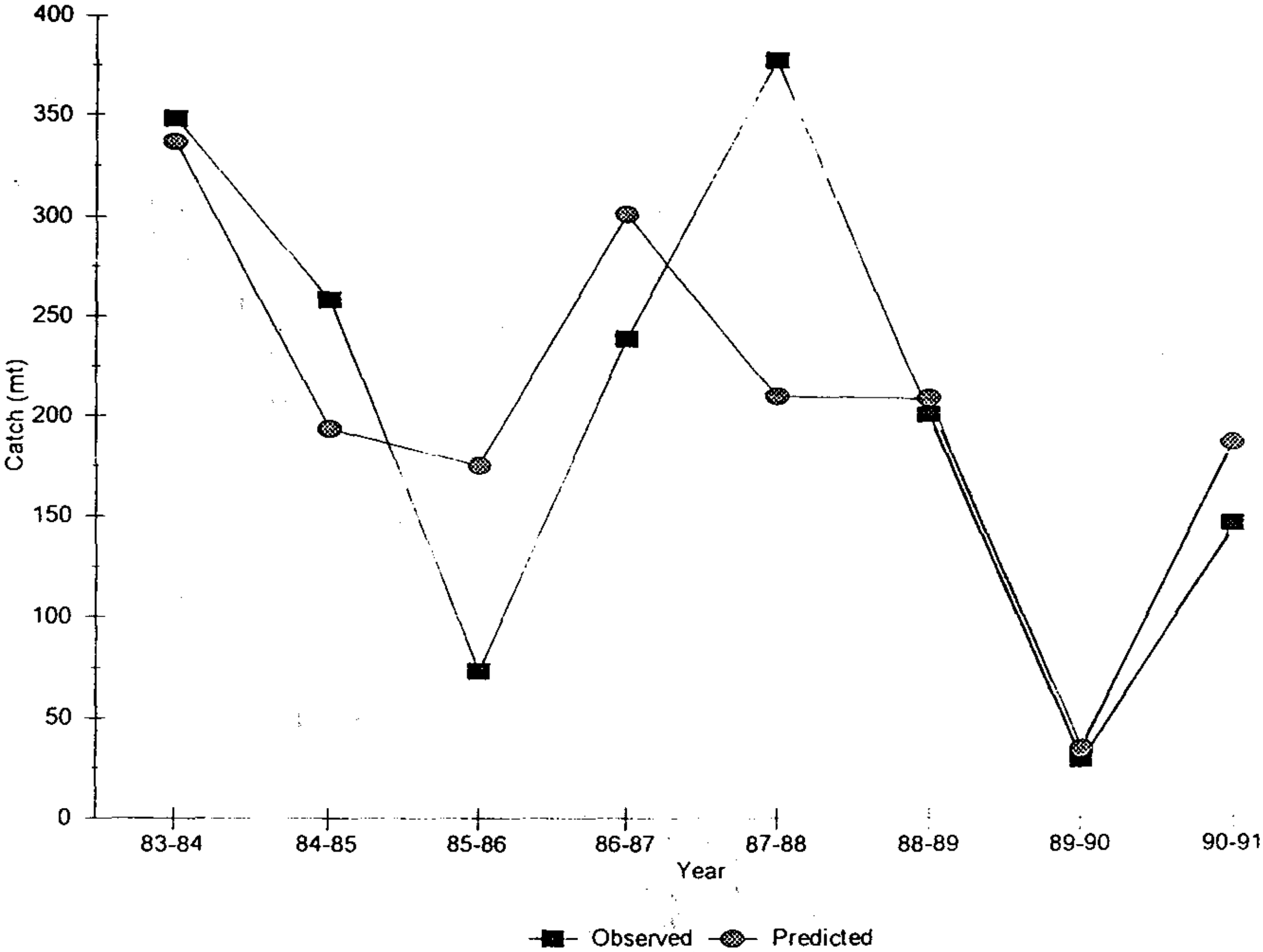


Table 6.8 Predictors for Monsoon Rainfall

I Pressures

(i) Location of a 500 hPa ridge over India
(ii) Port Darwin Pressure in April
(iii) Pressure over Argentina in April
(iv) Indian Ocean equatorial pressure
(v) Northern hemispherical pressure anomalies from January to May
(vi) 50 hPa ridge-trough pattern over northern hemisphere during January and February

II Upper winds and temperatures

(i) 10 hPa westerly winds over Balboa
(ii) Central Indian minimum temperatures in May
(iii) Northern Indian minimum temperatures in March
(iv) Minimum temperatures over the east coast of India in March
(v) Northern hemispherical temperatures in January and February

III Snow cover and atmospheric oscillations

(i) Eurasian snow cover in previous December
(ii) Himalayan snow cover from January to March
(iii) The ENSO Index (Tahiti-Darwin pressure) from March to May
(iv) The El-Nino category (measured by sea surface temperatures over the equatorial south-eastern Pacific) of previous year
(v) The El-Nino category of current year (October of previous year to May of current year)

(Source: Long Range Weather Forecasting Techniques in India by H N Srivastava and S S Singh, 1994)

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