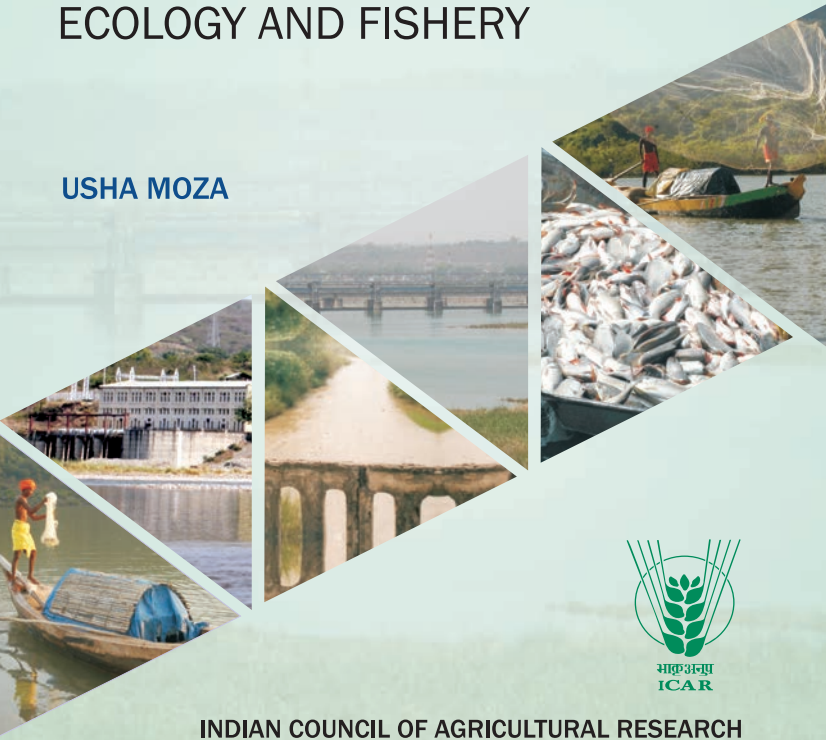
RIVER RAVI

ECOLOGY AND FISHERY

USHA MOZA



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ECOLOGY AND FISHERY

USHA MOZA

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Preface

River Ravi one of the five rivers of Indus system is 720 km long, out of which 320 km is in India, of which 158 km lies within Himachal Pradesh and 162 km within Punjab, where it is exploited for fishery resources.

Ravi known as *Irawati* to ancient Indians, originates from northern face of Rohtang pass in the Himachal Pradesh and flows through the junction formed by the BaraBang- Dhauladhar range of the Himalayas as two channels namely *Budhil* and *Tantgari* at an elevation of 4,423 msl and 4,418 msl. After joining, it flows through Himachal Pradesh mainly Chamba district, where it receives many tributaries. The river enters Punjab around *Shahpur* town of Pathankot, forms international boundary while passing through Gurdaspur and Amritsar districts of Punjab and finally leaves Indian Territory at *Goina/ Kakarmani* village some 80 km away from Lahore city. It is one of the rivers which still have good drinking water.

The rhitherone zone of Ravi within the Himalayas has been maneuvered extensively for generation of power by formulation of many dams, Chamera I, II, III and Ranjitsagar/Thein .The potomoan zone within

plains has been exploited for irrigation by carving of canals so much so that river becomes isolated entity after Modhupur, but it regains its riverine habitat due to induction of number of perennial and flashy torrents between Modhupur to Derababa-Nanak. These large-scale changes in river must have effected ecology and thereby fishery of this basin, but how much and in what way, is not known. The river has been analyzed only for its water characteristic between Chamba (Himachal Pradesh) to Modhupur (Punjab) by Central Pollution Control Board (1995-96) and at Chamera dam by Central Inland Fisheries Research Institute (2000). The river has not been evaluated for its fishery resources (fish catch, composition etc) by any agency so far, although it carries subsistence fishery especially around Ranjitsagar reservoir and to some extent in the plains of Punjab, where the resources are responsible for raising an amount of ₹ 5.7 to 6.15 lakh/year in Gurdaspur and ₹ 8.90 to 11.5 lakh/year in Amritsar district by way of auction money to the exchequer along with other natural resources.

The work presents the results of investigation carried over on potomoan zone of river Ravi during 2005-07. The investigations give complete picture of present ecology and fishery (Fish catch estimate,

composition, diversity) and also some managerial suggestions to sustain this resource. I am sure the comprehensive account of environment and its impact on fishery in the plains of Punjab on this river system, unknown so far would be of immense use to planners and development authorities mainly Punjab State Fisheries; Ministry of Environment and Forest; Wet land authority of India; Academicians and Researchers in general and to that of aquatic ecology and fishery in particular

Place: New Delhi **Usha Moza**

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Last not least, I would like to thank the Directorate of Knowledge Management in Agriculture, ICAR for bringing out this publication in an elegant manner.

Author

Contents

1. Introduction

THE RIVER RAVI having catchment area of about 5,957 km^2 is fed by many streams along its course both in the Himalayas and its foot-hills. The main streams joining in the Himalayan zone are *Sai* near Sahu village coming from Pirpanjal mountains; *Panjpula*, *Channd* and *Naini* near Dalhousie from Dhauladhar mountains. Within Punjab the main tributaries are (i) *Sukhal khad* (seasonal) joining at Shahpur, (ii) *Ujh*, from Trikuta hills of Jammu and Kashmir at Mukoda Pattan around Kathlour, (iii) *Purani Ravi* (perennial) at village Gajoo (Dist Gurdaspur) and *Saki*, at village Rania around Derababa-Nanak (Dist Amritsar).In addition many seasonal *nallahs* like Kiran**,** Niomi etc join river in district Gurdaspur. Out of all these tributaries, *Ujh* and *Purani Ravi* are important for their water resource and *Saki* for fishery resource.

Ravi river

The river Ravi is subjected to maximum manipulation along the Himalayan zone at several places resulting in Chamera I, II and III, earth–cum-

rock-fill dams of 950, 180 and 135 ha area respectively and at village Thein resulting in Thein/Ranjitsagar reservoir, again an earth-cum-gravel shell dam of 87 to 90 km ^{2} area having maximum height of 160 m, storage capacity of 3,280 million cusecs and live storage capacity of 2,344 million cusecs. Along plains its resources (water) are abstracted almost fully at Modhupur for irrigation purposes leaving river basin almost dry below barrage for approximately 30 km distance between Modhupur to Kathlour. The basin in the zone is sustained by leakage water from barrage. Diverted resources are canalized into 3 main canals, *Kashmir, UBDC* (Upper Bari Doaba canal) and *Hydel*. Amongst the three, Kashmir canal has a capacity of 900 cusecs and is carved out before the barrage; UBDC having capacity of 11,200 cusecs and Hydel with capacity of 6,900 cusecs, originate below barrage. Its resources are diverted into river Beas also via Ravi-Beas link canal (offshoot of UBDC) 15 km long earthen canal which puts its resources into the river Beas via *Chaki nalla* at Malikpur (dist: Gurdaspur). The river Ravi although devoid of its basin flow, nonetheless is sustained by influx of many perennial and seasonal tributaries joining along its course making it a full fledged river from Kathlour onwards,

draining almost 60 km of Punjab along the border. The river Ravi is not subjected to much industrial and municipal effluents as adjoining areas of river Ravi do not have any heavy or small-scale industries. There is only one distillery and paper factory (owned by the Punjab Government) at Gurdaspur which too operates seasonally. Moreover, river Ravi flows some 30-40 km away from big cities/towns within India as such is subjected to less municipal effluents.

Aim

The main mandate of the study was to generate information on the production potential of the riverine ecosystem of the river Ravi with a view to develop fishery management norms of the river system. Out of the three river systems originating from the Himalayas (Ganges, Brahmputra, and Indus) draining India, Indus system is one, wherein hardly any documented information is available regarding its production potential and existing fishery especially of its Potomoan zone (Fig. 1). Thus a study was undertaken on 'Assessment of Ecology, Biodiversity and Production potential of Indus System in Potomoan zone'. The two contributory rivers of the system, important from fishery resource point of view i.e.

Fig. 1 Contributory tributaries of Indus System within Punjab

Sutlej and Beas have been worked out earlier. The river Ravi, the third contributing river of Punjab segment of the system, so far India is concerned needed to be

probed thoroughly because of following points.

1. The river Ravi although contributing less to natural fishery resources of Punjab compared to Sutlej and Beas, nonetheless is significant as it provides subsistent fishery to local population in far flung areas and livelihood to local fishermen. As there is no record by any agency regarding its fish produce, fish diversity, fishery exploitation and extent of exploitation, the same needs to be probed for management of this resource for sustainable production within the system.
2. The river Ravi within Punjab has extreme conditions regarding water resources, water flow, depth etc. Study of fishery in relation to different water resources can give insight on impact of water flow regime on different fishes and aquatic biodiversity.
3. Shahpur weir is coming up on the river Ravi below *Ranjitsagar Dam*. The study will form base line data of pre-impoundment period which will be of immense use to fishery resources in post-impoundment period.
4. The river Ravi is subjected to minimum pollution load within Indian territory compared to other two main rivers of the system, Sutlej and Beas (Anonymous, 2004 and 2007), thus the comparative

account of 3 main rivers of the system will give insight to the changes in biotic diversity that must be occurring/have occurred due to pollution and will give insight to the bio-indicators for the system as a whole.

Approaches of the study were based on Environmental factors affecting the river Ravi, Ecological status of the river Ravi and Fishery status of the river Ravi that are discussed in the given chapters.

2. Environmental Evaluation

MAIN ENVIRONMENTAL CONSTRAINS affecting the river Ravi is water abstraction and mining to some extent compared to other impacts

Environmental constrains

Water abstraction: Main anthropogenic activity, water abstraction in the studied stretch takes place at Modhopur barrage in district Pathankot of Punjab state (Fig.2)

Fig. 2 Madhopur Barrage on Ravi river

The data for same was collected at Head Waters of barrage from Punjab Irrigation Department on daily basis for 2 years. Day-to-day data was computed on

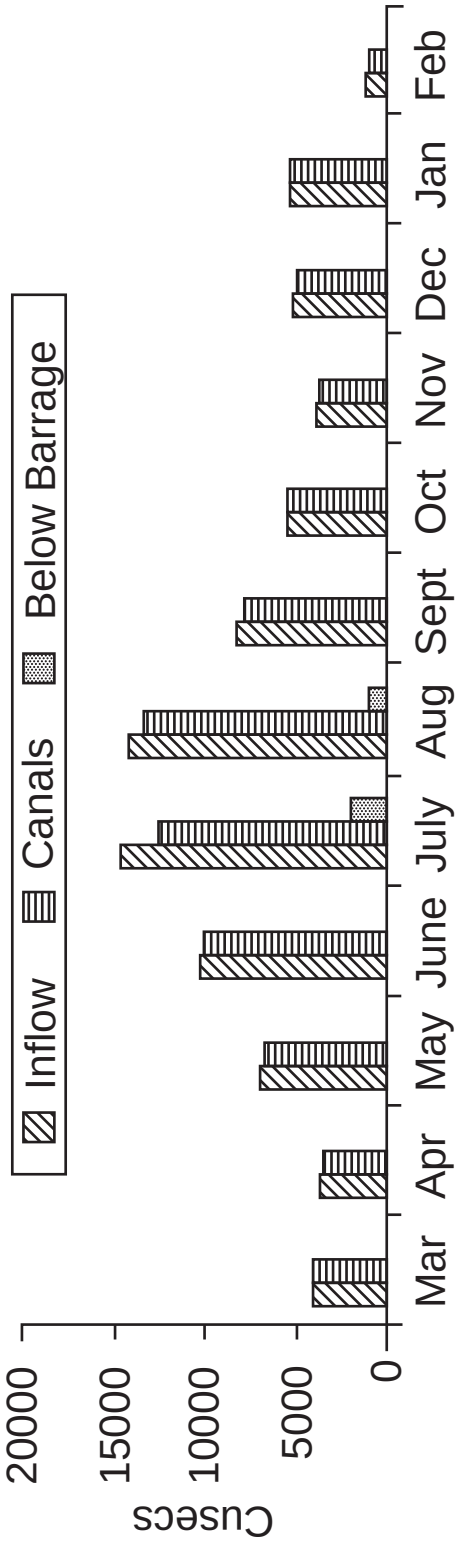

Fig. 3 Water availability (cusecs) within Ravi (2005-07)

monthly basis and average monthly data was drawn from 2 years observations from March 2005 to February 2007 (Fig.3).

The river Ravi basin around Shahpur-Madhopur area some 20 km stretch, depict sufficient water resources, maximum (10,209-14,470 cusecs) in monsoon (June to August), substantial in pre- (3565-6842cusecs) and post-monsoon (8,154-3,806 cusecs) and minimum (1094-5229 cusecs) in winter between November and February (Fig. 3). The availability depending upon water resources in Ranjitsagar Dam which in turn is subjected to rain/snow fall in catchment areas.

Fig. 4 Ravi at Shahpur above Madhopur barrage showing the site of **Kashmir Canal (↘)**

First water abstraction within river Ravi takes place in this zone-wherein some water is diverted to *Kashmir Canal* (Fig. 4) which has a capacity of 900 cusecs. The water is released into the canal round the year barring February-March owing to scarcity of water.

Main water abstraction in the system within Potomoan zone takes place at Modhopur below barrage, where water is diverted into 2 main canals, Upper Bari Doaba Canal (UBDC) and Hydel canal, former having capacity of 11,200 cusecs (Fig.5a) and latter 6,900 cusecs. UBDC is further bifurcated into (*i*) *Ravi - Beas-Link* Canal (Fig. 5b) and (*ii*) Main line;

Fig.5 (A) Diversion of water from Madhupur into UBDC and Hydel Canal, (B) Ravi-Beas link Canal

former putting its resources into river Beas via Chaki *Nallah* at Malikpur.

Due to large-scale abstraction only leakage water is allowed into river bed after barrage which is sufficient (844-2006 cusecs) during July and August only (Fig.6a), rest of the year it is only seepage from the barrage (Fig. 6 b and c). Comparative availability of water above and below barrage show large-scale fluctuation between the two years .The availability of

Fig. 6 Ravi river below Barrage at Madhopur

water being less during 2006-07 due to less rain in catchment areas.

It was observed that the stressed stretch extends from barrage (Fig. 2) to Kathlour. This wholesome abstraction of water causes loss of habitat for fishery.

This abstracted situation remains till *Ujh* tributary coming from Trikuta hills of Jammu (J&K) meets river Ravi at Makoda-Pattan around Kathlour (District Gurdaspur), Figs 7 and 8.

Fig. 7 Ravi after induction of Ujh Nalla at (pre-monsoon) Kathlour

Fig. 8 Ravi during (monsoon) at Kathlour

After that river Ravi gets sustained by induction of many perennial and seasonal tributaries as stated above and runs as a fully fledged river with enough water resources which are utilized for fishery resources (Figs 9 to 10).

Fig. 9 The river Ravi at Derababa Nanak (Dharamkot Pattan) after induction of Suboh and Saki tributaries

Fig. 10 Ravi during Monsoon at Goina village (Distt. Amritsar) before leaving Indian Territory

Mining : Large-scale mining of stone and sand takes place along river bed of Ravi especially along Modhupur- Kathlour region (Fig.11) where river bed is stony , gravel and scarce of water resources with the result even growth and breeding of minor fishery is constrained

Other Impacts : The river Ravi on the whole especially in Indian Punjab is not subjected to much industrial and municipal effluents as the catchment as well as adjoining area of river do not have many heavy or small-scale industries. Moreover, river flows some 20 to 30 km away from big cities and towns, with the result is not subjected to much municipal effluents too. The tributaries inflowing into it along Potomoan zone

Fig. 11 Stone/Sand Mining along river bed. (Modhupur–Kathlour) during lean seasons

come from foothills of Himalaya bringing mainly silt load. The only tributary bringing some municipal effluents into Ravi is *Saki* tributary which passes through Derababa Nanak town. The impact of this drainage has been assessed and is documented in Chapter 5, Associated Drainage: Saki Tributary.

3. Ecological Evaluation

ECOLOGICAL STATUS OF RIVER (approximately 162 km) was assessed from 4 different sites having different environment.

Shahpur

Shahpur is a reference zone between Ranjitsagar reservoir and Madhupur barrage where the river Ravi enters Punjab. The site is along foot-hills of the Himalayas, representing app.20 km stretch of river, having sufficient water resources (1,094-5,229 cusecs) even in lean season, winter (Figs. 4 and 12).

Fig. 12 Entrance of Ravi into Punjab after leaving Ranjit Sagar Reservoir (Shahpur)

Madhopur

Madhopur is an abstracted zone below Madhopur barrage where river basin contains only leakage water and is almost devoid of water resources except in monsoons. The segment represents approximately 30 km of abstracted zone of river between Madhopur to Kathlour within Gurdaspur district (Figs. 6 a,b,c)

Kathlour

Kathlour is a recovery zone again along foot-hills (Kandi region) of the Himalayas (Trikuta hills) where river Ravi has recovered some of its water resources due to induction of a perennial tributary, Ujh (Figs.7 and 8).

Dharamkot Pattan

Dharamkot Pattan is a lower stretch, represents the stretch of river within plains (district Amritsar) wherein river Ravi has sufficient water resources due to induction of all tributaries and flashy torrents (Figs 9 and 10).

Physical study of river Ravi water

The river Ravi water within Punjab was observed to have average temperature range between 21.6° and

25.3°C. The upper, Shapur stretch does not exhibit much temperature variation. It ranged between 20° and 22.5°C only, even during peak winter and summer. Lower stretch exhibit wide seasonal variation between 17 and 31.5°C, lowest during post-monsoon and winter (17°C and 19°C) and highest during pre-monsoon and Monsoon (31.5°C and 31°C) (Tables 1a and b).

The river Ravi is clear, transparent up to bottom up to Kathlour. The water starts turning muddy under the influence of rivulets like *Purani* Ravi, *Saki* and other seasonal *nallahs*, which bring in suspended material making it turbid. Transparency decreases to 38.65 cm (average) from Derababa Nanank, Dharamkot Pattan onwards. The water of river Ravi was alkaline throughout its course and showed less amplitude for variation along the gradient, pH ranging between 7.36 and 7.49 only. pH do not exhibit much seasonal variation too. It alters between 7.20 and 7.75 only in different seasons. The river is well oxygenated having dissolved oxygen in the range of 7.25 and 7.7 mg/liter. The oxygen content remains almost similar, 7.1/mg and 7.8/mg at Shahpur in different seasons but vary between 6.8 (Pre-monsoon) and 9.0/mg (winter) in lower stretch, there by exhibiting influence of

macrophyte vegetation (comparatively high density) and low temperature (Table1a & b).

Table 1a. Water characteristics of river Ravi (2005 to 2007)

Parameters	Shah-pur	Madh-opur	Kath-lour	Dharam-kot Pattan
Temperature (°C)	21.6	22.2	25.65	25.3
Transparency (cm)	55.4	46.8	52.05	38.65
pH	7.49	7.47	7.43	7.36
Dissolved Oxygen (mg/ litre)	7.4	7.7	7.6	7.25
B.O.D ((mg/ litre)	0.78	0.92	1.17	1.10
C.O.D (mg/ litre)	2.60	3.0	3.64	3.75
Total Alkalinity (mg/ litre)	87.5	86.0	103.25	112.75
Sp. Conductivity (μ mhos/cm)	166.0	166.87	207.8	249.5
Nutritional Status				
Calcium (mg/ liter)	24.15	24.3	30.8	34.05
Magnesium (mg/ litre)	13.0	13.55	16.35	15.6
Silicate (mg/ litre)	4.62	5.1	5.95	6.3
Chloride (mg/ litre)	12.0	12.87	14.87	14.0
Inorganic phosphate (mg/ litre)	0.18	0.20	0.24	0.26
Average Primary Production (mg $C/m^3/hr$)				
GPP	119.14	144.52	135.02	129.16
NPP	91.14	86.57	94.00	84.63

Total alkalinity range of 78.7 to 112.75 mg/litre indicate that the river is productive. Alkalinity was high in lower stretch (Table1a) due to influence of nutrients brought in by tributaries. Alkalinity like other parameters do not exhibit much seasonal fluctuation at Shahpur (72 to 88 mg/litre) compared to lower stretch (85 to141mg/ litre) indicating influence of external factors in this case tributaries.

Specific conductivity: The specific conductivity range of 166 to 166.8 μ mhos/cm at upper stretch compared to 207.8 to 249.5 μ mhos/cm range at lower stretch show Shahpur- Madhopur area contains less dissolved solids as is evident by comparatively low content of Calcium (24.15 to 24.3 mg/litre) and Magnesium (13- 13.55 mg/litre) in former stretch compared to 30.8 to 34.05 mg/litre of Ca and 16.35-15.6 mg/litre of Mg in latter stretch. Seasonal variation in conductivity (Table 1b) is also more profound in lower stretch (165-311μmhos/cm) than upper stretch (152-188 μ mhos/cm) like other parameters. The values were maximum, 281 μ mhos/cm during monsoon at Kathlour while in rest of river Ravi it was during summer (311 μmhos/cm) indicating tributary Ujh exhibit profound influence on dissolved salts within the river. The overall conductivity was low

Table 1b Seasonal changes in water characteristics of river Ravi (2005-07)

Parameters	Site	Season			
		Pre-monsoon	Monsoon	Post-monsoon	Winter
(1)	(2)	(3)	(4)	(5)	(6)
Water Temperature (°C)	Shahpur	21.5	22.5	20.0	20.5
	Madhopur	25.0	24.0	18.0	19.0
	Kathlour	31.5	29.5	19.0	18.5
	Dharamkot Pattan	30.5	31.0	17.10	17.5
Transparency (cm)	Shahpur (upto bottom)	78.5	49.0	35.0	51.5
	Madhopur	66.5	40.0	40.0	42.5
	Kathlour	43.0	60.0	65.0	52.0
	Dharamkot Pattan	43.0	38.0	38.0	52.0
pH	Shahpur	7.45	7.52	7.20	7.67
	Madhopur	7.35	7.37	7.50	7.65
	Kathlour	7.25	7.35	7.75	7.55
	Dharamkot Pattan	7.27	7.20	7.70	7.33
Dissolved Oxygen	Shahpur	7.4	7.1	7.6	7.8
	Madhopur	7.8	7.2	7.2	8.6

(*Contdinued to page 20*)

Table 1b (*Continued from p 19*)

(1)	(2)	(3)	(4)	(5)	(6)
(mg/litre)	Kathlour	7.2	7.0	7.6	9.0
	Dharamkot Pattan	6.8	6.9	7.2	8.6
Total alkalinity	Shahpur	75.0	80.0	88.0	72.0
(mg/litre)	Madhopur	90.0	104.0	80.0	70.0
	Kathlour	93.0	141.0	94.0	85.0
	Dharamkot Pattan	122.0	118.0	88.0	123.0
Specific	Shahpur	188.0	169.0	152.0	155.0
Conductivity	Madhopur	200.0	179.0	132.0	156.5
(μ mhos/cm)	Kathlour	210.0	281.0	165.0	172.5
	Dharamkot Pattan	311.0	263.0	192.0	232.0
B.O.D	Shahpur	0.1	1.05	1.35	0.6
(mg/litre)	Madhopur	0.25	1.2	1.55	0.7
	Kathlour	0.45	1.7	1.75	0.8
	Dharamkot Pattan	0.75	1.55	1.35	0.75
C.O.D	Shahpur	1.2	3.0	3.4	2.8
(mg/litre)	Madhopur	0.8	3.4	4.2	3.6
	Kathlour	0.6	4.8	5.0	4.16
	Dharamkot Pattan	1.0	4.2	5.0	4.8

(*Contdinued to page 21*)

Table 1b (*Continued from p 20*)

(1)	(2)	(3)	(4)	(5)	(6)
Calcium (mg/litre)	Shahpur	23.5	25.5	30.0	21.0
	Madhopur	21.0	27.5	28.0	23.5
	Kathlour	24.5	38.0	32.0	31.0
	Dharamkot Pattan	35.0	35.5	34.0	33.0
Magnesium (mg/litre)	Shahpur	12.9	11.4	13.2	14.4
	Madhopur	11.4	13.5	12.0	16.5
	Kathlour	12.9	16.5	15.0	20.1
	Dharamkot Pattan	10.8	14.4	15.6	20.7
Chloride (mg/litre)	Shahpur	13.0	11.0	13.0	11.0
	Madhopur	13.0	10.5	15.0	13.0
	Kathlour	14.0	15.0	14.0	16.5
	Dharamkot Pattan	13.5	13.5	12.0	17.0
Silicate (mg/litre)	Shahpur	4.5	5.4	4.0	4.6
	Madhopur	5.1	6.0	3.6	5.5
	Kathlour	5.2	7.0	5.2	6.4
	Dharamkot Pattan	4.3	7.1	6.0	7.5
Inorganic phosphate (mg/litre)	Shahpur	0.20	0.20	0.18	0.15
	Madhopur	0.19	0.21	0.22	0.19
	Kathlour	0.21	0.27	0.28	0.23
	Dharamkot Pattan	0.23	0.22	0.36	0.24

during post-monsoon to winter (132-192 μ mhos/cm) due to low temperature and less influx of water thereby suspended load from tributaries.

Nutrient status: The average Inorganic phosphate values within river Ravi ranged between 0.18 and 0.26 mg/litre, Silicates between 4.62 and 6.3 mg/litre, Chloride between 12.0 and 14.87 mg/litre (Table 1a). Comparative high values in lower stretch may be due to inclusion of nutrients along induction of sub-soil of torrential streams. The same is evident by high-values of silicates (5.4 to 7.1mg/litre) in monsoon season at all places (Table 1b) .Dissolved solid content of calcium (24.15 to 34.08 mg/litre) and magnesium (13.6-16.38 mg/litre) indicate moderate nutrient values being comparatively more in lower zone (Table 1a).

Pollution load: The pollution load as assessed by Biological Oxygen Demand (0.78-1.17 mg/litre) and C.O.D (2.6 to 3.75 mg/litre) indicate that river Ravi waters do not carry much organic load as well as chemical pollutants especially in upper Shahpur-Madhopur stretch as the values for former are below 1mg/litre and for latter below 3 mg/litre. The same is substantiated by low values of specific conductivity (166-166.87 μmhos/cm) in the stretch.

B.O.D and C.O.D values do not exhibit much

seasonal variation as river is not subjected to major effluent load. The slight increase in B.O.D (1.05 mg/ litre to 1.75 mg/litre) and C.O.D (1.2 mg/litre to 3.4 mg/litre) during monsoon to post monsoon in lower stretch (Tables 1a and b) is under the impact of *Saki* and other tributaries which is rich in nutrients and biotic components as observed in Chapter 5.

Gross primary production (GPP): GPP was observed to vary between 119.14 and 144.52 mg C/ m^3/hr, lowest at Shahpur Kandi and highest at Madhopur (Table. 1c) depicting that contrary to nutrient status, primary production is better at Madhopur, the reason may be, total transparent waters, low depth, diminishing water flow, pool like conditions in this specific region which induce better production in spite of low nutrients. The river Ravi shows high amplitude of variation especially in gross productivity in different seasons in lower stretch. It being low (75.00-90.62 mg C/m^3/hr) in monsoon (August-September) and high (148.43 to 187.50 mg C/m^3/hr), in pre- and post-monsoon thereby showing the flow and turbidity have direct bearing on it (Table1c).

River bed of Ravi

Soil texture: River bed of studied stretch of Ravi

Table 1c Seasonal changes in primary productivity (mg C/m^3/hr), 2005-2007

Palce	*Monsoon	Monsoon	**Monsoon	Winter
Shahpur				
Gross P.P	171.87	62.50	132.81	109.37
Net P.P	125.00	46.87	93.75	62.50
Respiration	56.25	18.75	46.87	56.25
Madhopur				
Gross P.P	125.00	140.62	234.37	78.12
Net P.P	93.75	93.75	140.62	46.87
Respiration	37.50	56.25	112.50	37.50
Kathlour				
Gross P.P	148.44	90.62	187.50	78.12
Net P.P	93.75	46.87	162.50	31.25
Respiration	65.62	52.50	37.50	18.75
Dharamkot Pattan				
Gross P.P	171.87	75.00	171.87	93.75
Net P.P	109.37	54.68	109.37	62.50
Respiration	75.00	24.37	75.00	37.50

*Pre-mansoon; **Post-mansoon

within Indian Punjab is mostly made of boulder and gravel (Figs. 4, 6, 7 and 11) up to Gurdaspur as it flows along the foot hills of Himalayas – Kandi areas till this district of Punjab and many torrential streams enter in between, hence the soil texture of this zone is sandy having 64.6-73.15% sand, 19.35-23.95% silt and 7.50-

Table 2a Soil Characteristics of the river Ravi (2005-07)

Soil texture	Shah-pur	Madh-upur	Kath-lour	Dharam-kot Pattan
Sand (%)	73.15	67.23	64.6	57.95
Silt (%)	19.35	22.40	23.95	27.65
Clay (%)	7.50	10.43	11.45	14.40
Soil characteristics				
pH	7.46	7.51	7.45	7.50
Organic Carbon (%)	0.33	0.38	0.35	0.39
Specific Conductivity (μ mhos/cm)	210.15	195.0	276.5	210.8
Free $CaCO_3$ (%)	3.19	2.66	2.56	2.99
Average N (mg/ 100g)	13.2	13.65	14.77	17.92
Average P (mg/100 g)	0.93	0.88	0.92	0.97

11.45% clay (Table 2a). The percentage of sand decreases and that of clay increases as river flows down the gradient.

From Dharamkot Pattan onwards river becomes loamy sand having 57.95% sand, 27.65% silt and 14.4% clay (Table 2a). The texture of bed soil fluctuates seasonally in different zones. Bed becomes sandier at Shahpur during monsoons having 77.2% of sand and percentage of silt increases when flow is reduced between post-monsoon to winter (Table 2b).

Table 2b Seasonal changes in soil texture of river Ravi (2005-07)

Parameters	Site	Seasons			
		Pre-monsoon	Monsoon	Post-monsoon	Winter
Sand (%)	Shahpur	72.0	77.2	70.7	70.3
	Madhopur	70.0	72.2	63.25	66.7
	Kathlour	66.15	63.85	63.35	62.1
	Dharamkot Pattan	55.0	55.85	60.0	57.7
Silt (%)	Shahpur	16.3	17.0	23.20	24.3
	Madhopur	21.5	16.7	24.5	25.0
	Kathlour	22.5	22.65	26.65	27.6
	Dharamkot Pattan	28.6	27.8	28.75	26.9
Clay (%)	Shahpur	11.7	5.8	6.1	5.4
	Madhopur	8.5	11.1	12.25	8.3
	Kathlour	11.35	13.5	10.0	10.3
	Dharamkot Pattan	16.4	16.35	11.25	15.4
pH	Shahpur	7.50	7.32	7.50	7.30
	Madhopur	7.34	7.40	7.65	7.40
	Kathlour	7.35	7.30	7.80	7.30
	Dharamkot Pattan	7.32	7.20	7.85	7.60

(*Contdinued to page 27*)

Table 2b (*Continued from page 26*)

Parameters	Site	Seasons			
		Pre-monsoon	Monsoon	Post-monsoon	Winter
Free	Shahpur	2.12	2.75	3.87	4.50
$CaCO_3$ (%)	Madhopur	1.75	3.25	2.75	3.0
	Kathlour	1.37	2.87	3.25	2.50
	Dharamkot Pattan	2.62	3.62	2.87	2.0
Organic	Shahpur	0.22	0.39	0.37	0.17
Carbon (%)	Madhopur	0.30	0.40	0.34	0.14
	Kathlour	0.31	0.44	0.33	0.15
	Dharamkot Pattan	0.33	0.52	0.39	0.18
Average N	Shahpur	15.82	11.06	12.32	14.0
(mg/100g)	Madhopur	12.60	12.80	14.28	14.50
	Kathlour	15.40	14.98	13.58	15.65
	Dharamkot Pattan	21.42	18.62	15.82	16.24
Average P	Shahpur	0.77	0.98	0.88	0.80
(mg/100g)	Madhopur	0.67	0.82	0.80	0.70
	Kathlour	0.75	1.09	0.77	0.88
	Dharamkot Pattan	0.64	1.16	0.80	1.22

(*Contdinued to page 28*)

Table 2b *(Continued from page 27)*

Parameters	Site	Seasons			
		Pre-monsoon	Monsoon	Post-monsoon	Winter
Specific Conductivity (µ mhos/cm)	Shahpur	186	232.5	181	292
	Madhopur	229	280	124	256
	Kathlour	334	360	132	366
	Dharamkot Pattan	271	279	107.5	170

Soil characteristics: Ravi bed had alkaline reaction throughout with little variation in pH, (7.36-7.49) because of less variability in free calcium, carbon content, 2.5 to 3.18%. Available phosphorus (0.88 to 0.97 mg/100g) and Organic carbon (0.33 to 0.39%) also do not vary much, depicting presence of low organic pollutants although available nitrogen showed little variation between 13.2 and 17.92 mg/100 g (Tables 2a) being on higher side in lower stretch due to the impact of *Saki* tributary. All these parameters depict system having low production values.

Soil Conductivity is moderate all along river Ravi, (195-210.8 µ mhos/cm), except at Kathlour where it is slightly high (276 µ mhos/cm) due to influence of Ujh tributary. Seasonal variation in soil characteristics of Ravi was not profound as shown by its pH values but marginal variation in availability of nitrogen and phosphorus was observed in different seasons (Table 2 b).

Biotic component

Plankton: Average standing crop of plankton within river Ravi was 69 µ/litre showing it having poor plankton growth. Plankton density ranged between 53 and 114 µ/litre, minimum at Dharamkot Pattan and maximum at Kathlour (Table 3a). Poor growth at Dharamkot Pattan coincides with poor primary productivity, which may be due to low transparency (38.5 cm), high turbidity and great temperature variation (17 to 31.5°C). Plankton population was mainly formed by phyto-group. Zoo-group was present occasionally at Madhopur (nil-8%) and regularly at Kathlour (11to13.18%), represented exclusively by rotifers. Phytoplankton population was dominated by diatoms 57.5-84%, followed by green algae 15 to 27.5 %. Blue green algae to the tune of

Table 3a Plankton density (µ/litre) and composition (%) along river Ravi (2005-07)

Sites	Total Density (µ/litre)	Phyto-plankton (µ/litre)	Zoo-Plankton (µ/litre)	Bacill. (%)	Chloro. (%)	Myxo. (%)	Rotifers (%)
Shahpur	69	69	-	82.5	15	-	-
Madhopur	79	71	8	68	23.5	-	8
Kathlour	114	102	12	57.5	27.5	3	12
Dharamkot	53	53	-	84	16	-	-
Pattan							

3% were present only at Kathlour. High incidence of green algae (27.87%) and presence of rotifers (12%) and blue green algae (3%) at Kathlour envisage site productive as evident by total alkalinity(103.25mg/litre) also (Table 1a). Plankton composition (Table 4c) envisages that Ravi water is clean.

The density exhibit seasonal variation, being high in winter (67-168 µ/litre) and low in monsoon (33-67 µ/litre). The plankton growth do not exhibit usual riverine bimodal peaks, rather density is high between post-monsoon to winter (Table 3b) when the external influence is less

Table 3b Seasonal changes in plankton density (µ/litre) and composition (%) along Ravi

Place	Family	(1)	(2)	(3)	Winter
Shahpur					
Total density (µ/litre)		67	33	84	133
% composition	Bacillariophyceae	75.37	100	83.5	75.15
	Chlorophyceae	24.62	-	16.6	25.0
Madhopur					
Total density (µ/litre)		67	50	100	134
% composition	Bacillariophyceae	50.34	100	67	50
	Chlorophyceae	49.25	-	16.6	24.62
	Rotifers	-	-	16.6	25.0
Kathlour					
Total density (µ/litre)		100	67	134	168
% composition	Bacillariophyceae	50	74.5	50.3	39.88
	Chlorophyceae	33.5	25.5	24.6	39.88
	Myxophyceae	16.6	-	-	-
	Rotifers	-	-	25.0	20.23

1. Pre-monsoon; 2. Monsoon; 3. Post-monsoon (*Continued to page 32*)

Table 3b *(Continued from page 31)*

Place	Family	(1)	(2)	(3)	Winter
Dharamkot Pattan					
Total density (µ/litre)		50	33	67	67
% Composition	Bacillariophyceae	50	50	25	-
	Chlorophyceae	50	50	74.5	100

1. Pre-monsoon; 2. Monsoon; 3. Post-monsoon

and low between summer and monsoon when incoming tributaries flush in enough water resources, thereby showing that productivity of Ravi is influenced by tributaries. Plankton composition exhibited seasonal variation, diatoms were dominant during monsoon (74.5-100%) followed by post-monsoon (50.3-83.5%) up to Kathlour whereas these were mainly present during pre-monsoon to monsoon at Dharamkot Pattan (50 %) and absent in winter. Green algae was dominant in pre-monsoon (24.62-49.25%) up to Kathlour but in winter at Dharamkot Pattan (100%). Presence of rotifers and blue green algae at Kathlour only shows the region comparatively rich in organic matter as is observed by B.O.D. (1.28

mg/litre), C.O.D. (3.4 mg/litre) and conductivity in bed soil (276.5 μ mhos/cm). Plan-kton population exhibited yearly variation in upper stretch compared to lower (Dharamkot Pattan) not influenced by water resources within the river.

Periphyton

Average Periphyton concentration within river Ravi was high, 528 μ/cm^2 being maximum (608-639 μ/cm^2) in stretch above barrage and minimum, 333 μ/cm^2 at Dharamkot Pattan (Table 4 a) , mainly due to influence of river substratum, being stony and gravel with transparency up to bottom in former and turbid and clayey soil in latter stretch.

Periphyton concentra-tion was maximum in winter (467 to 1,100 μ/cm^2) and minimum in monsoon (150-

Table 4a Periphyton density (μ/cm$^{2)}$ and composition (%) along river Ravi (2005-07)

Site	Total Density (μ/cm^2)	1 (%)	2 (%)	3 (%)
Shahpur	639	77.03	9.5	12.77
Madhopur	608	74.5	9.0	16.5
Kathlour	534	76.0	8.0	16.0
Dharamkot Pattan	333	73.85	13.08	12.70

[1]Bacilliariophyceae; [2]Chlorophyceae; [3]Myxophyceae

467 µ/cm^2) depicting that periphyton concentration is directly co-related with water column and turbidity. Maximum fluctuation in concentration was observed at Madhopur (317-1100 µ/cm^2) and minimum at Dharamkot Pattan (150 to 467µ/cm^2) due to maximum fluctuation in water column and transparency at former compared to latter site (Table 4b).

Periphyton population like plankton was dominated by diatoms 73.8 to 77.03%, but unlike plankton, had presence of blue green algae (12.7 to 16.5%) also. Shahpur and Dharamkot Pattan site with 12.7% of blue green

Table 4b Seasonal changes in periphyton concentration and composition (%) in the river Ravi.

Total concentration (µ/ cm ^{2})	Families of algae	Pre-monsoon	Monsoon	Post-monsoon	Winter
Shahpur					
Total concentration:		589	467	484	1068
% composition	Bacillariophyceae	62.33	88.18	82.61	75.0

(*Continued to page 35*)

Table 4b (*Continued from page 34*)

Total concentration (μ/ cm ^{2})	Families of algae	Pre-monsoon	Monsoon	Post-monsoon	Winter
	Chlorophyceae	29.67	-	3.5	6.27
	Myxophyceae	8.0	11.81	13.0	18.27
Madhopur					
Total concentration		517	317	500	1100
% composition	Bacillariophyceae	62.66	88.80	75.0	66.63
	Chlorophyceae	14.12	-	10.0	12.09
	Myxophyceae	24.0	11.2	15.0	21.27
Kathlour					
Total concentration		501	351	518	767
% composition	Bacillariophyceae	57.5	85.78	81.14	78.22
	Chlorophyceae	19.90	5.00	5.50	4.30
	Myxophyceae	22.0	9.7	13.8	17.47
Dharam Kot Pattan					
Total concentration		334	150	384	467
% composition	Bacillariophyceae	43.99	100	79.9	71.52
	Chlorophyceae	31.21	-	14.15	7.06
	Myxophyceae	23.5	-	5.9	21.41

algae is in concurrence with low nutrient load in the area compared to Kathlour (16.0%) as observed through water characteristics (Table 1a).

Green algae to the tune of 8 to 13.08% was also present throughout, being less (Table 4a) upto the region having gravel river bed and fast flowing water (Kathlour). Periphyton composition like plankton had dominance of diatoms (85.5 to 100%) during monsoon to post-monsoon, green algae during pre-monsoon (14.12 to 31.21%) and blue green algae in winter (17.47 to 21.41%), all along the course (Table 4b). Absence of green algae during monsoon along the river shows the impact of flushing by torrential streams on river bed thereby on biotic flora.

Micro-vegetation diversity

Micro-vegetation showed minimum diversity within the river Ravi both in planktonic and periphyton forms (Table 4 c). The population was observed to be formed by 28 genera out of which 26 were from phyto- group and only 2 from zoo-group. Amongst the 28, 10 belonged to Bacillariophyceae, 9 to Chlorophyceae, 5 to Myxophyceae and 2 each to Desmids and Rotifers. Desmids and myxophceaen forms were present only in attached form (Periphyton).

Table 4c Micro-vegetation diversity within river Ravi both in planktonic and periphyton forms.

S. No	Families of algae	Sha-pur	Madho-pur	Kath-laur	Dhar-amkot Pattan	Sakii
1.	Bacillariophycea					
	Navicula	+	+	+	+	+
	Diatoma	+	+	+	+	+
	Cymbella	+	-	+	-	-
	Amphora	+	+	+	+	-
	Frustulia	+	+	-	+	-
	Nitzschia	+	+	+	-	-
	Cocconia	-	+	+	-	-
	Fragillaria	-	+	+	+	-
	Tabellaria	-	+	-	-	-
	Synedra	-	+	-	+	-
2.	Chlorophyceae					
	Crucigenia	+	+	+	-	-
	Protococcus	+	-	-	-	-
	Tribonema	-	+	+	+	-
	Oedogonium	-	-	+	-	+
	Scendesmus	-	-	-	+	-
	Spirogyra	-	+	+	+	-
	Microspora	+	+	+	+	-
	Cladophora	-	-	+	+	-
	Pleurococcus	-	+	-	-	-
3.	Myxophyceae					
	Microcystis	+	+	+	+	+
	Anabaena	+	+	+	-	-

(*Continued to page 38*)

Table 4c (*Continued from page 37*)

S. No	Families of algae	Sha-pur	Madho-pur	Kath-laur	Dhar-amkot Pattan	Sakii
	Phormidium	+	+	-	-	-
	Merismopedia	+	-	-	-	-
	Oscillatoria	+	+	+	-	-
4.	Desmids					
	Closterium	-	-	-	-	+
	Cosmarium	+	-	-	-	-
5.	Rotifera					
	Polyarthra	-	+	+	-	+
	Brachionus	-	+	-	-	-

The dominating genera being *Navicula*, *Diatoma*, *Amphora*, *Nitzschia* and *Fragillaria* among diatoms. *Crucigenia*, *Tribonema*, *Spirogyra* and *Microspora* among green algae, *Microcystis*, *Anabaena*, *Oscillatoria* among blue green algae. *Cosmarium* among desmids and *Polyartha* among rotifers.

Macro-zoobenthos: River Ravi sustains rich benthic population in the range of 654 to 3,700 µ/m^2, highest at Kathlour and lowest at Dharamkot Pattan. The reason may be that former has conducive substratum for benthic population-stony gravel bed, low depth (30 to 100 cm) transparent waters up to

bottom while at Dharamkot Pattan river is deep, bed is of clay nature, water is turbid (Tables 5a).

Benthic population exhibited substrate and thermal influence. Trichoptera Plecoptera and Ephemeroptera nymphs were present in the river segment having rhitherone characteristics i.e. Shahpur to Kathlour while Dharamkot Pattan had mainly molluscans and

Table 5a Macro-zoobenthic population and composition in river Ravi (2005-07)

Site	Shah-pur	Madh-opur	Kath-loor	Dharam-kot Pattarn
T. density (μ/m^2)	1154	2130	3700	654
Percentage composition (%)				
Trichoptera	11.05	1.5	1.06	-
Pelecoptera	14.5	1.5	0.25	-
Ephemeroptera	17.15	33.24	7.95	-
Coleoptera	-	16.13	8.50	4.70
Hemiptera	5.5	10.77	3.62	14.50
Odonata	0.20	3.1	5.61	18.95
Diptera	2.5	7.37	14.27	4.29
Gastropoda	15.99	14.37	23.26	13.14
Bivalves	19.82	10.8	28.20	12.62
Decapoda	-	-	1.16	13.97
Annelids (Hirudinea)	12.75	0.3	8.50	-
Miscellaneous	-	1.0	0.5	17.85

decapods although nymphs of Coleoptera (nil-14.28%), Hemiptera (nil-42.8%) and odonate (nil-40.3%) were present in different seasons (Tables 5a).

The density was generally high during pre-monsoon, (681 to 5,992 µ/m^2) and post-monsoon (1,132- 3,695 µ/$m^{2)}$ and low during monsoon (149 to 1979 µ/m^2) as is the riverine norm except at Shahpur, where density was highest during winter (2,562 µ/m^2) due to presence of *Ephemeroptera numphs* (being their breeding season). Sufficient benthic density at Madhopur (1,731 µ/m^2) during monsoon shows the impact of physical characteristics of river like water current, depth, turbidity etc on growth of macro-organism. The least fluctuation in water temperature and minimum monsoon flushing cause minimum disturbances to river bed thereby to macro-benthic organisms, hence retention of good crop during monsoon at this site (Table 5b). Benthic population especially the sensitive groups were generally present during monsoons to winter and were observed to be influenced by water flow/resources as evident by the analysis between two years. Caddis fly nymphs, present to the tune of 0.60 to 37.60% in 2005-06 were present only to the tune of nil-2.29% in 2006-07. May fly nymphs, dominant (50%) during 2005-06 were

reduced to 3.2% of total population in 2006-07; instead colonization of beetle nymphs (1.89-7.19%) was observed below barrage. The assumption is drawn because all the environmental characteristics especially within Shahpur area were same except water inflow, which was very less in year 2006-07 than that of 2005-06. The dominance of Caddisfly nymphs (nil to 34%), Stone fly nymphs (nil to50%) at Shahpur, presence of May fly nymps, 12.65 % at Kathlour and 71.56 % at Madhopur indicate the river stretch clean especially up to Kathlour

More presence of Bivalves (10.8-28.20%) than that of Gastropods (13.14-23.26%) among molluscans also indicate that whole river Ravi within Indian territory is not polluted, but site specific absence of sensitive forms from Dharamkot Pattan depict change in river ecology from this site onwards. Fish fry mostly of *Chela* and *Osteobrama* sp. to the tune of 14.28% at Daramkot Pattan and fish fingerlings of Eel to the tune of 1.14% at Kathlour were observed during monsoon along with benthic organisms, thereby showing that this fishery breeds in the river at specific sites.

Macrophyte: Macrophytes were mainly present at Madhopur (200 g/m ^{2}) and Kathlour (100-290 g/m^2) between pre-monsoon to post-monsoon being absent

Table 5b Seasonal changes in Macro-zoobenthic density and composition (%)

Parameters		Pre-monsoon	Monsoon	Post-monsoon	Winter
		Shahpur			
Total density (µ/ m^2)		466	565	1648	2562
% composition	Trichoptera	-	34.0	3.6	6.5
	Pleceoptera	-	8.0	50.0	-
	Lepidoptera	-	2.0	-	-
	Ephemeroptera	-	27.7	-	40.9
	Hemiptera	-	22.2	-	-
	Diptera	-	4.0	5.1	-
	Hirudinea	-	2.0	23.0	26.2
	Odonata	-	-	1.03	-
	Bivalve	57.15	-	9.0	13.15
	Gastropoda	42.85	-	8.0	13.14
	Misc.	-	-		-
		Madhopur			
Total density (µ/m^2)		2445	1731	2213	232
% composition	Trichoptera	-	-	5.54	-
	Pleceoptera	4.44	1.51	-	-

(*Continued to page 43*)

Table 5b (*Coninued from page 42*)

Parameters		Pre-monsoon	Monsoon	Post-monsoon	Winter
	Lepidoptera	-	-	-	-
	Ephemeroptera	26.66	32.5	2.27	71.56
	Hemiptera	-	15.1	28.01	-
	Coleoptera	-	5.5	30.58	28.44
	Diptera	1.6	22.2	5.68	-
	Hirudinea	1.11	-	-	-
	Odonata	3.9	-	8.5	-
	Bivalve	43.13	-	-	-
	Gastopoda	18.0	20.2	19.31	-
	Decapoda	1.11	-	-	-
	Misc.	-	3.0	-	-
		Kathlour			
Total density (μ/m^2)		5992	979	3695	2629
% composition	Trichoptera	-	4.25	-	-
	Peleceoptera	-	0.9	-	-
	Lepidoptera	-	-	-	-
	Ephemeroptera	1.45	17.2	0.50	12.65

(*Continued to page 44*)

Table 5b (*Continued from page 43*)

Parameters		Pre-monsoon	Monsoon	Post-monsoon	Winter
	Hemiptera	2.17	3.57	0.50	12.65
	Coleoptera	2.17	8.61	3.7	-
	Diptera	-	47.46	3.3	6.32
	Odonata	1.4	17.20	3.84	-
	Hirudinea	0.14	-	16.3	17.6
	Bivalve	36.26	40.17	11.4	25.30
	Gastropoda	7.68	-	60.09	25.30
	Decapoda	2.96	1.70	-	-
	Misc.	-	1.70	0.93	-
		Dharamkot Pattan			
Total density (μ/m^2)		681	149	1132	232
	Hemiptera	-	7.14	8.05	42.84
	Coleoptera	2.94	-	1.61	14.28
	Diptera	8.34	-	8.83	-
	Odonata	-	7.14	40.32	28.36
	Bivalve	50.49	-	-	-
	Gastropoda	38.3	-	-	14.28
	Decapoda	-	14.25	41.66	-
	Misc.	-	71.42	-	-

in winter. At Shahpur site, these were present only in winter to the meager tune of 0.9 g/m^2 formed exclusively by *Potomogeton* sp. (50%) and emergent weeds. At Dharamkot Pattan , the density was, 20 g/m^2 in pre-monsoon season only but having wide diversity. Macrophyte composition was almost similar all along the course except the absence of *Chara* sp., from lower site-Dharamkot Pattarn, depicting change in river ecology from this site as is witnessed by abiotic and biotic parameters. Vegetation exhibited seasonal variation like *Ceratophylla echinatum* was present only during pre-monsoon and *Chara* sp. during post-monsoon, (Table 6).

Macrophyte associated fauna: Macrophyte associated fauna was present all along river Ravi, even at sites/seasons without the vegetation, wherein epiphytic forms were attached with algal scum or emergent grass along with banks of river (Table 7a). Average meiofauna density varied between 27 and 178 µ/kg/m^2, lowest at Madhopur and highest at Kathlour. The density exhibited site specific and seasonal fluctuation, It was high in winter (144 µ/kg/m^2) and low in post-monsoon (46 µ/kg/m^2) at Shahpur, while as it was low in winter (nil - 44 µkg/m^2) and high in post-monsoon (203-380 µ/kg/m^2) in lower stretch

Table 6 Average biomass (wet) and composition of macro-vegetation present all along Ravi.

Seasons	Modhopur		Kathlour		Dharamkot Pattan	
	Weight	Composition	Weight	Composition	Weight	Composition
Pre-monsoon	04 g/m^2	*Ceratophyla echinatum* 100%	200 g/m^2	*Hydrilla* 45 % *Vallsenaria* 25%	25 g/m^2	*Ceratophyla echinatum* 80%, *Valls-neria* 10%, *Potomoge-ton* 10%
Monsoon	05 g/m^2	*Hydrilla* 100%	100 g/m^2	*Hydrilla* 90% *Vallsenaria* 10%	-	-
Post-monsoon	200 g/m^2	*Potomogeton* -30 %, *Hydrilla*-20% *Vallsenaria*-20% *Chara*-20%	290 g/m^2	*Potomogeton* 20% *Hydrilla* 30% *Vallsenaria* 20% *Charra* 20%	-	-
Winter	-	-	Negligible		-	-

again depicting that water availability there by depth and temperature played a vital role in macro-organism growth.

The density exhibited variation between two years. It was reduced almost to half at all places during 2006-07, when sites (Shapur to Madhopur) influenced by water flow from main river basin got less water due to less rains in catchment area, while as density

Table 7a Macrophyte associated fauna, density and composition in river Ravi (2005-07).

Sitess	Shah-pur	Mad-hopur	Kath-lour	Dharmkot Pattan
T. density (μ/kg/m^2)	68	27	178	123
Percentage Composition (%)				
Trichoptera	16.5	-	-	-
Pelecoptera	8.70	-	1.65	-
Ephemeroptera	16.6	1.38	10.6	2.45
Coleoptera	0.22	9.6	7.2	6.24
Hemiptera	8.66	33.4	6.9	23.39
Odonata	5.0	25.9	11.6	16.9
Diptera	20.34	2.77	9.2	-
Gastropods	22.6	17.2	21.0	3.3
Bivalves	1.9	8.3	2.4	2.98
Decapoda	-	-	26.17	34.2
Annelids	2.76	1.4	-	-
Miscellaneaus	-	-	3.3	10.5

remained almost same 122 to 125 μ/m^2 at Dharmkot Pattan, influenced by tributaries than actual river. Epiphytic population mainly comprised of insect nymphs, molluscans and decapods. Upper stretch from Shahpur to Madhopur had dominance of Insect nymphs (72.75-73.12%) followed by molluscans (24.5-25.5%). The Kathlour stretch too had dominance of Insect nymphs (47.15%)but contained decapods (26.17%) and molluscans (23.4%) almost equally. At Dharmkot Pattan, population comprised primarily of insect nymphs (47.1 to 48.89%) and secondarily of decapods (26.17 to 34.2%). Molluscans being very less (2.9-3%) because of the change in river bed from sandy to clayey nature (Table 2a). Epiphytic population exhibited thermal influence thereby site specific variation, Trichoptera and Plecoptera nymphs were present only at Shapur where temperature did not exceed above 22.5°C, rest of the population were present all along although May fly nymphs were dominant (16.6%) at Shapur. Seasonal fluctuation was exhibited by specific population, Stone fly nymph (5.0 to 10%) and May fly nymphs (4.76 to 22.72%) were abundant during post-monsoon and winter respectively; Decapods were present during pre-monsoon (43.4 to 39.14%) and post-monsoon (30.57

to 51,5%) in lower region. Fish fry (60%) at Dharm-kot Pattan during monsoon.

Macro-organism diversity

The macro-organism population both as benthic organisms or epiphytic forms were observed to be formed by 66 genera, of which 2 belonged to stone flies, 3 to caddis flies, 6 to May flies, 7 to Hemiptera, 7 to Odonata, 12 to Coleoptera, 3 to Diptera, 2 to Crane fly larvae, 9 to Gastropods, 2 to Pelecypoda, 2 to Decapoda, 2 to Oligochaeta, 1 to Hirudina, 2 to Acari and rest miscellaneous (Table 7b).

Table 7b Insect population present in river Ravi in different seasons as macro–zoo benthos and epiphytic forms between 2005 and 2007.

S. No.	Name of the genera	Shapur	Madho-pur	Kath-laur	Dharam kot Pattan
1.	Plecopetera (stone flies)				
	Nymphula	+	+	+	-
	Perterella	-	+	-	-
2.	Trichoptera (caddis flies)				
	Hydropsyche	+++	-	+	-
	Neopytaris	+	+	-	-
	Laptocella	-	-	+	-

(*Continued to page 50*)

Table 7b (*Continued from page 49*)

S. No.	Name of the genera	Shapur	Modho-pur	Kath-laur	Dharam kot Pattan
3.	Ephemeroptera (may flies)				
	Ephemerella	++	+	++	+
	Ephemera nymphs	+++	++	+	-
	Heptogenia	+++	-	++	-
	Amelelus	-	+++	++	++
	Caenis sp.	-	+	++	-
	Baetis nymphs	-	-	+	+
4.	Hemiptera (bugs)				
	Plea	++	++++	++	++++
	Notonecta	+	+++	++++	++
	Micronecta	-	++	-	-
	Lacotrephes maculates	-	-	++	-
	Anisops	-	-	+	++
	Belostoma	-	-	+	+
	Corixa sp.	-	-	-	++
5.	Odonata				
	Paltothemis	-	-	-	+++
	Gomphus nymphs	-	++	-	++++
	Enallogoma	-	-	++++	+++
	Damsel fly nymphs	-	+	+++	-
	Argia	-	-	++	-
	Lanthis nymph	-	-	+	-
	Dragonfly nymph	-	-	++++	-

(*Continued to page 51*)

Table 7b (*Continued from page 50*)

S. No.	Name of the genera	Shapur	Modho-pur	Kath-laur	Dharam kot Pattan
6.	Coleoptera(Beetle)				
	Hypophorus	-	+	++	++
	Promonesia	-	+	++	-
	Berosus larvi	-	++	-	-
	Psephenus larvi	+	-	+	-
	Diplonuchus sp.	-	-	+	-
	Regimbertia altenuata	-	-	+	+
	Hydaticus	-	-	++	++
	Dyticus	-	-	+++	-
	Beetle larvi	-	-	++	-
	Beetle	-	-	+	+
	Rhantaticus congesta	-	-	-	+++
	Cybister Limbatus	-	-	-	+
7.	Diptera				
	Chironomus pupae/larvi	++++	++	++++	+
	Dixa sp.	-	-	+	+
	Tabanus	+	-	++	-
8.	Cranefly larvae				
	Rhaphidolabis	-	-	+	-
	Elliptera	-	+	-	-
	Misc insect	-+	-	-	-
9.	Gastropods				
	L. pingus	++++	+++	-	+
	L. columella	-	++	-	-

(*Continued to page 52*)

Table 7b (*Continued from page 51*)

S. No.	Name of the genera	Shapur	Modho-pur	Kath-laur	Dharam kot Pattan
	L. auricularia	-	-	++	++
	Gyraulus	+++	+++	+++	+
	Cyclotopsis	+	+	+	-
	Faunus ater	+++	-	++++	-
	M.straitella	-	-	++++	-
	V.bengalensis	-	-	+	-
	Pleurocerca	-	-	+	-
	Glessula pelecypoda	-	-	+	-
	Carbicula	++++	++++	++++	+++
	pisidium	-	-	++	-
10.	Decapoda				
	Prawn sp.	+	-	++++	++++
	Gammarus	+	-	+	-
11.	Oligochaeta				
	Earthworm	++++	-	++++	-
	Tubifex sp.	+	-	+	-
	Pterobdella (Hirudinea)	+		+	-
12.	Acari				
	Hydrachana	-	-	+	+
	Halesus sp.	+	-	-	+
13.	Miscellaneous				
	Sepedon	-	-	+	+
	Fish fingerling (*osteobrama)*	-	+	+	+
	Fish fingerling and fry			+	+

Stone fly and Caddis fly nymphs were present exclusively in rhitherone zone and rest all along the studied stretch of the river.

4. Fishery Evaluation

THE RIVER RAVI contains subsistence fishery all along its course, maximum fishery resources are confined to Ranjitsagar reservoir, where approximate catch was 2 q/day. The catch comprise mainly of *Tor putitora* (60%), *Cyprinus carpio* (30%) and minor carps (10%) in winter and 60% of *Cyprinus carpio* and 40% of *Tor putitora* in summer (Fig. 13).

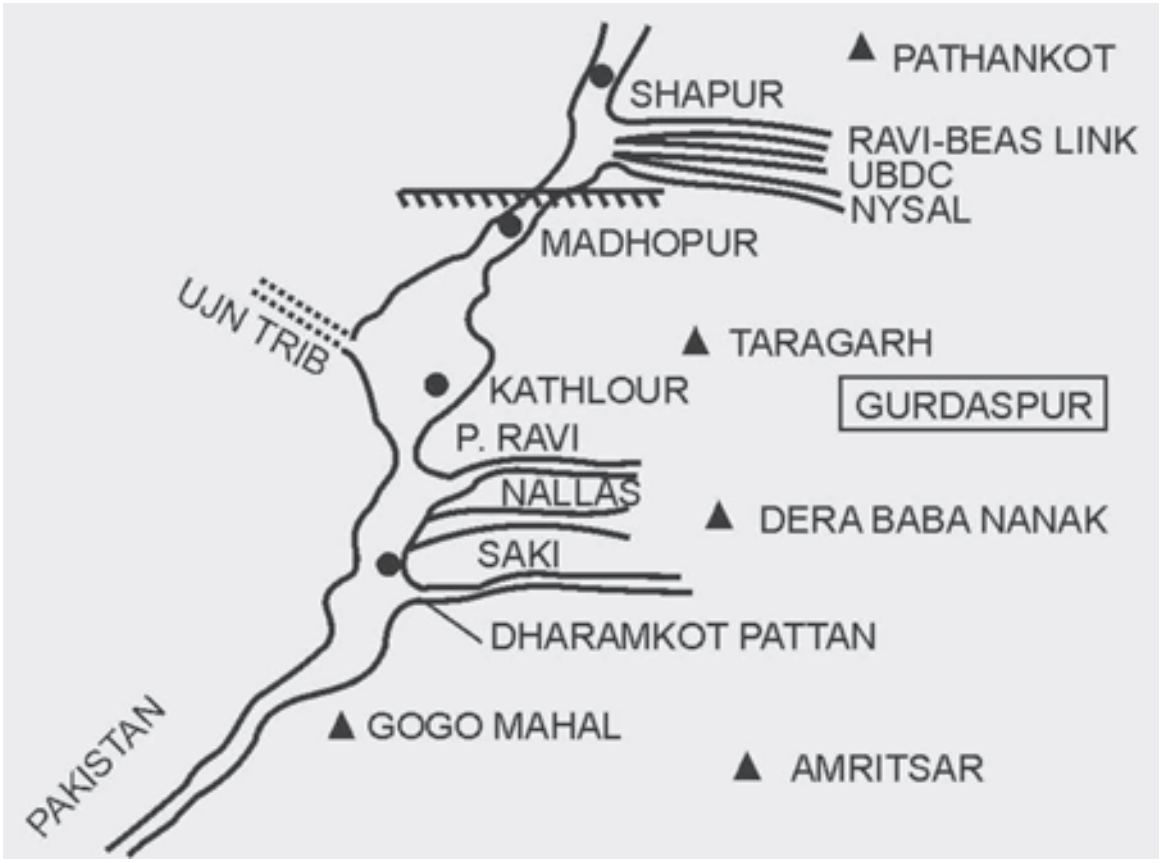

Fig. 13 The river Ravi showing landing sites (▲) and sampling centers (•).

The potomoan zone of the river Ravi within Punjab is also exploited commercially for fish resources but at selected places due to it forming international border. The river is auctioned annually, district-wise along with other natural fishery resources of the district in September by Punjab Fisheries Department. Fishing is carried round the year barring during July and August, observed as closed season. The catch procured is disposed off at nearest landing centre but when meager is disposed off locally. Four (4) fish landing centers were observed along the studied stretch (Fig.13) namely Pathankot, Taragarh (dist: Gurdaspur), Derababa Nanank and Amritsar (dist. Amritsar).

Fishery spectrum: The river Ravi contains subsistence fishery all along its course, maximum along Ranjitsagar reservoir wherein approximate catch of 2 q/day is harvested. The catch comprise mostly of mahseer, common carp and to some extent snow trout and minor carps. The catch availability of different groups varies with different seasons. Mahseer dominates winter catch and common carp summer catch. Compared to this Potomoan zone of Ravi contains fewer fisheries resource, hence the zone is not much viable commercially. Less fishery resources may be due to (i) maximum diversion of water resources

at Shahpur leaving river basin almost devoid of water for 30 km long stretch, (ii) river after re-orientation is fast flowing, shallow in nature, hence contains small-sized fishery for most of its length, and (iii) fishing is prohibited at certain places since the river forms international boundary.

Fishing activity: This activity along the reservoir varies as it is spread in Himachal Pradesh, Jammu and Kashmir, and Punjab.Area around Dam is under control of Punjab and is auctioned for fishing by Punjab Government (Panchayat).Along the area under the control of Jammu and Kashmir, the fishing is done by issuing licenses to individual fisherman by State Fisheries Department.

The potomoan zone of Ravi along plains is auctioned for fishery resources by the Punjab State Fisheries department annually on district-wise basis from Madhopur onwards. All natural resources within a district are auctioned together, as such the two districts-Gurdaspur and Amritsar wherein Ravi flows include river Beas also as that river too drains these two districts of Punjab. The auction amount for the Gurdaspur ranged between ₹ 5.7 and 6.15 lakhs and that of Amritsar district ₹ 8.90 to 11.55 lakhs during 2005-07. Revenue generated from the source is generally high than auctioning amount.

Fishing rights of each district are taken up by main contractor, who sublets the different stretches to small contractors.In river Ravi instead of subletting, main contractor issues license to individual fishermen for operation and fisherman is free to dispose of catch at will. The license fee range from ₹ 800 to ₹ 2000/ individual depending on the gear. ₹ 1,200/individual/ year is charged for hook and line operation. Along the studied stretch some 20 to 30 local fishermen operate but indulge in this activity on part time basis.

Contract fishing also takes place along Ravi but mostly during post-monsoon along Pathankot, Kathlour and *Saki* tributary. Fishermen from eastern Uttar Pradesh and Bihar are engaged in contract fishing. These are full time fishermen and get 50% of the whole sale price as remuneration from contractor.

Fish disposal: Fish catch from upper stretch of Ravi (Shapur-Kathlour) is disposed off at Pathankot and Taragarh while from lower stretch at Derababa Nanak and Amritsar (Fig 13). Out of these, first and last landing centers are permanent and big ones and the catch is disposed off along with other resources mainly of river Beas. During post-monsoon surplus catch from Kathlour also finds assess to Pathankot landing centre, because of it having high consumption

and market value. In addition local disposal at Ajnala town (Gogo mahal) during monsoons was also observed.

Mode of disposal depends on fish catch and type of fishing-individual or contract.

Channel I (Fisher to consumer) and Channel II (Fisher-Retailer-Consumer). These modes are at Taragarh, Derababa Nanak and Gogomahal centers-small landing centers, operated by individual fisherman.

Channel III (Fisher-Contractor-Retailer- Consumer), this mode is at Pathankot and Amritsar, operated by contract fishermen.

Crafts and Gear used

Crafts : No crafts are used generally in upper stretch as river is shallow. Small country boats are used from Kathlour onwards during monsoon to post-monsoon (Fig. 8)

Gears : The gears used in river Ravi are as follows:

Fandi Jal : Innovative fish gear used in upper Shahpur area.

Caste Net : 30-50 mm mesh size used in upper Ravi. (Figs 14a)

Small gill net : 20-30 mm mesh size used around (Figs 14b) in Kathlour region.

Hook and line : All along Ravi (Fig. 15a).

Patti jal : From Dharamkot pattan onwards (Fig. 15b)

Fishing in upper Ravi (Shahpur–Kathlour) by cast net/ Gillnet

Fig. 14a winter

Fig. 14b Post-Monsoon

Fishing in lower stretch (Dharamkot Pattan) of Ravi

Fig. 15a By Hook and Line

Fig. 15b Patti jal

Fishery resources

Estimated fish catch: The average estimated catch per year from the river Ravi was 48.50 tonnes ranging between 44.0 (4.40 tonne/m) in 2005-06 and 51.30 tonnes, (5.13 tonne/m) during 2006-07. The marginal increase in catch in latter year was observed from the rhitherone zone of Ravi (district Gurdaspur) facing water resource crunch during 2006-07, thereby causing strain on shelter which culminated in more catch (Table. 8)

Catch composition: Fishery of Ravi was mainly formed of minor carps (59.12%) followed by miscellaneous group (23.40%) and to some extent by common carp (9.14%). Rest of the groups were marginal and almost equally present, IMC (2.70%), Mahseer (2.54%), large size catfishes (1.76%), and snow trout (1.3%), Table 8. IMC were mainly represented by *Labeo rohita* (1.52%) followed by *Labeo calbasu* (0.68%). *Catla catla* was totally absent. Large-sized catfishes were mainly represented by *Wallago attu* (1.27%) and *Mystus* sp. (0.49%). Minor carps were mainly represented by *Labeo dero*, *L. dyocheilus*, *Cirrhinus reba* and *Labeo gonius*, the former three almost equally present in Kandi areas and latter in lower portion. Miscellaneous group was

Table 8 Fishery resources of river Ravi between 2005 and 2007

Fish	2005-2006		2006-07		Average
	Composition				
Major Carps	tonne/year	%	tonne/year	%	%
C. mrigala	0.1	0.23	0.4	0.78	0.50
Labeo rohita	1.0	02.27	0.4	0.78	1.52
Labeo calbasu	-	-	0.7	1.36	0.68
Sub-total	1.1	2.50	1.5	2.92	2.70
Minor Carps	24.5	55.68	32.1	62.57	59.12
Mahseer *(Tor putitora)*	1.9	4.31	0.4	0.78	2.54
Common carp (*Cyprinus carpio)*	5.3	12.05	3.2	6.24	9.14
Snow trout (*Schizothorax richardsonii)*	0.8	1.82	0.4	0.78	1.3
Catfishes					
Mystus.	-	-	0.1	0.19	0.49
M. seenghala	0.1	0.23	0.3	0.58	0.40
Wallago attu	0.6	1.36	0.6	1.18	1.27
Sub-total	0.7	1.59	1.0	1.95	1.76
Misc. groups	9.7	22.05	12.7	24.76	23.40
Grand Total	44.0		51.3		47.60

formed of Murrels, *Bagarius bagarius, Rita rita, Clupisoma garua, Notopterus notopterus and N. chitala* , out of which *C. garua* was mainly found in Kathlour region and *N. chitala* in lower Amritsar zone.

Persistent presence of *Cyprinus carpio* in all age groups and sizes all along contributing substantially to total population, envisage its establishment within the system.

Comparative account of fish composition (Table 9) within river Ravi between the two years show that there is not much change in catch composition except the catch of Mahseer, Common carp and Snow trout. Mahseer (*Tor putitora*) and Snow trout (*S. richardsonii*), cold water carps preferring fast flowing streams were less 0.89 and 1.78 tonne/year when inflow from Dam was less during 2006-07; thereby showing that local migration of these gets affected by river flow regime also in addition to temperature . It being less when surface run off is less while as in case of common carp it being more (13.33 and 36.32 tonne/year) when flow was less. The same observations were witnessed in Sutlej also wherein common carp was more in the areas not subjected to much flow like Talwara dam and Ferozpur sector (stretch of river between Harike and Hussaniwallah barrage. (Annon, 2007)

Monthly fish catch: Monthly estimation (Table 10) of fish catch computed from two (2) year data show that the fish catch was minimum during February to March, 3.5 to 2.5 tonne and maximum in May 7.70

Table 9 Comparative fishery composition of river Ravi between 2005 and 2007

Year	Stations	Total (tonne/ year)	IMC %	Minor Crops %	C. carp %	*T. putitora* %	S. *richard sonii* %	Cat-fish %	Misc. %
2005-06	Pathankot	16.20	2.46	44.45	0.62	11.73	4.94	1.23	34.57
2006-07		22.50	3.56	59.11	13.33	0.89	1.78	1.33	20.0
2005-06	Taragarh	9.8	1.02	87.76	-	-	-	-	11.22
2006-07		12.20	1.64	77.87	-	1.64	-	-	18.85
2005-06	Dera Baha	3.8	-	81.58	-	-	-	-	18.42
2006-07	Nanak	8.4	5.95	51.19	2.38	-	-	1.19	39.29
2005-06	Amritsar	14.20	4.22	39.44	36.62	-	-	3.52	16.20
		8.20	-	60.97	-	-	-	7.32	31.71

tonne, wherein maximum biomass was contributed from the Pathankot landing centre. Data show that average fish catch at Pathankot was1.74 tonne/m, ranging between 0.68 and 3.30 tonne barring May (5.88 tonne). The enhancement in catch was due to presence of IMC caught at the confluence of Ravi-Beas-link canal and marketed as fishery of Ravi. IMC fishes are not present at all in this zone of Ravi as observed through experimental fishing. During this month, IMC from river Beas might have migrated to upper Beas there on into canal for breeding purposes. The presence of IMC fishery from Pathankot landing centre during May only signifies the importance of Ravi-Beas link canal for sustenance of IMC fishery within Beas.

The catch at Pathankot exhibit seasonal variation being low 0.68 to 1.46 tonne during winter to summer (December to April) and formed mainly by Mahseer, Minor carps and Snow trout, (*Schizothorax richardsonii*) and high during post-monsoon (2.57-3.30 tonne) formed by miscellaneous group,common carp and small cat fishes . High catch during post-monsoon is because most of the catch from Tragarh landing centre is diverted to this landing centre because of demand and high economic returns

The average fish catch/m from Taragarh was 1.091 tonne in the range of 0.60 to 1.94 tonne, maximum during post-monsoon. The low fluctuation in catch is deceptive because of the excess catch being diverted to Pathankot centre.

Average monthly catch at Dera Baba Nanak was 0.743 tonne in the range of 0.39 to 1.25 tonne maximum (0.88-1.25 tonne) between April and June while minimum (0.39 – 0.52 tonne) during post-monsoon. The increase in former period was due to presence of IMC and large-sized catfishes. Their

Table 10 Average Monthly Catch Estimate from River Ravi (2005-07)

Months	Pathankot	Taragarh	Derababa Nanak	Amritsar	Total
January	1.46	1.09	0.55	1.10	4.20
February	1.30	0.60	0.40	1.20	3.50
March	0.90	0.60	0.40	0.60	2.50
April	0.68	1.32	1.88	1.12	5.00
May	5.88	0.94	0.88	-	7.70
June	1.38	0.74	1.25	1.03	4.40
September	3.30	1.18	0.52	-	5.00
October	2.57	1.94	0.39	1.10	6.00
November	2.72	1.16	0.45	0.87	5.20
December	1.40	1.34	0.76	1.50	5.00

Mean of 2 years.

presence during pre-monsoon to monsoon envisages that this fishery ascends up to this site for breeding. Average monthly catch at Amritsar was 0.849 tonne ranging from nil to 1.50 tonne. The catch was almost similar in all months.

Fish diversity

Fishery present within Ravi was observed to be contributed by 31 species mainly, almost all economically viable (Annexure1).

The upper stretch running along foot-hills of Shiwalik Himalaya hold cold water to eurythermal carps as observed at pathankot landing centre (Fig .16) which caters to this area (Table.9). The region in

Fig.16 Fish catch at Pathankot (Mahseer dominant)

Fig.17 Fish catch at Taragarh (*Labeo dero & Xenentodon cancilla)*

addition to minor carps (44.45 to 59.11%), mahseer, *Tor putitora* (0.89 to 11.73%), and common carp, *Cyprinus. carpio* (0.62 to 13.33%) also contains snow trout, *S. richardsonii* (1.78 to 4.94%). IMC fishery present mainly from April to June pertains to river Beas than Ravi as the catch is from the Ravi – Beas link canal as per field enquiry. Taragarh centre (Fig.17) too cater to the stretch along foothills of river Ravi. This area contains mainly minor carps, (77.87 to 87.76%) and miscellaneous fishes (11.22 to 18.35%). The latter formed mostly by *Eel, Xenantodon cancilla, Notopterous notopterus* and small catfish, *Clupisoma garua*. Presence of occasional mahseer (1.64%) may be from Ujh tributary

Fishery in the lower stretch between Derababa Nanank to Amritsar differ from upper stretch in (i) presence of more catfish population. The catfishes present are large ones i.e. *Mystus* and *Wallago* sp (Fig.18), (ii) presence of *Bagarius bagarius* and *Notopterous chitala* within miscellaneous group. The former contributing substantially (35%) during April under the influence of mountainous streams, (iii) Presence of IMC fishery (25% of catch) during pre-monsoon at Derababa Nanank shows that these belong to further down stretch and take upward

Fig. 18 Fish catch at Dera baba -Nanak (Monsoon) Note presence of big size cat fishes

breeding run up to this site . The diversity envisage that upper Ravi although has subsistence fishery all along (Table 9) but major economically viable fishery is present from Derababa Nanak onwards.

Length-frequency

Length frequency of different groups of important fishery could not be ascertained because of lack of number of specimens. The size composition of fishery present in the river Ravi is as in Table 10a.

Experimental fishing

Experimental fishing was done to assess actual fishery existing in river Ravi in view of (i) mixing up of catch with that of river Beas at Pathankot and (ii) diversion of almost whole water at Modhupur. The fishing was conducted at two places, Shahpur (Fig 19)

Table 10a. Length and weight of fish species.

Fish species	Length (mm)	Weight (kg)
Labeo rohita	380-650	0.650-3.750
L. calbasu	280-550	0.300-1.800
Crirrhinus mrigala	415-420	0.650-0.850
Cirrhinus reba	200-250	0.090-0.150
L.abeo bata	190-360	0.110-0.650
L. dero	150-360	0.060-0.500
L. dyocheilus	230-420	0.150-0.560
Clupisoma. garua	250-280	0.150-0.160
Tor. putitora	200-480	0.080-0.850
Cyprinus. carpio	295-510	0.500-2.100
Mystus. seenghala	245-640	0.110-1.300
Wallago. attu	420-530	0.400-0.700

Fig. 19 Experimental Fish catch (*S. richardsonni*) around Shahpur

Fig.20a Kathlour catch. Note presence of Eel, *Mastocembelius* sp

Table 11 The results obtained during Experimental fishing.

Sites	Seasons	Catch/man/ hr (kg)	Net employed	Fish composition	Catch composition by number
Shahpur	Monsoon	0.075	Fandi Jal	*S. richardsonii*	100%
	Pre-monsoon	0.416	Caste net	*C. reba*	
				L. dero	100%
				L. dyocheilus	
Kathlour	Monsoon	0.246	-do-	*C. garuva*	5%
				X. cancilla	20%
				L.dero, L. bata, l.gonius	75%
	Post-monsoon	0.273	-do-	*L.dero, L. bata, l.gonius*	80%
				T. putitora	10%
				X. cancilla	10%
	winter	0.190	-do-	*L.dero* etc	95%
				Puntius sp.	05%

and Kathlour (Fig 20 a & b) as these two stretches cater to Pathankot landing centre and have diverse water resources.

Fig. 20(b) Kathlour during monsoon. Note the presence of *Clupisoma. garua (৲)*

The results obtained during experimental fishing are shown in Table 11.

5. Associated Drainage *Saki* Tributary

SAKI a perennial tributary joins river Ravi along eastern bank above Dharamkot Patan. The tributary passes through thickly populated area and is influenced by municipal effluents (Figs. 21 and 22). It sustains fishes and is exploited commercially for its resources (Figs.23 & 24). It was auctioned for ₹ 90, 000/- during 2006-07.The tributary provides good breeding ground for Ravi fishery hence is very important.

Fig. 21 Saki tributary passing through Derababa Nanak (Post Monsoon to winter)

Fig. 22 Saki at Raina Village. Presence of Weir for irrigation

Fig. 23 Fish catch from Saki tributary by caste net (monsoon)

Fig. 24 Fish Catch from Saki by drag net (pre-monsoon to winter)

Ecology

Water characteristics: Water temperature of Saki waters varies greatly between 18 and 34°C (Table 12)

as is the case of lower Ravi (Table. 1b). Variation is due to great seasonal difference in air temperature of the region. The water is alkaline (pH 7.2-7.3) clear (transparency 32 to 48 cm) containing sufficient oxygen, D.O., 6.4 to7.2/mg. Biological Oxygen Demand (BOD) of 2.7/mg^{1} and C.O.D. value of 8.8/mg indicates tributary not polluted in real sense. But tributary waters are comparatively rich in nutrients as depicted by presence of calcium (Ca), 40/mg, magnesium (Mg), 22.2/mg and silicate (Si), 8.5/mg values. Chloride (Cl) content of 20.0/mg. Specific conductivity of 499 µ mhos/cm and total alkalinity range of 220 to 236 mg/ liter indicate it to be eutrophic in character. The presence of 0.18/mg of inorganic phosphate (PO_4) predicts waters moderately productive.

Soil characteristics: Soil of Saki is sandy loam, 60.35% sand; 25.85% silt and 13.8% clay. Soil is alkaline, pH 7.35; having moderate available nitrogen (N) 16.52 and phosphate (PO_4) 1.86 mg/100 g (Table.12).The soil exhibit little variation in organic carbon (C) 0.63 to 0.66% and free calcium carbonate ($CaCO_3$) 4.0 to 4.25%. Specific conductivity range of 500 µ mhos/cm in monsoon and 144 µ mhos/cm in post-monsoon exhibit that dissolved solid load within tributary is temporary and mostly present during

Table 12 Ecological Characteristics of Saki Tributary (2006-07)

a	Water charac-teristics	Temp. (0ºC)	Trans. (cm)	pH	D.O. (mg^{-1})	Alkal inity (mg^{-1})	Specific cond-uctivity (mm bos/cm)	D.OM (mg^{-1})	Total Hard ness (mg^{-1})
	Average	26	38	7.3	6.8	226.0	499.0	3.75	192.5
	Range	18-34	32-44	7.2 - 7.4	6.4-7.2	220-232	438-560	-	175-210
b	Nutrient status	Calicm (mg^{-1})	Mag. (mg^{-1})	Chlorie (mg^{-1})	Silicate (mg^{-l})	Inorganic phosphae (mg^{-1})	–		
	Average	40	22.2	20.0	8.5	0.18			
	Range	-	18-26.4	18-22	8.2-8.8	0.12-0.24	-	-	
c	Soil quality	Sand (%)	Silt (%)	Clay (%)	P^H	-	-	-	
	Average	60.35	25.8	13.8	7.35				
	Range	60-60.7	25.26.7	13.3-14.3	7.1-7.6	-	-	-	
d	Soil charac teristics	Organic carbon (%)	Free $CaCO_3$ (%)	Average Conduc. (ìmbos/cm)	Nitrogen mg/ 100g	Average Phosp-horus (mg/100g)			
	Average	0.64	4.12	322	16.52	1.86			
	Range	0.63-0.66	4 0-4.25	144-500	16.2-16.8	1.8-1.92			

monsoons because of overflow of various small drains from adjoining populated areas bringing in municipal effluents. The seasonal pollution load and moderate nutrients within tributary soil depict that Saki no doubt eutrophic, does not carry much pollution load, hence has minimum influence on river Ravi visa – visa organic/inorganic load.

Biotic assessment plankton: Saki has slightly more plankton crop than river, density being 134 μ/liter, dominated by phytoplankton (62%). The phyto-group is formed by diatoms (62%) and green algae (25%) only. Zoo-plankton (13%) is exclusively formed by rotifers (Table 13).

Periphyton: Periphyton concentration along Saki was high, 668 μ/cm^2, dominated by diatoms (72%), followed by blue green algae (11%); desmids (10%) and green algae (7%), (Table 13). Presence of desmids indicates richness of nutrients, but simultaneous dominance of diatoms indicates it eutrrophic but not polluted. Micro-vegetative population was mainly formed by *Navicula*, *Diatoma*, *Nitzschia*, *Amphora*, *Microspora*, *Microcystis*, *Closterium*, *Spirogyra* and *Polyarthra*

Macro-zoobenthos: Macro-zoobenthic population was high, average density being 2530 μ/m^2 in the range

Table 13 Biotic characteristics of Saki tributary (2006-07)

a Plankton Density (μ^{-1}) and Composition (%)

	Density (μ^{-1})				Composition (%)		
	Total	Phyto	Zoo	Bacill:	Chloro:	Myxo	Rotifera
Range	100-268	100-134	0.0-34	50-75	-	20-32	10-16
Average	134	117	17	62	-	26	13

b Periphyton concentration (μ cm^{-2}) and Composition (%)

Range	634-701	-	-	72.4	12.6	10	4.7
Average	667	667	-	71.3-73.6	9.5-15.7	9.5-10.5	0-9.5

c Macro-zooobenthic density (μm^{-2}) and Composition

	T. density	Percentage Composition (%)								
		Coleop.	Hemp	Odonata	Diptera	Gastro	Biv.	Deccapoda	Ann elida	Misc
Range	119 8 - 2862	-	-	-	0-3	1.7-75	-	-	25-43.0	-
Average	2530	-	-	-	27.15	38.32	-	-	34.0	-

(*Continued to page 78*)

Table 13 (*Continued from page 77*)

Plankton Density (μ^{-1}) and Composition (%)	Density (μ^{-1})			Composition (%)						
	Total	Phyto	Zoo	Bacill:	Chloro:	Myxo	Rotifera			
d Macrophyte associated fauna (μ/m/kg^{-2}) and composition										
	T. density	Percentage Composition (%)								
Range	90-114	0.8-8	0-11.11	0.24.5	0-11.11	49-60	0-17.5	0-8.8	0-4.4	0-4.4
Average	102	4.44	5.55	12.27	5.55	54.5	8.6	4.4	2.2	2.2

of 1198 to 3862 μ/m^2 being high in post-monsoon when current is slow and transparency is high compared to monsoon (Table 13). The popula-tion was contributed by 3 groups only diptera (27.15%) among Coleop-terans, Annelida (34.0%) and Mollusca (38.32%). Population showed seasonal variation, during monsoon it was domina-ted mainly by gastropods (75.0%) and during post-monsoon by Annelids represented exclusively by *T. tubifex* (43%) and diptera represented by *Chironomous larvii* (54.30%) only.

Macrophyte: Saki water was generally free

of submerged weeds, but banks had heavy infestation of emergent grass which provided shelter to epiphytic insects.

Macrophyte associated fauna: Epiphytic population like benthic macro-organisms was high during post-monsoon (114 μ/kg/m^2) than monsoon (90 μ/kg/m^2), Table 13. The average density was high 102 μ/kg/m^2, contributed by nymphs of *Coleoptera* (4.44%), *Hemiptera* (5.55%). Chironomous (5.55%) present in monsoon only; Odonata (12.27%), Prawns (4.38%) present in post-monsoon only. Gastropoda (54.55%) was the only group present in both seasons between 49.11 to 59.99% of total population. Along epiphytic forms were present fish fry of *Chela* sp. (4.44%) also. Presence of 4.44% of *Nais* sp. within Annelids indicate waters rich in nutrients but not polluted as *Nais* sp do not sustain in polluted waters.

Fishery

Saki contains enough fish resources to be exploited commercially. Fishing is done both by individual license holders and by contractors. Fish disposal is done accordingly, in former case as channel 1 and in latter case as channel III. Contractors fish during post-monsoon when water level is low.

Table 14 Fish catch estimate (tonne/year) and percentage composition (%) of saki tributary (2006-07)

Minor carps species	Catch (tonne/ year)	Percen- tage	Miscella- neous species	Catch (tonne/ year)	Percen- tage
Labeo bata	0.6	8.3%	Murrels	1.2	16.66%
L. dero	1.1	15.27%	Eel	0.3	4.16%
L. dyocheilus	1.2	16.66%	*B. bagarius*	0.2	2.77%
Cirrhana reba	0.1	1.38%	*X. cancilla*	0.5	6.94%
			Others	2.0	27.77%
Sub-total	3.0	41.66%		4.2	58.2%
Grand total				7.20	

Fishing activity: Fishing is done by small gill net and caste net during high water level and mostly by individual fishermen (Fig. 23) and by drag net made of mosquito cloth during low water levels during pre- and post-monsoon as contract activity (Fig. 24). Latter type of fishing is detrimental not only for Saki fishery but also for Ravi fishery, as every conceivable biomass is dragged out of the system which includes juvenile fishery of

commercial species like IMC and Catfishes.

Fish catch and composition: Estimated fish catch for 2006-07 was 7.20 tonne/year which comes to 0.72 tonne/ month, contributed mainly by minor carps (41.66%) and miscellaneous (58.2%). Miscellaneous had dominance of *Murrels, Mystus tengra* and included juveniles of IMC and catfishes too especially in post-monsoon (Table 14).

Presence of commercially important juvenile fishery in Saki tributary indicates that fishes from lower Ravi ascend into it for breeding purposes. Presence of sufficient water resources round the year, balanced nutrient load and good food web in the form of periphyton and benthic organism forms good habitat for fishery, conducive not only for breeding but providing food to juveniles also.

6. Conclusion

THE present study of river Ravi within plains of Punjab showed that river from Madhopur to Kathlour has almost lost its existence barring two months of monsoon due to formation of Ranjitsagar dam and then whole-scale water abstraction into Upper Bari Doaba-Canal, Hydel and Kashmir canal. But river gets reoriented due to inclusion of torrents and some perennial tributaries from Kathlour onwards. River is not subjected to industrial and municipal effluents as observed through B.O.D. 0.75 to1.10 mg/litre and C.O.D. 2.60-3.75 mg/litre load but gets affected due to silt load brought down by surrounding hills via torrents, which affects its productivity at Dharamkot Pattan.

Impact of water abstraction: Manipulation of water resources has decreased water volume in approximately 30 to 50 km stretch of river Ravi resulting in habitat loss for some biotic communities mainly plankton (69 to 79 units/litre) resulting in low gross primary productivity, 119.14 mg C/m^3/hr and low fish production.

Impact of siltation: Heavy siltation along river Ravi can be observed after Kathlour region onwards, stretch

subject to many seasonal torrents. The siltation causes water to be loaded with suspended particles, diminishes transparency from totally transparent to 35 cm. Biotic loss especially of plankton (53µ/litre) causes diminished primary productivity (129.16 mg C/ m^3/hr) and fish yield being minimum 3.8-8.4 tonne/ year in the stretch although having sufficient water resources.

Fishery in the river Ravi: Study of two years data showed that Ravi contains subsistent fishery from Chamera dam onwards being maximum in Ranjitsagar reservoir. Along potomoan zone, the fish catch estimate from Ravi was 47.60 tonnes/year being 4.76 tonne/month contributed by 31 fish species almost all contributing to its commercial fishery. Upper stretch above Madhopur barrage contains mostly. The *Schizothorax richardsonii* and Kathloour, the wetland stretch contains mainly minor carps (87 to 77.8%) and miscellaneous (11.2-18.6%). Miscellaneous is composed mainly by *Notopterous notopterus* and *Xenantodon cancilla* verified through experimental fishing. Presence of IMC at Pathankot landing Centre mainly in May is not true reflection of river resource as the catch was from *Ravi-Beas Link Canal* where this fishery migrates from lower Beas for spawning.

Presence of IMC (nil-5.95 tonne /year) and large-sized catfishes (3.32-7.30 tonne /year) in Amritsar landing Centre, showed that river Ravi has enough water resources to sustain this kind of fishery in lower stretch, which need to be exploited by doing some sort of cage culture of these fishes in the system to augment their production.

Presence of *Cyprinus carpio*, mainly mirror carp in river Ravi wherever water resources are available show that the species have become resident fishery of this system.

The difference between catch compositions of river Ravi from other two rivers of the system is that fish diversity within the river is less, only 31 species compared to 54 to 55 species in Beas and Sutlej. Absence of *Catla catla* and presence of *Clupisoma garua* in the observed stretch. Existence of juvenile fishery of IMC and large size Catfishes in Saki tributary shows its importance as a breeding ground.

Recommendations for conservation and sustenance of fisheries in river Ravi

Sustenance of resources of fish germplasm and to bridge the gap between production and demand especially of those fishes which are not cultured but are greatly sought after, it is imperative to conserve

the capture fisheries resources within Ravi sub-basin of Indus System

Eco-conservation: Eco-conservation in river Ravi like any other river having trans state boundaries and fed by many streams coming from different regions (States) necessitates national approach beyond state boundaries, as the action in uplands greatly affect the lower basin, like siltation, decline in transparency etc., which diminish productivity of the system as witnessed in the Ravi along Dharam Kot Pattan. Hence, massive forestation programme along the Himalayas, both Dauladhar and Pir Panjal range needs to be undertaken to halt soil erosion.

Commercial exploitation of Ravi bed below Modhupur barrage for extraction of stones, etc. should not be allowed throughout the year. It affects food web and breeding activity of fishes. Exploitation needs to be banned during breeding season.

Drag net type fishing by mosquito net cloth in Sakki be made offensive , punishable act. This type of fishing activity causes great harm not only to Saki fishery but to Ravi fishery in general, particularly to IMC and large size catfishes as juveniles of this fishery are caught indiscriminately by this method.

Development measures: The development measures

which can be taken in this river basin are enumerated here.

1. The Shahpur Kandi area of the river Ravi was observed to be conducive for cold water carps like *Tor putitora* and *Schizothorax richardsoii* . Production of same can be enhanced by (*i*) Ranching the stretch with their seed, and (*ii*) Giving them protection and environment for growth by declaring the stretch as sanctuary. The two fishes besides are resident fishery of the area as such the exercise will prove fruitful.
2. The river stretch around Kathlour farms a sort of wetland for most part of the year and is highly productive as observed through abiotic and biotic characteristics as such the area needs to be managed along wetland norms having culture cum capture fisheries.

   Fishes to be propagated should be Murrels, *Xenantodon cancilla*, eel and minor carps as these are its resident fishery , do not migrate long distance as such can form produce of the same area. These are economically very important, fetch high returns than IMC. Seed availability of these fishes i.e artificial propagation of this fishery needs to be developed.

3. Gene pool of *Clupisoma garua* and *Xenentodan cancilla* from river Ravi need to be preserved for future as these two fishes have healthy growth in this river compared to other rivers of the system as well as of other basins mainly the Ganges.
4. Ujh tributary needs to be exploited for the brooders of *Tor putitora*. The seed obtained from there can be utilized in Shahpur Kandi stretch of system
5. For existence of river Ravi system within Indian region, maintenance of at least 200 cusecs of water should be made available to river bed after Madhopur barrage round the year.
6. Full utilization of water resource of river Ravi by Indian authorities as per indus treaty can be met by building a barrage on the river around the Derababa Nanak area. This way the incoming water resource through number of torrents and tributaries which flow to other country and remain unutilized for our purpose can also be utilized and ground water resources of the system can get recharged. River Ravi can have its full existence, productivity will be increased thereby its fishery.
7. The eastern bank of the river Ravi along Indian territory from Dharamkot Pattan to its exit to other country – Pakistan should be utilized for production

of fish seed/table-sized fish through cage culture techniques, as the river is manageable and do not interfere with any irrigation process. This way the water resource can be utilized without any environmental perturbations.

7. References

Anonymous, 2004. Final Report on river Sutlej under Project RI/B/2 (Karnal Centre of CIFRI, Barrackpore)

Central Inland Fisheries Research Institute, 2000. Final Report on Chamera Reservoir.

Ibid, 2007. Bulletin No 150, "River Beas , Ecology and Fishery"

Central Pollution Control Board, 1995-96. "*Tributaries of Indus"* MINRAS Publication No 10

Annexure I

Fishery recorded from river Ravi between Shahpur and Goggo Mahal (Amritsar)

Stations		Shahpur	Kathlour	Dera Baba Nanak	Amritsar Goggo Mahal
Family	*Notopteridae*				
	Notopterus notopterus	-	+	-	+
	N. Chitala	-			
# Order	*Cypriniformes*				
Family	*Cyprinidae*				
Subfamily 1	*Abramidinae*				
	Chela bacaila	-	+	-	+
Subfamily 2	*Cyprininae*				
	Tor putitora	+			
	Puntius sarana	-	+	+	+
	Catla catla	-	-	+	+
	Cirrhinus mrigala	-	+	+	+
	Cirrhinus reba	-	+	+	+
	Labeo rohita	-			
	Labeo calbasu	-	+	+	+
	Labeo dero	+	+	+	+

(*Continued to page 91*)

Annexure I (*Continuded from page 90*)

Stations		Shahpur	Kathlour	Dera Baba Nanak	Amritsar Goggo Mahal
	Labeo dyochilus	+	+	+	+
	Labeo gonius .	-	+	-	-
	Cyprinus carpio specularis	+	+	+	+
	Schizothorax richardsonii	+	-	-	-
# Order	*Siluriformes*				
Family 1	*Bagridae*				
	Mystus aor(Ham.)	-	-	-	+
	Mystus seenghala(Ham.)	-	+	-	+
	Mystus Tengara(Ham.)	-	+	-	-
	Rita rita (Ham.)	-	+	-	+
Family 2	*Sisoridae*				
	Bagarius bagarius	+	+	+	+
Family 3	*Siluridae*		+	+	+
	Wallago attu	-	-	+	+
Family 4	*Schilbeidae*	-	+	-	+
	Clupisoma garuva	-	+	-	+
	Eutropilchthys Vacha(Ham)	-	+	-	+

(*Continued to page 92*)

Annexure I (*Continued from page 91*)

Stations		Shahpur	Kathlour	Dera Baba Nanak	Amritsar
				Goggo Mahal	
Family 5	*Heteropneustidae*	-	+	+	+
	Heteropneustes fossilis	-	+	+	+
Family 6	*Claridae*				
	Clarias batrachus(Linnaeus)		-	+	+
+					
Order	*Belonifarmes*				
Family	*Bedlonidae*				
	Xenentodon Cancilla	+	+	-	+
Order	*Channeformes*				
Family	*Channidae*				
	Channa marulius(Ham)	-	+	-	+
	Channa punctatus(B.loch)	-	+	-	+
# Order	*Mastacembeliformes*				
Family	*Mastacembelidae*				
	Mastacembelus armatus (Lecepedae)	+	+	+	+
	Mastacembelus puncalus (Ham.)	+	+	+	+

RIVER RAVI

ECOLOGY AND FISHERY

The river Ravi, provides subsistence fishery thereby nutritional security especially to people dwelling in interior areas along international border and is a means of livelihood to local fishermen; therefore evaluation of its fishery resources like fish catch, fish composition and fish biodiversity along with ecological evaluation of its physical and biological characteristics gives a valuable information for planners and development authorities to manage this river and it's produce (fish) in a sustainable manner.