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Environment and fishery status of major rivers of Indus system within India

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ABSTRACT

Rivers within India harbor rich fish bio-diversity and are still a good repository of fish germplasm and source of fishery potential, providing means of livelihood to large sections of society. The detailed information regarding above parameters and even time scale changes that have taken place, exists, mainly with relation to Ganga and Brahmaputra systems and to some extent with relation to East and West coast river systems. The similar information is lacking so far as Indus system is concerned, hence a detailed survey was undertaken to assess the fishery potential, fish germplasm resource, status of ecology and the constrains subjugated to the system so that proper management policies could be framed for conservations of its resource. Present communication describes briefly the environment, fishery and biodiversity of 3 major rivers namely Sutlej, Beas and Ravi, which form the main component of Indus system so far India is concerned.

Key words: Ecology, Fish catch estimate, Fishery resource, Sediment, Water quality

Indus system one of the 3 groups of perennial rivers of country drains the 3 northern States of India namely, Jammu & Kashmir, Himachal Pradesh and Punjab before leaving the Indian territory. Although the bulk of the system lies within Pakistan, but origin of all the tributaries (Beas, Ravi, Chenab, Jhelum) except Sutlej lies in western Himalaya within India, where these along with Sutlej drain combined catchment area of 321,289 km^2. Out of the 5' tributaries namely Sutlej, Beas and Ravi form the main component of the system so far India is concerned. Amongst the 3, Sutlej the longest tributary has total length of 1,450 km, out of which, 740 km is with India, of which 360 km is within Punjab. River Beas the only tributary of system confined solely within India is 470 km long out of which it drains 165 km of Punjab. River Ravi the third tributary is 720 km long out of which 370 km is within India of which 170 km passes through Punjab (Fig. 1a,b).

The Head waters of the system within Himalaya are maneuvered into reservoirs for multipurpose activities such as Gobindsagar on Sutlej, Pong on Beas and Ranjitsagar on Ravi. All these are good source of fishery and support abundant biological wealth (Sehgal 1974, Dhanze and Dhanze 1998, Johal 2002, Kumar 2002, Raina and Joshi 2006). The Potomoan zone of this system draining the plains of Punjab passes through thickly populated, industrialized and agriculturlised area of the country (Fig.1a,b), hence subjected to organic and industrial influxes as well as to extensive water abstraction. The stretch is economically important as it provides livelihood to a large section of population in terms of fishery and this component is being discussed in the present communication.

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MATERIALS AND METHODS

Ecological estimate: The data on ecological status was assessed through physico-chemical characteristics of water and soil as per standard methods (APHA 1989) and biological characteristics like plankton, periphyton, macro zoobenthos, within the system as per standard methods from 22 sampling stations along the contributory rivers for 7 years corresponding to fish evaluation data between 2000–2007, 12 stations from Sutlej, 6 stations from Beas and 4 stations from Ravi. The sampling sites, corresponding to the catchment area of respective fish landing centres as well as to effluent discharge channels and water abstraction points. The same was done to ascertain biological productivity within fish catchment areas as well as impact of anthropogenic activates on fish production. Identification of biological characteristics was made with the help of standard key (Ward and Whipple 1959, Needham and Needham 1972, Tonapi 1989).

Fishery resource estimate: Fishery resource assessment was done by total enumeration of daily arrivals of fish catch from 15 landing centers along the 3 contributory rivers for 7 years during different periods. It being five along 280 km stretch of Sutlej at Roopnagar, Ludhiana, Sultanpur, Harike and Ferozpur; Six in case of Beas along the 165 km stretch at Talwara, Mukerian, Pathankot, Amritsar, Sultanpur and Harike; and four namely Pathankot, Taragarh, Dearbaba Nanak and Amritsar along 170 km stretch of Ravi.

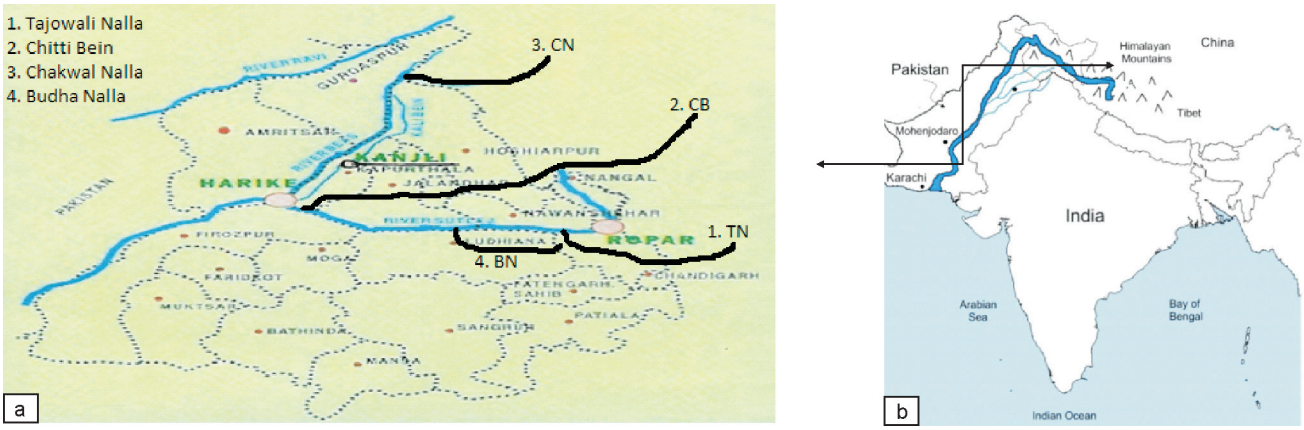

Fig. 1. River Indus within Indian Punjab showing three tributaries(blue) and main effluent channels (black).

Consideration of landing centers depended upon the commercial disposal of catch from respective river.

The common centers like Sultanpur and Harike between Sutlej and Beas and Pathankot and Amritsar between Ravi and Beas is due to the presence of these rivers within the same districts of Punjab (Figs. 1 a,b).Differential catch assessment and composition from different contributory rivers at common centers was possible due to availability of catch from different rivers with different parties at the landing centre.

Each station was surveyed for 2 days in a month from March to February and catch per month was assessed after Jhingran *et al.*(1969). Total catch per year was assessed by adding the catch of all months barring closed period of 2 months (July and August).

Population composition was calculated by segregating commercial species, noting their number and size, calculating total weight (Jhingran *et al*. 1969), on the day of assessment. In case of Ravi, experimental fishing was also done to ascertain biodiversity.

RESULTUS AND DISCUSSION

Environmental concerns: The Punjab component of Indus system is influenced mainly by industrial pollution via large/medium units (410), small units (181, 530) and Municipal effluents, which are carried via Tajowali *nallah* (Ropar), Budha *nallah* (Ludhiana) and East Bein (Sultanpur) into Sutlej; Chakwal *nallah* (Mukerian) and west Bein (above Harike) into Beas (Fig.1b). The domestic pollution in terms of B.O.D (kg /day) was estimated as 200048 brought in by Budha *nallah* and 6620 by East Bein in Sutlej and 800 (Chakwal *nallah*) in Beas. In addition the system is influenced by stone and sand mining along the foothills- Kandi areas and agricultural runoff which is to the tune of 165 kg/ha in Punjab compared to 75kg/ha in rest of the country (PPCB 1995).

Accordingly, the respective rivers of system within the state were demarcated on the basis of different anthropogenic activities. In case of Sutlej, it was found that it gets influenced by Tajowali *nallah* at Ropar, by Budha *nallah* at Ludhiana, by East Bein at Sultanpur and the effect persists up to Harike. The ecology changes drastically (based on preliminary observations) before and after induction of these *nallas*/tributaries, therefore river was categorized into Upper, Eutrophic and Diluted segment. Two stations after Nangal dam and Kanjali above Ropar barrage before induction of any effluent discharge, along foot hills of Punjab Himalaya were designated as upper segment. Nine stations were taken between Ropar and Harike, 2 at Ropar, 3 at Ludhiana, 3 at Sultanpur and 1 at Harike corresponding with induction points as well as above and below it and are designated as Eutrophic zone. Two stations, one after Harike barrge and another at Firozpur was sampled for diluted segment to assess impact of joining river Beas with it.

In case of Beas, the influence was mainly water abstraction at Talwara and to some extent industrial and municipal pollution brought in by Chakwal *nallah* at Mukerian. Upper segment denotes the zone of river along foothills before water is abstracted and was sampled at one station above Talwara barrage. The abstracted zone had three stations, one below barrage and two at Mukerian corresponding to anthropogenic influence. Two stations Beas Bridge and Harike were pooled for diluted segment as Beas gets back its water resources through induction of Shah nehar cannal at out skirts of Mukerian.

In case of Ravi the influence was mainly water abstraction. Upper segment again denotes the zone along foot hills before water is abstracted and was sampled at one station, Shahpur, above Modhopur barrage. The abstracted zone had two stations, one below barrage and other at Kathlour distt Gurdaspur. Dera Baba Nanak represents diluted segment as the Ravi regains riverine status after induction of many tributaries.

Sediment composition: River bed of contributing rivers of Indus along foothills of Himalaya (upper) is sandy loam along Sutlej containing 53.7% sand, 29.7 % silt and 16.6% clay however the percentage of sand increases to 63–75 % and that of clay decreases to 10.3% within plains mainly under the influence of two channels, Budha *nallah* and East (*Chitti*) bein, which are actually small tributaries converted into effluent channels. River bed of Ravi and Beas is sandy

Table 1. Ecological evaluation of Indus System (soil phase)

Stretch	Upper (Above Barrage)			Eutrophic / Abstracted			Diluted		
	Sutlej	Beas	Ravi	Sutlej (Roopnagar-Harike)	Beas (Talwara-Mukerian)	Ravi (Modhopur-Kathlour)	Sutlej Firozpur (Modhopur Kathlour)	Beas (B. bridge-Harike)	Ravi (Dera Baba Nanak)
Sand (%)	53.7	77	72.4	65.660–73.5	66.272–77	6661–71	69.4575.4–63.5	6263.1–61.2	57.95
Silt (%)	29.7	16.6	17.3	24.018.8–30.4	24.620–29.4	28.1719.8–36	20.2516.8–23.7	26.426–26.8	27.6
Clay (%)	16.6	6.3	10.3	10.46.5–14.3	9.18–10.3	10.759–12.5	10.37.8–12.8	11.4510.9–12	14.40
pH	7.7	7.0	7.3	7.37.1–8.0	7.4	7.2	7.67.8–7.5	7.557.6–7.5	7.50
Sp. conduct. ($\mu S\ cm^{-1}$)	289.2	2.55	212	265140–415	211.3194–228.4	365270–460	145.7126–165	193.4142–244	210.8
Organiccarbon (%)	0.47	0.34	0.18	0.510.39–0.77	0.330.31–0.35	0.360.33–0.39	0.550.50–0.61	0.350.28–0.43	0.39
Free $CaCO_3$	5.56	5.4	1.62	5.13.9–7.2	6.05.6–6.5	2.612.66–2.56	7.44.8–10	5.675.19–6.15	2.99
Av. nitrogen ($mg\ 100g^{-1}$)	19.4	8.0	14.0	19.016–23.7	9.18.4–9.9	13.611.5–16	15.2613.8–16.7	7.87.6–8.0	17.92
Av. phosphorus ($mg\ 10g^{-1}$)	1.09	1.6	0.45	1.070.8–1.73	1.851.8–1.9	0.60.56–0.69	0.510.46–0.57	2.182.45–1.91	0.97

containing 77–72% sand, 16–17% silt and 6–10% clay. However, the proportion of sand decreases to 62% and that of silt and clay increases within plains to 26.4 % and 9–11.4% in case of Beas while in case of Ravi decrease in sand content (57.9%) and increases in clay is (14.4%) is more in lower stretch after Kathlour to its exit point. Sudden transformation of *Ravi* bed may be due to influx of many perennial tributaries like Purani Ravi and Ujh into it after Kathlour which pass mainly through clayey bed. The river bed of all the tributaries is alkaline having pH in the range of 7.0 to 7.5 (Table 1).

Water quality: The water in all the 3 tributaries has buffering capacity and showed little fluctuation in pH (73–7.8). Water parameters both physical e.g. temperature (20–23°C); transparency (clear up to bottom) and chemical e.g. dissolved oxygen (7.6–8.2 mgl^{-1}); total alkalinity (68.5–76.6 mgl^{-1}) and hardness (103.2–129 mgl^{-1}) is almost similar in all contributing rivers along Kandi regions. The water quality changes differently in different rivers along its course under the influence of effluent discharge and diversification of water resources (Table 2). Sutlej shows lot of variation from Ludhiana onwards due to induction of pollutants via Buddda *Nallah* and Chitti Bein. The effluents cause decrease in transparency (50.6 to 28.2 cm) and dissolved oxygen (7.8 to to 5.7mgl^{-1}) at certain stations (induction points) as low as 2.8 mgl^{-1} and increase in Specific conductance (261.6 to 720.3 $\mu S\ cm^{-1}$). The effect persists right up to Harike and is high at induction of Chitti bein at Sultanpur. The pollutant load dilutes after Beas meets Sutlej at Harike, the same is evident by the water characteristics at Ferozpur having transparency 100 cm, dissolved oxygen, 7.8 mgl^{-1}, specific conductance, 181$\mu S\ cm^{-1}$ and hardness, 189.5 mgl^{-1}. In case of Beas, variations are comparatively less (pH 7.5 to7.3; dissolved oxygen 8.2 to 7.2 mgl^{-1}, although at induction point of Chakwal *nallah* at Mukerian, parameters are uncondusive, dissolved oxygen being 6.8 mgl^{-1}; total hardness, 168.51mgl^{-1}; and conductivity 330 $\mu S\ cm^{-1}$. The impact is restricted and does

Table 2. Ecological evaluation of Indus system (water phase)

Stretch	Upper (Above barrage)			Eutrophic / Abstracted			Diluted		
	Sutlej	Beas	Ravi	Sutlej	Beas	Ravi	Sutlej	Beas	Ravi
Temp (°C)	20.0	23.3	20.0	22.1(22–23.4)	24(23.8–24)	23.922.2–25.6	23.923.1–24.7	23.5(23.8–24.3)	25.3
Trans. (cm)	50.6	37.4	71.5	28.27(15.4–40.7)	35.5(31–40)	Up to bottom	10092–108	33.5(30–35)	38.6
pH	7.8	7.5	7.3	7.4(7.1–7.7)	7.32(7.4–7.1)	7.47.47–7.43	7.87.73–7.87	7.3(7.3–7.4)	7.36
Dissolved oxygen (mgl^{-1})	7.8	8.2	7.6	5.7(2.8–8.7)	7.2(6.8–7.6)	7.87.4–8.4	9.68.7–10.5	7.5(7.4–7.4)	7.2
Free CO_2 (mgl^{-1})	5.4	0.5	_	6.3(2.8–18.7)	0.11(Nil- 0.33)	_	1.652.0–1.3	0.11(0.15–0.12)	-
Total alkalinity (mgl^{-1})	76.6	68.5	70	121.8(78–219)	81.4(79–84)	94.686–103.25	8794–80	66.3(63–72)	112.7
D.O.M.(mgl^{-1})	1.88	1.4	0.97	2.6 (2–3.9)	2.0(1.6–2.4)	1.0	2.252.5–2.0.	1.4(1–1.7)	1.35
Total hardness (mgl^{-1})	103.2	128.9	103.5	141.6(111–203)	156(143–168)	116	189.5	133(123–150)	152
TDS (mgl^{-1})	92.8	96.0	84	180(108–360)	138(109–167)	94.168.4–103.9	102113–90	96(93–102)	124.7
B.O.D mg ^{1}	1.50	3.83	neg	25.14(18–32.4)	15.0(10.1–20.1)	1.040.92–1.17	2.23 1.1–3.8	5.1 (3.0–8.0)	1.10

not last long as was observed by characteristics like dissolved oxygen,7.6 mgl^{-1}; total alkalinity,79 mgl^{-1}; total hardness,143 mgl^{-1} and specific conductivity, 187.7 μS cm^1 after re-induction of diversified water resources at Mukerian itself. The dissolved salts get further diluted in lower stretch between Beas and Harike as envisaged by decrease in dissolved organic matter to 1.4 mgl^{-1}, total hardness to 133 mgl^{-1} and B.O.D levels to 5.1 mgl^{-1}. Ravi does not exhibit much variation in water quality. pH in the range of 7.3–7.4,dissolved oxygen,7.8 to 7.2 except little increase in alkalinity from 70 to 112.7 mgl^{-1}; hardness, 152 mgl^{-1} and specific conductivity, 225–273 μS cm^{-1} in stretch below Kathlour, where many dissolved salts are brought in by rivulets from adjoining hills.

Biological communities

Plankton: Biotic communities like plankton and periphyton exhibited wide variation in density and composition in different seasons in all the 3 tributaries. It being high in pre-monsoon and winter and low during monsoons. The average plankton density was more in Sutlej (180–283 μl^{-1}) compared to river Beas (80–199μl^{-1}) and Ravi (53–96 μl^{-1}). The density being low in upper Kandi regions (barring river Sutlej) and effluent induction stretches and high in non effluent induction stretches (diluted segment) along plains (Table 3). The high density at Sutlej is due to more water resources and high available phosphorus content (1.05 mgl^{-1}) in river above barrage.

Periphyton: Periphyton concentration within the system was high in Ravi (333–639 μ/ cm^{-2}) and Beas (188–634 μ/ cm^{-2}) compared to Sutlej (204–350 μ/ cm^{-2}). Concentration being more in upper Kandi regions where rivers have low depth, high transparency and river bed formed mainly of stone and gravel. Concentration was low in effluent affected stretches, between Ludhiana to Sultanpur in Sutlej especially at induction points of effluent channels 50 μ/ cm^{-2} and 58 μ/ cm^{-2}, whereas in Beas at induction of Chakwal channel. The density is 128 μ/ cm^{-2} showing the carcinogenic nature of effluents of channels draining into Sutlej are more detrimental than that of Chakwal *nallah*. As organisms in the form of periphyton get easily influenced by pollutants and are better indicators of pollution along with benthic organisms (Moza and Koleka 2002).

Biotic population represented by plankton and periphyton were formed mainly by phyto group representing 80–95 % of population in Sutlej and Beas and 92–100% in Ravi; zoo group formed 5–20 % of population in Sutlej and Beas and nil to 13.18% in Ravi. The percentage of microphytic population observed high incidence of diatoms all along Ravi and upper Beas, forming 48–100% of plankton population and 68–86% of periphyton population. Green algae were dominant (43%) in lower (Harike to Ferozpur) stretch of Sutlej and blue green algae (40–54%) in eutrophic zone of Sutlej (Ludhiana to Sultanpur) and Beas (Mukerian). Zooplanktons were present from middle stretch onwards formed by Copepods, Cladocerans and Rotifers, river Ravi having only latter group.

Microphytic vegetation comprised 36 genera in Sutlej formed by diatoms (13), green algae (13), blue green algae (9) and desmid (1); in Beas, by 28 genera formed by diatoms (15), green algae (8) and blue green algae (5); and in Ravi by 26 genera formed by diatoms (10), green algae (9), blue green algae (5), and desmids (2). Microorganism as zooplanktons in Indus were present between middle eutrophic to lower diluted stretch only comprised 11 genera in Sutlej, 9 in Beas and 2 in Ravi.

Macrobenthos: Macrobenthic population within Indus was mainly present between post monsoon to winter and exhibited great variation both in density and diversity among the 3 contributing rivers.

The population in Sutlej showed direct relation with nature and intensity of effluent induction. It was low (325 and 489μm^{-2}) in upper and lower stretch where impact of effluents is minimum as evident by water characteristics like dissolved oxygen and B.O.D (Table 1) and high (1104 μm^{-2}) along middle stressed stretch barring the induction sites where it is mainly composed of chironomids, tubificids and ostracods, all organic pollutant indicators. The presence of all these forms and their high density was also observed in stressed stretch of river Yamuna (Moza and Kolekar 2002) and is an indicator of high intensity of pollution. Upper and lower stretch had insect nymphs mainly ephemeropterans (5–25%), gastropods (24–34%), bivalves (3–13%) in addition to chironomids (45–79%). Presence of these forms which are pollution sensitive but not pollution tolerant showed that the stretches are comparatively clean as also observed in river Yamuna (Moza and Kolekar 2002). In Beas population density in addition to effluent influx showed influence of river substratum also. It being moderate (605μm^{-2}) at upper (Talwara), low (303 μm^{-2}) in stressed and fluctuates between 1580–316 μm^{-2} in lower stretch. Population was mainly formed by insect nymphs (24.68%)), insect larvae (chironomids, 19.53%), gastropods (30.79%) and bivalves (19.56%) but lower stretch had presence of

Table 3. Biological characteristics of Indus system

Stretch	Upper (Above barrage)			Eutrophic / Abstracted			Diluted		
	Sutlej	Beas	Ravi	Sutlej	Beas	Ravi	Sutlej	Beas	Ravi
T.density plankton (μl^{-1})	233	80	69	18050–234	8060–101	96 79–114	283217–350	199149–270	53
Periphyton (μcm^2)	350	634	639	20453–289	188128–249	571608–534	293285–301	304245–364	333
Macrobenthos (μ m^{-2})	325	605	1154	110458–2947	293236–350	29152130–3700	489309–670	948 1580–316	654

annelids (27.88%) mainly *Tubifex* sp, decapods (29%) and Cladocerans (6.5%) also, which are normally present in organically rich waters; thereby depicting that water in lower *Beas* may not be polluted because having proper flushing by its water resources but river bed is rich in dissolved salts due to induction of municipal discharge of Beas city as shown by specific conductivity (Table 2). In Ravi benthic population was in the range of 1,154–2,915 μm^{-2} highest at Kathlour and lowest (654 μm^{-2}) in lower diluted stretch (Dharam kot Pattan onwards). Population was mainly formed by insect nymphs (1–33%), gastropods (1 3–23.2%); bivalves (10–28%) and annelids (nil-12.7%) mainly leech. The high density and nature of population along upper Beas and all along Ravi showed that in addition to nutrient load, nature of substratum also plays great role as stony gravel bed is known to form breeding grounds of insects.

Macro organism population was observed to be formed by 87 genera in Sutlej, 100 genera in Beas and 63 in Ravi.

Fish and fisheries

Estimated catch: The average fish catch estimate from the contributing rivers of Indus system was 374.2 t/yr from 280 km stretch of Sutlej; 255t/yr from 165 km of Beas and 47.65 t/yr from 170 km of Ravi having a yield estimate of 1.336, 1.545 and 0.280 t/km/yr from respective rivers, thereby depicting that out of the 3 rivers, Beas is slightly more productive than Sutlej and Ravi is least productive in nature.

Analysis of catch estimate (Table 4) within Sutlej showed that segment affected by effluents between Roper to Harike (Fig.1 b) has low production, 271.8 t /yr and productivity of 1,181 t km/yr compared to the lower 50 km Ferozpur stretch having catch estimate of 102.4 t /y and yield of 2.048 t/km/yr. Observations revealed that Beas like Sutlej holds more fish in lower stretch, Amritsar to Harike (48.75–64.93 t/yr) having maximum water resources than upper (20.6–31.4 t/yr) between Talwara to Mukerian having water resource crunch due to diversion of water to canals, hence catch per km is less, 1.166 t/yr, for first 65 km and more, 1.850 t/km/yr, for lower 100 km stretch. Sectarian assessment of fish catch of Ravi, showed that it contains more fish (19.35–11 t/yr) in upper stretch along Gurdaspur compared to lower stretch (6.1–11.2 t/yr) in Amritsar. Maximum catch is from Kathlour (distt. Gurdaspur) where a sort of wetland is formed due to induction of a permanent tributary- Ujh and other seasonal tributaries into river, increasing its water resources and food availability. Low catch in lower stretch may also be due to restricted fishing activity as Ravi forms international border in the region (Fig.1a,b).

Fishery resources: The observations (Table 5) indicated Sutlej and Beas has similar fishery mainly composed of IMC (25.91 and 28.28%) and minor carps (20.13 and 22.44%). Large size catfishes although contributing less towards total population are also of similar magnitude in both, being 12.13 and 8.54% respectively. The difference lies mainly in contributing percentage of common carp, miscellaneous fishery and presence of some cold water species. Similar magnitude of main fishery is, because upper segment of both these rivers traverse similar terrain and lower segment merge together at Harike to form a single entity-Harike wetland, providing shelter and similar habitat to fishery of both rivers. Abundance of common carp in Beas (22.02%) compared to Sutlej (11.69%) is due to dominance of this group at upper Talwara stretch caused by the external manipulation, as its seed is being inducted into Talwara Dam by concerned agency. High incidence of miscellaneous fishery (29.94%) in Sutlej than in Beas (17.71%) is because miscellaneous fishery within Sutlej was mostly formed by small sized catfishes and air breathing fishes, mainly present in middle polluted stretch between Ludhiana to Sultanpur (Fig. 1b). In contrast Ravi catch (Table 5) is predominantly composed of minor carps (59.12%) and miscellaneous group (23.40%). The reason being that Ravi within India pass mainly through lower Shivalik range (Kandi region) is shallow, maximum depth

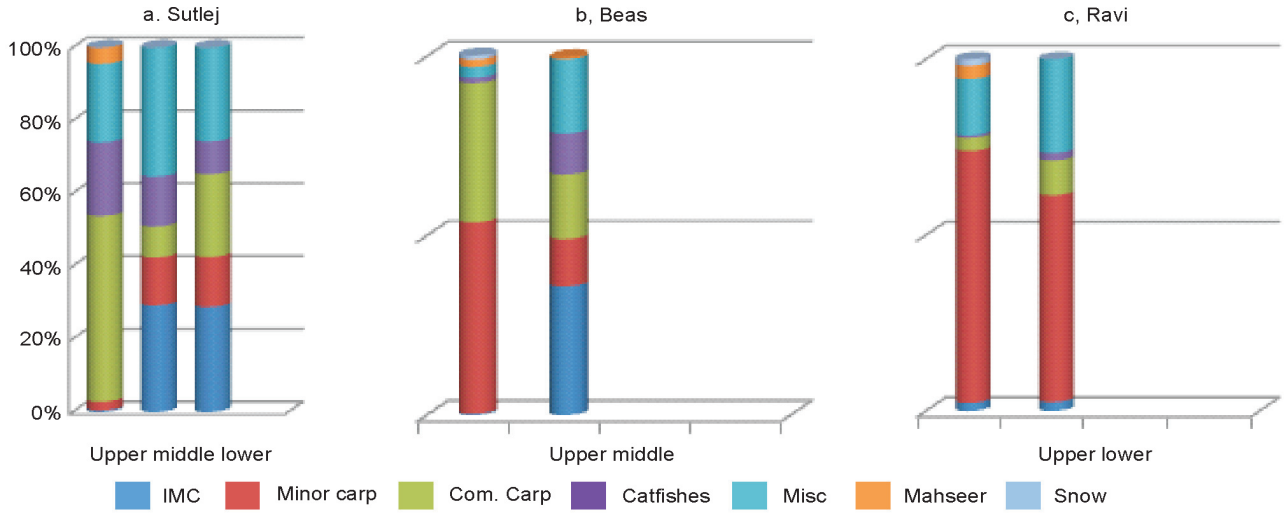

Fig. 2. Fish composition along Indus drinage

Table 4. Fish catch estimate along Indus

River Av. Catch (tonne/year)	Stations Catch (tonne/year)					
Sutlej 374.2	Roopnagar 37.65	Ludhiana 26.2	Sultanpur 91.2	Harike 116.75	Ferozpur 102.4	
Beas 255	Talwara 20.60	Pathankot 31.40	Mukerian 24.50	Sultanpur 48.75	Amritsar 64.82	Harike 64.93
Ravi 47.65	Pathankot 19.35	Taragarh (Kathlor) 11.0	Derababa Nanak 6.10	Amritsar 11.2		

Table 5. Fishery resources along Indus

Fish groups (%) River	IMC	Minor carps	C. carp	Catfish	Mahseer	Snow trout	Misc.	Thai magur
Sutlej	25.91	20.13	11.69	12.13	0.18	-	29.94	-
Beas	28.88	22.44	22.02	8.54	0.73	0.08	17.71	0.21
Ravi	2.70	59.12	9.14	1.76	2.54	1.3	23.40	-

being 71cm, having sandy gravel bed and low temperature range of 17–24°C,thereby having low primary production (Moza 2006) that too in the form of substrate attached algae.

Fish composition: The composition within the Potomoan zone of Indus was observed to be composed of 56 species belonging to 29 Genera, 18 families and 7 orders (Annexure 1) mainly composed of Cypriniformes (48%) and Siluriformis (25%). Maximum number of species (54) is present in Sutlej and Beas and minimum (32) in Ravi. Ravi within the Himalyan zone also has been reported to sustain minimum fish species (Johal 2002). Toor *et al.* (1992) reported 86 fish species in Beas, 64 in Ravi and 53 in Sutlej within Punjab during the survey conducted between 1989 and 1991. Fishes reported in Beas and Ravi are mostly mountainous species belonging to genus, *Barrilius*, *Salmotoma, Gara, Danio* and *Tor* which is the type of fishery reported in Himalayan zone of most of the Indian rivers (Dhanze and Dhanze 1998, Johal 2002, Moza and Mishra 2001), as such, these cannot be considered fishery of Potomoan zone of these rivers. Therefore fishery of Sutlej with 53 reported fishes will only be taken into account. With this background, there does not seem much change in species composition within the last decade except the invasion of *Clarias gariepinus* (Thai magur) which is being cultured illegally in many parts of India so in Punjab, the invasion must have been from any pond during floods. The species was observed from 2002.

The fish composition along the studied rivers (Fig. 2a,b,c) showed that upper stretches of contributory rivers contain mainly minor carps like *Labeo dero*, *L. dyocheilus, Puntius* sp etc (53.39–67.99%). Other fishes present being coldwater carps (*T. putitora* and *S. richardsonii)*, eel *(Mastacembelus armatus* and *M. Pancalus),* giant freshwater catfish (*B. bagarius)* and *Xenantodon cancilla* because all these rivers run along the foothills of Shiwalik Himalayas in initial stage, have temperature range between 15 and 22°C forming natural habitat for this type of fishery (Moza 2002). The extent of presence differs in different rivers depending upon the length traversed in such terrain. Middle stretch of the system having pure lotic type of environment within Sutlej and Beas contains sufficient IMC (29.29–35.94%), large size catfishes (11.40–13.73%) and minimum common carp is (8.45–18.0%), although the stretch is subjected to effluent load through various channels indicating free flowing system is more limiting factor to this type of fishery than pollution load. Lower diluted stretch of Indus in and around Harike to Ferozpur section (tail point) has in addition to IMC (28.82%) and catfishes (11.40%), maximum presence of common carp ranging between 18 and 23.98% at Harike and 22.75% at Ferozpur indicating that these prefer lentic type of environment caused by river being confined within 2 barrages (Harike and Husaniwalah) providing conducive habitat in the form of good depth, slow current, large scale submerged weeds useful for breeding of this fishery.

The main difference between the three rivers is: Ravi has negligible presence of minnows and other miscellaneous fishery, presence of *Botia birdii* and *Lepidocephalicthys guntea* in Kandi region of Beas and that of *Clupisoma garua* in kandi regions of Ravi only, and presence of *Clarias gariepinus* at Harike .

From the above observations on the ecological and fishery status of Indus, it can be concluded that the system on the whole gets influenced by pollution influx as well as diversification of water resources, In case of Sutlej it is the influx of effluent load mainly from Budha *nallah* and Chitti/ white bein which has adverse impact on production potential. River becomes unproductive as envisaged by total alkalinity (101.7–218.6 mgl^{-1}) and deficiency of oxygen (2.80–5.2 mgl^{-1}), high B.O.D (18–32.43 mgl^{-1}) level. Food web especially plankton get drastically reduced at induction points 33–50 $\mu l\text{-}^{1}$. Food structure gets changed, unfavourable items like blue green algae (100%), Chironomiids, tubificids (69–75%), Ostacods (9.8–11%) show their presence within the system in polluted stretch. Minimum availability of fish was observed in polluted sectors like Ludhiana (26.2 t/year) compared to diluted Harike (116.7t/year) and Ferozpur (102.4t/year) sector. The two channels which are erstwhile tributaries of Sutlej have become effluent carriers of domestic and industrial waste and death traps of brooders as well as general fishery affecting the overall population. Change in environment

Annexure. 1

Important fish species recorded in Indus within Punjab between 2000–07 from upper stretch (Kiratpur to Roopnagar in Sutlej; Talwara to Mukerian in Beas and Shapur to Kathlour in Ravi) middle stretch (Ludhiana to Harike in Sutlej; Mukerian to Harike in Beas) lower stretch (Harike to Ferozpur in Sutlej and Gurdaspur to Amritsar in Ravi)

Order	Species	Sutlej	Beas	Ravi	Maximum incidence
Cluppeiformes	*Gadusia chapra*	+	+	-	
	Notopterus chitala	+	+	-	Ferozpur
	N. notopterus	+	+	-	
Cypriniformes	*Tor putitora*	+	+	+	upper stretch
	S. richardsonii	+	+	+	Ravi, Beas
	Puntius sarana	+	+	+	upper Sutlej
	Puntius sophore	+	+	+	
	P. straitus	+	+	-	
	P. conchonius	+	+	-	
	P. Puntius	+	+	-	
	P. Punjabensis	+	+	-	
	P. ticto	+	-	-	
	P. chrysopterus	+	-	-	
	P. cirrhinus	+	+	-	
	Oxygaster bacaila	+	+	+	Ludhiana
	Catla catla	+	+	-	Harike
	Cirrhinus mrigala	+	+	+	
	Labeo rohita	+	+	+	
	L. calbasu	+	+	+	
	C. reba	+	+	+	
	L. dero	+	+	+	Upper Beas and Sutlej
	L. dyocheilus	+	+	+	
	L. gonius	+	+	+	Harike
	L. bata	+	+	+	
	Osteobrama cotio	+	+	-	
	Cyprinus carpio communis	+	+	+	Talwara.Firozpur
	C.c. specularis	+	+	+	
	Botia birdii	-	+	-	Upper Beas
	Lepidocephalicthysguntea	-	+	-	
Siluriformis	*Mystus aor*	+	+	+	
	M. seenghala	+	+	+	
	M. vittatus	+	+	+	
	M. tengra	+	+	-	
	M. bleekeri	+	+	+	
	Rita rita	+	+	-	Harike
	Bagarius bagarius	+	+	+	Harike
	Ompak pabda	+	+	-	Roopnagar
	O. bimacullatus	+	-	-	
	Wallago attu	+	+	+	
	Eutropiichthys vacha	+	+	+	Kathlour (Ravi)
	Clupisoma garua	-	-	+	Kathlour (Ravi)
	Heteropneustes fossilis	+	+	+	Ludhiana and Kathlour
	Clarias bataraclus	+	+	+	Ludhiana and Kathlour
	C. gariepinus	+	+	-	Harike
Beloniforms	*Xenantodon cancilla*	+	+	+	Ravi
Channiformes	*Channa marulius*	+	+	+	
	C. punctatus	+	+	+	
	C. straitus	+	+	+	
Symbranchiformes	*Amphipnuous cuchia*	+	+	-	
Perciformes	*Ambasis ranga*	+	+	-	
	A.nama	+	+	-	
	Nandus nandus	+	+	-	
	Gobius giuris	+	+	-	
	Colisa fasciata	+	+	-	
Mastacembeliformes	*Mastacemblusarmatus*	+	+	+	Upper Ravi and Beas
	M .pancalus	+	+	+	

affect feeding, breeding of fish thereby their growth and population as is observed in all riverine environments (Vass and Moza 2011).

In Beas the observations indicated that it is the diversion of water resources at Talwara barrage up to Mukerian which affect the productivity than pollution influx as Beas characteristics at no point become critical having reasonable alkalinity 84 mgl^{-1} and dissolved oxygen, 6.87 mgl^{-1} even at affected stretch, i.e induction of Chakwal nalla. Availability of food spectrum,plankton 80–101ul and macrobenthos 455–343 um^{-2} is comparatively less in abstracted zone than lower Beas (plankton 140–273um^{-1}, macro benthos, 621–657 um^{-2}) . Concurrent to availability of food, the fish production is more in lower Beas. The fish catch estimate between Talwara to Pathankot (Abstacted zone) was in the range 0f 20.6–31.4 t/yr compared 48.7–64.9t/yr from lower stretch (Amritsar –Harike) having more water resources.

In Ravi the general productivity thereby fish productivity is influenced to great extent by diversification of its water resources and by physical characteristics of river water and sediment mainly temperature, depth and flow regime.

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