Riverine Fisheries Resources of India

Acharya K.V. [1]*, Pethkar M. [2], Jadhav S.[3]
*1. Ph.D. Research Scholar, Swami Ramanand Teerth Marathwada University, Nanded Maharashtra, India.
2. Asst. Professor Baburao Patil College of Arta & Science, Angar. Tq. Mohol, Dist- Solapur.
3. Asst. Professor Dayanand Science College, Latur
*Corresponding author: Ph.D. Research Scholar, Swami Ramanand Teerth Marathwada University, Nanded Maharashtra, India

ABSTRACT: *India's fisheries resources are rich and diverse as they are plentiful, comprising ocean, rivers, floodplains, estuaries, mangroves, estuarine impoundments, lagoons, upland lakes, reservoirs and ponds. India has blessed with Major rivers 14 & Minor rivers are 44. (Handbook of fisheries & aquaculture, 2011). In 2013-14 India is the second largest producer of fish in the world contributing to 5.68% of global fish production as per FAO statistics. Total fish production during 2013-14 registered 9.58 million tons of which 3.44 million tonns from marine & 6.14 million tonns from inland sectors. Average growth of fish production stands at 5.9%. During 2013-14 volume of fish and fish products exported was 983756 tonns. Earning Rs. 30213.26 Crores. During 2013-14 total GDP (Gross domestic product) of India 9388876, GDP from Agriculture, Forestry & Fishing 1644926 & GDP from Fisheries 78053 Crore. (Handbook on Fisheries Statistics,2014). Fisheries sector is a source of livelihood for over 14.49 million people engaged fully, partially or in subsidiary activities related to the sector. India is a major producer of fish through aquaculture and ranks second in the world after China. About 35% of Indian population is fish eaters and the per capita consumption is 9.8 kg whereas the recommended intake is 13 kg (Manual on fishery statistics 2011). In view of the above, the present paper would definitely throw some light to understand Fisheries resources, their utilization and actual growth rates in compare to previous years. Development of the resources should comprise measures to augment the abundance level of the resources, strategies to exploit them in such a manner that food security is ensured, the exploitation process being economically viable and the resources conserved at a steady state allowing maximum potential for exploitation in present and future.*

Keywords: *Fisheries resources, River basins, Inland, Alien/exotic species, NRLP*

1. Introduction

Inland waters provide a wide range of services to human population, being a basic element in development of agriculture, transport, industry and power generation. It also provides fundamental ecological services, such as those required to support a healthy ecosystem and demand-derived services, such as fish production for fisheries. Human influences on rivers, lakes and estuaries usually result in changes to the form and function of inland aquatic systems with an associated decline in the ecosystem services that they offer.

River fisheries, and in general inland fisheries, in the tropical regions of the world provide a range of benefits including a means of livelihood and a source of food for millions of people. However, national

policies relating to crucial issues, such as economic development, poverty alleviation, food security, conservation and sustainability, often fail to recognize these important attributes. Taking cognizance of these issues the FAO members have responsibility to maintain aquatic ecosystems in a state consistent with the sustainability of fish stocks and the fisheries they support. The right to fish carries with it the obligation to do so in a responsible manner so as to ensure effective conservation and management of living aquatic resources. The growing awareness of the general degradation in the form and function of rivers caused by water abstractions and pollution is focusing attention on the need to improve the health of such ecosystems. In this context the conservation and sustainable fishery from our rivers in India assumes importance.

2. Materials and methods

1.Data Sources: Handbook on Fisheries Statistics, 2014

2.Data Sources: For this study secondary data were used. Relevant secondary data were collected from FAO database, publication and various research bulletins.

3.Data Type: Secondary Data Collected from various annual reports, research papers and conferences published time by time by Department of Animal Husbandry Dairying & Fisheries (DAHDF).

4.Catch statistics Data collected by the Central Inland Fisheries Research Institute (CIFRI), Barrackpore

3. Objective of the study: To study and understand different Inland Fisheries resources, their utilization and actual growth rates. Development of the resources should comprise measures to augment the abundance level of the resources, strategies to exploit them in such a manner that food security is ensured, the exploitation process being economically viable and the resources conserved at a steady state allowing maximum potential for exploitation.

4. Data source: Present study is based on secondary data information. Secondary data was collected from different books, journals, articles, periodicals, research papers.

5. River basins

There are large numbers of rivers in the country which run into a total length of 45,000 km. These rivers fall under 113 river basins having a total catchment area of 3.12 million km^2. There is a large network of perennial rivers, all of which are characterized by very large seasonal variations in their discharge due to seasonal rainfall and prolonged dry periods. The Indian mainland is drained by 15 major (drainage basin >20,000 km^2), 45 medium (2,000 to 20,000 km^2) and over 102 minor (<2,000 km^2) rivers, besides numerous ephemeral streams in the western arid region. These river systems are traditionally grouped, according to their origin, into Himalayan and Peninsular rivers, or according to directions of flow into east-flowing and west-flowing rivers (Table 1).

Map of Rivers in India

Table 1. Profile of major river systems in India

River system	Name of main rivers	Approximate length (km)	States
	Extra Peninsular Rivers		
Himalayan Ganges	Ganga	2,525	Uttatakhand, Uttar Pradesh, Jharkhand, Bihar, West Bengal
	Ramganga	569	Uttar Pradesh
	Gomti	940	Uttar Pradesh
	Ghagra	1,080	Uttar Pradesh, Bihar
	Gandak	300	Bihar
	Kosi	492	Bihar
	Subernarekha	395	Bihar, Odisha, West Bengal
	Yamuna	1,376	Uttarakhand, Haryana, Delhi, Uttar Pradesh
	Chambal	1,080	Madhya Pradesh, Uttar Pradesh, Rajasthan
	Tons	264	Uttarkhand
	Sone	784	Uttar Pradesh
	Ken	360	Madhya Pradesh, Uttar Pradesh
Brahmaputra	Brahmaputra, Dibang, Siang, Lohit, Manas, BuriDihang, Dhansiri, Koppili	4,000	Arunachal Pradesh, Asom, Nagaland Sikkim, Manipur.
Indus	Jhelum	400	Jammu and Kashmir
	Chenab	330	Jammu and Kashmir, Himachal Pradesh

	Beas	460	Himachal Pradesh, Punjab
	Sutlej	1,450	Himachal Pradesh, Punjab
	Ravi	725	Jammu and Kashmir, Himachal Pradesh, Punjab
	Peninsular Rivers		
East coast	Mahanadi	851	Odisha, Madhya Pradesh
	Brahmani	799	Odisha, Bihar
	Godavari	1,465	Maharashtra, Andhra Pradesh
	Krishna	1,401	Andhra Pradesh, Karnataka, Maharashtra
	Cauvery	800	Karnataka, Tamil Nadu
	Pennar	597	Karnataka, Andhra Pradesh
	Bhima	861	Karnataka
West coast	Narmada	1,322	Maharashtra, Gujarat, Madhya Pradesh
	Tapti	720	Gujarat, Maharashtra
	Mahi	583	Gujarat
	Sabarmati	371	Gujarat, Rajasthan

Mahi, Sabarmati and Luni rivers flowing through the arid regions of Rajasthan and Gujarat carry relatively little flow. Some of them flow to Arabian Sea through Gujarat while others are lost through internal drainage.

Mahanadi, Brahmani, Baitarni, Subernarekha, Damodar, Krishna, Godavari and Cauveri are all east flowing peninsular rivers. They all flow into the Bay of Bengal along the eastern coast and cover a range of climates.

In coastal parts of Maharashtra, Karnataka, and in Kerala there are several short rivers in the Western Ghats and carry significant amount of water due to high rainfall in the region. These rivers drain only 3% of the India's land area but carry about 11% of the country's water resources.

Most Indian rivers, at present, are highly regulated numerous multipurpose reservoirs for irrigation, water supply, hydropower have been constructed, along with many barrages for water diversion. Many long reaches of river passing through urban areas go almost completely dry for greater part of the year, except during monsoon, as the flow is diverted to irrigation and other needs, flood plains are lost and even river beds are cultivated during dry periods. During the past few decades, rivers have also received increasingly large discharges of industrial effluents, agro-chemicals, and domestic wastes. All this has affected the riverine ecology and its biodiversity. It is a matter of serious concern that out of the 30 rivers basins marked as global level priorities for the maintenance and protection of aquatic biodiversity, ten are from India (Cauvery, Ganga, Brahmaputra, Godavari, Indus, Krishna, Mahanadi, Narmada, Pennar, and Tapi). Observation from other study with regard to flow fragmentation and regulation in these nine basins, showed that eight (except Ganga-Brahmaputra) basins strongly affected. Though some efforts have been made towards cleaning of these rivers and enforcement of treatment of industrial effluents, there have been no systematic efforts to maintain the ecological integrity of these river systems and associated waters.

6. Main rivers systems

6.1 Ganga river system

The Ganga river systems, which has a total length of about 8,047 km, is the most important river systems in India and one of the largest in the world. It drains the southern slope of Central Himalayas and covers the states of Uttarakhand, Uttar Pradesh, Bihar, Jharkhand, West Bengal and parts of Haryana, Rajasthan and Madhya Pradesh. The main river, Ganga has its source in two headwaters (Gangotri and Alaknanda), at a height of about 6,000 m above sea level (asl), in Garhwal Himalayas ($30^0$55'N and $79^0$07'E) in Uttarakhand. The river first flows in a westerly direction for about 30 km before turning southwards. Gorging a distance of about 220 km and after cutting its ways through the Shiwaliks, it enters the plains at Haridwar. Then it flow south-east and meanders over a distance of about 2,290 km in the Indo-Gangetic plains in Uttar Pradesh, Bihar, Jharkhand and West Bangal before ultimately joining the Bay of Bengal. Many major and minor tributaries (rivers Ramganga, Yamuna, Tons, Varuna, Gomati, Basu, Karamnasa, Thora, Ghaghra, Sone, Gandak, Punpun, BurhiGandak, Man, Jumania, Kosi, Gumani) join river Ganga during its course through the plains. The main channel of river Ganga, after Farakka barrage (West Bengal), flows in south-easterly direction as river Padma, through Bangladesh, where it is joined by Brahmaputra (Jamuna) and Meghna rivers finally leading to Bay of Bengal.

In India, below the barrage, through a 41 km long feeder canal, river Ganga meets its tributary, river Bhagirathi, after flowing for about 150 km in West Bengal it enters the long estuarine zone, where it is better known as river Hooghly, which after flowing through Kolkata and Diamond Harbour reaches its destination (Bay of Bengal). About 300 km from the sea face, the Bhagirathi-Hooghly river system begins to spread into many small distributaries forming the great Gangetic delta. The lower Gangetic delta circumscribes extensive marshy area, called the Sunderbans. The Hooghly estuarine system extends for about 300 km from north to south and about 150 km from east to west. The entire estuarine systems is estimated to be about 8,029 km^2 and the total area of Sunderbans estuarine water in India is about 2,340 km^2.

6.2 Brahmaputra river system

The mighty Brahmaputra, a freshwater moving ocean of the north-east India, rises from the snout of Chemayungdung mountains near Tachhong (Tomchok), KhambabChhorten, about 100 km south-east of the lake Mansorovar in Tibet, at an altitude of 5,150 m. It runs for about 1,250 km through Tibet, as river Tsangpo, almost parallel to the main Himalayan range, before taking a sharp turn southwards to enter India near Tuting in Siang district of Arunachal Pradesh. Running for about 160 km in Arunachal Pradesh, as river Dihang/Siang, it enters Asom on the north-west of Sadiya where it meets two equally important trans-Himalayan tributaries, Dibang (Sikong) and Lohit. After joining with these tributaries the river assumes the name Brahmaputra. Fotrified by 41 main tributaries (25 on the northern bank and 16 on the southern bank), the river flows through the heart of Asom for about 740 km before entering Bangladesh, the river joins river Padma (Ganga) at Goalando, which reaches Bay of Bengal through Meghna estuary. The total length of this river is about 2,900 km of which about 900 km falls in India. The combined length of the river, with its 41 main tributaries, in India is about 4,000 km with a catchment area of about 580,000 km^2 (195,000 km^2 in India) and average water discharge of 510,450 m^3.

6.3 Indus river system

The Indus is one of the great rivers of the world. From its source up to the sea it is 2,000 km in length while principal tributaries the Kabul and the Swat drain Afghanisthan region on its right bank and the Jhelum, Chenab, Ravi, Sutlej and Beas as its left bank tributaries have a total stream length of 5,600 km.In India the river Indus flows at an elevation of 3,200 masl for a short distance in the town of Leh in Ladakh(J& K) and flows into Pakistan. The other rivers of this system, viz. Jhelum and Chenab, flow partly though Jammu and Kashmir, while Ravi, Sutlej and Beas flow through Himachal Pradesh and Punjab, before entering Pakistan.

6.4 River Jhelum: This river has its origin from a spring (Verinag) in Kashmir and flows northward receiving large number of tributaries. It flows through the city of Srinagar into the Wularlake, its delta and finally drains into Pakistan.

6.5 River Chenab: This river originates in high altitudes in Himachal Pradesh, enters the Jammu and Kashmir at, 1,820 masl and flows for about 290 km in different towns and finally enters Pakistan.

6.6 River Ravi: This river originates from Bara Bang-Dhauladhar range of the Himalayas as two channels, namely Budhil and Tantgari, at an elevation of 4,423 and 4,418 masl. After receiving number of tributaries, skirting Chamba town of Himachal Pradesh and being dammed at many places (Chamera I, II, III and Ranjitsagar/Thein), the river enters Punjab at ShahpurKandi (foothills of Shivalik), where its resources are extensively diverted for irrigation purpose as a result very little water remains in river basin. River regions water resources due to introduction of many tributaries from adjoining Shivalik hills and flows through Gurdaspur and Amritsar districts of Punjab forming international border between India and Pakistan. Out of total river length of 725 km, it is 320 km within India, of which 158 km lie within Himachal Pradesh and 162 km within Punjab.

6.7 River Beas: This river takes its origin in the southern slope of Rohtang pass from sources Beas Kund (4,060 masl) and Beas Rishi (4,350 masl). It has a catchment area of 12,130 km^2 and drains 25,900 km^2 of Himachal Pradesh and Punjab. In its downstreams flow the Beas receives number of tributaries. At Pandoh the river has been dammed at village Pong in Kangra District. The river enters plains at Talwara town of Punjab where it is again manoeuvredextensivlely for irrigation purpose. The river has total 470 km length and is the only tributary of Indus confined to India. It culminates with river Sutlej near village Lohian at Hari-ke-Pattan (confluence of 3 districts of Punjab, Amritsar, Kapurthala and Firozpur).

6.8 River Sutlej: Sutlej, the longest tributary of Indus system, has its source in the Trans-Himalayas at an elevation of 4,630 masl at south-west of Tibetain lakes, Ralkarthal and Mansarovar. The river enters into India at Shipki pass (Himachal Pradesh) passes through deep gorges traversing greater and lesser Himalayas. Has total length of 1,450 km out of which 740 km lie within India. The river enters into plains at Ropar in Punjab. In its upper reaches in Himachal Pradesh, it has been dammed at Bakhra where there is a hydro-electric project as well, the lower reaches at Ropar are also maneouvered extensively for irrigation purposes.

7.0 East coast river system

The East coast river system in Peninsular India is a composite system of rivers. Its main constituents are rivers Mahanadi, Godavari, Krishna and Cauvery. The total combined length is about 6,437 km. This system

drains the entire Peninsular India (from east of Western Ghats in the west to Bay of Bengal in the east) and southern parts of Central India (including Chhota Nagpur hill ranges).

7.1 River Mahanadi: River Mahanadi rises from Sihawa hills (near village Pharsia) in south-west of Raipur district in Chhattisgarh. With a total length of about 857km, in Chhattisgarh, Madhya Pradesh and Odisha, it drains an area of about 141,600 km^2. After a brief run westwards in turns north and then eastward at Khargoni to reach Mahadeopalli, 140 km away, where HIrakund dams is located on this river. After Hirakus reservoir, it runs east for about 415 km in the state of Odisha before joining Bay of Bengal at Paradip.

7.2 River Godavari: River Godavari, the largest of Peninsular rivers and the third largest river in India (next to rivers Ganga and Brahmaputra), is about 1,465 km long from its origin near Triambakeswar in Deolali hills near Nasik (Maharashtra) in Northern-Western Ghats to its tidal limits below Rajahmundry (Andhra Pradesh). It flows across the Deccan plateau from western to eastern Ghats through Maharashtra (about 693 km) and Andhra Pradesh (about 722 km). Below Dhawaleswaram (Andhra Pradesh), river Godavari splits into Vainateyam and the main Vasishta before opening into Bay of Bengal near Narsapur and Vadalarevu respectively. Between these distributaries lies the extensive fertile region of Godavari delta. The main major tributaries of river Godavari are rivers Manjira, Waingunga and Indravati with rivers Purna, Maner and Sabari, and a host of rivulets and seasonally active streams as minor tributaries of river Godavari is about 312,812 km^2 in Maharashtra (48.6%), Andhra Pradesh (23.8%), Madhya Pradesh (20.7%), Odisha (5.5%) and Karnataka (1.4%).

Two reservoirs (Gangapur and Nathsagar) are situated on mainstreams of river Godavari in Maharashtra. A 321 km long irrigation barrage is also situated on this river at Vishnupuri (near Nanded) in this state. In Andhra Pradesh a large reservoir (Sriramsagar) has been formed at Pochampad in Nizamabad district on this river. Two large anicuts on this river, constructed a century ago, exist at Dhawaleswaram (for irrigation and vavigation) and Dummagudem (navigation) in Andhra Pradesh. The Dhawaleswaramanicut has been replaced by a barrage in 1985.

7.3 River Krishna: The Krishna river system has a total length of about 1,280 km from its origin in Mahabaleshwar hills in the Western Ghats, south of Pune (Maharashtra), to its delta on the east coast. Traversing the states of Maharashtra, Karnataka and Andhra Pradesh, it has a catchment area of about 233,229 km^2. Krishna and Godavari water sheds are contiguous over major terrain of Deccan plateau. The main tributaries of river Krishna are Bhima and Tungbhadra is perennial with greater volume of flow than main Krishna itself.

Many reservoirs have been built eithin the Krishna drainage (Lakkavali, Tungbhadra, Koyna, Vanivilassagar, Osmansagar, Hussainsagar etc.). A number of anicuts or weirs on riversTungbhadra and Bhima have also been established for irrigational needs.

8.0 West coast river system

The west coast river system drains the narrow belt of Peninsular India west of Western Ghats. In north it includes the basins of rivers Narmada and Tapti and the drainage of Gujarat. Rivers Narmada and Tapti are the main rivers of this system. All other rivers, arising from Western Ghats are short, though perennial. The total length of rivers of this system is about 3,380 km.

8.1 River Narmada: The largest west flowing river of the country, Narmada, originates from Maikala highlands near Amarkantak in Shahdol district of Madhya Pradesh. Its drainage area is the northern extremity of Deccan plateau. Of its total length of about 1,312 km, it traverses for about 1,077 km in Madhya Pradesh, forms boundaries between the Maharashtra and Madhya Pradesh, and Maharashtra and Gujarat (for about 35 and 39 km respectively), flows through Gujarat for about 161 km before joining the Gulf of Cambay (Arabian Sea) near Broach (Gujarat). River Narmada is fed by 41 major tributaries during its course, 22 from the south bank (21 in Madhya Pradesh and 1 in Gujarat) and the rest from north bank (18 in Madhya Pradesh and 1 in Gujarat). Total catchment area of river Narmada is about 94,235 km^2.

8.2 River Tapti: River Tapti, also called Tapi, is the other westerly flowing river of the Peninsular India. Rising from the Vindhya mountain of the Satpura range, it flows westward through Madhya Pradesh, Maharashtra and Gujarat before joining the Arabian Sea at Dumas near Surat (Gujarat). The total catchment area of this river is about 48,000km^2.

With a view to utilize huge quantities of rainwater to develop the regions of the lower Tapti valley and also to control the floods in Surat district, a weir has been constructed on this river at Kakrapar in Mandvitaluka of Surat district. Ukai, a big multipurpose dam, has been constructed above the Kakrapar weir, just on border of Maharashtra and Gujarat. An anicut has also been constructed on this river in the district to Jalgaon (Maharashtra) near Adilabad.

8.3 Fish and fisheries

Riverine fisheries scene is a complex mix of artisanal, subsistence and traditional fisheries with a highly dispersed and isolated nature of fishing and landing areas, diverse fishing gears and tackle, migratory fishers, fish merchants buying off catches from fishing boats at the fishing spots itself, the multi-species composition of the catches and their landing in unsorted conditions and above all an unorganized marketing system. This frustrates all attempts to collect exact data on total fish yield of the resource. A firm data base of riverine fisheries being, thus, elusive, for understanding the fish catch trend, one has to depend on whatever information has been collected by the Central Inland Fisheries Research Institute (CIFRI), Barrackpore from selected stretches of various rivers of the country during different years. The river-wise information furnished here regarding fish catch of the freshwater stretch (i.e. excluding the estuarine fishery) is, thus, mainly based on catch statistics collected by the CIFRI.

9.0 Ganga river system

9.1 Fish diversity:

Table : Important fish species recorded in the river Ganga from the upper stretch (Tehri to Kannauj), middle stretch (Kanpur to Patna), lower stretch (Sultanpur to Katwah), estuarine stretch (Nabadwip to Diamond harbor/ Roychowk).

P-Available; A-Not available.

Species	Upper stretch	Middle stretch	Lower stretch	Estuarine stretch
Catla catla	P	P	P	P
Cirrhinus mrigala	P	P	P	P
Labeo rohita	P	P	P	P
Channa punctata	A	A	P	P
C. marulia	A	A	P	P

C. striata	A	A	P	P
Sperataseenghala	P	P	P	A
Bagariusbagarius	P	P	P	P
Nandusnandus	A	A	P	P
Chitalachitala	P	P	P	P
Notopterusnotopterus	P	P	P	P
Ompok bimaculatus	P	P	P	A
O. pabda	A	P	P	A
Pangasiuspangasius	A	A	P	P
Polynemusparadiscus	A	A	A	P
Puntiussarana	P	P	P	P
P. sophore	P	P	P	A
Rhinomugilcorsula	A	A	P	P
Rita rita	P	P	P	P
Scatophagusargus	A	A	A	P
Schizothoraxrichardsonii	P	A	A	A
Setipinnaphasa	A	P	P	P
Silaginopsispanijus	A	A	A	P
Siloniasilondia	A	A	P	A
Sperataaor	P	P	P	A
Tenualosailisha	A	P	P	P
Tor tor	P	A	A	A
T. putitora	P	A	A	A
Wallago attu	P	P	P	P
L. bata	P	P	P	P
L. calbasu	P	P	P	P
Latescalcarifer	A	A	A	P
Liza parsia	A	A	A	P
Macrognathusaral	A	P	P	P
M. pancalus	A	P	P	P
Mastocembelusarmatus	P	P	P	P
Mystuscavasius	P	P	P	P
M. bleekeri	A	A	P	P
M. gulio	A	A	A	P
M. vittatus	A	P	P	P
C. reba	A	P	P	A
Clariasbatrachus	A	P	P	P
Clupsisomagarua	P	P	P	P
Eutropiichthysvacha	P	P	P	P
Gudusiachapra	P	P	P	P
Heteropneustesfossilis	A	P	P	P

11.0 Climate change and fisheries:

Perceptible changes on a global and regional scale are evident in earth's climate. In India observed changes include an increase of air temperature, regional monsoon variation, frequent droughts and a regional increase in severe storm incidence in coastal states of India along with indication of Himalayan glacier recession. The impact is being felt in the inland aquatic resources and their fisheries. Analysis of time series data of 30 years from published literature and from current investigations on the River Ganga

and water-bodies in its plains indicate increased minimum water temperatures, 1.5^0c in colder stretches of the Ganga and 0.2 to 1.6^0c in the aquaculture farms of the West Bengal in the Gangetic plains. Rainfall has also increased in the post-monsoon months of September-December. The impact is manifested in the breeding failure of the Indian major carps and a consequent decline in fish spawn availability in the river Ganga. Fish production showed distinct change in the last two decades in the middle stretch of river Ganga where the contribution of IMC has decreased from 41.4% to 8.3% and that of miscellaneous and catfish species increased. Climate change in India will put an additional stress on ecological and socio-economic systems that are already facing pressure. Thus the specific climate variables of importance to inland fisheries, viz. enhanced water temperature, extreme events like flood and drought, storms and water stress require specific adaptation actions.

12.0 Alien/exotic species:

Alien species are non-native or exotic organisms that occur outside their natural adapted ranges and dispersal potential. Many alien species support our farming and forestry systems in a big way. However, some of the alien species become invasive when they are introduced deliberately or unintentionally outside their natural habitats into new areas where they express the capability to establish, invade and outcompetes native species. International Union for Conservation of Nature and Natural Resources (IUCN) defines Alien Inva-sive Species as an alien species which becomes established in natural or semi-natural ecosystems or habitat, an agent of change, and threatens native biological diversity. These invasive are widely dis-tributed in all kinds of ecosystems through-out the world, and include all categories of living organisms. Nevertheless, plants, mammals and insects comprise the most common types of invasive alien species in terrestrial environments.

During the period 1870-1947 under the British rule, 9 species of exotic fishes were introduced. They were temperate food carps, *Tinca tinca*, *Carassius carassius, Cyprinus carpio* (European strain), and the tropical osphronemid, *Osphronemus goramy*; the salmonid game fishes, the brown trout and the rainbow trout and larvicidal *Gambusia affinis* and Lebistes reticulatus. The post- independence India witnessed introductions of 8 exotic species. They were the *cyprinids, Cyprinus carpio*, (chinese strain), *Ctenopharyngodon idella*, *Hypophthalmicthys molitrix, Puntius javanicus*, and the cichlid, Tilapia mossambica, all of food species and the salmonids, *Salvelinus fontinalis*, *Onchorhyncus nerka*, and *Salmo salar*. Unauthorized introductions were: *Aristicthys nobilis*, *Tilapia nilotica* and red tilapia.

Introduced species occasionally replace native species in natural habitats through competition or predation, but most replacement occurs in altered environments that provide the introduced species an ecological advantage. One-way that introduced species eliminate native species is through the introduction of diseases. Thai Mangur (*Clarias gariepinus*) and Chinese grass carp (*Ctenopharyngodon idella*) are some of the introduced species in the Ganges river system. Details of impact on the native fish fauna are not well understood. In 1998, Physa (Haitia) Mexicana, a North American snail was reported for the first time in the Indian subcontinent in the Ganga. The species flourished profusely by 2001. However, nothing is known if the species spread any disease. Similarly, well known South African aquatic plant, *Eichhornia crassipes*, has badly affected the lentic water-bodies in the Gangetic plains.

The tropical freshwater cichlidae fish, Tilapia (*Oreochromis mossambicus* Peters, 1852) is suitable for any aquatic ecosystems due to its adaptable life history, prolific reproduction, maternal care and ability to tolerate adverse environmental conditions. Tilapia is worldwide fish species and due to its potential and

affordability it is considered as aquatic chicken. Tilapia, a native of South Africa was brought to India by CMFRI at August 1952 (Tamil Nadu) in the same year few fingerlings were brought to Madras. For making detailed investigations a few fingerlings were brought to CIFRI centre cuttack,1953. It was stocked in the reservoirs of Tamil Nadu and Kerala where its performance was initially quite good as large- sized tilapias (1.5-2.5 kg) were caught, but soon the reservoirs, being small in size, were overpopulated and the size of the fish started declining and so was its value in the market. In ponds, it did not do well from the very beginning as stunted population made their appearance rather soon and the impact was found to be quite severe on major carps, pearl spot and milk fish.

Besides fishes, turtles, gavialis, crocodile, birds, otter and freshwater dolphins are also exploited to different extents. Exploitation of crocodile, otter and dolphins depends on their abundance in the river. Rampant killing of the soft shell turtles, *Aspideretes gangeticus*, has reduced the population to scarce. In the last two years hundreds of freshwater turtles were confiscated by enforcement agencies in Bihar. The species is a natural scavenger of the river and as a part of the Ganga Action Plan about 40,000 turtles were released in the Ganges near Varanasi, but it couldn't be proved worthy due to their rampant killing.

13.0 Cleaning of rivers

The Government of India initiated River Cleaning Programme in 1985 as GAP-I (Ganga Action Plan) and GAP_II was initiated in 1993 subsequently extended to other rivers in 1995. As per the document cleaning of rivers is a mammoth task requiring the involvement of all stake-holders and also it is not a onetime efforts but a continuous one with increase in population and other stresses on such ecosystems. The main objective of the River Action Plan is to improve the water quality of the major rivers, which are the major fresh water source in the country through the implementation of pollution abatement schemes.

14.0 Interlinking of rivers

The National River Linking Project (NRLP) envisaged transferring water from the surplus river basins to ease the water shortages in western and southern India while mitigating the impacts of recurrent floods in eastern India. The NRPL constitutes two basic components-the links which will connect the Himalayan rivers and those which will connect the peninsular rivers. When completed, the project would consist of 30 river links and 3,000 storage structures to transfer 174 km^3 of water through a canal network of about 14,900 km. The recent revival of the idea of interlinking of 'surplus' basins with 'deficit' basins has been the result of work done by the National Water development Agency (NWDA) and bears a conceptual continuity with DrRao's proposal.

14.1 Components of NRLP:

The Himalayan component proposes to transfer 33 km^3 of water through 16 river links. It has two sub-components:

(a) The Ganga and Brahamputra basins to Mahanadi basin (links 11-12); and
(b) Eastern Ganga tributaries and Chambal, Sabramati river basins (links 1-10).

The Peninsular component proposes to transfer 141 km^3 water through 14 river links. It has four sub-components:

(a) Mahanadi and Godavari basins to Krishna, Cauvery and Vaigai rivers (links 1-9);
(b) West-flowing rivers south of Tapi to north of Mumbai (links 12 and 13)

(c) Ken River to Betwa River and Parbati, Kalisindh rivers to Chambal rivers (links 10 and 11); and
(d) Some west flowing rivers to the eastern rivers (links 14).

15.0 Conclusions

Modern rivers in India have been studied in different geographical and geological settings. Human imprints are being manifested significantly in the processes and morphology of all the modern rivers. Such studies require multiple datasets, such as hydrological and morphological data, remote sensing based spatial datasets, geochemical data, climate models and their projections, glacial runoff models and their outputs, field observations and measurements, and the application of different river models. Studies on modern rivers in the background of the Anthropogenic context are still in the initial stage in India, and there is a need to develop new inter-disciplinary approaches to understand feedback mechanisms in these large and complex river systems. Such approaches are of considerable interest for designing sustainable scientific strategies for stream management in the scenario of climate change and human disturbances, and will also help to gain insights on the future trajectories of river systems. It is also important to consider that a river is not a closed geomorphic system. River processes are governed by flux and energy transfers and it maintains equilibrium with the inherent climatic, geological and landscape settings. Unless human impact on modern rivers is documented in such complex framework, threshold dynamics and sensitivity of the various components of large river basins cannot be understood. Given the importance of rivers as a fundamental resource for the large human population of our country, it is imperative that suitable initiatives are taken and implemented by the various Earth Science organizations in India for strengthening the different facets of River Science.

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