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Inland Aquatic Resources of India and the Ecosystem Services Management

Status, Issues and Some Policy Suggestions



2019-2020

ICAR-National Bureau of Fish Genetic Resources
Canal Ring Road, P.O. Dilkusha, Lucknow – 226 002, India
&
The Alliance of Bioversity International and CIAT
New Delhi – 110 012, India

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List of Abbreviations

ABS	Access and Benefit Sharing
BD Act	Biological Diversity Act
AICTE	All India Council for Technical Education
BOD	Biological Oxygen Demand
BHS	Biodiversity Heritage sites
BMC	Biodiversity Management Committee
BMP	BetterManagement Practices
CBA	Capture Based Aquaculture
CBD	Convention on Biological Diversity
CBF	Culture Based Fisheries
CIFRI	Central Inland Fisheries Research Institute
CMS	Convention on Conservation of Migratory Species
CCRF	Code of Conduct for Responsible Fisheries
DPSIR	Drivers, Pressure, State, Impact and Response
EAF	Ecosystem Approach to Fisheries
EGREE	East Godavari River Estuarine Ecosystem
EHC	Ecosystem Health Card
EIA	Environmental Impact Assessment
EPBR	Electronic Peoples' Biodiversity Register
EPI	Environmental Performance Index
ETP	Effluent Treatment Plant
FAO	Food and Agriculture Organisation
GAP	Ganga Action Plan
GCA	Gross Cropped Area
GR	Genetic Resources

MEA	Multilateral Environmental Agreement
MGNREGA	Mahatma Gandhi National Rural Employment Guarantee Act
M.ha	Million hectare
MMT	Million Metric Tonnes
MPA	Marine Protected Area
MoEFCC	Ministry of Environment, Forest and Climate Change
MoUD	Ministry of Urban Development
MSC	Marine Stewardship Council
NBA	National Biodiversity Authority
NBT	National Biodiversity Target
NBFGR	National Bureau of Fish Genetic Resources
NEP	National Environmental Policy
NMP	National Mariculture Policy
NRCP	National River Conservation Plan
OECM	Other Effective Area-Based Conservation Measures
PA	Protected Areas
PBR	Peoples' Biodiversity Register
PES	Payment for Ecosystem Services
PFA	Production Function Approach
SBB	State Biodiversity Board
SDG	Sustainable Development Goals
SHC	Soil Health Card
SHG	Self Help Group
TEEB	The Economics of Ecosystem and Biodiversity
UNFCCC	United Nations Framework Convention on Climate Change
UT	Union Territory

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Summary

India's inland aquatic resources have rich genetic diversity and it provides various ecosystem services, which include provisioning, regulating, supporting and spiritual services. The aquatic biodiversity of India encompasses 9,456 animal species representing 3145 fish species from deferent ecosystems. The Inland fisheries contribute significantly to overall production which has enabled the country to become the second-largest producer of inland fisheries and aquaculture nation in the world. The total fish production of India touched 13.42 million tonnes in 2018-19, with a contribution of 9.71 million tonnes from the inland sector. Some of the concerns identified in the inland water bodies are declining diversity, habitat loss and degradation. These impacts are due to agricultural runoff, pollution, water abstraction, obstruction of river flows by dams, impaired environmental flows, sedimentation, destructive fishing practices, overexploitation and spread of invasive alien species, etc. For governing the inland resources, India has signed various Multilateral Environmental Agreements and enacted numerous legislations. India has further developed National Biodiversity Targets in line with the global Aichi Biodiversity Targets, and action plan for area-based conservation measures. The present document analyses policies, schemes, plans, programmes and projects of the inland sector and brings out recommendations for conserving the aquatic genetic resources and the ecosystem services.

1.0 Introduction

1.1 India's aquatic genetic resource

India possesses rich aquatic biodiversity spread across different ecosystems. Nearly half of the aquatic genetic resources contributing to India's food security comes from the wild bioresources. The aquatic genetic resources of India comprise 9,456 species, which is approximately 9.7 percent of the total number (97,708) of animal species reported by the Zoological Survey of India (Table 1)[1]. Approximately 35,797 species of fishes are recorded in the world.[1a] Aquatic Genetic Resources Information System (AqGRISI) of India, an online databse developed by ICAR-NBFGR, containing information on fish taxonomy, biology, genomics and diesases covers 3145 native fish species encompassing 248 familes and 49 orders (www.nbfgr.res.in). The commercially viable warm water fish species observed in the Indian waters are murrels *(Channa striata, C. marulius, C. punctata);* catfishes (*Clarias magur, Heteropneustes fossilis, Sperata aor, S. seenghala, Wallago attu, Pangasius pangasius, Silonia silondia, Bagarius bagarius* and *Rita rita);* major and minor carps (*Labeo bata, L. rohita, L. calbasu, L. fimbriatus, catla, Cirrhinus mrigala, C. cirrhosa* and *C. reba*)[2].

Table 1: India's aquatic biodiversity

Invertebrates and chordates	Number of Species
Arthropoda	5923
Nematoda	422
Rotifera	419
Mollusca	217
Annelida	167
Platyhelminthes	163
Amphibians	275
Aves	243
Reptiles	46
Mammals	06

Source: Zoological Survey of India, 2017

1 Kailash Chandra, Gopi, K.C., Rao, D.V., Valarmathi, K. and Alfred, J.R.B., 2017. Current status of freshwater faunal diversity in India: 1-624pp. Zoological Survey of India (ZSI), Kolkata.

1a Fricke, R., Eschmeyer, W.N. & Van der Laan, R. (eds) 2021. Eschmeyer's Catalogue of Fishes; Genera, Species, References (Electronic version accessed on June, 2021)

2 Kuldeep K. Lal and J.K. Jena, 2016. National Bureau of Fish Genetic Resources: A centre for aquatic genetic resource management research in India. IAC Souvenir, 1st International Agrobiodiversity Congress, Science, Nov.6-9, 2016, New Delhi, xxvii+142.2a. Fricke, R., Eschmeyer, W. N. & R. van der Laan (eds) 2021. ESCHMEYER'S CATALOG OF FISHES: GENERA, SPECIES, REFERENCES.(http://researcharchive.calacademy.org/research/ichthyology/catalog/fishcatmain.asp). Electronic version accessed 27 March2021.

1.2 India's water resources

Freshwater resources of India primarily depend on precipitation, transboundary and within country river flows, which is estimated to be around 4000 km^3/year. The availability of surface and replenishable groundwater is estimated to be around 1869 km^3. Due to various constraints of topography, uneven distribution of resources over space and time, it has been estimated that only about 1123 km^3 (including 690 $km)^3$ from surface water and 433 km^3 from groundwater resources are put to beneficial use[3]. A detailed account of water resources is given in Table 2.

The diversity of aquatic flora and fauna in inland water bodies depends on water quality, quantity and timing of availability of water. The chemical composition of water is constantly modified by the living species present in the environment, especially the mineral and dissolved gas content[4]. The discharge of industrial and sewage waste into the inland water bodies has resulted into changing physicochemical or biological parameters of water quality, which impacts biodiversity and the ecosystem services. Thus, it is very important to maintain good water quality in rivers and lakes to enhance biodiversity and its aquatic ecosystem services.

Table 2: Water resources of India

Annual Precipitation	Unit in km^3
Annual precipitation (including snowfall)	4000
Run-off received from upper riparian countries	500
Average annual natural flow in rivers and aquifers	1869
Estimated utilisable water	**1123**
Surface	690
Ground	433
Water demand ≈ utilization	
Domestic	42
Irrigation	541
Industry, energy & others	51
Total	**634**

Source: National Water Mission, 2019

1.3 India's aquatic resources

India's inland water bodies comprise of rivers, lakes, reservoirs, canals, ponds, tanks, wetlands, estuaries, brackish water, floodplain lakes (oxbow lakes), bheels, etc. The inland water bodies are used for culture and capture fisheries (Table 3). The unutilized and underutilized vast and varied inland resources offer great opportunities for livelihood development and ushering economic prosperity. This inland open water is the repository of aquatic biodiversity and nurtures natural broodstock of the native species. The alarming decline in riverine fish stocks in rivers has been noticed over the years resulting in poor returns to fishers. The reasons for this scenario in inland open-waters,

3 National Water Mission, 2019. Prepared under the National Action Plan on Climate Change, Comprehensive Mission Document, Volume – II. Prepared by the Ministry of Water Resources, Government of India (GoI).

4 Anne Marie Harper, 2015. The hand book for management and restoration of aquatic ecosystems in river and lake basins; ISBN: 978-91-87823-15-2; www.inbo.news.org/www.gwp.org.

especially in rivers, estuaries and lagoons, include reduced water flow, industrial and domestic pollution, sedimentation, increased fishing pressure, destructive fishing and poor enforcement of regulations. Conservation of indigenous fisheries resources and enhancement of productivity, together with ecosystem restoration of the rivers, would be the cornerstone for addressing the livelihood concerns of resource-poor fishers. The minimum environmental flow and habitat conservation of inland water bodies will help in protecting and rehabilitating native fish stocks[5].

The reservoirs, wetlands and freshwater aquaculture would be the main pillars of growth in the inland fish production sector. It is estimated that around 0.65 million ha of water area has been brought under fish farming, covering nearly 1.1 million beneficiaries. The average annual yield is around 3.0 tonnes/ha and the manmade reservoir resources cover more than 3.0 million hectares (M.ha). The average fish production potential in reservoirs was estimated at 250 kg/ha and about 350 kg/ha in wetlands.

Table 3: Aquatic resources in India and their utilisation modes

S.No	Resource type	Resource size	Fish production system
1	Continental Shelf area (Million Sq.Km)*	0.53	Capture fisheries
2	Exclusive Economic Zone (Million Sq. Km)*	2.02	Capture fisheries
3	Rivers and canals (Lakh. Kilometer)*	1.95	Capture fisheries
4	Ponds and tanks (Lakh hectare) *	24.1	Aquaculture
5	Reservoirs (Lakh hectare)	31.5	Culture-based fisheries/Stock enhancement/Cage culture
6	Floodplains and lakes (Lakh Hectare)*	8.12	Culture-based fisheries and pen culture
7	Brackish water area (Lakh Hectare)	12.4	Aquaculture
8	Bheels (M.ha)	1.3	Culture-based fisheries/ Aquaculture
9	Wetland (Inland and coastal) (M.ha)	15.26	Capture and aquaculture
10	Mangrove (Sq.km) **	4975	Livelihood enhancement
Source:* Draft National Fisheries Policy 2020. ** India State of Forest Report 2019,			

1.3.1 River

India's river systems comprise of 153 small, 44 medium and 14 major rivers, and the large network of inland water bodies provides great potential for economic capture fishery and harbour the richest biodiversity[6]. The major river basins of the country are the Ganga, Brahmaputra, Brahmani, Cauvery, Godavari, Indus, Krishna, Mahanadi, Mahi, Narmada, Periyar, Sabarmati, Subarnarekha and Tapti, which cover about 85% of the surface flow. The Gangetic system harbours around 265 species of fish; the Brahmaputra system with 126 species and the peninsular rivers are reported to harbour around 76 fish species[7].

6. Vision 2050, 2015, Published by ICAR-Central Inland Fisheries Research Institute (CIFRI), Barrackpore, Kolkata.

5. Scheme on Development of Inland Fisheries and Aquaculture - An Analysis. Standing committee on Agriculture,2017-18, Fifty Third Report, Sixteenth Lok Sabha, Published by the Department of Animal Husbandry, Dairying and Fisheries (DAHDF), Ministry of Agriculture and Farmers' Welfare (MoA & FW), Government of India (GoI).

7. Das, M. K., Samanta, S. & Saha, P. K. 2007. Riverine Health and Impact on Fisheries in India. Policy Paper No. 01, Central Inland Fisheries Research Institute, Barrackpore, Kolkata. 120

1.3.2 Estuaries

An estuary is an area where a freshwater river or stream meets the ocean. When freshwater and seawater combines, the water becomes brackish or slightly salty. Estuaries are the finest nurseries and breeding grounds for some commercially as well as ecologically important fish, prawn and other organisms such as, oysters, mussels, lobsters, crabs, dolphins and crocodiles[8]. India has 53 estuaries, major estuaries being Cauvery, Godavari, Tapi, Krishna, Mahanadi, Hooghly, and Narmada. Estuaries consist of diverse habitats, such as mangroves, salt marshes, sea-grasses and mudflats. Brackish water estuaries are having the peculiarity of fluctuating salinity due to tidal effects which have huge potential for both fish and shellfish culture. India has 1.24 million ha of brackish water area spread over all maritime States / Union Territories (UTs). Some of the aquatic organisms cultured in the brackish water are mussels, crabs, lobsters, shrimps, oysters, sea bass, groupers, mullets, milkfish, cobia, silver pompano, pearl spot, ornamental fishes, seaweeds, etc[9].

1.3.3 Coastal Lagoons

Coastal lagoons are "semi-enclosed coastal water bodies, which has a free connection with the open sea and within which the seawater is diluted with the freshwater derived from land drainage". Lagoons are rich in biodiversity due to the coexistence of different ecosystems. In India, there are around 17 coastal lagoons viz. Chilika, Vembanad, Pulicat, Ashtamudi, Pennar, Paravur, Bendi, Ettikulam, Nizampatnam, Murukumpuzha, Muttukadu, Veli, Muthupet, Talapady, Gulf of Mannar and Lagoons of Mumbai and Lakshadweep[10].

Chilika lake, located in Orissa, is one of the largest brackish water lagoons in Asia and it is the first Ramsar site of India. It is an assemblage of marine, brackish and freshwater ecosystems and comprises 317 finfish species, of which 278 species are food fishes. Of these 271 are migratory and 46 are resident species. The highly productive lake ecosystem supports nearly 0.2 million fishermen and generates a revenue of more than ₹ 750 million annually[11]. Some of the rare and threatened animals that live in this lake include Green sea turtle (endangered), *Dugong dugon* (vulnerable), Irrawaddy dolphin (vulnerable), Blackbuck (near threatened), spoon-billed sandpiper (critically endangered) and Fishing cat (endangered). The annual maximum sustainable yield of the lake is around 11, 376 Million Tonnes (MT)[12].

Chilika is also one of the major waterbird congregation areas within the Central Asia flyway. A total of 226 bird species were recorded, which includes 20 species of ducks and geese, 48 species of waders, 17 species of gulls and terns, 14 species of birds of prey and 11 species of herons and egrets. Of these species, nearly 100 are migratory

8. Das, M.K., Sharma, A.P., and Samanta, S. 2014. Health of Inland Aquatic Resources and its Impact on Fisheries Policy Paper No. 4, ISSN, 0970-616X, ICAR-CIFRI, Barrackpore, Kolkata. P.43.
9. Scheme on Development of Inland Fisheries and Aquaculture - An Analysis. Standing committee on Agriculture, 2017-18, Fifty Third Report, Sixteenth Lok Sabha, Published by the DAHDF, MoAFW, GoI.
10. Mahapatro et al., 2013, Coastal Lagoon: Present Status and Future Challenges, International Journal of Marine Science, Vol.3, No.23 178-186.
11. Chilika Newsletter, 2015, Volume VIII. Published by wetland International.
12. Arun Pandit, A.Ekka, D.K.Biswas,L.Chakraborthy,S.K.Mohanty, Piyashi Debroy & B.K.Das, ICAR, Barrackpore, Kolkata. Published in the books of abstracts, International symposium on culture-based fisheries in Inland open waters and satellite symposium.

birds coming from the Caspian Sea, Baikal Lake, remote parts of Russia, Mongolia, Ladakh, Siberia, Iran, Iraq, Afghanistan and Himalayas[13]. It also provides habitat for near-threatened species, such as the River tern, Asian dowitcher, Spot-billed pelican, Oriental darter, Eurasian curlew, Eurasian spoonbill, Pallas's fish eagle, Painted stork and Black-tailed godwit. Chilika lagoon also maintains a healthy population of endangered Dolphin (*Orcaella brevirostris*).

1.3.4 Mangroves

Mangroves are salt tolerant evergreen forest ecosystem, observed mainly in tropical and subtropical coastal and/or inter-tidal regions. They exhibit morphological and physiological adaptations (e.g., succulent leaves, sunken stomata, aerial breathing roots, vivipary, stilt roots, buttresses, etc.) to survive the harsh climatic conditions. They provide a fertile breeding ground for the aquatic organisms and an important source of livelihood (viz. honey, tannins, wax, etc) for the coastal communities. They also acts as a carbon sink. The mangrove cover of India is around 4,975 sq km, which is 0.15% of the country's total geographical area. West Bengal is having 42.45% of India's mangrove cover, followed by Gujarat (23.66%) and Andaman & Nicobar Islands with 12.39%[14].

The Sundarbans mangrove forest accounts for half of the total area of mangroves in India and provides a home for threatened species, such as Gangetic dolphin (*Platanista gangetica*), snubfin dolphin (*Orcaella brevirostris*), common otter (*Lutra lutra*), estuarine crocodile (*Crocodylus porosus*), fishing cat (*Prionailurus viverrinus*), water monitor lizard (*Varanus salvator*), river terrapin (*Batagur baska*), marine turtles like Olive Ridley (*Lepidochelys olivacea*), green sea turtle (*Chelonia mydas*) and hawksbill turtle (*Eretmochelys imbricata*)[15]. The East Godavari River Estuarine Ecosystem (EGREE) is the second largest mangrove forest in the country with 35 species that include one nearly threatened species (*Ceriops decandra*) and also species, such as *Avicennia officinalis, A. alba* and *A. marina*[16].

1.3.5 Wetlands

Wetlands are transition lands between terrestrial and aquatic ecosystems, where the water table is usually at or near to the surface, or the land is covered by shallow water permanently or seasonally. Wetlands can be classified as glacial, tectonic, crater, oxbows, marshes, swamps, flood plains, fens, bogs, estuaries, backwaters, mudflats, coral reefs and manmade wetlands. Wetlands range from high altitude lakes of Himalayas, floodplains and marshes of Ganga-Brahmaputra alluvial plains, saline flats of Great Indian Desert to extensive marshes and coral reefs bordering the country's coastline and islands. Nearly two thousand bird species make regular seasonal movements, travelling thousands of miles between breeding and non-breeding areas to escape the harsh winters of the polar and temperate regions[17]. Migrating birds use

13. Panda,S. et al, 2008. The Atlas of Chilika, published by the Chilika Development Authority, Bhubanneswar, Orissa.
14. India State of Forest Report, 2019. Forest survey of India, Edition 16 Vol, 2019. Published by MoEFCC, Government of India.
15. Sundarban Biosphere Reserve (Web Source: http://sundarbanbiosphere.org).
16. Amal Aldababseh and Thomson Jacob, C., 2019. Terminal evaluation report on Mainstreaming Coastal and Marine Biodiversity into Production Sectors in the East Godavari River Estuarine Ecosystem, Andhra Pradesh, GEF-United Nations Development Programme (UNDP) report, 123pp.
17. Kaul, S. Kumar, R. 2019. Wetland conservation Ethos, New Delhi: Wetland International South Asia, pp.64.

wetlands as stopover sites for feeding, resting and breeding. Indian wetland connects the Central Asian and East Australasian flyways. Several wetlands are habitats of a many endemic and highly threatened to near-threatened species. The Keibul Lamjao National Park on the south of Loktak is the known natural habitat of globally endangered brown-antlered deer (*Rucervus eldii*). The largest remaining populations of critically endangered Gharial (*Gavialis gangeticus*) are found around the river son, Girwa and Chambal of Central India. Over 70% of the global population of vulnerable Great Indian Rhinoceros (*Rhinoceros unicornis*) is largely confined within the grasslands and swamps of Kaziranga National Park, Assam. Wetlands also support unicellular algae, bryophytes, mosses, ferns and woody angiosperms. Some of the faunal species found in the wetlands are dolphins, otters, swamp deer, hog deer, fishing cats, elephants and wild buffaloes, etc[18].

1.3.6 Coldwater resources

Coldwater fisheries have a great potential in generating income in the hilly states of Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Sikkim, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura, Meghalaya, Assam and West Bengal. The cold water resources harbour a diverse group of fishes belonging to 258 species, constituting approximately 17% of the total fish fauna of the country. The Himalayan region has around 8,243 km long streams and rivers, 20, 500 ha natural lakes, 50,000 ha reservoirs and 2500 ha brackish water lakes[19]. Out of these, 203 species have been recorded from the Himalayas and 91 from the Deccan plateau. Among the recorded species, schizothoracids and mahseer support sizable capture and sport fishery in rivers and lakes. Jammu & Kashmir, Himachal Pradesh and Sikkim are leading states in the commercial farming of trout[20]. Presently, the coldwater sector contributes about 75,000 MT, which is about 1.5% of total inland fish production.

The Directorate of Coldwater Fisheries Research has made significant contributions towards documentation of fish fauna; assessment of resources; breeding and culture practices of selected species; and technology transfer. The culture and breeding protocols have been developed for mahseer, snow trout and minor carps to maintain their abundance in the natural system, as part of conservation and aquaculture initiatives. The technical support for rearing and seed production of rainbow trout has been extended and certain new candidate species identified. Breeding protocols have been developed for chocolate mahseer *Neolissocheilus hexagonolepis, Labeo dero, L. dyocheilus, Osteobrama belangeri and Semiplotus semiplotus*[21].

18. Ministry of Environment, Forest and Climate Change (MoEFCC) & The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), 2014. The Economics and Ecosystems and Biodiversity, TEEB India Initiative: Interim Report-Working 7 Document, 92pp.
19. Singh A. K. and Debajit Sarma (Eds) 2017. Aquatic resources and fish diversity of the Himalayas. Narendra Publishing House New Delhi. 345pp. ISBN: 978-93-86110-81-7.
20. Scheme on Development of Inland Fisheries and Aquaculture - An Analysis. Standing committee on Agriculture, 2017-18, Fifty Third Report, Sixteenth Lok Sabha, Published by the DAHDF, MoAFW, GoI.
21. Directorate of Coldwater Fisheries Research (Indian Council of Agricultural Research) Bhimtal-263 136, Nainital, Uttarakhand, India www.dcfr.res.in

1.3.7 Ornamental fish

Ornamental fish farming contributes to the overall growth of the fisheries sector and it provides livelihood opportunities for the urban and rural communities. Over one billion ornamental fish, comprising more than 4000 fresh water and 1400 marine species are traded internationally. Globally, 90% of the freshwater species are traded and these species are mostly collected from the wild[22]. India contributes less than one percent of the total global ornamental fish population and about 15 commercially important ornamental fish species are collected from the rivers. During 2014-15, nearly 69.26 tons of ornamental fishes were exported generating a revenue of ₹ 566.66 corers[23].

1.4 Fish production in India

India is the second-largest inland fish producer, next to China, and more than 1.4 crore people in the country are dependent on fisheries and aquaculture for their livelihood. The total fish production was 13.42 MT during 2018-19 with the contribution of inland sector being 9.71 MT (72%)[24] (Figure 1).

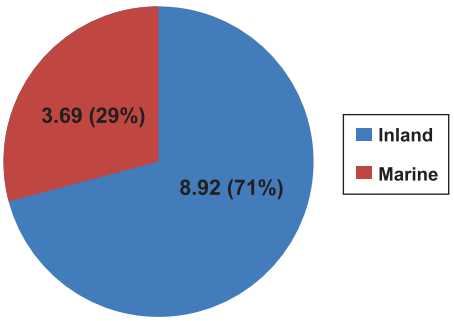


Figure 1: Marine and Inland fish production during 2017-2018.

India's aquaculture involves over 600 freshwater and marine species occupying various trophic levels. The freshwater aquaculture primarily depends on cultivating carp species. Some of the species used for freshwater aquaculture are Indian carps, catla (*Catla catla*), rohu (*Labeo rohita*) and mrigal (*Cirrhinus mirgala*) (contribute > 75% of the total freshwater fish production); silver carp, grass carp, pearl spot, tilapia, common carp and catfish (25%-30%). Besides, the giant freshwater prawn (scampi) is produced widely in freshwater ponds in West Bengal, Odisha, Andhra Pradesh, Telangana, Karnataka, Kerala, Bihar, Jharkhand, Madhya Pradesh, Chhattisgarh, Rajasthan and Uttar Pradesh[25].

22. Krishna Kumar.K, Rajeev, Raghavan, G.Prasad, A.Bijukumar, Minisekharan, Benno Pereira and Anvar Ali, 2009. When pets become pests – exotic aquarium fishes and biological invasion in Kerala. Current science, vol.97
23. Ravi Ranjan, Anjana Verma, 2017. A study on diversity of ornamental fish species available in Bokaro district of Jharkhand, India. International Journal of Zoology Studies. ISSN: 2455-7269, Impact Factor: RJIF 5.14, Volume 2; Issue 5; September 2017; Page No. 139-142.
24. Draft National, Inland Fisheries and Aquaculture Policy, F.No13001/12016-FY, Published by the MoAFW, GoI (source).
25. Thomson Jacob. C., Sugunan V.V., Meenakumari, B., 2019. Mainstreaming Biodiversity into Inland Fisheries and Aquaculture: A Key for food and nutritional security, ISBN: 978-81-940589-5-3. Published under the Centre for Biodiversity Policy and Law Programme (CEBPOL), National Biodiversity Authority (NBA).

The main brackish water fish species include mullets, milkfish, pearl spots, sea bass and crustaceans *viz. Penaeus monodon, P. merguiensis and P. semisulcatus, Fenneropenaeus indicus* and crab *Scylla serrata*. About 15% of the brackish water area is used for aquaculture purpose. Some of the traditional brackish water aquaculture practices in India include Bheries (manmade impoundments in coastal wetlands) in West Bengal and Pokkali cultivation (salt-resistant deep-water paddy) in Kerala. In the traditional system of Pokkali cultivation, tidal water is impounded in the inter-tidal mudflats by raising bunds during the low saline phase from (May-June) and the marketable sized fish and shrimps are harvested during spring (September-October). These systems have been sustaining production levels between 500-750 kg/ha/year with shrimps contributing 20-25 percent of the total production[26]. Geographical Indication has tagged Pokkali cultivation practices; it is widely cultivated in the coastal fields of Alappuzha, Ernakulam and Thrissur districts of Kerala and grown in over 5,000 hectares. Pelagic finfishes dominate marine fish landings contributing more than 50% of the marine capture fisheries. Indian oilsardine, mackerel, ribbon fish, lesser sardines and Bombay duck are the major fishes contributing to pelagic fish landings. Of this, oilsardine alone accounted for about 15% making it one of the single species fishery across the world. The major demersal resources include threadfin breams, croakers, silver bellies, bullseyes and catfishes. Crustaceans comprise high value resources like shrimps, crabs and lobsters. Molluscs comprising squids, cuttlefish, dams and oysters also contribute to marine capture fisheries. Mariculture research has strengthened across country by increased demand and importance in *Epinephelus coioides*, *Trachinotus blochii*, *Rachycentron canadum*, *Trachinotus mookalee*, *Lutjanus argentimaculatus* among many others (CMFRI, 2018).

1.5 Ecosystem services in the inland ecosystem

An ecosystem can be defined as a structural and functional unit of biosphere or segment of nature consisting of a community of living beings and the physical environment, both interacting and exchanging materials between them'[27]. Ecosystem services are the numerous and varied benefits that humans freely gain from the natural environment and the properly-functioning ecosystems. The Millennium Ecosystem Assessment report defines ecosystem services as services provided by the natural environment that benefits people, which includes: provisioning (food, water supply, raw materials); regulating (air, water quality and climate); supporting (genetic resources, nutrient cycling, production of oxygen, habitat for biodiversity) and cultural services (spiritual, religious, aesthetic, recreational, art and design)[28] (Figure 2).

26. Vision 2050. Published by ICAR-Central Institute of Brackish Water Aquaculture, ICAR, Tamil Nadu (www.ciba.res.in). CMFRI 2018. Annual Report 2017-18. Central Marine Fisheries Research Institute, Kochi. 304 p

27. Eugene P Odum; Gary W Barrett, 2005. Fundamentals of ecology, Published by Belmont, CA and Thomson Brooks Cole.

28. MA, Millennium Ecosystem Assessment: Ecosystems and Human Well being: Wetlands and Water. World Resources Institute, Washington, DC. 2005.http://www.maweb.org/documents/document.358.aspx.pdf. MA Scenarios. http://www.millenniumassessment.org/en/Scenarios.aspx.

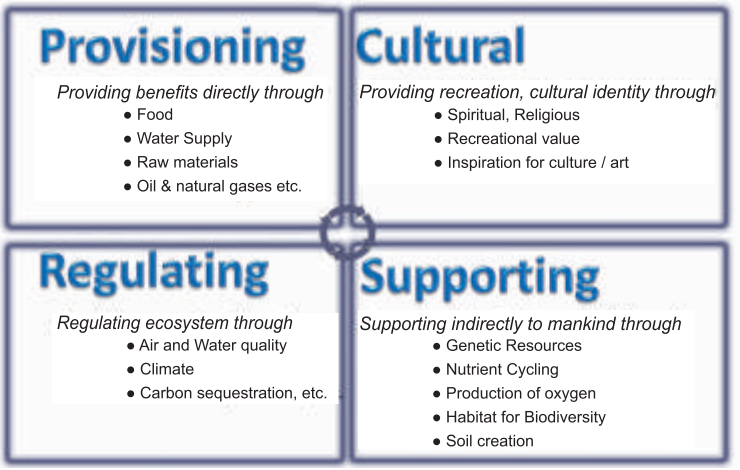


Figure 2: Ecosystem services provided by the inland ecosystem

The inland waters are characterized by high endemicity of freshwater species and it includes all life forms such as micro-organisms, aquatic plants, mangroves, fishes, prawns, crabs, snail, oyster, insects water birds, semi-aquatic animals such as amphibians, crocodiles, etc[29]. Biodiversity and ecosystems services are closely linked and the earth's diverse species are crucial for the functioning of ecosystems, which in turn provide essential goods and services on which local community, business, and global economies rely. According to FAO, natural resources and ecosystem services are the foundation of agrobiodiversity and therefore, its sustainable management requires the protection of both.

Biodiversity can be interpreted as a form of natural insurance for risk-averse ecosystem managers against the over or under-provision of ecosystem services, such as biomass production, control of water run-off, pollination, control of pests and diseases, nitrogen fixation, soil regeneration etc. Thus, biodiversity has an insurance value by providing resilience for current and future stocks. There are two categories of services provided by the aquatic ecosystem, namely 'fundamental' and 'demand-driven'. The 'fundamental ecosystem services' are essential for ecosystem function, resilience and they are prerequisite for human existence (e.g., plant, fish, animals and their products; fresh water, wood, fibre, medicine etc). The 'demand driven' ecosystem services (e.g., carbon sequestration, climate regulation, detoxification, waste decomposition, purification of waste water, flood protection, pest and disease control, mitigate natural disaster and pollination) are formed by human values and demands, and not necessarily fundamental for the survival of human societies. Nevertheless, all demand-driven ecosystem services ultimately depend on natural systems[30].

29. Convention on Biological Diversity (CBD), 2017(www.cbd.int).
30. Cecilia M. Holmlund, Monica Hammer, 1999. Ecosystem services generated by fish populations. Published in Elsevier Science, Ecological Economics 29 (1999) 253-268; 921-8009/99/S: PII: S0921-8009(99)00015-4. Natural Resources Management, Department of Systems Ecology, Stockholm University, S-106 91. Stockholm. Sweden.

1.6 Ecosystem valuation and incentive mechanism

Ecosystem valuation is the process of assessing a value to an ecosystem by quantifying its services (biodiversity-ecosystem function-ecosystem services-benefits-value) in terms of monetary value and their unprized flows of public goods and service benefits to people (e.g., direct values: fish, fruits, wood, medicine, fibre, tourism; indirect values: biodiversity conservation, grazing, groundwater recharge, habitat conservation, species conservation, carbon sequestration, irrigation).

An economic valuation is a tool used to compare natural capital to physical and human capital and their contributions to human welfare[31]. The ecosystem services can be measured using various economic valuation tools. The economic importance of most of these values can be measured in monetary terms and the economic valuation of bio-resources help policymakers in fixing taxes, controlling over-exploitation of environmental resources, conservation of biodiversity and in restoring degraded ecosystems[32]. It is emphasised that the valuation tools must be included in the policy framework for better decision making[33]. Some of the valuation methods used for estimating ecosystem services are as follows[34]:

1.6.1 Direct market valuation approaches

A) Market price-based approaches

The market-based approach is a method of determining the value of an asset based on the selling price and it estimates the economic value of ecosystem services or products that are bought and sold in the commercial markets. The market price can be taken as accurate information on the value of commodities, and the price of a commodity is an indicator of the value of the service provided by an ecosystem. For example, the value of ecosystem products or services that are bought and sold in commercial markets, such as fish, prawn, timber, medicine, honey, etc.

B) Cost-based approaches

Cost-based approaches are based on estimations of the costs that would be incurred if ecosystem service benefits needed to be recreated through artificial means[35]. The techniques available for computing the costs include the avoidance cost method; replacement cost methods and mitigation or restoration cost method.

i) Avoidance cost method

The avoided cost method is used to estimate the cost paid for the natural assets, such as mangroves, coral reefs for protecting the properties from natural disasters like cyclone,

31. Shuang Liu, Robert Costanza, Stephen Farber and Austin Troy, 2010. Ecological Economics Reviews - Theory, practice, and the need for a trans-disciplinary synthesis. Valuing ecosystem services. Ann. N.Y. Acad. Sci. 1185 (2010) 54–78 c 2010 New York Academy of Sciences, ISSN 0077-8923.
32. Roel Slootweg and Pieter van Beukering. 2008. Valuation of Ecosystem Services and Strategic Environmental Assessment Lessons from Influential Cases ISBN: 978-90-421-2537-7.
33. An introductory guide to valuing ecosystem services. Published by the Department for Environment, Food and Rural Affairs Nobel House 17 Smith Square London SW1P 3JR Website: www.defra.gov.uk.
34. McVittie A., Hussain S. S. (2013) The Economics of Ecosystems and Biodiversity – Valuation Database Manual.
35. Garrod, G.D., Willis, N.D., 1994. 'Valuing biodiversity and nature conservation at a local level'. Biodiversity and Conservation 3,555–565.

storms etc, which relates to the costs that would have been incurred in the absence of ecosystem services. The avoidance and averting cost helps in the early diagnosis of environmental issues and helps in avoiding future environmental damage or biodiversity loss.

ii) Replacement cost method

Replacement cost is used to calculate the investment made for technologies for replacing or restoring an ecosystem service provided by an ecosystem. E.g., wetlands provide important services of drainage, natural irrigation, stormwater protection and flood mitigation, etc. In the urban areas, the wetland services are replaced by water treatment plants.

iii) Mitigation cost-based evaluation method

Mitigation cost-based valuation methods are a group of 'exchange-based' techniques that use the cost of actual measures to maintain ecosystem service provision as a proxy for the value of avoiding, mitigating or restoring the loss of services the ecosystem provides. Cost-based methods give a conservative estimate of the value of ecosystem services, provided that the most cost-effective actions for avoiding, mitigating, restoring, compensating and offsetting environmental damages have been undertaken.

C) Production functions

Production function approaches (PFA) estimate how much a given ecosystem service (e.g., regulating service) contributes to the delivery of another service or commodity which is traded on an existing market. The PFA can be used in situations where a marketed good or service is produced with both man-made and ecosystem inputs. For example, several crops depend on insect pollination. An increase in yield resulting from the pollinator services component can be estimated through PFA. The challenges involved in its application are that the data on the relationships between the services (regulation and provision services) and on other non-environmental inputs are often difficult to obtain.

(i) Revealed preference approaches

Revealed preference techniques are based on the observation of individual choices in existing markets that are related to the ecosystem services for valuation. In this case, it is said that economic agents “reveal” their preferences through their choices. The two main methods within this approach are:

(a) Travel cost method

The travel cost method is used to assess the non-market value of recreational sites. This tool is used to calculate how much people are willing to pay for their travel to nature/recreational sites. The travel cost method is most relevant for determining recreational values related to biodiversity and ecosystem services. It is based on the rationale that recreational experiences are associated with a cost. The value of a change in quality or quantity of a recreational site can be inferred from estimating the demand function for visiting the site that is being studied[36].

36. Bateman, I.J., Mace, G.M., Fezzi, C., Atkinson, G.,Barbier, E.B. and Turner, K. 2010. Economic analysis for ecosystem services assessment, Drat paper, Na onal Ecosystem Assessment, Defra, London. Bergstrom, J.C., St

(b) Hedonic pricing approach

The price of real estate is determined based on environmental assets. In the real estate business, park facing, lake view and beach view property gets a premium price. The property values in the real estate business are associated with the aesthetic qualities of natural ecosystems. The hedonic method is used to quantify the environmental services that have a direct impact on market prices. For instance, houses or property in general consist of several attributes, some of which are environmental, such as the proximity of a house to a forest or whether it has a view to a nice landscape. Hence, the value of a change in biodiversity or ecosystem services will be reflected in the change in the value of the property (either built-up or land that is in a (semi-) natural state). By estimating a demand function for a property, the analyst can infer the value of change in the non-marketed environmental benefits generated by the environmental good.

D) Stated preference approaches

Stated preference approaches simulate a market and demand for ecosystem services through surveys on hypothetical (policy-induced) changes in the provision of ecosystem services. Stated preference methods can be used to estimate both use and non-use values of ecosystems and/or, when no surrogate market exists from which the value of ecosystems can be deduced. The main types of stated preference techniques are:

(i) Contingent valuation method

This method uses questionnaires to ask people how much they would be willing to pay to increase or enhance the provision of an ecosystem service, or how much they would be willing to accept for its loss or degradation. Contingent valuation is a technique used to measure environmental parameters. (e.g., willingness to pay for cleaner air, clean water, green belt, biodiversity conservation, wetland conservation, etc.). It is an economic tool used for valuing non-market resources such as wetland, lake, mountain, biodiversity, the natural beauty of an ecosystem, etc. This tool is used to calculate how much money people are willing to pay for the maintenance of environmental aesthetics.

(ii) Choice modelling

The contingent choice method can be used to estimate economic values virtually for any ecosystem or environmental service, and can be used to estimate non-use as well as use-values. The contingent choice method asks the respondent to state a preference between one group of environmental services or characteristics, at a given price or cost to the individual, and another group of environmental characteristics at a different price or cost. As it focuses on tradeoffs among scenarios with different characteristics, the contingent choice is especially suited to policy decisions where a set of possible actions might result in different impacts on natural resources or environmental services. For example, improved water quality in a lake will improve the quality of several services provided by the lake, such as drinking water supply, fishing, swimming, and biodiversity.

1.6.2 Access and benefit-sharing and Nagoya Protocol

The Nagoya Protocol on Access to Genetic Resources is a supplementary agreement to

the CBD to provide a legal framework for the implementation of it's objectives. India was among the first signatories to this agreement. The Nagoya Protocol was the basis for formulating the guidelines for Access and Benefit Sharing (ABS) and the ABS guidelines were notified by India under the Biological Diversity (BD) Act. The agreement generates incentives to conserve, sustainable use of genetic resources (GRs), and offers greater legal certainty and transparency for both the resource providers and the resource users. It also helps to ensure benefit-sharing, when GRs leave the country of origin.

Under the ABS principle, the benefit should be shared with the resource provider countries. The sharing is subject to mutually agreed terms and the benefits may be monetary or non-monetary, such as royalties, sharing of research results, etc. The access to the GRs has to be subject to prior informed consent or approval and involvement of indigenous and local communities based on fair and non - arbitrary rules and procedures. The protocol's objective also stresses appropriate transfer or relevant technologies and appropriate funding as a set of means to equitable benefit sharing that would promote the conservation of biological diversity and the sustainable use of its components. The traditional knowledge associated with GRs is also addressed in the Nagoya Protocol[37].

37. Shivendu K. Srivastava, 2017. Users' Guide to Access and Benefit Sharing. Published by the National Biodiversity Authority.

2.0 Concerns

The IUCN Red List says that globally 37,400 species have been threatened, which includes: 41 percent of amphibians, 36 percent sharks and rays, 33 percent of reef-building corals, 26 percent of mammals, 14 percent of birds, and 34 percent of conifers. Over the past 50 years, ecosystems have been extensively modified to meet the demands for natural resources from a rapidly growing global population. As a result, it is estimated that around 60% of examined ecosystem services are now degraded or being used unsustainably (Millenium Ecosystem Assessment, 2005). Moreover, human-induced climate change, as well as a growing human population and economic expansion, has continued to exacerbate ecosystem degradation and biodiversity loss. One of the primary threats to freshwater biodiversity worldwide is river impoundment and modification of natural hydrologic regimes as it affects the species composition and community structure by ecosystem fragmentation, extirpation of native species dependent on lotic conditions and changes in patterns of trophic structure and energy flow. These alterations disrupt the ability of an ecosystem to provide goods and services.

2.1 Pollution

The quality of aquatic resources of the country is deteriorating significantly with increasing pollution caused by rapid industrialisation and indiscriminate unscientific discharge of wastewater in inland water bodies. The Central Pollution Control Board has reported that nearly 61,948 million litres of urban sewage are generated daily in India. The existing sewage treatment infrastructure has capacity to handle only 38% of the amount. As a result, more than 38,000 million litres of waste water goes into the major rivers, water bodies and percolate into the groundwater. The top five states sharing the maximum number of polluted stretches are Maharashtra, Assam, Madhya Pradesh, Gujarat and West Bengal and the estimated polluted river length is 12,363 km[38] covering 351 rivers stretches which include 650 towns and 35 cities. About 70-80 percent of the pollution load in rivers such as Ganga and Yamuna contain organic waste, sewage, trash food and human and animal remains which lead to eutrophication. The remaining 20-30 percent is effluents from industries, carrying chemicals that impact the ecosystem integrity and biota. The industrial effluents include a wide variety of chemical toxicants and heavy metals contributing substantially to the Biological Oxygen Demand (BOD).

2.2 Agricultural runoff

The chemical intensified agricultural farming has led to the usage of large quantities of agrochemicals, organic matter and drug residues. These chemicals pollute the surface/groundwater and pose high risks to aquatic ecosystems and human health[39]. In the food

38. State of India's Environment, 2018. Published by the Centre for Science and Environment, New Delhi.
39. UNEP. 2016. A snapshot of the world's water quality: towards a global assessment. Nairobi, United Nations Environment Programme (UNEP).

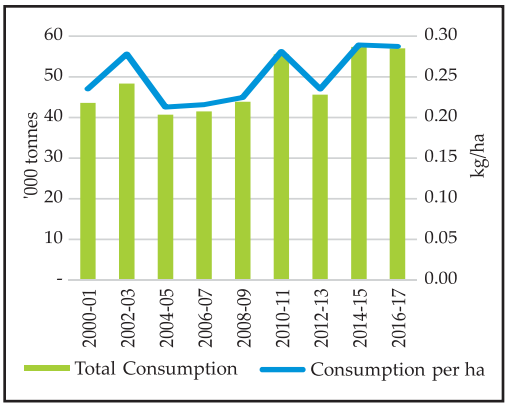
cycle, some of these unused chemicals get mixed with soil, water and plants and it bio-accumulates, bio-magnifies and finally enters into the human system and causes health risk. Though, few assessments of acute toxicity are in place, assessment of the impact of chronic toxicity across biota are lacking. The chemical fertilizers used to supplement nutrient sources often result in eutrophication in aquatic bodies. Studies have reported the complex effects of fertilizers on community structure. Some of the impacts caused due to eutrophication include increase in production and biomass of phytoplankton, algae, macrophytes; shift in habitat of the aquatic organism; production of toxins by certain algae; changes in water quality; loss of recreational use of water due to slime, weed infestation and noxious odour from the decay of aquatic plants and animals.

Globally, the use of chemical fertilizer, insecticide and pesticide has increased and this has led to the decline of wild bees and honeybees. Agricultural production depends upon pollinators. More than 75 percent of the crops are pollinated by bees, and the absence of pollinators will lead to the loss of productivity. Neonicotinoids dissolve in water and easily make their way into waterways via agricultural runoff. It is reported that around 8,500 detections of pesticides in bee and incident-related plant samples submitted to the European pesticide poisoning incident (bee-kill) schemes and nearly 50% contained insecticides, 40% contained fungicides and 11% contained varroacides[40].

In European Union, nearly 38 percent of water bodies were polluted due to agricultural runoff [41] and in United States of America, the intensified farming had led to the contamination of rivers, streams, wetlands and lakes[42]. Globally it was reported that nitrate is the major source of contaminant for groundwater aquifers. India ranks second in the total world consumption of fertilizer and this has increased from 69.84 kg per/ha in 1991-92 to 128.08kg/ha in 2014-15. The total production of major chemicals and petrochemicals during 2018-19 was 27,847 thousand MT, in which pesticides and insecticide production were around 217 thousand MT[43].

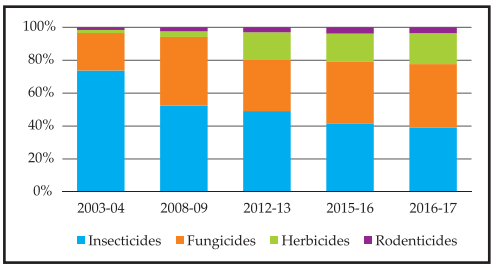
There is a significant increase in the consumption of pesticides in India (Fig. 3), during the year 2014-15, pesticide consumption was 0.29 kg/ha of the Gross Cropped Area (GCA)[44]. The Agricultural Input Survey data has shown that, during the year 2011-12, the

40. IPBES (2016). The assessment report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services on pollinators, pollination and food production. S.G. Potts, V. L. Imperatriz-Fonseca, and H. T. Ngo, (eds). Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Bonn, Germany. 552 pages.
41. Nations World Water Assessment Programme (WWAP) 2015. Water for a sustainable world. UN WWAP, Paris, United Nations Educational, Scientifc and Cultural Organization.
42. US EPA 2016. Water quality assessment and TMDL information. Washington, DC, United States Environmental Protection Agency (US EPA) (https://ofmpub.epa.gov/waters10/attains_ index.home).
43. Annual Report 2018-2019. Published by the Government of India Ministry of Chemicals & Fertilizers Department of Chemicals and Petrochemicals, Shastri Bhawan, Dr. Rajendra Prasad Road,New Delhi.



Source: Based on data from Ministry of Chemicals and Fertilizers.

Figure 3: Trend in consumption of pesticides in India



Source: Ministry of Chemicals and Fertilizers.

Figure 4: Share of pesticide groups in total pesticide production

application of pesticides were high in cotton (66.70%), arhar (64.74%), jute (53.27%) and paddy (48.62%) and low in maize (25.01%). Pesticide production is dominated by insecticides, fungicides, herbicides and rodenticides (Fig.4). The major pesticides produced in India include Mancozeb, 2,4-D, Acephate and Profenofos[44].

The excess concentration of pesticides in the river system brings anoxic conditions to the aquatic ecosystems, which prevents the development of eggs, inhibit reproduction, causes dysfunction of the ecological system, affects the endocrine system of an organism and immensely contributes to the loss of biodiversity[45]. Pesticides have a significant role in deaths, cancers, tumours and lesions on fish and other aquatic organisms. The pesticides in the aquatic ecosystem suppress the immune system,

44. Subash, S.P., Prem Chand, Pavitra S., Balaji. S.J., and Suresh Pal , 2017. Policy brief-pesticide use in Indian agriculture. Published by ICAR-National Institute of Agricultural Economics and Policy Research (source).
45. Ulrich Kremser, Ewald Schnug, 2002. Impact of fertilizers on aquatic ecosystems and protection of water bodies from mineral nutrients. Published in: Landbauforschung Völkenrode 52(2002)2, pp.81-90

cause cellular and DNA damage and teratogenic effects (physical deformities). These chemicals also result in bioaccumulation in non-target organisms, as several of these pesticides are rapidly soluble in fat[46]. The Central Pollution Control Board has reported that around 12,363 km of river stretches are polluted due to sewage discharge, human and animal remains, industrial effluents and agricultural runoff[47].

2.3 Water abstraction

In India, natural flow of all major rivers have been diverted for fulfilling the water demand of the agriculture and power sectors, and this has resulted in the loss of aquatic resources. The abstraction of river water changes the water balance, hydro morphology and biocenosis components of an ecosystem. Reducing or blocking a river's continuity by creating a sill or dam will affect the migratory pattern of the fishery resources. The riverine fishes are extremely sensitive to change in flood regime because of their dependence on seasonal floods, which inundate the grounds needed for feeding and reproduction. The sizable fractions of the resident fishes that take shelter in the systems are destroyed when the water level decreases to a minimum. Similarly, many of the mature fishes coming from the lower reaches for breeding to the upstream during monsoon and post-monsoon seasons are killed due to water abstraction or minimum water flow in the riverine system[48].

Fisheries in Krishna, Godavari, Mahanadi, Pennar, Narmada, Tapi, Sabarmati, Mahi and Cauvery estuaries have declined due to the absence of fresh water all round the year and destruction of the mangrove forests. Salinity changes due to water abstractions are affecting mangrove forests of Bhitarkanika and Sunderbans, which are breeding and nursery grounds of several freshwater as well as marine fishes. Riverine and estuarine fisheries in Narmada are affected by the Sardar Sarovar, Narmada Sagar, Omkareshwar, Maheshwar, Tawa and Bargi Dams and reduced flows to the estuary. The Central Inland Fisheries Research Institute (CIFRI) has reported that the “water abstractions” affected the recruitment of several species and curtailed the livelihood options of the local communities[49].

2.4 Environmental flows

Dams and weirs are built to generate electricity, flood control, water supply, and irrigation, which affects the transportation of natural sediment, resulting in the retention of sediment upstream from dams and consequently leads to the loss of sediment downstream. Dam construction has a significant effect on ecological continuity and it

46. Anju Agrawal, Ravi S. Pandey, Bechan Sharma, 2010. Water Pollution with Special Reference to Pesticide Contamination in India. Published in the Journal of Water Resource and Protection, 2010, 2, 432-448
47. Annual Report 2015-16. Central Pollution Control Board, MoEFCC, GoI.
48. Joshi K.D and Lal K.K, 2017. Status of Coldwater Fish Diversity in India and Strategies for Conservation. Published in the Souvenir on National seminar on 'Strategies, innovations and sustainable management for enhancing, Coldwater fisheries and aquaculture, ICAR-DCFR, Bhimtal, Nainital.
49. Pathak et al, Riverirne Ecology and Fisheries, vis a vis hydrodynamic alterations: Impacts and Remedial measures, CIFRI, 2010.

prevents fish from migrating from upstream to downstream. It causes an increased fish mortality, when it passes through hydraulic turbines during their downstream migration. Hilsa is a classic example of anadromous fish affected due to obstruction in upriver migratory path due to barrages and dams. The lucrative Hilsa fishery, recorded up to 350 km of upper stretches above the Farakka barrage, has collapsed after commissioning the barrage in 1972. The Buxar landing centre recorded a mean catch of less than 2 tonnes of Hilsa from 1972 to 1986 (after erecting the Farakka barrage in 1972), against a massive catch of 41.3 tonnes recorded in the pre-Farakka period (during 1961 to 1967)[50]. Catadromous migrants like eels, freshwater prawns and catfish (*Pangasius pangasius*) have also been affected by the barrage. Mahseer, once an abundant game and food fish in India, is now on the list of endangered species, with extremely limited range in river Narmada due to dams and barrages[51].

2.5 Sedimentation

The erosion of topsoil in the catchment area leads to increased sedimentation load in rivers, which reduces transparency, light penetration and chemical quality of water. Removal of forest cover in the slopes for logging, cattle grazing and road makes the soil susceptible to erosion, leading to increased sedimentation in the river. Heavy siltation from catchment areas cut off floodplain oxbow lakes and deep pools during summer. During heavy rain, the silt, cobbles and boulders from the mountain slopes find their way to adjoining streams, rivulets, rivers, lakes and reservoirs and deteriorate the feeding and breeding grounds of fishes. The sudden influx of the massive silt load in the stream or river waters, after heavy rains, causes choking of the gill rakers and eye, causing mass mortality in fishes and also affecting the breeding process. Fish mortality also occurs when the residues of forest fire alter the physicochemical parameters of the natural waters[52]. Forest fire increases the water temperature, reduces the solubility of the dissolved oxygen, increases pH, nutrient level and sedimentation. Sedimentation, gives way to the low-value exotic species, exhibiting an alarming swing in the population structure. During 1995-2000, the Ganga silt load increased up to 20 times at Allahabad and 30 times at Varanasi and this has coincided with the worst fishery period for the river. In Allahabad, the yield of major carps and large catfish has come down from 935 kg/km in the sixties to 368 kg/km in 2001-06 due to sedimentation. The exotics have increased sharply as they prefer lower and more stagnant water levels which are not preferred by the carps[53].

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50. Sinha, M., De, D. K. & Jha, B. C. 1998.The Ganga-Environment & Fishery. Central Inland Capture Fisheries Research.
51. Cumulative Impacts of Hydropower Dams on Alaknanda & Bhagirathi Rivers on Aquatic and Terrstrial Ecosystems, Wildlife Institute of India, 2012
52. Joshi K.D and Lal K.K, 2017. Status of Coldwater Fish Diversity in India and Strategies for Conservation. Published in the Souvenir on National seminar on 'Strategies, innovations and sustainable management for enhancing Coldwater fisheries and aquaculture, ICARDCFR, Bhimtal, Nainital.
53. Pathak et al, Riverine Ecology and Fisheries, vis a vis hydrodynamic alterations: Impacts and Remedial measures, CIFRI, 2010

2.6 Destructive fishing

Destructive fishing practices are reported in most of the riverine systems and people catch fish with the help of locally fabricated gears such as cast nets, gill nets, mosquito net, traps, rod and lines. The fishers are almost completely replaced by poachers in the smaller streams or rivers during summer when the water level is at its minimum. Several highly destructive and illegal fishing methods, such as dynamite fishery, poisoning using plant extracts, electrocution, complete sieving and mass destruction of fishes on religious grounds are practised in the hilly regions. The Indian Fishery Act, 1897 stipulates restrictions in the destruction of fish by explosives, poisoning in inland waters and on the coast.

2.7 Invasive alien species (IAS)

In India, around 300 exotic fish species have been brought for sport fishing, mosquito control, aquaculture and aquarium purposes. The exotic species compete with the indigenous fishes and cause genetic 'erosion' of indigenous species and degrade the aquatic ecosystems[54]. Of the eight worst invasive fish species in the world, five were present in India. Mosquito fish (*Gambusia affinis*) was introduced for the biological control of mosquito larvae; Brown trout (*Salmo trutta*) and Rainbow trout (*Oncorhynchus mykiss*) were introduced for recreational and consumption purposes. These three highly predatory fishes eat the eggs of economically desirable fish and prey on endangered rare indigenous fish and invertebrate species. The population of common carp (*Cyprinus carpio*) and Mozambique tilapia (*Oreochromis mossambicus*) are increasing in river Ganga. The occurrence of African catfish is reported in rivers such as Yamuna, Sutlej, Ganga, Godavari and Periyar and Vembanad lakes[55]. In Kerala, the occurrence of tilapia has brought the extinction of native species such as *Labeo kontius* and *Puntius dubius*[56].

In India, around 600 exotic ornamental fish species dominate the aquarium trade and are propagated for domestic and export purposes. About 96 percent of ornamental fishes are freshwater species and many of these species escape from culture facilities and some are deliberately released into the riverine system. It is reported that nearly 85 percent of the ornamental fish are caught from the wild stock for export purposes. The ornamental alien fishes alter the aquatic ecology and hybridize with native species and dilute the wild genetic stock leading to long-term introgression of gene pools[57]. An European study evaluated the ecological damage and financial cost of Invasive Alien

54. A. Biju Kumar, 2000. Exotic Fishes and Fresh water Fish Diversity, ZOOS' OPINION ZOOS' PRINT JOURNAL 15(11): 363-36, Published by the Science, Technology and Environment Department, Sasthra Bhavan, Near Planning Board Office, Pattom, Thiruvananthapuram, Kerala, India.
55. Singh, A.K. 2014. Emerging Alien speciesin Indian Aquaculture: Prospecys and threats. Journal of Aquatic Biology and Fisheries, 2(1) 2014:32-41
56. Pimentel. D et al 2001. Economic and environmental threats of alien plant, animal and microbe invasions. Agriculture, Ecosystem and Environment 84:1-20.
57. Sandilyan, S. et al, 2018. A review on Impacts of invasive alien species on Indian inland aquatic ecosystems. Published by CEBPOL, National Biodiversity Authority, Chennai, ISBN: 978-81-932753-3-7.

Species. This study has reported that a single-celled toxic algae in Norway (8.2 million euro/year) and water hyacinth in Spain (3.4 million euro/year) and the coypu in Italy (2.8 million euro/year) have brought considerable damage to the environment[58]. Some of the plant invasive species reported in India includes water hyacinth (*Eichhornia crassipes*), pink morning glory (*Ipomea carnea*), butterfly fern (*Salvinia auriculata*), parrot's feather (*Myriophyllum aquaticum)*, and reed canary grass (*Phalaris arundinacea*). It is documented that, the water hyacinth causes heavy siltation in the wetland, blocks irrigation channels and obstruct the flow of the water to the crop field.

58. Anne-Marie Harper, 2015. The Handbook for management and restoration of aquatic ecosystems in river and lake basins, ISBN: 978-91-87823-15-2.

3.0 Biodiversity Governance

Biodiversity governance can be defined as 'how stakeholders participate effectively in policy setting and decision making based on the rule of law of transparency, equity and accountability. India is a signatory to various Multilateral Environmental Agreements (MEAs) and has enacted various legal frameworks and policies towards safeguarding natural resources.

3.1 International conventions

India is committed to various international conventions, such as the United Nations Convention on Law of Seas (UNCLOS), Convention on Conservation of Migratory Species (CMS), Ramsar Convention on Wetlands, 1982, United Nations Framework Convention on Climate Change (UNFCCC), Convention on Biological Diversity (CBD) 1993, Food and Agriculture Organisation (FAO) guidelines on eco-labelling for inland fisheries; FAO technical guidelines for aquaculture certification, FAO technical guidelines for small scale fisheries and FAO Code of Conduct for Responsible Fisheries (CCRF). The CCRF is a voluntary set of global principles, that guides countries in formulating and implementing responsible fisheries management policies and practices. The CCRF was adopted by FAO members in 1995 and it serves as an important reference point for setting international standards for responsible practices, mainly aimed at effective conservation and management of biodiversity along with ecosystem.

3.2 National legislations and policies

At the National level, India has enacted various legislation to conserve the inland aquatic resources, which includes: Indian Fisheries Act, 1897; Indian Wildlife Protection Act, 1972; Water (Prevention and control of pollution) Act, 1974; Environment (Protection) Act, 1986; Biological Diversity Act, 2002; Coastal Aquaculture Authority Act, 2005; Wetlands (Conservation and Management) Rule, 2017; and Coastal Regulation Zone Notification, 2018.

The draft National Mariculture Policy (NMP) supports rearing brood bank and hatchery; rearing of juveniles to a size conducive for stocking and aquaculture of marine plants and animals. It also supports culture-based fisheries; capture-based aquaculture; conservation of endangered, threatened and protected (ETP) species for the replenishment of marine stocks; farming of non-food species, such as microbes, algae and seaweeds for the extraction of bioactive compounds, biomarkers, bio-fuel, biochemical's, nutraceuticals and natural growth promoters it also supports farming of marine ornamental fishes, invertebrates, pearl and oysters[59].

59. Draft National Mariculture Policy, 2019, Published by CMFI, MoA & FW, GoI.

The Department of Fisheries (Ministry of Fisheries, Animal Husbandry and Dairying), Government of India has brought out a draft National Fisheries Policy, 2020 towards the restoration of natural productivity and conservation of indigenous fisheries resources. It guides States/UTs to put in place appropriate plans for habitat conservation, measures for the protection and rehabilitation of native fish stocks. The population of native species in the rivers will be enhanced through seed ranching (native stock) by developing dedicated seed production units in the vicinity. Some of the fishing regulations advocated are closed season, mesh size, wanton killing of juveniles, destructive fishing, etc. It also says that the ecological integrity of important natural wetlands has to be conserved and restored for the promotion of sustainable fisheries; and the connectivity between natural wetlands and rivers has to be maintained. The States/UTs will demarcate public water bodies, prevent encroachments and regulate their use. Facilities for hatcheries and seed rearing will be developed in the vicinity of potential areas following scientific practices and State/ UTs to declare water bodies as "Reserves for fish" to conserve important fish species in the suitable wetland.

3.3 Aichi and National Biodiversity Targets

The tenth meeting of the Conference of the Parties to the Convention on Biological Diversity (CBD), held in Nagoya, Aichi Prefecture, Japan, 2010 has adopted a revised Strategic Plan for Biodiversity, including the Aichi Biodiversity Targets, for 2011-2020 period. This Plan provides an overarching framework for the entire United Nations system. The CBD has urged parties to develop national and regional biodiversity targets, using the strategic plan and its global Aichi targets[60]. The Aichi target emphasises that 17 percent of terrestrial and inland water areas, especially areas of particular importance for biodiversity and ecosystem services are conserved by well-connected systems of PAs and effective relevant conservation measures. Some of the Aichi targets related to the inland water bodies are elaborated in Table 4[61].

In line with the CBD's Strategic Plan 2011–2020, India has formulated 12 National Biodiversity (NBT) Targets[62]. Responses and suggested actions to key targets are mentioned below.

60. CBD Wesite: www,cbd.int/sp/targets
61. Strategic Plan for Biodiversity 2011-2020, including Aichi Biodiversity Targets. Web source: www.cbd.int/sp/default.shtml
62. National Biodiversity Action Plan (NBAP) Addendum, 2014 to NBAP 2008. Published by the MoEFCC, GoI.

Table 4: Aichi biodiversity targets

	By 2020, at the latest, biodiversity values have been integrated into national and local development and poverty reduction strategies and planning processes and are being incorporated into national accounting, as appropriate, and reporting systems.
	By 2020, the rate of loss of all natural habitats, including forests, is at least halved and where feasible brought close to zero, and degradation and fragmentation is significantly reduced.
	By 2020 all fish and invertebrate stocks and aquatic plants are managed and harvested sustainably, legally and applying ecosystem based approaches, so that overfishing is avoided, recovery plans and measures are in place for all depleted species, fisheries have no significant adverse impacts on threatened species and vulnerable ecosystems and the impacts of fisheries on stocks, species and ecosystems are within safe ecological limits.
	By 2020 areas under agriculture, aquaculture and forestry are managed sustainably, ensuring conservation of biodiversity.
	By 2020, pollution, including from excess nutrients, has been brought to levels that are not detrimental to ecosystem function and biodiversity.
	By 2020, invasive alien species and pathways are identified and prioritized, priority species are controlled or eradicated, and measures are in place to manage pathways to prevent their introduction and establishment.
	By 2020, at least 17 per cent of terrestrial and inland water, and 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well connected systems of PAs and other effective area-based conservation measures, and integrated into the wider landscapes and seascapes.
	By 2020 the extinction of known threatened species has been prevented and their conservation status, particularly of those most in decline, has been improved and sustained.
	By 2020, ecosystems that provide essential services, including services related to water, and contribute to health, livelihoods and well-being, are restored and safeguarded, taking into account the needs of women, indigenous and local communities, and the poor and vulnerable.

3.4 Achievements of National Biodiversity Targets

Target 1: By 2020, a significant portion of the country's population, especially youth, is aware of the values of biodiversity and steps they can take to conserve and use it sustainably.

Response: The All India Council for Technical Education (AICTE) and the State education departments promote the integration of environmental concepts and issues in the curricula of schools and colleges. The National Policy on Education, 1986 stressed creating consciousness about the environment, including biodiversity. Some of the initiatives of MoEFCC are the National Environmental Awareness Campaign, National Green Corps programme, Paryavaran Mitra (friends of the environment) programme. The Environmental Information System was established as a planned programme of Government of India for collecting, collating and disseminating environmental information to various users, which includes decision-makers, researchers, academicians and policy planners, etc.

Action:

- The fish resources database available with the ICAR-National Bureau of Fish Genetic Resources can be shared with the National Biodiversity Authority for the preparation of the Electronic Peoples' Biodiversity Register (E-PBRs).
- The list of native species available in the aquatic water bodies can be shared with the local Biodiversity Management Committees (BMCs) and awareness needs to be created for conserving these species.

Target 2: By 2020, values of biodiversity are integrated with national and state planning process, development programmes and poverty alleviation strategies.

Response: India has enacted the Mahatma Gandhi National Rural Employment Guarantee (MGNREG) Act in 2005 to promote livelihood security in rural areas. The objective of the act is to create durable assets and strengthen the livelihood resource base of the rural poor. India is also working on developing an Environmental Performance Index (EPI). The EPI is to serve as a measure of a State's green initiatives and is to be linked to financial assistance from the centre to states. Under the Economics of Ecosystem and Biodiversity (TEEB) initiative, the MoEFCC has evaluated the natural capital and ecosystem services values of different ecosystems namely forest, wetland and coastal and marine ecosystem. There is a need to evaluate ecosystem services of the inland water bodies so that it helps the policymakers to take appropriate policy decisions for conserving the inland resources.

Action:

- Valuation of ecosystem services provided by the inland open waters such as river stretches, wetlands must be carried out. This will help the policymakers to prioritize, manage and conserve the biodiversity-rich areas.
- A suitable Indian model for the valuation of ecosystem services is needed. To facilitate this, a pilot study needs to be implemented.

Target 3: Strategies for reducing the rate of degradation, fragmentation and loss of natural habitats are finalized and actions put in place by 2020 for environmental amelioration and human well-being.

Response:

India is endowed with vast forest resources. To increase the forest cover, the National Afforestation and Eco-Development Board provide support to the Forest Development Agency through the National Afforestation Programme. Green India Mission is one of the eight missions under the National Action Plan on Climate Change and the objectives of the Mission is to increase forest/tree cover of 5 m.ha of forest/non-forest lands and improving the quality of forest cover of another 5 m.ha of non-forest/forest lands. The Chilika lake restoration has brought several positive changes in the lagoon area, which

includes: the reappearance of 6 species of fish, 4 prawns, 7 crabs, and 2 Indian spiny lobster; decrease in area under the freshwater weed water hyacinth, expansion of seagrass meadows and increase in population of Irrawaddy dolphin from 70 to 152.

India has declared 42 wetlands as Ramsar sites. The National Wetland Inventory and Assessment, 2011 identifies 2.02 lakh wetlands in India, covering an area of 1.52 crore hectares. This amounts to 4.63 percent of the geographic area.

Action

1. The existing water infrastructure can be made more amenable to fisheries and other sectors through interventions like minimum flow requirement/ environmental flows, installing fish passes or ladders and protecting the fish migratory pathways by designating them as sanctuaries.
2. The wetlands (Conservation and Management) rules require the states to prepare inventories of wetlands within their jurisdiction and prioritise them for regulation and management.
3. Some of the pristine rivers with high biodiversity value can be declared as PAs and we need to identify such protected riverine zones in each ecological zone in every state.

Target 4: By 2020, Invasive alien species and pathways are identified and strategies to manage them are developed so that populations of prioritized invasive alien species are managed.

Response:

The Convention of Biological Diversity (CBD, 2002), defines invasive alien species (IAS) as 'a species, sub-supecies or lower taxon, introduced outside its natural past or present distribution, which includes any part, gametes, seeds, eggs or propagules of such species that might survive and subsequently reproduce[63]. The Zoological Survey of India (ZSI) has recorded 159 IAS in India. Out of which, 58 species are found in land and fresh water habitat and 99 species are found in marine ecosystem (ZSI, 2017)[64]. Under the Centre for Biodiversity Policy and Law (CEBPOL) program, a review study was carried out on the impact of IAS on India's coastal and inland aquatic ecosystem (Sandilayan, 2018 et. al., 2018)[65]. India's National Biodiversity Action Plan (NBAP) calls for developing strategies for managing the IAS and so far, India do not have any policy framework for controlling the spread of IAS.

63. CBD, 2002. Decision VI/23 (Annex, footnote): Alien species that threaten ecosystems, habitats and species, Document UNEP/CBD/COP/6/23. Convention on Biological Diversity Secretariat, Montreal, Canada (Web source: https://www.cbd.int/decision/cop/?id=7197.
64. ZSI, 2017. Biodiversity under Alien attack, Published in the Hindu (Web source: https://www.thehindu.com/sci-tech/energy-and-environment/biodiversity-under-alien-attack/article21823042.ece).
65. S. Sandilyan et al., 2018. Guidelines for prioritization of invasive alien plants of India for management. Published by National Biodiversity Authority, Chennai, India.

Action:

- To identify the extent of damage caused by the spread of animal and plant invasive species in the inland water bodies through research study using valuation tools;
- It is recommended to list out the worst aquatic invasive alien species of India and strategies need to be developed for managing and controlling the spread of these species.

Target 5: Ecologically representative areas under terrestrial and inland waters, and also coastal and marine zones, especially those of particular importance for species, biodiversity and ecosystem services, are conserved effectively and equitably, based on protected area designation, management and other area-based conservation measures and are integrated into the wider landscapes and seascapes, covering over 20% of the geographic area of the country, by 2020.

The Aichi biodiversity target and the proposed global framework 2020 suggest countries to increase the PAs and adopt other area-based conservation measures for conserving biodiversity. The proposed 2020 framework has asked countries to increase 30 percent of the terrestrial waters and contiguous zones of semi-enclosed seas. It also says that by 2030 at least 30% of the earth be covered by well-connected systems of PAs and Other Effective Area-Based Conservation Measures (OECMs) and managed, where appropriate, as ecological networks.

Response:

India has over 20 percent of the total geographical area under biodiversity conservation, thereby exceeding the global Aichi target of 17 percent. India is taking action for increasing the area of "other area-based conservation measures", along with the PAs designated under the Wildlife (Protection) Act, 1972. India has 769 PAs covering 1, 62,072 sq. km, which includes national parks, wildlife sanctuaries, community reserves and conservation reserves. It also has 25 Marine Protected Areas (MPAs) covering 8231.49 sq. km and nearly 9,14,074 sq. km areas covered under the Wildlife Protection Act, 1972, Indian Forest Act, 1927, designated wetlands under the Environmental (Protection Act) and Biodiversity Heritage Sites under the Biological Diversity Act, 2002. The OECM initiatives include: designation of 18 biosphere reserves, eco-sensitive zones, community conserves areas, etc.

Action:

- The unique and ecologically fragile ecosystems (namely inland water bodies and river stretches with the purpose of high endemism, rare and threatened species, keystone species, species of evolutionary significance, wild relatives, migratory routes, spawning and breeding areas) can be designated as fish sanctuaries or biodiversity heritage sites by the concern state governments/ UTs in consultation with the local bodies.
- Similarly, the North-East region and the Western Ghats being the biodiversity

hotspots, the state governments along with the SBB and BMCs must identify areas of aquatic biodiversity importance and notify these areas as BHS.

- The OECMs can be identified by demarcating biodiversity important aquatic ecosystems such as mangroves, marshland, fen, swamp, lake, flood plain, bog, etc.

3.5 Sustainable Development Goals

Water is linked with the Sustainable Development Goals {3(health); 6(Water & sanitation); 11 (Cities); 2 (Sustainable consumption and production); 15 (Biodiversity forest and desertification} that touch climate change, biodiversity, food security, energy security, health, gender equality, urbanization, institutional capacity sustainable consumption and production. Some of the targets linked with water and biodiversity are given in Table 5[66].

Table 5: Sustainable Development Goal and its targets

SDG 14	Conserve and sustainably use the oceans, seas and marine resources for sustainable development.
14.1	By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution.
14.2	By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration to achieve healthy and productive oceans.
14.4	By 2020, effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices and implement science-based management plans, to restore fish stocks in the shortest time feasible, at least to levels that can produce maximum sustainable yield as determined by their biological characteristics.
14.5	By 2020, conserve at least 10 per cent of coastal and marine areas, consistent with national and international law and based on the best available scientific information.
SDG 15	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.
15.1	By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements.
15.5	Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species
15.6	Promote fair and equitable sharing of the benefits arising from the utilization of GRs and promote appropriate access to such resources, as internationally agreed
15.7	Take urgent action to end poaching and trafficking of protected species of flora and fauna and address both demand and supply of illegal wildlife products
15.8	By 2020, introduce measures to prevent the introduction and significantly reduce the impact of invasive alien species on land and water ecosystems and control or eradicate the priority species
15.9	By 2020, integrate ecosystem and biodiversity values into national and local planning, development processes, poverty reduction strategies and accounts

66. Sustainable Development Goals Knowledge Plat form, Web source: https://sustainabledevelopment.un.org

4.0 Recommendations

4.1 Valuation of ecosystem functions and services

Biodiversity in inland water bodies provides provisioning, regulatory, supporting and cultural services for human wellbeing. Biodiversity has multiple values - some of which can be quantified in monetary terms, and others that are more abstract. This study recommends valuing ecosystem services of inland water bodies so that planners and policymakers have a better understanding of these resources while planning or formulating development projects related to aquatic ecosystems. The value of inland water bodies and their biodiversity need to be documented and integrated into the national and state planning process. Integrating the values of biodiversity into national accounting and reporting systems can help ensure that the importance of biodiversity remains visible and is appropriately accounted in decision making.

4.2 Restoration of inland water bodies

Inland water bodies are facing different levels of habitat degradation, fragmentation and the loss of natural habitats, which lead to the decline or loss of biodiversity. It is important to conserve the habitat rich in aquatic biodiversity. It is suggested to prepare an Ecosystem Health Card (EHC) for major rivers, lakes and wetlands. The major water bodies need to be regularly monitored and classified based on the index value and the restoration activities should be prioritized in the degraded stretches. Rivers with a high number of endemic and endangered species should be protected in their free-flowing condition. At least one river in each ecological zone should be protected.

Ecologically representative areas in the inland water bodies with importance for species, biodiversity and ecosystem services are conserved effectively through the national river and lake conservation programmes. Environmental Impact Assessment (EIA) notification needs to be appropriately modified and the EIA of dam projects should consider the downstream impacts on fisheries and associated livelihoods.

The environmental flow requirements should be made mandatory and fish passes/ diversion channel for dams and barrage need to be recognised as an effective tool for facilitating upstream and downstream migration of fish species and community-based co-management of open water fisheries strengthened. Fishing in open water resources should be under a strong co-management platform involving cooperative societies, self-help groups (SHGs) and BMCs to ensure responsible fishing practices.

4.3 Incentives and subsidies for promoting ecological farming practices

It is recommended to phase out incentives/subsidies that are harmful to biodiversity to minimize the negative impacts. Incentives must be given for promoting organic agriculture, producing bio-fertilizers and micronutrients *viz.,* bio NPK, Biophos+, Biozinc, Biopotash, etc. It is also recommended for implementing the Soil Health Card (SHC) scheme more effectively to promote the judicious use of chemical fertilizers.

Usage of nitrogen fertilizer should be calculated based on the crop's nitrogen balance.

It is recommended to prohibit the use of pesticides within a 10 m radius of lakes, rivers, watercourses, wetlands and conserved areas. This would achieve some level of pesticide protection for aquatic ecosystems. Buffer strips (aquatic plants) can be used to reduce the effects of sedimentation from the agricultural landscape. Buffer strips are vegetated filter strips that are planted in the margins of farms, rivers, lakes, canal for decreasing the concentrations of pollutants entering waterways. In the buffer zones of agriculture and forest areas, vegetative strips act as a filter to remove the sediment and pollutants. Buffer strips can also perform other functions, such as stream shading, carbon sequestration, biomass production, channel stabilization, water purification, habitat for biodiversity and also provide cultural and recreational services;

Integrated farming such as aquaculture–agriculture–forestry systems can be promoted in which crops, vegetables, livestock, trees and fish are managed collectively and this will increase the production stability, resource - use efficiency and environmental sustainability. Integrated farming ensures that waste from one enterprise becomes input to another; thereby optimizing the use of resources and reducing pollution.

The Payment to Ecosystem Services can be used in providing incentives for the fishing communities who adopt responsible fishing practices and the polluter-pay principle can be used for penalising industries that are polluting the inland water bodies. The damage or compensation amount received from industries can be used for restoring and reversing the ecology.

4.4 Blue labelling and ABS certification

Fishery products produced through environment friendly means should be brought under a strong certification regime. Hence, it is recommended to develop guidelines for Access and Benefit Sharing (ABS) certification, branding, organic certification, blue labelling, by identifying accreditation agency/organizations. The Ashtamudi Lake, in Kerala has received the Marine Stewardship Council (MSC) certificate. Similarly, it is suggested to promote local and national level certification process towards achieving sustainable fishing practices and for enhancing the blue growth/blue economy.

4.5 Regulatory framework for open water fisheries and ornamental trade

The inland open water fisheries and freshwater aquaculture should be governed by the statutory institution. The unsustainable practices such as high stocking, import of exotic fish seed, hyper-intensive aquaculture, illegal import of feed and accessories should be brought under a strong regulatory framework and strictly monitored. A fool-proof system, to prevent the escape of fish from aquaculture to open water bodies, must be ensured and best management practice protocols for culture systems, like cage culture, intensive aquaculture, stock management and seed production, need to be prepared. There is a need for framing and implementing and guidelines for hobbyists and

ornamental fish keepers about holding and disposal of stock to avoid these species from reaching natural water bodies.

To conserve the wild ornamental fish species, it is suggested to develop a database on the native and endemic ornamental fish species. Indiscriminate exploitation of the brooders and juveniles should be curbed through the legislative framework. For the trading of ornamental fish species, a policy needs to be developed by ensuring strict compliance of quarantine measures and the collection of wild stocks of ornamental fishes must be curbed and the monitoring mechanism needs to be strengthened.

4.6 Strengthening the implementation of the Biological Diversity (BD) Act

For conserving the biodiversity in the inland water bodies, it is suggested to identify the unique and ecologically important aquatic ecosystems, and these areas can be designated as Biodiversity Heritage Sites (BHS). The Telangana State Biodiversity Board has notified Ameenpur Lake, Hyderabad as the first aquatic BHS in the country under provisions of the Biological Diversity Act.

The ABS mechanism can be facilitated by identifying the economically important bioresources in the inland water bodies. States/UTs must notify the inland aquatic organism, which is under threat and appropriate rehabilitate measures should be taken to rehabilitate these species. The Biodiversity Management Committees (BMCs) can play an important role in documenting the locally available aquatic bioresources through Peoples' Biodiversity Register and help in the restoration of aquatic water bodies.

A national-level policy on invasive alien species is required. A database on blacklisted invasive alien species for the aquatic ecosystem needs to be prepared based on risk assessment studies. Also, voluntary guidance to avoid the unintentional introduction of invasive alien species as pets, aquarium species, terrarium species, live bait and live food must be prepared.

Conclusion

Inland water bodies are important natural resources that provide various ecosystem services, vital for human development, poverty reduction, mitigate climate change, and provide habitat for biodiversity. The services accrued from the inland water bodies for human wellbeing largely depend upon biodiversity. It is reported that Asia's three fourth of rice is produced inland. The inland wetlands also provide habitat for migratory birds. These birds use the inland water resources as stopover sites for feeding, resting and breeding. The coastal wetlands like mangroves, coral reefs and estuaries mitigate climate change and act as physical barriers against natural disasters like tsunami and cyclone. It is estimated that around 60% of examined ecosystem services are now degraded or being used unsustainably. The continuing depletion and degradation of natural capital have generated concerns over the capacity of the economic system to substitute these losses. The present study strongly recommends the valuation of

biodiversity and suggest using some of the economic instruments such as payment to ecosystem services and polluter-pay principle for conserving the aquatic biodiversity and its ecosystem services. It is highly recommended to undertake biodiversity assessment periodically to take stock of the native varieties, to provide incentives for promoting indigenous varieties and to prohibit the collection of wild stocks from the water bodies. It is also advocated to certify seeds, feeds, hatcheries, aquaculture products; and high priority should be given for conserving the native aquatic genetic resources. An action plan must be prepared for states/UTs to evaluate the number of water bodies with biodiversity potential so that these water bodies can be utilised optimally and their potential can be explored fully. The derelict water bodies are an immensely useful resource to increase the biodiversity wealth of our country. Water quality plays a vital role in maintaining good biodiversity, hence it is recommended that the water quality status of the major inland water bodies need to be assessed and monitored regularly, and an ecosystem index needs to be prepared to understand the wealth of an aquatic ecosystem. A national-level policy on invasive alien species is required and it is strongly recommended that the Biological Diversity Act should be implemented at the ground level by making the local BMC functional. Adequate capacity building is required for the policymakers on the importance of biodiversity and to mainstream biodiversity action plans into the existing state and national programmes towards enhancing the aquatic genetic resources.

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* Imaginations of young school children on the theme," Swatch Nadiyan, Saksham Bharat (Clean Rivers, Empowered India); Paintings on Agricultural Education Day 3rd December, 2020

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