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Wetland Ecosystem Management for Sustainable Fisheries and Aquaculture in Bihar: Potential and Perspectives

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ABSTRACT

Bihar has a huge water resource in the form of wetlands, which accounts for 403, 209 ha. The rivers and the wetland are the major water resource, which is untapped to explore for their full potential. The proper utilization and conservation shall be seen and planned to be tapped at the entrepreneurial level and government level as a conjoint effort. The region needs scientific effort for wetland-based aquaculture and a holistic effort for conservation. The most important resource potential lies in the form of indigenous fish species, more than 20 indigenous species are commercially demanded in the local market. However, more than 30 species of finfishes can be taken in culture in Bihar, the species of prawn and ornamental fishes will be additional. The wetland is native ground for breeding and culture of these demanded indigenous freshwater fishes and will be a revenue-generating resource from wetlands. A parallel approach for utilization of these river prawns and their domestication in culture, though a proper, package of practice, will create a new avenue in freshwater prawn fisheries and aquaculture. The production of export-oriented scampi, pabda and ornamental fish like tiger loach has huge export potential. The diversified method of culture, some other biological and technological interventions are required to utilize wetland, in an eco-friendly manner. Aquaculture in wetlands has huge potential, but the major objective for such activity shall be culture and conservation both. To use this giant resource in the state, in a sustainable manner, the ecosystem of the wetland shall be kept untouched and conserved. The linkage of wetland and river will be more successful, if the river is linked to the wetland so, it will ensure the distribution, natural breeding, and ranching of fish genetic potential and it will add to the conservation and biodiversity protection of the wetland. A fine balance between livelihood, conservation and utilization will ensure

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Table 1. District Wise-area of Wetlands in Bihar (National wetland atlas : Bihar 2010).

Sl. No.	District	District geogra-phical area (sq km)	Wetland area (ha)	Total wetland area (%)	District geogra-phical area (%)	Open water (ha) post-monsoon	Open water (ha) pre-monsoon
1.	West Champaran	4250	21697	5.38	5.11	11924	10118
2.	East Champaran	4155	12477	3.09	3.00	8915	5119
3.	Sheohar	443	1476	0.37	3.33	845	782
4.	Sitamarhi	2628	2601	0.65	0.99	906	588
5.	Madhubani	3478	8958	2.22	2.58	2411	2280
6.	Supaul	2985	19285	4.78	6.46	9004	9021
7.	Araria	2797	4157	1.03	1.49	2245	1930
8.	Kishanganj	1939	10954	2.72	5.65	5542	4886
9.	Purnia	3203	12401	3.08	3.87	5279	3365
10.	Katihar	3010	31011	7.69	10.30	17135	14574
11.	Madhepura	1797	3539	0.88	1.97	1589	967
12.	Saharsa	1196	12086	3.00	10.11	7202	4125
13.	Darbhanga	2502	8709	2.16	3.48	5171	2467
14.	Muzaffarpur	3123	10490	2.60	3.36	6984	4048
15.	Gopalganj	2003	7122	1.77	3.56	5128	3783
16.	Siwan	2213	7105	1.76	3.21	4295	2117
17.	Saran	2624	21170	5.25	8.07	12118	7950
18.	Vaishali	1995	17148	4.25	8.60	11405	5970
19.	Samastipur	2579	15022	3.73	5.82	10867	7133
20.	Begusarai	1889	20365	5.05	10.78	10628	7703
21.	Khagaria	1486	1645	2.89	7.84	9060	5807
22.	Bhagalpur	2502	24171	5.99	9.66	16237	10273
23.	Banka	3020	9895	2.45	3.28	5151	3847
24.	Munger	1419	11979	2.97	8.44	7001	5498
25.	Lakhisarai	1229	4177	1.04	3.40	1759	1447
26.	Sheikhpura	689	296	0.07	0.43	163	73
27.	Nalanda	2362	1589	0.39	0.67	756	283
28.	Patna	3130	20678	5.13	6.61	11943	7570
29.	Bhojpur	2337	11154	2.77	4.77	5700	2435
30.	Buxar	1634	3717	0.92	2.27	2449	1408
31.	Kaimur	1840	796	0.20	0.43	296	174
32.	Rohtas	3838	18641	4.62	4.86	9259	4040
33.	Jehanabad	1569	4345	1.08	2.77	1843	564
34.	Aurangabad	3389	8116	2.01	2.39	3428	1436
35.	Gaya	4941	11422	2.83	2.31	3979	626
36.	Nawada	2498	5464	1.36	2.19	2445	1241
37.	Jamui	2997	7351	1.82	2.45	3593	2734
	Total	91689	403209	100.00	4.40	224655	148382

sustainability in production. The production and sustainable utilization require mass awareness and knowledge sharing between major stakeholders like fishers, aqua farmers, and local inhabitants of the wetland zone.

Keywords Wetland, Ecosystem management, Freshwater fishes, Sustainable, Aquaculture per-spective.

INTRODUCTION

Bihar is an inland state with a high population density and a total geographical area of 94,163 sq. km. Bihar is fully an agrarian state and almost 90% of rural populations depend on agriculture for their sustenance and Income. The state is bestowed with

Fig. 1. Wetland water resources of Bihar (National wetland atlas : Bihar 2010).

huge water potential but the water has not been used as a resource parallel to land and soil. The huge water resource of the state lies in form of tanks and ponds (69,000 ha), Ox-bow lakes or Maun (9,000 ha), reservoirs (7, 276 ha) flowing rivers (3, 200 km) and the total geographical area of wetland in Bihar is 403, 209 ha (in the total area of Bihar 94,163 sq km). The rivers and the wetland come to be the major water resource, which is untapped to explore for its full potential. The best benefit to the aquaculture sector of the state lies in that (1) There is a huge demand for fresh and live fish domestic market and (2) The market supply deficit in the state is more than 3 lakh tons, which is being trapped by supply from Andhra Pradesh and West Bengal. These opportunities shall be seen and planned to be tapped at the entrepreneurial level and government level as a conjoint effort. The region needs scientific effort for pond, river, and wetland-based aquaculture and a holistic effort for conservation of these resources in the state. As, there is a lack of technical knowledge, awareness and farmer support service in aquaculture in the state shall be the first milestone. Mass awareness is required for aquaculture and culture cum conservation of these natural resources to ensure sustainability through proper ecosystem management.

Status of wetland area in Bihar

Wetland areas are the natural water resource that consists of mass biodiversity in form of amphibians, animals, aquatic animals including (Fishes and Plants). The wetland ecosystem has been a source of genetic biodiversity and gene pool from ancient times. Wetland waters are the breeding and nursing ground for most of the indigenous fishes. It can be a seasonal or potential, river-fed or rainwater fed connected to river tributaries of a stream or direct a major river, through its flood plain. Fortunately, almost all major types of wetland are present in Bihar. In Bihar total of 4,416 wetland has been mapped at a 1:50,000 scale. Additionally, 17,582 small wetland (with an area of less than 2.5 ha) has also been recorded. Overall estimated wetland area in Bihar is 403209 ha which is extended in 94,163 sq km. geographical area of the state. It accounts for 4.6% of the total geographical area of the state and 2.54% of the total natural wetland area of the nation (National wetland atlas : Bihar 2010).

The country has huge water resources in terms

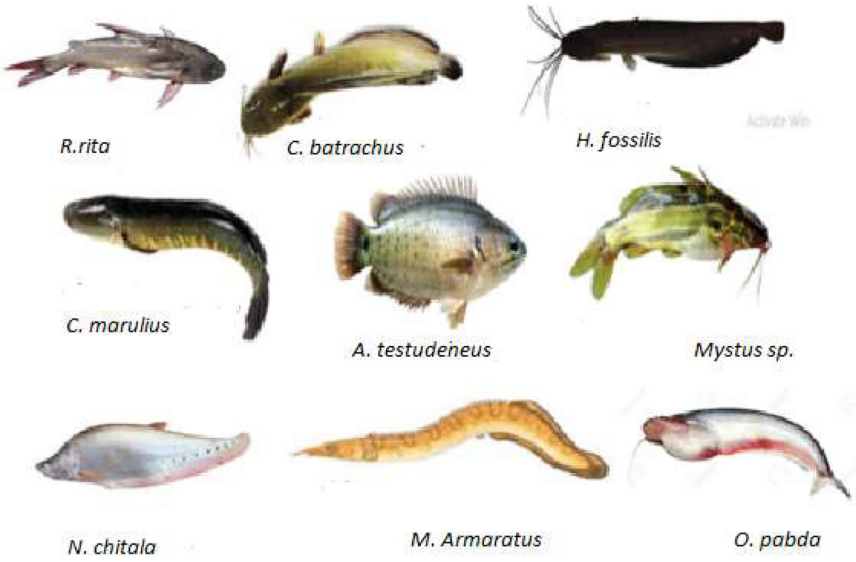

Fig. 2. Highly demanded and preferred fish in the domestic market but mostly unavailable.

of wetland reservoirs and rivers. Bihar especially has huge water resources in form of rivers and wetlands. Parallel to the country's policy for conservation and sustainable utilization, Bihar also needs to synergize its effort for sustainable use of the aquatic resource. For conservation and management of identified wetlands including Ramsar sites in the country, the Centrally Sponsored Scheme of National Wetlands Conservation Program (NWCP) was implemented till the year 2012-13. To have better synergy and to avoid overlap, the NWCP has been merged in February 2013 with another scheme called the National Lake Conservation Plan (NLCP) into a new integrated scheme of 'National Plan for Conservation of Aquatic Eco-systems (NPCA) for holistic conservation of lakes and wetlands. Bihar also has its three lakes Kabar Tal (1988), Barilla (2004), Kusheshwar Sthan (2004) under the conservation plan (ENVIS Center, Ministry of Environment and Forest, and Govt of India printed date : Thursday, August 12, 2021). Wetland of Bihar Kabar Tal has become the first Ramsar site in Bihar and 39th in India. It witnesses the global faces of the wetland and so at the regional level awareness must be created for its sustainable use and conservation. The vast wetland resource of Bihar is presented in Tables 1 and 2, the state has an almost uniform distribution of wetland in North Bihar and the area of the river flood plain is the prominent and wetland dense region (Fig. 1).

Thousands of ponds, tanks and Chaurs (land depressions) and Mauns (Ox-bow Lake) constitute the lifeline of the area by serving as the source of irrigation and pisciculture. Kabar Tal (Begusarai), Kusheshwar sthan (Darbhanga), Gogabeel (Katihar), Saraiyaman (West Champaran), Baraila (Vaishali) are some important wetlands in this region that perform the job of groundwater recharge, irrigation, and aquaculture and sustain the livelihood of human beings and other organisms to a considerable extent. Jha *et al.* 2014 and Ghosh *et al.* 2004 have provided an account of spatiotemporal changes in the wetlands of north Bihar.

River and wetland : Major water resource

Most of the rivers in Bihar are east flowing from the Himalayas to the Bay of Bengal except the Son River. This river flows throughout the year. But the flowing water and huge flood plains of these rivers have not been used as a resource, till the time due to improper infrastructure or lack of holistic planning. These riv-

Fig. 3. Locally demanded small prawns from wetland.

ers, their tributaries and associated flood plains have huge genetic biodiversity especially of indigenous and demandable fish and shellfish. Almost 70% of the aquatic biodiversity of the wetland is turning to be endangered. So, the loss of genetic potential & diversity of fishes, aquatic animals, and plants are the major loss for the state and future generations. If we see the agricultural use of such wetland, peripheral areas are only being used that too with one or less than one crop intensity. So it is high time now to create a sustainable model for utilization of these wetland aquatic resources and conservation of the wetland ecosystem as a bilateral approach.

The most important resource potential lies in form of indigenous species of fish (Kumar 2013). As given in Table 3, more than 20 indigenous species are commercially demanded in the local market. However; more than 30 species of finfishes can be taken in culture from a wetland in Bihar. Additionally, if we consider, the species of prawn and ornamental fishes, a list will go on. River and wetland are native grounds for breeding and culture of these fishes including almost all demanded indigenous freshwater fishes of India. Earlier, in aquaculture, the seed collected from rivers and wetlands was used. But the same practice has been dropped or is not being perfect

Table 2. Area estimates of wetland in Bihar (National wetland atlas : Bihar 2010).

Sl. No.	Wet code	Wetland category	Number of wetlands	Total wetland area	Wetland area (%)	Open water Post-monsoon area	Open water Pre-monsoon area
	1100	Inland wetlands – Natural					
1	1101	Lake/pond	514	20281	5.03	11506	6345
2	1102	Ox-bow Lake/cut- off meander	989	16172	4.01	10130	5264
3	1103	High altitude wetland	-	-	-	-	-
4	1104	Riverine wetland	200	2118	0.53	1664	777
5	1105	Waterlogged	1300	34878	8.65	21185	9507
6	1106	River-stream		238	298408	74.01	168984
	1200	Inland wetlands- man-made					
7	1201	Reservoir/Barrage	90	8612	2.14	7587	6005
8	1202	Tank/Pond	1067	4822	1.20	3363	1870
9	1203	Waterlogged	18	336	0.08	236	133
10	1204	Salt pan	-	-	-	-	-
		Sub-total	4416	385627	95.64	224655	148382
		Wetlands	(<2.25 ha)	17582	4.36	-	-
		Total	21998	403209	100.00	224655	148382

Categorized area of wetland

Area under aquatic vegetation	25179	17360
Area under aquatic levels		
Low	132318	316
Moderate	75292	146269
High	17045	1797

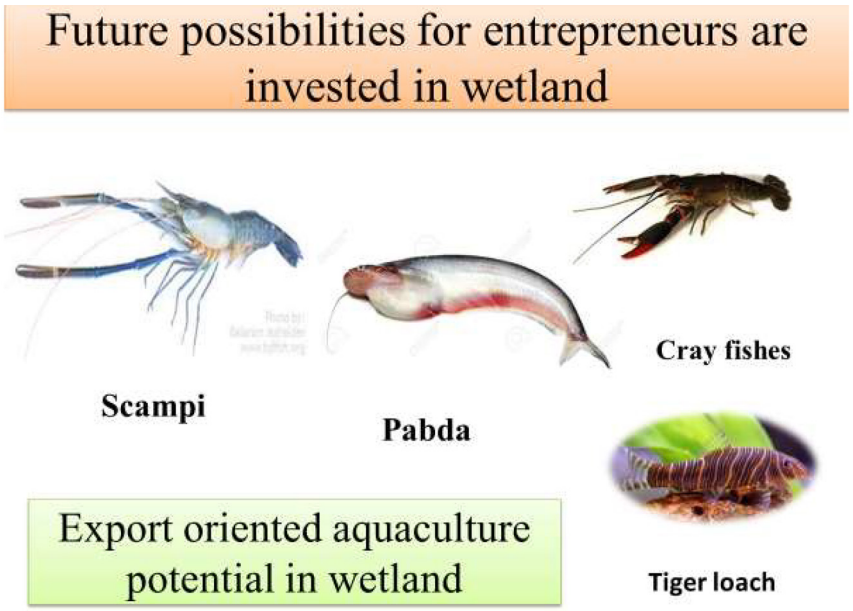

Fig. 4. Export-oriented candidate species for culture in wetland.

with planning and scientific approach. With some scientific interventions, government planning and proper care of these wetlands will create ample scope for seed and brooder collection. The same if perfected at the hatchery level with proper species-specific local standardization will lead Bihar into a national seed

Table 3. Commercially important fish species available in wetland area of Bihar (Kumari Sushma Saroj and Jitendra Prasad 2020).

Sl. No.	Common name	Scientific name	Sl. No.	Common name	Scientific name
1.	Rohu	*Labeo rohita*	22.	Reba	*Cirrhinus reba*
2.	Catla	*Catla catla*	23.	Koi/Kawai	*Anabas testudineus*
3.	Mrigal Carp	*Cirrihinus mrigala*	24.	Rita	*Rita rita*
4.	Grass Carp	*Ctenopharyngodon idella*	25.	Chitala	*Notopterus notopterus*
5.	Common Carp	*Cyprinus carpio*	26.	Channa	*Channa punctatus*
6.	Silver Carp	*Hypophthalmichthys molitrix*	27.	Channa sp.	*Channa gachua*
7.	Black Rohu	*Labeo calbasu*	28.	Kuria labeo	*Labeo gonius*
8.	Bighead Carp	*Hypophthalmichthys nobilis*	29.	Pool Barb	*Puntius sophore*
9.	Bata	*Labeo bata*	30.	Olive barb	*Puntius sarana*
10.	Wallago Buari	*Wallago attu*	31.	Spotted sail barb	*Pethia phutunio*
11.	Tengra	*Mystus seenghala*	32.	Flying barb	*Oxygaster bacaila*
12.	Magur	*Clarias batrachus*	33.	Indian glass barb	*Laubuka laubuca*
13.	Singhi	*Heteropneustes fossilis*	34.	Gangetic ailia	*Ailia coila*
14.	Gaichi	*Macrognathus aculeatus*	35.	Indian river shad	*Gadusia chapra*
		https://en.wikipedia.org/wiki/Heteropneustes_fossilis			
15.	Loach	*Lepidocephalus guntea*	36.	Phasa	*Setipinna phasa*
16.	Sour/Sol/Snake head	*Channa marulius*	37.	Ocellated pufferfish	*Tetradon cutcutia*
17.	Garai/ Channa	*Channa striata*	38.	Kauwa fish	*Xenentodon cancila*
18.	Kotari	*Colisa fasciatus*	39.	Chanda nama	*Ambassis nama*
19.	Pangas/Pyasi	*Pangasius pangasius*	40.	Indian glassy perch	*Ambassis ranga*
20.	Pabda	*Ompok pabda*	41.	Gangetic leaf fish	*Nandus nandus*
21.	Ticto barb	*Puntius ticto*	42.	Zig-zag eel	*Mastacembelus armatus*

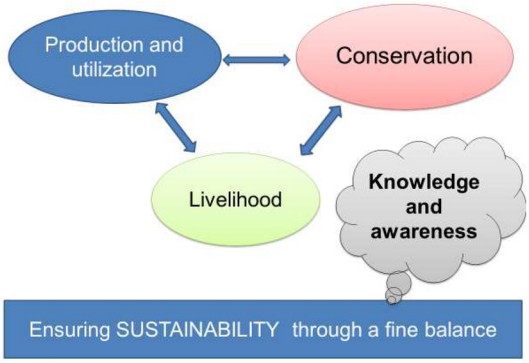

Fig. 5. Balancing the use and conservation and livelihood to ensure sustainability.

hub for aquaculture in the nation.

Local indigenous and Lacerative fish species of wetland

National domestic demands of fishes are very diverse, but the overall responsibility for indigenous species is better than the exotic species, say Tilapia, Pangasius or Exotic carps in the Bihar fish market. Fortunately, the wetland of Bihar is a natural breeding ground for all indigenous carps including major and medium carps. Additionally, if, we see the market trend, we find local indigenous species are highly demanded with 3 to 5 times more prices than the Exotic Carp and Catfishes including Tilapia. These indigenous fishes like Magur (*C. batrachus*), Singhi (*H. fossilis*) Sour/Murrels (*Channa marulius*), Rita (*Rita rita*), Rewa (*Cirrhinus reba*), Koi/Kawai (*Anabas testudineus*), Tengra (*Mystus* sp.), Chital (*N. chitala*), Spiny eel (M. armatus), Pabda (*Ompok pabda*), Buari (*Wallago attu*), are high price and highly demanded. The wetland of Bihar can be a major source for the seed of these fishes as well as tables' fishes. Flooded low land and wetland have the potential to be used for the mass scale seed production of these indigenous species, which is highly preferred but out of the market (Fig. 2). The table size production of these fishes will be a high revenue-generating venture for aqua-culturist in the area. It will create drive or awareness for proper utilization and conservation of these wetlands and rivers. It will prevent indiscriminate use and destruction of these resources, which are under-utilized and being diverted for other purposes.

The fishes as the potential for being used as table fish or as ornamental fishes. The perspectives of seed production and production of fish under a suitable culture system will create a novel avenue for its conservation. It will create a sense of resource conservation with a cultural approach. Similarly, another revenue-generating resource from wetlands can be the production of river prawns says scampi, or other small river prawns (Fig. 3). Most of these have the ability to breed in wetland and in wetland-associated streams. A parallel approach or utilization of these river prawns and their domestication in culture, though a proper, package of practice, will create a new avenue in freshwater prawn fisheries and aquaculture.

Wetland has potential for export market as an avenue for entrepreneurs

The present production of Scampi, Pabda and Ornamental fish like tiger loach has huge export potential (Fig. 4). Such species need to be explored in the wetland of Bihar. The mass seed production will lead to the mass production of such export-oriented fishes and the state can lead in the export of these fishes. Similarly, scope lies in importing the huge value exotic species example crayfishes for culture in closed aquaculture systems or with integrated systems. This has high demand in the international market and can be easily cultured as monoculture or with paddy farming integration in such wetlands. Such intervention will create additional income for farmers and will create employment for people in the vicinity of the peripheral zone of the wetland.

Technologically and ecosystem-driven empowerment of the wetland for sustainable utilization.

The wetlands are of diverse terrain and morphological features. Such as water depth and presence of aquatic weeds/plants. Therefore, with the diversified methods of culture, some other biological and technological interventions are required to utilize it, in an eco-friendly manner. For most weed-infested areas and underproductive areas ; the traditional, modified traditional and extensive methods of fish culture will be cost-effective and eco-friendly methods. Similarly, in the peripheral zone of wetland or even in small wetland semi-intensive forms of aquaculture can be

practiced. Eventually, intensive methods with biosecurity and effluent treatment facilities can be used in aquaculture production in these wetlands or areas associated with wetlands. However trophic integration-based culture, aquaculture through RAS and Biofloc system or with an integrated multi-trophic approach will give a more sustainable and eco-friendly approach of its utilization. We will discuss now step by step about this technological diversity and potential in the wetland of Bihar.

Traditional fish culture in the open water of aquatic vegetation rich wetland

The species combination and stocking size of seed are two approaches to improve the production in such wetlands infested with aquatic weeds. The Grass carp 50% with 25% Common Carp and 25% Mrigal gives the best combination. As latter two are bottom feeders and they feed on the partially digested fecal matter of grass carp turning as detritus at the Bottom. Similarly stocking with some Air-breathing fishes like Anabas (*A. Testudineus*), Singhi (*H. fossilis*), and Magur (*C. batrachus*), give an additional benefit. But the stocking size of carps must be 150 gm to 200 gm. With such a combination, the average production of 600 kg per acre can be easily achieved. However up to 1200 kg per acre production can be achieved, if the Grass Carp is made available with aquatic grass or terrestrial grass on a daily and ad-libitum basis with a total stocking of 3000 numbers per acre.

Traditional farming in wetland with clear water

Wetland areas with clear water especially small wetlands or even utilization of wetland post-monsoon can be done with alternate day or weekly fertilization of water with inorganic fertilizer or with organic compost. The addition of Cow Dung mix with Mustard Oil Cake (MOC) has been found to give better results. The fertilization-based method needs the stocking of filter-feeding fishes like Silver Carp (H. *molitrix*), Bighead Carp (*H. nobilis*), Catla (*C. catla*), Rohu (*L. rohita*) and 20% only for Mrigal (*C. mrigala*) or Common Carp (*C. carpio*). In such a system, stocking size around 100 gm or more gives a better result. And the production of 10-12 quintals per acre can be achieved, if daily 200 kg cow dung 10 kg mustard oil cake applied per acre with stocking of 3000 Numbers of these carp per acre.

Semi-intensive pond culture

Such techniques can be practiced in the small, less biodiversity wetland or at the peripheral zone of the wetland. The shallow area of marshy land may be shaped in a series of small earthen ponds. Along with the fertilization of small ponds in wetlands, supplementary feeding is recommended. Strongly 6 species combination is the best to use all niche and trophic levels of ponds. So the eutrophication-based interference can be avoided in the wetland. On average production of 25-30 quintals per acre can be achieved with scientific best management practices of aquaculture.

Intensive pond culture

In wetlands, intensive farming can't be directly permitted, as it may alter the balance of the ecosystem and may favor specific kinds of aquatic community growth. But, the practice may be adopted, in the peripheral zone of the wetland or in shallow areas with well-designed ponds having effluent treatment and a biosecurity facility. The intensive pond may be constructed at the peripheral shallow areas of wetland or at the peripheral zone of wetland so the biodiversity is kept untouched. Through pond based intensive system 50 to 60 quintals per acre can be easily achieved. Additionally, a culture of local and indigenous fishes in such a system will add the value in form of production and conservation of local species in the area.

5. Cement tank-based flow-through system

Large, water bodies of wetland, has the potential to be used for making flow-through system in the peripheral upper land. Where cemented tanks made at the peripheral tank can be utilized for intensive farming of local species. The water can be recirculated and exchanged on daily basis even up to 100%. So the culture of local species will be done in controlled conditions. The only caution to be taken is that the affluent and organic load going to the wetland shall be monitored

and should be kept below the permissible level. On average 50 quintals per tank of 100 m^3 productions can be obtained in such a system, especially of the local Air-breathing fishes.

Advanced technique-oriented aquaculture in wetland

Wetland-based aquaculture shall be most eco-friendly and sustainable with the orientation of wetland ecosystem management. In most cases, anthropogenic activities have caused disturbances in the wetland ecosystem. So using the wetland for aquaculture without keeping it damaged is the major objective. In pond-based aquaculture, there are chances of impact on flora and fauna. So, the intensive and advanced methods of aquaculture like RAS, Biofloc, and Integrated multitrophic aquaculture are the major friendly ecosystem and low waste to the environment systems. In such a system culture of local species shall be standardized and practiced, so the better market demand of such indigenous fishes will give profitability. And a culture of these fishes will add to conservation. Average production of 50 quintals per 100 m^3 can be achieved in such culture systems.

Culture and conservation

Aquaculture in wetlands has huge potential, but the major objective for such activity shall be culture and conservation both. To use this giant resource in the state, in a sustainable manner, the ecosystem of the wetland shall be kept untouched and conserved (Prasad 2002). The best approach for the same shall be through.

(1) First mapping of the aquatic resource.
(2) Mapping of the biodiversity and fish genetic potential in the area.
(3) Enlistment of the local cultivable species and their demand.
(4) Standardization of the species and resource-specific model/or wetland specific package of practice with a concern of culture and convention.

The culture of the indigenous local species will create economic sense in the people, which will temper them for conservation of the wetland and associated aquatic resources. It can be aimed through a proper awareness program. Culture will create a way of natural stocked enrichment in the wetland. Culture-oriented conservation will have the following concern and will create a new avenue.

1. Bilateral approach to use the resource.
2. Conservation of fish genetic potential and destructed natural habitat in a wetland.
3. Protection of perennial wetland from indiscriminate use (Parikh and Parikh 1999). Specially fishing in breeding season or monsoon.
4. Fishing ban in rivers and wetland during breeding season parallel like a marine fishing ban.
5. Protection of young juveniles, fish seed from catch through mesh size regulation to ensure recruitment.
6. Fish-specific eco-friendly craft and gear use shall be promoted with proper awareness.
7. Studies on import of agriculture run off based xenobiotic on reproductive performance and rearrangement of local indigenous fishes in wetland.
8. Advanced approach to collect the wild seed caught through the net in river and wetland to use for culture.
9. Arrangement for breeding and ranching of the local indigenous fishes to this wetland on a government level.
10. Ensuring river linkage to this wetland to keep pumping and circulation of the water and biological resource of wetland to and fro through rivers.

River and wetland linkage for the sustainability of aquaculture : -

The aquaculture potential of freshwater systems is yet to be explored up to its maximum sustainable level intern of vertical and horizontal exportation. In India, only Indian and Exotic Major Carps, a few Catfishes, and Tilapia are the common groups of fishes being practiced in the culture system. But a huge fish genetic potential is yet to be explored. Similarly, the inbreeding in the common cultivable species is another threat to gene heterogeneity loss in fishes. Therefore, keeping natural stock of the available fishes in wetland and using alternate indigenous species from a wetland in culture is a very sustainable approach. This particular approach will be more successful, if the river is linked to the wetland so, it will ensure the distribution, natural breeding and ranching of fish genetic potential. It will be on regular basis in these areas. It will add

to the conservation and biodiversity protection of the wetland. Such effort will be a way for culture in swift flood and use of these wetlands for income generation and livelihood. The wetland area shall be ranched on regular basis to get maximum benefit. The advantage of linkages of river and wetland can be so that river function like,

1. Supply source of germplasm for cultivable fishes.

2. To ensure the heterogeneity in seed and brooder as major resources.

3. It may help in the selection of high-yielding species and a variety of fishes.

4. It will work as the natural source of seed and will reduce the burden on hatcheries.

5. It will prevent inbreeding and create stock refreshment.

6. Linkage along with the fishing bans in the area will improve the natural production of both wetland and rivers.

Similarly, aquaculture may be advantageous to rivers and wetlands in terms of conservation and propagation of local and endangered fishes. It will help in eliminating the effect of natural disasters and anthropogenic effects on wetlands, rivers and their fish genetic potential.

Need of fine balance for sustainable use of wetland :

Wetland gives diverse functions naturally; to achieve its all function and to use the resources in a sustainable manner a fine balance between the different factors is essential. When we target the eco-friendly use of wetland for aquaculture, it becomes more essential and pivotal. The three attributes : like

1. Production and utilization
2. Conservation of aquatic resources of wetland
3. Livelihood

These attributes are interrelated, to ensure better production (Fig. 5). Therefore, the average productivity and resource-specific utilization have to be standardized. In all decisions and the production process. It should be taken care that indigenous species to the wetland shall be promoted and practiced (Srivastava 2013). Besides the production and utilization, the objective shall be conservation and utilization. The livelihood of fisher and local community shall be improved by ranching of the stock and harnessing the sustainable potential of the wetland. A fine balance between livelihood, conservation, and utilization shall be established. The balance between these factors will ensure sustainability in production. The production from these natural resources, as well as the production of aquaculture in long run, will depend on mass awareness and knowledge sharing between major stakeholders like fishers, Aqua farmers and local inhabitants of the wetland zone.

Effort needed for sustainable and eco-friendly use of wetland

Utilization of wetland with an objective to use and conserve is need of the hour, the sense of economic return will place the monetary as well as environmental value in people residing around the wetland. The livelihood can be restored with cultural practices so the other indiscriminate use of wetland will reduce. The sustainable use of wetland through sustainable aquaculture practices needs effort at different levels. The foremost needed effort can be as follows :

1. A robust policy framework on the use of aquaculture for blue revolution and ecosystem management.

2. An effort to convert policy into practice with help of awareness and knowledge sharing.

3. Better technical help and hand-holding with a demonstration of the technique in the ecosystem-sensitive areas of wetland.

4. Eliminating the wish makers and selecting actual entrepreneurs and training, making them environment aware before utilization of such wetland for aquaculture.

CONCLUSION

The rivers and the wetland come to be the major water resources in the state. These resources shall be planned to be explored at the entrepreneurial level and government level together as a conjoint effort. The most important resource potential of the wetland is the indigenous species of fish. Almost more than 20 indigenous species are commercially demanded in the local fish market in Bihar. However; more than 30 species of finfishes and many shellfishes (Prabhakar and Roy 2009) can be taken in culture from a wetland in Bihar. Wetland connected to rivers is the native ground for breeding and culture of these fishes. Similarly, another lucrative and revenue generating resource from wetlands can be the production of River Prawns say Scampi or other small river prawns. Most of these have the ability to breed in wetland and in wetland-associated streams.

A parallel approach or utilization of these river prawns and their domestication in culture, though a proper, package of practice, will create a new avenue in freshwater prawn fisheries and aquaculture. The present production of Scampi, Pabda and Ornamental fish like Tiger Loach has huge export potential. Such species need to be explored in the wetland of Bihar. The mass seed production will lead to the mass production of such export-oriented fishes and the state can lead in the export of these fishes. The wetlands are of diverse terrain and morphological features. Such as water depth and presence of aquatic weeds/ plants . Therefore, diversified methods of culture and other biological and technological interventions (Prabu *et al.* 2009b and 2012) are required to utilize it, in an eco-friendly manner. For most weed-infested areas and underproductive areas; the traditional, modified traditional and extensive methods of fish culture will be a cost-effective and eco-friendly method. Similarly, in the peripheral zone of wetland or even in small wetland semi-intensive forms of aquaculture can be practiced. Eventually, intensive methods with biosecurity and effluent treatment facilities can be used in aquaculture production in these wetlands or areas associated with wetlands. However trophic-based culture, aquaculture through RAS and Biofloc system or with an integrated multi-trophic approach will give a more sustainable and eco-friendly approach of its utilization.

Aquaculture in wetlands has huge potential, but the major objective for such activity shall be culture and conservation both keeping the ecosystem untouched and conserved. Therefore, keeping natural stock of the available fishes in wetland and using alternate indigenous species from a wetland in culture is a very sustainable approach. This particular approach will be more successful, if the river is linked to the wetland so, it will ensure the distribution, natural breeding and ranching of fish genetic potential. It will be on regular basis in these areas. It will add to the conservation and biodiversity protection of the wetland. A fine balance between livelihood, conservation and utilization shall be established. The balance between these factors will ensure sustainability in production. The production from these natural resources, as well as the production of aquaculture in long run, will depend on mass awareness and knowledge sharing between major stakeholders like fishers, aqua farmers, and local inhabitants of the wetland zone.

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REFERENCES

Das BK, Ganesh Chandhra, Suman Kumari, Meena DK, Kaushlesh SK, Raju Baitha, Raman K Trivedi. Roadmap for Fisheries Development in Maun and Chaur. ICAR- CIFRI, Barrackpore, Policy Paper 6.

Jha Vidyanath, Verma AB, Prajna Jha, Manishankar Jha, Rajeev Kumar (2014) Wetlands in North Bihar provide A basis to its Sustainable Development. *J Aqua* Biol Fish 2 : 843 — 851.

Kumar N, Singh NP (2013) Studies on the ichthyofauna of Kararia Lake of Motihari, East Champaran, Bihar, India. *Res J Animal Vet Fish Sci* 1 (9) : 8—12.

Kumari Sushma Saroj, Jitendra Prasad (2020) Diversity status of fishes in Mauns and Chaurs of Samastipur, North Bihar. *Appl Ecol Environm Sci* 8 (1) : 21—24.

National Wetland Atlas : Bihar (NWAB) (2010) Sac/Resa/Afeg/ Nwia/Atlas /23/2010, Space Applications Center (ISRO), Ahmedabad, India, pp 222.

Parikh J, Parikh K (1999) Sustainable Wetland. Environmental Governance – 2, Indira Gandhi Institute of Development Research, Mumbai.

Prabhakar AK, Roy SP (2009) Ethnomedicinal uses of some shell

fishes by people of Kosi river basin of north Bihar, India. *Ethno Med* 3 (1) : 1 — 4.

Prabu MJ (2009b) Fishes come true for an entrepreneur in Bihar. Science and Technology/Agriculture page, Farmers Notebook. The Hindu 25th Sept. 2009.

Prabu MJ (2012) Scientists must work with farmers to achieve food security. Science and Technology/Agriculture page, Farmers Notebook. The Hindu 13th July 2012.

Prasad SN, Ramachandra TV, Ahalya N, Sengupta T, Alok Kumar, Tiwari AK, Vijayan VS, Lalitha Vijayan (2002) Conservation of Wetlands of India – a review. *Trop Ecol* 43 (1) : 173—186.

Srivastava PK (2013) Fish Diversity and Conservation Perspectives of Gandak River, India. Our Nature, 11 (1) : 7.