Wetland ecosystem - a study on fish-aquatic food crops diversity for enhancing productivity and economic stability for fish-farm families in Indian subtropics

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ABSTRACT

An intensive case study was undertaken at the farm fisheries from during wet months under NAZ of Indian subtropics for characterization and integrated utilization of *Tal* wetland ecosystem through pisciculture [Live (magur - *Clarias batrachus* & singi - *Heteropneustes fossilis*) and sweet water fishes (rohu - *Labeo rohita* & katla - *Katla katla*) both category in 1:1 ratio] along with protein and starch-rich 2 aquatic food crops (*Trapa bispinosa* & *Euryale ferox*) as sole and mixed stand, being to be more productive for rural farm families. Results from the study, fish-crop diversity was much important and substantial enough for more production. For easy comparison among variables, yield of fishes and crops were converted to makhana yield equivalent (MYE) due to heterogeneous characteristics. Sole yield of all fishes (0.59, 0.54, 1.18 and 1.32 t ha^{-1}) and water chestnut and makhana (8.39 & 2.36 t ha^{-1}) dominated individually in respect to their associated yield. However in MYE study, among the combinations, superior results obtained with L-fishes (1.90 & 1.35 t ha^{-1}) + makhana (1.72) in respects to their cumulative yield (4.97 t ha^{-1}) followed by L-fishes (2.05 + 1.49 t ha^{-1}) + water chestnut (1.28 t ha^{-1}) due to their compatibility with the system. Regarding economic outcome, GMR, NP and B-C ratio (US$ 3244 & 2557 ha^{-1} and 3.71) were also very promising with the system, which economically viable particularly for rural farm families. Among the combined system, lowest values obtained with SW-fishes + makhana, due to their non-compatibility characteristics. From the study it concluded that it is thus imperative to utilize this vast unused wetland ecosystem in the regions with impetuously for food, livelihood, engagement of household labours and ultimately economic stability that are inextricably linked with rural sustainability as well.

Key words: live and sweet water fishes; aquatic food crops; productivity and economic stability; aquatic ecosystem

Abbreviations: **AAS**, Atomic absorption spectrophotometer; **B-C**, benefit-cost; **BOD**, biological oxygen demand; **COD**, chemical oxygen demand; **DAT**, days after transplanting; **eq,** equivalent to; **GMR**, gross monetary return; **LF**, live fishes; **L**, litre; **Mak**, makhana; **MSL,** mean sea level, **MYE**, makhana yield equivalence; **NP**, net profit; **RK**, rohu + katla; **SW**, sweet water fishes and **WC**, water chestnut

INTRODUCTION

In the way of development, Ramsar Convention held in Iran (1971), the first Global Conservation Convention brought this subject to the International arena and framed a universally accepted wetlands, highlighted on this subject. Actually, the Ramsar Convention is an international treaty is being used for wetland conservation and the 'Convention on wetlands of International Importance especially as Waterfowl Habitat'. This indicates wise use of wetlands, which is interpreted to mean the maintenance of the ecological character of wetlands [1]. The Convention uses a particularly broad definition of wetlands in Article 1:……. 'areas of marshes, fens, peat land or water, whether natural or artificial, permanent or temporary with water that is static or flowing, fresh, brackish or salt, including areas marine waters the depth of which at low tide does not exceeds six meters". Moreover, the area of coverage is broadened by Article 2, which provides that wetlands ……… may incorporate riparian and coastal zones adjacent to the wetlands and islands or bodies of marine water deeper than six meters at low tide lying within the wetlands. Navid [1] observes that, as a consequence, the Convention includes habitat types including rivers, coastal areas and even coral reefs.

Soil and water are the integral part of global natural resources, determined greatly wetlands and its diversity, habitats of thousands aquatic flora and fauna. Categorically, wetlands are the transitional phase between dry terrestrial and permanently aquatic ecosystem, where, the soil is frequently waterlogged, and the water table is at or near the surface and the land is oftenly covered by shallow to certain depth of water exists either permanently or semi-permanently or temporarily. Wetland comprises 6.4 per cent (855.8 million ha) of the world total area [2] of which 23.5 million ha covered in India, dominated mostly in north-eastern and coastal part (25-30%) of the country [3]. In the country, this has possible due to have chains of main river system (*The Ganges, Brahmaputra, Padma, Mahanadi* etc.) intersected with so many tributaries and canals, - possible to make a saucer shaped wetland ecosystem bounded by land terrestrial. Survival of human civilization is inextricably linked with the wetlands, which sustained economic stability of hundred million of people. And this swampy environment of the carboniferous period produced and preserved many of the fossil fuels on which we greatly depend now, for this James has rightly termed as *'nature's kidney'* of the world [4].

Besides, in scattered way this swampy, fertile, productive wetlands are continuously used by the rural farmers for production of aquatic food crops (deep water rice, fish, water chestnut, makhana, water lilly, *Colocasia* spp. etc.) and non-food crops (*Cyperus* spp., *Typha* spp., *Clinogyne dichotoma*, *Aeschynomene aspera*, *Brachiaria mutica*, *Coix* spp. etc.), ornamental and beneficial medicinal plants including fish genotypes which are immense valuable, nutritious, important and more popular in these regions. Wetlands are continuously enriched by adding of large quantity of biomass, enriched the soil in consequence. Makhana or fox nut (*Euryale ferox* Salisb.) under the family - Nymphaceae and water chestnut (*Trapa bispinosa* Roxb.) under the family Trapaceae or Onagraceae are the annual floating-leaved herbs (with C_3 type of photosynthesis), important aquatic food crops growing in diverse areas from tropics to the Frigid Zone with a great importance to wide sector of rural people. It is a native to South-East Asia with the prevalence of tropics to sub-tropics accomplished by humid to sub-humid environmental countries like China, Japan, Malaysia, Thailand, Philippines, Java, Sumatra, Nepal, Bangladesh, Sri Lanka and India. Fresh immature kernels of water chestnut fruits is used as a popular article of food in raw or cooked form, which are abundant source of starch (23.3%), protein (4.7%), minerals (1.1%), amino acids, vitamins including medicinal and therapeutic value. Similarly, mature makhana kernels posses high nutritive value comprised rich in carbohydrate (76.9%), protein (9.7%), minerals (1.3%) and fat (0.1%), are used as milk pudding, varieties of sweetmeat dishes, vegetable curry and as costly popped form. Both are cultivated scatteredly in water bodies mainly of north-eastern coastal part of the country.

Resource Utilization

Meeting the challenges of sustaining food security and economic outturn for the poor and marginal farmers, it is thus possible with the resource utilization of the area. Development of improved farming systems in rainfed semi-aquatic to permanent aquatic wet areas that will diversity the farm through integration of aquatic food crops (water chestnut, makhana) along with pisciculture along with other components in multi-nature cropping system. Such approach can ensure higher and stable farm productivity, income and year-round employment opportunity without degrading the environment. This will generate year round more income 2-3 folds than that of existing at present over the area. This will play a significant role for the economic utilization of waste wetlands through the production of aquatic food crops along with fish variables. The relationship between the systems is obvious, but the techniques and economic aspects require further study, as it seems future prospects appear very promising. Encouragement of scientific culture on the integration of food crops - fish farming in wetland ecosystem is, therefore, most desirable due to the following sharing of advantages, which could possible to utilize at its maximum levels,

1. The synergistic effect of fish on aquatic food crops (water chestnut & makhana)
2. Control of aquatic weeds and associated insects by fish,
3. Increased efficiency of resource utilization, reduced investment risk through crop diversification and additional sources of food and income,
4. More frequent visits to the field particularly for fish genotypes by the farmers, resulting in better crop management,
5. Low risk for poor water chestnut and makhana growers with modest capital investment,
6. Year round employment opportunity for the farm family and
7. Consequently, improvement of farm family income and nutrition level.

Integrated Approach

Indigenous energy rich air breathing live fishes like (including snake-headed) - *Channa striatus, Channa punctatus, Channa marulius, Clarias batrachus* and *Heteropnuestes fossilis*) are most important. This was tried successfully under this integrated system as it can able to fetch more money in the market due to its high price and prefers most by the common people than that of sweet water fishes, particularly in village and urban areas of eastern part of the country.

From the literature survey, it is recommended that very limited or no information is still available in the study zone as well as our country, regarding the evaluation of the system of such aquatic food crops like water chestnut and makhana along with fish genotypes under integrated aqua-terrestrial ecosystem. The introduction of fish along with deep water rice in waste wetland ecosystems are common for the utilization of food, total productivity [5, 6, 7, 8, 9] as well as for improving soil fertility by grazing on aquatic biomass and contributing through their feaces to nitrogen accumulation at soil surface [10, 11].

To realize the facts with great significance, a case study on the integration of such important aquatic food crops along with fish culture at farmers' level was undertaken in wet body (pond) during pre to post-monsoon season for productivity and economic stability of the system in the coasts and north-eastern part of Indian sub-tropics.

METHODOLOGY

The field study at farmers' level was undertaken during pre to post-monsoon season at *'tal'* wetlands in the subtropics under new alluvial zone of West Bengal, India situated at $23^{0}5^{/}$ N latitude and $89^{0}0^{/}$ E longitude and elevated at 9.75 meter MSL. Experiment was carried out in statistically randomized block design replicated four, where, individual aquatic food crops and fish genotypes [T_1 - LF (singi - *Clarias batrachus*) & T_2 - LF (magur - *Heteropneustes fossilis*); T_3 - SW fish (rohu - *Labeo rohita*) & T_4 - SW fish (katla - *Katla katla*) and T_5 - water chestnut (*Trapa bispinosa* Roxb.) & T_6 - makhana (*Euryale ferox* Salisb.)] were considered as six sole treatments along with four mixed treatments combined of crops with fish variables (T_7 - water chestnut + LF (both in 1:1 ratio); T_8 - water chestnut + SW fish (both in 1:1 ratio); T_9 - makhana + LF (both in 1:1 ratio); T_{10} - makhana + SW fish (both in 1:1 ratio) altogether ten treatments. In the sub-plot treatments, four combinations of both fish groups were allowed for their competitive effect of two variables. Statistical analysis was done individually on crop and fish basis, where, minimum 12 degrees of freedom was maintained which accomplished with the replications.

In the system approach, particularly in sole system, both crops (water chestnut & makhana) were transplanted maintaining 1.5 m x 1.5 m row to row and plant to plant apart, and all individual fish fingerlings were stalked in the respective pond @ 6,000 fingerlings when these were cultured as sole system. But water chestnut and makhana were maintained at 2.0 m x 2.0 m row to row and plant to plant apart, when it combined with fish of different types. In mixed system, fishes were allowed 75% of the main plot (4,500 fingerlings ha^{-1}). Makhana was transplanted during first week of April (in 50 cm of water depth), while, water chestnut during first week of July (in 70 cm of water depth due to accumulation of rainwater). All fishes were stalked during the second week of July after initial establishment of both the crops for synchronous effect of fishes on it. Seedlings of both the crops were transplanted 2-3 plants/stool. For fertilization, crops received N, P_2O_5 and K_2O @ 20 : 30 : 20 kg ha^{-1}, applied as basal. Foliar application (as depth of water body is high, foliar application by spraying during growth stages of the crop) of zinc based micronutrient (Chelamin @ 150 g ha^{-1} 300 l^{-1} of water) + NPK (0.5% conc. of each nutrient at a time *i.e.* 0.5 + 0.5 + 0.5 = 1.5% conc.) at 20 days interval of 30 DAT and continued up to November 15.

On an average each fingerling weighed 6 g at the time of release. Besides NPK including spray materials, fishes were supplied feed of powdered mustard oilcake + rice husk in 1:1 ratio @ 6 times of body weight of fishes at weekly interval in sole fish system and 75% of feed in combined treatments of crop + fish systems.

Initial soil samples were collected from the bottom of the respective ponds for determination of physico-chemical properties viz. pH (6.48), organic carbon (0.58%), organic matter (0.98%), available nitrogen (0.072%), phosphorus and potassium (83.4 and 292.4 kg ha^{-1}) followed by the method described by Jackson (1973). Water samples were collected for analyzing initially for pH (6.86), BOD (1.56 μg l^{-1}), COD (2.16 μg l^{-1}), CO_3^- (1.16 m eq. l^{-1}), HCO_3^- (1.36 m eq. l^{-1}), NO_3^- N (26.85 μg l^{-1}), SO_4^- S (441.43 μg l^{-1}) and Cl^- (152.08 μg l^{-1}) by AAS followed the standard analytical procedure [12].

For easy comparison among the fishes of different categories and crops due to their heterogeneous characters, all the variables were converted to makhana yield equivalence (MYE) in terms of production (t ha^{-1}) was determined following the formula:

$$\text{Makhana yield equivalence (t ha}^{-1}\text{)} = \frac{\text{Total market price of the crop/fish to be compared (Rs.)}}{\text{Price of the makhana t}^{-1}\text{ (Rs.)}}$$

For calculation of MYE, GMR, NP and B-C ratio, market price of all the products were considered as follows,

Table I: Market price of water chestnut, makhana and different type of fishes

Items	Price (Rs. t^{-1})	Price (US \$ t^{-1})
Fishes		
Magur	1,50,000	3,260.9
Singi	1,40,000	3,043.5
Rohu	60,000	1,304.3
Katla	55,000	1,195.6
Aquatic food crops		
Water chestnut	6,000	130.4
Makhana	30,000	652.2

(1 US $ = Indian Rupees 46.0)

Water chestnut consumed as immature fresh fruit; pickings were started from September, continued up to first fortnight of December, when both makhana seed kernels and fish of different genotypes were harvested at a time.

RESULTS AND DISCUSSION

The outcome of the experimental data that generated in the field is capable enough and highlighted on the various aspects related to the problems, prospects and development of suitable agro-techniques in integrated way, particularly on the production system and economics in this situation. This will also help to develop techniques in consequence through adaptation to get an outyielding ability which will able to fetch more money in the market as well as able to improve the socio-economic status furthermore of these resource poor farm families in the regions.

Crop and Fish Yield

Due to non-homogenous characteristics of water chestnut, makhana and fish of different categories, yield were not comparable among themselves, described separately within the group of sole along with their combined effect (Table II). Both water chestnut and makhana crop individually yielded highest as sole (8.39 and 2.36 t ha^{-1}) compared to yield of combined system with significant difference, deviated the yield from 31.5 - 44.2 and 37.2 - 59.4%, respectively. Among the different combinations, highest and lowest yield of water chestnut obtained with, WC + L fish (6.38 t ha^{-1}) and WC + RK fish (5.82 t ha^{-1}); for makhana, Makhana + L fish (1.72 t ha^{-1}) and Makhana + RK fish (1.1.48 t ha^{-1}) without producing any statistical difference of the system. Yield increment in the former in respect to later one be only to the tune of 9.62% in water chestnut and 16.2% in makhana, probably due to some congenial effect of fishes on both the foliage.

Likewise food crops, individually all fishes were out yielded (magur - 0.59, singi - 0.54 and rohu - 1.18 and katla - 1.32 t ha^{-1}, respectively) as sole than that of grown in combination (Table II). In combined system, although differences were very narrow but highest yield of LF and RK fishes (0.41 + 0.32 & 0.86 + 0.98 t ha^{-1}) exhibited with water chestnut, probably due to compatibility with the crop of the system. It is estimated only 0.03 and 0.2 t ha^{-1}, than that of makhana (0.38 + 0.29 & 0.76 + 0.78 t ha^{-1}), assuming some inference occurred on the movement of fishes, particularly in makhana crop, obviously due to profuse spines on the herbs.

Makhana Yield Equivalence (MYE)

It is evident to compare among them on the basis of yield equivalent of any crops like makhana, which was calculated in terms of produce value that might be reflected in integrity of the establishment of the system (Table II). In sole system, among the aquatic food crops makhana produced highest (2.36 t ha^{-1}) than water chestnut (1.68 t ha^{-1}). Among the fishes, magur ranked high (2.95 t ha^{-1}) followed by singi, katla and rohu (2.52, 2.42 and 2.36 t ha^{-1}, respectively) due to of their produce value along with yield performance. In mixed system, although both LF and RK group of fishes performed better (2.05 + 1.49 & 1.72 + 1.80 t ha^{-1}), particularly when it associated with water chestnut. This might be due to easy movement of fishes in such media. But as cumulative effect of crop-fish diversity, it was more pronounced when it combined with makhana (4.97 t ha^{-1}) due to more sharing produce value of this crop (1.72 t ha^{-1}) accomplished with high market price of seed kernels than other combinations. Eventually, the seed kernels as well as popped-form of seed kernels of makhana are now being exported to other foreign countries with high price value, because of their nutritional quality as well. Farmers are gaining importance for their cultivation of this crop day by day.

Table II: Yield and makhana yield equivalence (t ha^{-1}) of water chestnut, makhana and fishes

Treatments	Individual yield (t ha^{-1})						Makhana yield equivalence (t ha^{-1})						
	M	S	R	K	WC	Mak	M	S	R	K	WC	Mak	Total
T_1 - Sole M	0.59	--	--	--	--	--	2.95	--	--	--	--	--	2.95
T_2 - Sole S	--	0.54	--	--	--	--	--	2.52	--	--	--	--	2.52
T_3 - Sole R	--	--	1.18	--	--	--	--	--	2.36	--	--	--	2.36
T_4 - Sole K	--	--	--	1.32	--	--	--	--	--	2.42	--	--	2.90
T_5 - Sole WC	--	--	--	--	8.39	--	--	--	--	--	1.68	--	1.68

T_6 - Sole Mak	--	--	--	--	--	2.36	--	--	--	--	--	2.36	2.36
T_7 - WC + LF	0.41	0.32	--	--	6.38	--	2.05	1.49	--	--	1.28	--	4.82
T_8 - WC + RK	--	--	0.86	0.98	5.82	--	--	--	1.72	1.80	1.16	--	4.68
T_9 - Mak + LF	0.38	0.29	--	--	--	1.72	1.90	1.35	--	--	--	1.72	4.97
T_{10}-Mak + RK	--	--	0.76	0.78	--	1.48	--	--	1.52	1.43	--	1.48	4.43
CD (*P=0.05*)	0.08	0.07	0.19	0.21	0.89	0.25	--	--	--	--	--	--	--

M, magur; S, singi; R, rohu; K, katla

Monetary Return

Based on the market value of the produce, GMR or gross monetary return (Rs. ha^{-1}) of the sole and mixed cropping systems were calculated and from the calculation it may thus possible to evaluate for the economic consideration for the adoption of agro-techniques for the benefit of the rural sector of these zones.

Table III: Gross monetary return and benefit-cost ratio of the system

Treatments	Gross monetary return (Rs.'000 ha^{-1})						
	M	S	R	K	WC	Mak	Total
T_1 - Sole M	88.50 (1924)	--	--	--	--	--	88.50 (1924)
T_2 - Sole S	--	75.60 (1643)	--	--	--	--	75.60 (1643)
T_3 - Sole R	--	--	70.80 (1539)	--	--	--	70.80 (1539)
T_4 - Sole K	--	--	--	72.60 (1578)	--	--	72.60 (1578)
T_5 - Sole WC	--	--	--	--	50.34 (1094)	--	50.34 (1094)
T_6 - Sole Mak	--	--	--	--	--	70.80 (1539)	70.80 (1539)
T_7 - WC + LF	61.50 (1337)	44.80 (974)	--	--	38.28 (832)	--	144.58 (3143)
T_8 - WC + RK	--	--	51.60 (1122)	53.90 (1172)	34.92 (759)	--	140.42 (3053)
T_9 - Mak + LF	57.00 (1239)	40.60 (883)	--	--	--	51.70 (1122)	149.30 (3244)
T_{10} - Mak + RK	--	--	45.60 (991)	42.90 (933)	--	44.40 (965)	132.90 (2889)

Table III: Gross monetary return and benefit-cost ratio of the system (contd.)

Treatments	Cost of cultivation (Rs.'000 ha^{-1})							Net profit (Rs.'000 ha^{-1})	Benefit-cost ratio
	M	S	R	K	WC	Mak	Total		

T_1	21.53 (468)	--	--	--	--	--	21.53 (468)	66.97 (1456)	3.11
T_2	--	20.21 (439)	--	--	--	--	20.21 (439)	55.39 (1204)	2.74
T_3	--	--	19.56 (425)	--	--	--	19.56 (425)	51.24 (1114)	2.62
T_4	--	--	--	19.62 (426)	--	--	19.62 (426)	52.98 (1152)	2.70
T_5	--	--	--	--	18.48 (4.02)	--	18.48 (4.02)	31.86 (693)	1.72
T_6	--	--	--	--	--	18.26 (397)	18.26 (397)	52.54 (1142)	2.88
T_7	8.68 (189)	8.16 (177)	--	--	15.55 (338)	--	32.39 (704)	112.19 (2439)	3.46
T_8	--	--	9.12 (198)	8.06 (175)	15.55 (338)	--	32.73 (711)	107.69 (2341)	3.29
T_9	8.68 (189)	8.16 (177)	--	--	--	14.86 (323)	31.70 (689)	117.60 (2557)	3.71
T_{10}	--	--	9.12 (198)	8.06 (175)	--	14.86 (323)	32.04 (696)	100.86 (2193)	3.15

M, magur; S, singi; R, rohu; K, katla; Parenthesis indicates US $ (1 US $=Indian Rs.46.00)

Highest GMR goes towards mixed system of crops + fish diversity than that of sole and among these, highest obtained with the combination of makhana + L fishes (Rs.1,49,300 ha^{-1} eq. US $ 3,244) due to dominating share of both fishes and market price of L fishes irrespective of lower yield performance than that of other combination (Table III). Practically, it is more invigorating in nature and lucrative in the market but are wiped off day by day. Next highest return obtained with water chestnut + LF fishes (Rs.1,44,580 eq. US $ 3,143) followed by water chestnut + RK fishes (Rs.1,40,420 ha^{-1} eq. US $ 3,053) in respect to their produce value. Among the combinations, lowest returns obtained with the integration of RK fishes along with makhana (Rs.1,32,900 ha^{-1} eq. US $ 2889), obviously due to some detrimental effect of the crop on rohu and katla fishes, particularly for movement and constraints of feeding system.

NP and Benefit-Cost Ratio

Subtracting the cost of cultivation, NP (Rs. ha^{-1}) including benefit-cost ratio were calculated and these are the right pathways to judge the acceptability of any system to adopt for the benefit of farmers in a region. However in mono-cropping system, like GMR highest NP and B-C ratio exhibited with makhana among the crops (Rs.52,540 ha^{-1} eq. US $ 1,142 and 2.88) and magur fish (Rs.66,970 ha^{-1} eq. US $ 1,456 and 3.11) among the fish variables. There was a more NP of 64.9% in makhana over water chestnut. Likewise, an increment of NP in magur fish was to the tune of 20.9 - 30.69%, respectively more than that of other fishes (Table III).

CONCLUSION

The vast wetland ecosystem may effectively be utilized through the cultivation of so many aquatic crops, fish variables which not only valued to human beings but also imperative for the upliftment of resource poor rural economy who are inextricably linked with the system. Besides, wetlands are continuously enriched by adding large quantities of biomass, enriched in sequence, which has possible to utilize this enriched biomass effectively for production of arable crops as well as improvement soil nutrient status in the zones.

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ENDNOTES

Wetland ecosystems are immense valuable for the production of aquatic crops, naturally sustainable and economic stability for rural people including maintenance of ecological balance in the system as well as it enriched biomass, which is valuable for soil health and cultivable for arable crops in consequence.