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Utilization of wetland ecosystem through fish-crop diversification for enhanced productivity and economic stability for the fish farm community of the Indian sub-continent

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ABSTRACT

The extensive wetland ecosystems intersected with the main river systems of the Ganges, Brahmaputa, Padma, Mahanadi, Mahananda, Rupnarayan their tributaries and associated water bodies like oxbow lakes (mauns, chaurs, jheels, beels, baors and nayanjali) are immensely valuable for a wide range of fish species, nutrient-rich aquatic food crops and offer possibilities for integrated fish-crops.

This paper deals with a number of case studies that were undertaken during the last 8-10 years in utilizing divergent *'Tal'* wetland ecosystems (deep, semi-deep, temporary in a range of agro-ecological zones like NAZ, OAZ and Coastal Zone of the region) for the development of integrated management programmes using a range of approaches. These included (i) system approach (excavation & renovation, methodological approach), (ii) management (fish-crop management, inter & post-harvest care & processing, marketing), (iii) integrated natural resource management utilizing organic as well inorganic sources, and (iv) low-cost fish-feeds, based on fish-crop diversification.

This paper also deals with some endangered indigenous fish species. The unique approach of watershed plans (*bherri* system), which were formulated for upright production systems, was economically successful. Economic indicators reveal there were comparative advantages of mixed farming systems compared to monoculture, exhibiting >2.5 fold gains even for resource poor fish farming families.

INTRODUCTION

Vast wetland ecosystems, especially in the north-eastern part of India are immensely valuable for the production of aquatic crops, fish and integrated aquatic crops as well as many other beneficial aquatic flora and fauna. Wetlands are environments that are subject to permanent or periodic inundation or prolonged soil saturation sufficient for the establishment of hydrophytes and/or the development of hydric soils or substrates. They are the transitional phase between dry terrestrial and permanently aquatic ecosystems, where the soil is frequently waterlogged, and the water table is at or near the surface. The land is often covered by shallow water, which exists either permanently, semi-permanently or temporarily. Some common wetland types include marsh, fen, wet meadow, swamp, bog, muskeg, wet tundra, tidal flat, river bottom, lowland, mangrove forest, tropical rainforest and floodplain swamp (Tiner, 1993).

Land which is subject to prolonged flooding during the rainy season, is known in West Bengal as *'Tal'* lands. These are low-lying flood plains including back water swamps and are mainly comprised of flat alluvial plains intersected with the main river systems (Ganges, Brahmaputra, Padma, Mahanad, Mahanadi, Rupnarayan etc.) and its many tributaries and canals covering around 300,000 ha.

The Ramsar Convention held in Iran in 1971, brought the subject of wetlands to the International arena, and highlighted and accepted a treaty on 'Conservation and Wise Use of Wetlands' (Navid, 1988). Wetlands comprise 6.4 per cent (855.8 million ha) of the world total area (Maltby and Turner, 1983) of which 23.5 million ha are in India, mostly in north-eastern and coastal parts of the country (Anonymous, 1986). The survival of human civilization has also been inextricably linked with wetlands.

Wetlands are continuously enriched by the addition of large quantities of biomass and the soil is enriched in consequence (Matsuo *et. al*, 1979, Seki *et. al*, 1979, Tsuchiya and Iwaki, 1979 and Yamamoto and Seki, 1979). These are mucky in nature, grey to blackish-grey in colour, sometimes partially decomposed due to anaerobic condition. The soil status may further be improved if a period is allowed for quick decaying during post-wet months under aerobic condition. In this region, one of the most conventional practices by the farmers is to utilize this resource-rich humus soil for production of succeeding arable crops. This practice not only saves a substantial amount of fertilizer including other important essential elements but also improves the physical condition of the soil (Puste and Das, 2001).

Wetlands are highly exploited. The development and management of wetlands should form an important part of integrated watershed management plans. Swampy, fertile, productive wetlands are continuously used by the rural farmers for production of fish, aquatic food crops (deep water rice, water chestnut, makhana, water lily, Royal water-lily, *Colocasia* spp. etc.) and non-food crops (*Cyperus* spp., *Typha* spp., *Clinogyne dichotoma*, *Aeschynomene aspera*, *Brachiaria mutica*, *Coix* spp. etc.), as well as ornamental and beneficial medicinal plants.

To meet the challenge of sustaining food security and economic returns for the poor and marginal farmers, it is necessary to develop improved farming systems with diversified production systems. This can ensure higher and more stable farm productivity, income and year-round employment opportunity without degrading the environment. This can generate up to 2-3 fold income gains compared to current systems and has the following advantages:

- There is a synergistic effect of fish on aquatic food crop production.
- The control of aquatic weeds and associated insects by fish.
- Increased efficiency of resource utilization, reduced investment risk through crop diversification and additional sources of food and income.
- More frequent visits to the field particularly for fish by the farmers, resulting in better crop management.
- Low risk for poor water chestnut and makhana growers with modest capital investment.
- Year round employment opportunity for the farming family.
- Improvements in farm family income and nutrition levels.

THE INTEGRATED APPROACH: FISH-CROP DIVERSITY

Indigenous, energy rich, air-breathing live fish like Shoil, *Channa striatus*; Taki, *C. punctatus*; Gajar, *C. marulius*; Magur, *Clarias batrachus*; Singi, *Heteropnuestes fossilis* and Koi, *Anabus testudineus* are most important. Besides*, Chanda ranga*, *Chanda nama, Punctius ticto*, *Punctius sophore*, *Punctius sarana*, *Colisa pectoralis*, *Colisa fasciata* including Indian major fresh water carps like Rohu (*Labeo rohita*), Katla (*Catla catla*) and Mrigal (*Cirrhina mrigala*) are also important. These were used successfully under integrated systems as they can fetch higher market prices because they are preferred by most of the common people, particularly in village and urban areas. The introduction of fish along with deep water rice in waste wetland ecosystems is common for the utilization of food and total productivity (Grist, 1975, Ghosh, and Saha, 1980, Dutta et. al, 1984, Jhingran, 1991 and Puste and Bandyopadhyay, 2000) as well as for improving soil fertility by grazing on aquatic biomass and contributing through their faeces to nitrogen accumulation in soils (Brahmanand and Mohanty, 1999 and Bandyopadhyay and Puste, 2001).

There appears to be very limited or no information available on the evaluation of integrated systems involving fish and aquatic food crops such as water chestnut and makhana. To address this, a number of farmer level case studies were undertaken through Government sponsored research projects in pond systems during, before and after the monsoon period. [I.C.A.R., Indian Council of Agricultural Research; NWDPRA, National Watershed Development Project for Rainfed Areas; TDEP, Technology Development and Extension Project of Department of Land Resources (DoLR); FPIH, Food Processing Industries and Horticulture etc.]

Importance of aquatic food crops other than rice
Makhana or fox nut (*Euryale ferox* Salisb.), family - Nymphaceae and water chestnut (*Trapa bispinosa* Roxb.), family Trapaceae or Onagraceae are annual floating-leaved herbs. They are important, familiar and nutritious aquatic food crops grown in diverse areas from the tropics to sub-tropics. The fresh immature kernels of water chestnut fruits are used as a popular and nutritious food in raw or cooked form. Similarly, mature makhana kernels possess a high nutritive value and are rich in carbohydrate (76.9%), protein (9.7%), minerals (1.3%) and fat (0.1%). They are used in milk puddings, sweetmeat dishes, vegetable curry and are also sold in a costly popped form, which is being exported to foreign countries.

METHODOLOGY

The present study had been conducted under in a range of different ecosystems including new alluvial soils, old alluvial soils as well as coastal zones with the objectives of disseminating the results of research on aquatic crop-cum-fish culture production systems. The pilot studies used an extensive system approach in wetland ecosystems in trials carried out at research stations to choose best one. This involved some excavation to create suitable water bodies called the *Bherri* system (Fig.1 & 2), because of their divergence as well as their production potential.

The objective was to find suitable zone-specific techniques for large-scale implementation at the farmer level as ‘On farm demonstrations’.
The main research areas were:

- Suitable planting varieties of aquatic crops adjusted with fish genotypes in integrated system,
- Integrated nutrient management systems (low-cost plant as well as improved fish-feed) sustainable for optimum production, and
- General management (fish-crop management, post-harvest care and processing, marketing etc.).

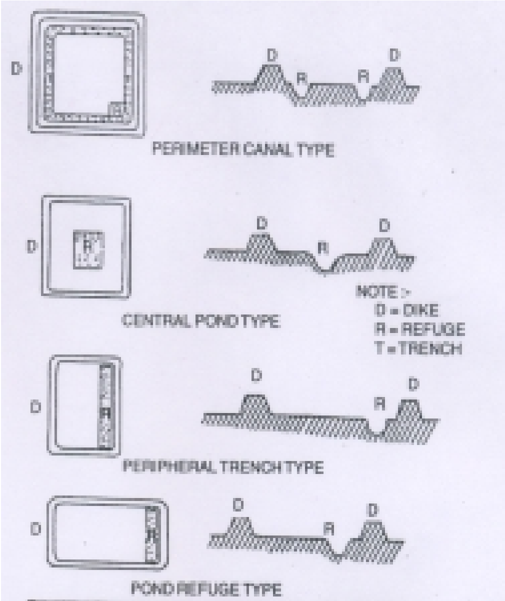

Fig.1 Different types of pond-refuges/bherrii system

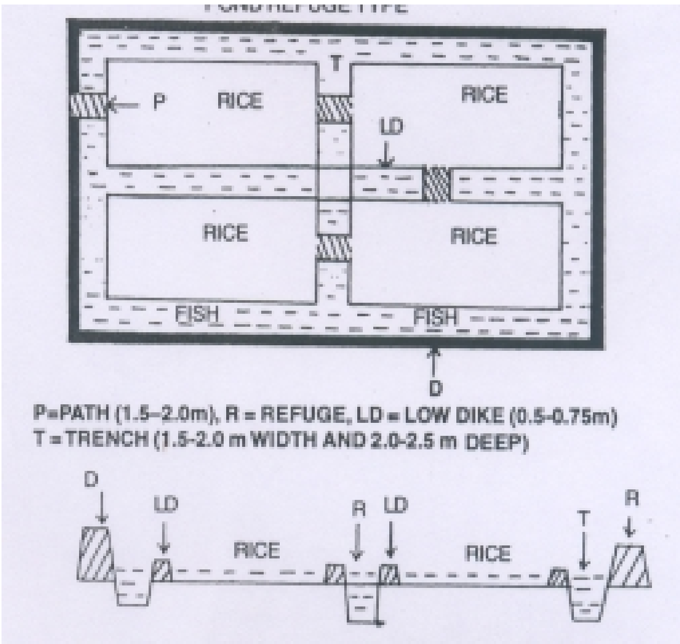

Fig.2 Field diagrams of combined fish-cum-rice/other crop culture

The work involved the NGOs, WATER, Sarvodaya, Taldi Netaji Sangha. Before on-farm demonstration trials, information was collected on background characteristics of the respondents and their socio-economic status in each of the zones. The field project trials were launched through an extension programme in each zone.

The main farming systems tested were:

- Major aquatic food crops – monoculture of water chestnut and makhana
- Rice-cum-fish culture
- Aquatic food crops (water chestnut and makhana)-cum-fish variables, and
- Aquatic food and non-food crops (mat-sedges)-cum-fish in a 3-tier system.

The trials were undertaken mainly during pre to post-monsoon season. In the monocultures both water chestnut and makhana were transplanted with spacings of 1.5 m x 1.5 m row to row and plant to plant apart, and fish fingerlings were stocked at 6,000 fingerlings/ha. In integrated systems, plants were spaced at 2.0 m x 2.0 m row to row and plant to plant apart, fish were allowed to occupy 75% of the main plot and were stocked at 4,500 fingerlings/ha. Makhana was transplanted during the first week of April (in 50 cm of water depth), while, water chestnut was transplanted in the first week of July (70 cm of water depth due to accumulation of rainwater).
All fishes were stocked during the second week of July after initial establishment of both crops. Seedlings of both the crops were transplanted with 2-3 plants/stool. For fertilization, crops received N, P_2O_5 and K_2O @ 20 : 30 : 20 kg/ha, as a basal application. A foliar application of a zinc based micronutrient (Chelamin) was also used and NPK was applied at 20 day intervals from 30 days after transplanting up to mid-November.

Fish fingerlings were stocked at 6 g at the time of release. They were fed powdered mustard oilcake and rice husk (1:1 ratio) at a rate of 6 times the estimated body weight of the fish at weekly intervals in monoculture systems, reduced to 75% of this amount in combined crop-fish treatments. Occasionally animal protein (e.g. fish-meal, silk-worm cocoons when available) was added to the fish feed. In all cases an extra 15% of fingerlings were stocked to allow for mortalities. A borderline area of 0.75 - 1.00 m of each individual plot was maintained as free water surface for easy movement of fishes as well as for feeding.

Water chestnut is consumed as immature fresh fruit with picking starting from September and continuing up to the first fortnight of December. Makhana seed kernels and fish were harvested at the end of December and April to May (at least 2 times) depending on the depth of submergence.

For ease of comparison among the different types of fish and crops, all the variables were converted to makhana yield equivalent (MYE) in terms of production (t/ha), according to the following formula:

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

For calculation of MYE, Gross Monetary Return, Net Profit and Benefit-Cost ratio, the following market prices in table 1 were used.

Table 1. Market price of water chestnut, makhana and different type of fishes

Items	Price (Rs. t–1)	Price (US $ t–1)
Fish		
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

The treatments applied included:
FG1: Fish species stocked - Magur, Singi, Shoil, and Gajar and
FG2: Fish species stocked - Rohu, Katla, Mrigal and Silver carp
F1: powered mustard oilcake + rice husk in 1:1 ratio,
F2: neem oilcake,
F3: poultry droppings + cowdung (1:1)
F4: without fish-feed (although very small amounts applied when available to the farmers as in local practice.

These were applied in 4 village based clusters with the aim of developing centres for further dissemination of new technologies on fish production as well as quality of produce (Puste and Basu, 2004). Initial soil samples were collected at every set of individual studies following standard analytical procedures (Jackson, 1973).

RESULTS

Individual fish yields

Individual fish yields in clusters I & II in both groups performed comparatively less well compared to clusters III & IV, perhaps because of water quality and the depth of submergence of the respective ponds. It is more contrasting and comparable enough with the local practice. The magnitude of yield increases in all the individuals were around 46 to 78 per cent, with the highest rises in production of Magur, Singi, Mrigal and Silver carp (Table 2). A significant price difference was noted between local markets and zonal trade centres. In most cases, fish farmers sell their output directly to the middlemen in the trade centres, with reasonable profit margins.

Table 2. Individual fish yield and their price

Variables	Av. yield (t ha^{-1})						Av. price of fishes (Rs. t^{-1})	
	Cl. I	Cl. II	Cl. III	Cl. IV	Av. yield	Av. local yield	Local market	Zonal trade
FG1								
Magur	0.57	0.59	0.68	0.64	0.62	0.38	1,30,000 (2,826.1)	1,50,000 (3,260.9)
Singi	0.52	0.56	0.62	0.58	0.57	0.32	1,20,000 (2,608.7)	1,40,000 (3,043.5)
Shoil	1.32	1.38	1.46	1.52	1.42	0.96	1,10,000 (2,391.3)	1,30,000 (2,826.1)
Gajer	1.38	1.44	1.50	1.52	1.46	0.92	1,10,000 (2,391.3)	1,30,000 (2,826.1)
FG2								
Rohu	1.14	1.19	1.27	1.24	1.21	0.83	50,000 (1,086.9)	60,000 (1,304.3)
Katla	1.28	1.35	1.43	1.38	1.36	0.86	40,000 (1,086.9)	55,000 (1,195.6)
Mrigal	1.09	1.15	1.26	1.22	1.18	0.68	40,000 (1,086.9)	50,000 (1,086.9)
S. carp	1.18	1.26	1.39	1.33	1.29	0.74	40,000 (1,086.9)	45,000 (978.3)

Av., average; Cl., cluster; Parenthesis indicates US$ (1US $ = INR 46.00)

Group fish yield

Application of fish feed (powdered mustard/groundnut oilcake + rice bran) had a strong influence on fish yields, as practiced in farmers' fish ponds in different villages of the zones. Almost all the feed items were more or less equally effective for such increment of fish yield and it significantly differed from control pond, where no food was applied (Table 3). The increase in production was 82.2 to 116.4% in FG1 and 98.5 to 131.0%, in FG2. However, among the 3 fish-feed materials the highest results were obtained with F1 (powered mustard oilcake + rice husk in 1:1 ratio @ 6 times body weight of fish at weekly interval), although the difference was not statistically significant. The practice of fish feeding was quite effective in increasing fish yields irrespective of fish type in the 4 different clusters of the zones (Puste and Basu, 2004).

Table 3. Fish yield in groups as influenced by fish-feeds

Variables	Cl. I		Cl. II		Cl. III		Cl. IV		Av. of clusters	
	FG1	FG2	FG1	FG2	FG1	FG2	FG1	FG2	FG1	FG2
Fish feed										
F1	1.02	1.28	1.19	1.34	1.21	1.33	1.18	1.32	1.15	1.32
F2	1.00	1.22	1.12	1.18	1.18	1.26	1.15	1.21	1.11	1.22
F3	1.04	1.18	1.13	1.22	1.12	1.24	1.09	1.22	1.09	1.21

F4	0.56	0.59	0.55	0.58	0.64	0.67	0.61	0.64	0.59	0.62

CONCLUSION

India is endowed with vast and varied inland water resources. The share of total fish catch caught in inland waters has increased over the years from 29 per cent in 1950-'51 to over 49 per cent in 2001 (Ayyapan and Venkateshwarlu, 2002). Carps in freshwater aquaculture and shrimps in brackish water aquaculture have mainly contributed to the increased quantity as well as value of the inland aquaculture sector.

The vast wetland ecosystem may effectively be utilized through the cultivation of so many aquatic crops and fish which are not only valued by human beings but are also important for the upliftment of the resource poor rural economy.

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