SUMMARY

The areas where deepwater rice (DWR) is grown (June to November) remain waterlogged for 5-6 months during rice growing season and water level of 50 cm or more persists at least for a month. The stagnant water under the DWR canopy and other biotic and abiotic factors of this particular rice ecosystem play a complex role on DWR yield which are often thwarted with uncertainty in terms of production. The excess water also impose certain impacts on the habit of rice cultivation practices, cropping patterns etc. Besides, it forms the habitat for various wild fish and other aquatic organisms like prawn crabs, snails etc. But still, there exists, paucity of detailed information regarding the aquatic environment and particularly about the fisheries potentialities of the ecosystem.

The present thesis deals with the "studies on the impact of aquatic environment on deepwater field with special emphasis on the development of improved rice-fish culture system."

The study included four main aspects of the deepwater rice agro-ecosystem which were i) the survey of rice-fish farming practices of DWR farmer of West Bengal, India, ii) the ecology of a typical open DWR field, iii) the environment of closed DWR field and iv) the possibilities of utilization of closed DWR environment for improved rice-fish production. All the studies were carried out during the period of four rice growing seasons (Kharif seasons, 1986-1989).
Following are the brief aspects of some important results which gave an impression about the agro-ecosystem and offer a scope of development of improved integrated rice-fish farming system for better productivity of such areas.

A. Survey:

1. The survey on field morphometry revealed that there were two main categories of DWR field i) Closed type - naturally bunded or artificially dyked ii) Open type - continuous unbunded field having large water sheet connected with river or perennial waterbodies.

2. The survey on agronomic practices revealed that weeding, fertilizer application, pesticide application etc. were, in general, not so frequent in DWR. But little better crop management were associated with closed type field having area > 1 ha where transplanting of seedlings, crop protection measures etc., were practiced by the farmers of certain areas of West Bengal. Pesticide use was noticed very irregular and when used, it was done generally during early growth phases and primarily during the period of critical pest infestation. In open field hardly any management system were followed except certain basic needs of rice cultivation. Rice production ranged from 1.3 t/ha to 2.2 t/ha in West Bengal.

3. The existing cropping of pattern in DWR area revealed that these areas were generally monocropped with rice particularly in the fields without having irrigation facilities during dry period. During wet season, most of the farmers were found to harvest wild resources as the companion crop of DWR through traditional captural system.

4. The traditional captural fishery production ranged from 40-125 kg/ha/season. Culture fishery was hardly observed.
5. The habit of capture among the farmers might be categorised as i) customery habit with less attention providing any input for the fish ii) voluntary habit with more attention for fish providing some input for digging trap ponds and renovation of field dykes etc.

6. Survey also revealed that *Channa punctatus*, *c. gachua* and *puntius* spp., were the dominant piscine resources of DWR field collected generally by DWR farmers.

B. Ecology of a typical open DWR field.

1. Water quality criteria: Dissolved oxygen (D.O.) content of the DWR field water ranged from 11.34 mg/l - 2.85 mg/l; pH ranged from 7.98 - 7.80; specific conductivity ranged from 119.05 μmhos/cm to 391.0 μmhos/cm; water temperature ranged from 33.8°C to 22.8°C; surface D.O. and temperature showed little higher values, than the bottom D.O. and temperature during the study seasons. The D.O., pH and water temperature showed diurnal cycle where D.O. reached peak level at 13.00 - 14.00 hrs. Results of co-relation analysis revealed that any parameters in such complex environment did not show any definite relationship with a single parameter because of prevalence of various conditioning interwined factors which in every moment collectively play a complex role to maintain stability of the whole system.

2. Physico-chemical characteristics of soil indicated that soil were nutrient rich; the soil nutrients showed increased level during flooding period than pre-flood and post-flood situation (except K level which showed uniformity throughout the period) soil was clay type with slightly acidic pH.

3. Climatic factors: Waterdepth, rainfall and light intensity were studied which indicated that these three had major controlling effect over the temporary aquatic environment. Three years studies revealed variable flooding pattern which was dependant on the rain fall of the area during season. During 1988, *Kharif* season
rainfall and waterdepth showed positive correlation. In the study field, maximum waterdepth attained upto 144 cm in 1987. The waterdepth pattern showed definite phases namely, raising, static, early receding and late receding phase throughout whole wet seasons. Study also revealed that amount of precipitation during the Kharif seasons (July-December) in the area were more than 86.0% of the total annual rainfall which maintained the ecosystem upto December though monthly rainfall declined sharply after October. Clear water flooding facilitated light penetration where incident light intensity on the canopy was ranged from $16.6 \times 10^3$ to $51.0 \times 10^3$ lux during study season.

4. Biotic Community Structure : The aquatic fauna and flora associated with deepwater rice field were rich in diversity.

Plankton population showed that in DWR it ranged from 850.0-1015.0 unit/l. Phyto plankton dominated over zooplankton throughout the season. Both of them showed increasing trend of population with the progress of season. The phytoplankton constituted mainly of chlorophyceae, cyanophyceae and bacillariophyceae.

Bacillariophyceae were dominant form in the field during study seasons. Zooplankton of the field was consisted of protozoa, copepoda, cladocera, ostracoda, rotifera, nematoda and cnedaria. The nauplii larval forms were very common among the zooplankters. Phytoplankton and zooplankton showed significant positive correlation during the season. The macro-invertebrate included mainly arthropods, molluscs and annelids. The aquatic insects community were mainly belonging to six orders viz., Ephemeroptera, Odonata (larval form) Hemiptera (adult and larvae), Coleoptera (adult and larvae) Lepidoptera (larvae) and Diptera (larvae). Crabs and prawns were very common in the study field.
Crabs and prawns were collected by the DWR farmers as their food during the season.

*Pila globosa* was the widely available molluscs in the open DWR field under study. Besides, *Digoniostoma Cerameopoma* and *Cyraulus Convexiusculus* etc. were the major macro-benthos of the DWR. The local people exploited some of the edible forms (e.g. *Pila* sp., *Bellamya* sp.) as the source of their daily protein food.

The diversity indices of arthropods and molluscs population of the ecosystem revealed that the population were in stability during the study seasons. Higher values of Shannon Weaver index (H) for arthropods and molluscs indicated that the ecosystem was stress free as a habitat for them. But recession of water level was a major factor which finally resulted disappearance of this temporary but stable population.

The DWR field was the ideal habitat for 34 genera of wild fish and 8 species of fresh water prawn of genera *Macrobrachium* and *Caridina*.

Besides, frogs, snakes, waterbirds, rats etc. were also common in the field during the study seasons.

Ninetyfive genera of macrophytes or weeds were noticed in the DWR ecosystem during dry and wet season together. The dryland weeds, after submergence, added nutrient to the soil and water. Aquatic weeds and rice plants supported various life forms of the ecosystem by providing shelter, food and breeding substrates etc.

Above community structure indicated a semi-natural aquatic ecosystem where as an 'agroecosystem' human interference was negligible in study field.

Periphyton content of the rice-field environment ranged from 107.1 unit/cm²/glass slide to 355.5 unit/cm²/glass slide and 90.2 unit/cm²/glass slide to 390.0 unit/cm²/glass slide respectively during 1988 and
Biomass on DWR stem revealed it ranged from 1.3mg/cm stem to 9.7mg/cm stem. Qualitative investigation showed abundance of chlorophyceae during early flood followed by abundance of bacillariophyceae during post flood field. These forms were very rich in diversity in DWR at Pearapur during the study periods.

Macrozoobenthos of the field showed the population density of arthropods ranged 0-133/m², molluscs ranged 120-1305/m² and annelids (Branchiura sp.,) ranged 53-933/m². Monthly average of three Kharif seasons indicated lower density of arthropods population during August, September and October than July and November; molluscs showed increasing trend where the annelids showed decreasing trend with the progress of season towards November.

5. Food web: Studies on food-web revealed that all the members of the biotic community formed an intricate relationship among each other through their food chain. The producers of the ecosystems were phytoplankton, filamentous algae and macrophytes (including DWR plant). The top consumers of this aquatic ecosystem were wild fish and they exploited all the trophic levels of the DWR ecosystem. Other predators like snakes, frogs were poor in population and mostly frequent visitor of the environment. Human beings entered the ecosystem as quaternary consumer as they harvested rice, fish and vegetables for their food.

C. Environment of closed DWR field:

Following were some environmental features which revealed that closed DWR are conducive for rice fish integration.

1. The field water contained higher amount of D.O. during the month of August-September (range: 3.07-8.78 mg/l) and gradual decrease was generally noticed as the season progressed, but the mean value did not fall
below 3.0 mg/l throughout the study period. pH fluctuated with a narrow range and normally remained at the neutral level. Water temperature showed higher values generally during August-September (range: 29.2-31.7°C) in most sites under study. The lower temperature level was noticed in November but always remained above 20°C. Specific conductivity of field water was found lower during early part of the season with a gradual increase during later part of the season. There were site and location wise variation in specific conductivity of water, particularly in the lower stretches of West Bengal (i.e. in the district of Midnapore and Gosaba) it was higher in contrast to Hooghly, Burdwan etc.

2. Waterdepth of certain closed DWR field revealed that water started accumulation during the month of July and persisted till to the month of December. Maximum depth ranged from 71.0 cm-112.0 cm in different study locations of West Bengal. The waterdepth remained above 50 cm during the season ranged from 59-91 days within the ten study locations of the state.

3. Studies on soil characteristics of twelve closed fields indicated that soil of closed DWR are generally fertile where average level of organic carbon, phosphate and potassium were respectively 0.63%, 72.4 kg/ha and 386.9 kg/ha. The pH was 6.29±0.47 in the study fields.

4. In those fields, phytoplankton dominated over zooplankton. The mean value for phytoplankton ranged from 560-2150 unit/l and zooplankton ranged from 65-291 unit/l in 14 closed DWR field of West Bengal.

5. Presence of natural or artificial dykes around the field (as evident from the survey) formed it some what as like as the weedy shallow pond with DWR during rice growing seasons.
D. Possibilities of utilizing the closed DWR environment for improved rice-fish production:

Several on-farm (in farmer's field) and on-station (in research station) trials were conducted on composite culture of carps along with DWR in closed field situations under different treatment condition [i.e. fish alone, DWR alone, DWR + fish (no feed) and DWR + fish (suppl. feed)] in West Bengal, India. An improved rice variety Sabita (NC 492) and eight carp species (viz., Rohu, Catla, Mrigal, Common carp, Silver carp, Javapunti, Bata and Calbasu) were used during the experiment. Stocking size of fish were advanced fingerlings (10-12cm, @ 10000/m²).

Following were the results which proved the possibilities of adopting improved system of rice-fish culture instead of prevailing captural system in closed DWR environment.

1. Among all the treatment conditions DWR+fish (suppl. feed) showed statistically significant superior production of both rice and fish in comparison to DWR+fish (no feed), fish only and rice only.

2. Fish yield was increased by 45.7% in the plots with DWR+fish (no feed) in comparison to control plots having fish only (no DWR) and further increase of 60% yield was noticed due to application of supplementary feed in comparison to that of treatment without feed.

3. Among the eight species of carps, in all the treatment conditions common carp (Cyprinus carpio) javapunti, (Puntius javanicus) Rohu (Labeo rohita) and Catla (Catla catla) performed best in both of average percent retrieval and weight gain compared to bata (Labeo bata), calbasu (L. calbasu) silver carp (Hypopthalmicthys molitrix), and mrigal (Cirrhinus mrigala).
4. Higher yields, retrievals and weight gains of fish in the plots with DWR+fish (no feed) in comparison to control (fish only) indicate that DWR provided better environment for the fish than the plot without rice.

5. The stocking density of 10000 fingerling/m², stocking size of 10-12 cm used in the trials were probably a suitable one for the DWR ecosystem.

6. The trench designs e.g. lateral trench type (1m deep x 1m wide) served as the refuge for the fish and finally it was used as the catch basin during harvest.

7. Regarding rice production, presence of fish with supplementary feed treatment gave statistically significant superior yield in comparison to DWR+fish (no feed) and DWR only (control).

   Grain yield increased to the level of 25.9% in plots with DWR+fish (suppl. feed) in comparison to control (DWR only) and 5.4% increase was noticed in the plots with DWR+fish as compared to control (DWR only).

8. No. of tiller/m², grains/panicle and test grain weight in two treatment conditions viz., DWR+fish (suppl. feed) and DWR+fish (no feed) clearly depicted the beneficial influence of fish on rice production.

9. The rice variety 'Sabita' (NC 492) is an elongating photosensitive variety which also showed improved yields of DWR (2.6-3.2 t/ha) in control plots (DWR only) in comparison to yields of traditional DWR (1.3 - 2.2 t/ha).

10. From the study, it is evident that improved varieties of rice (e.g. NC 492) and selected fish species like common carp, javapunti and rohu would be a compatible combination for improved rice fish system.

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