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RICE-FISH CULTURE *in* CHINA



EDITED BY
Kenneth T. MacKay

INTERNATIONAL DEVELOPMENT RESEARCH CENTRE

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Fish Culture in Ricefields: Rice-Fish Symbiosis

Xiao Fan⁴⁸

Fish culture in ricefields originated from natural symbiosis. The accidental discovery of wild fish in ricefields, and the subsequent catch of both adult fish and fry, induced people to make use of ricefields for fish rearing. Although the traditional rice-fish rearing was a modification of the natural system, modern rice-fish culture has undergone significant development in recent years. The improved systems have already surpassed traditional methods with respect to structure, carrying capacity, energy conversion and exchange, and use of materials, and produced ecological, financial, and social benefits.

Within the rice-fish ecosystem, the plants and animals complement and interact with each other. The organized food chains produce various materials (living and nonliving, organic and inorganic, molecular and ionic) that interact with the other biological, chemical, and physical activities in the ricefield. As a result, the food chains in the ricefield are rebuilt, soil in the fields is made fertile, the structure of the water and soil is improved, insect pests are diminished, diseases are controlled, and mosquitoes and weeds in the fields are reduced.

Rice-Fish Food Web

The long history of rice production in China has affected the natural ecosystem. In Jiangsu Province, the use of large quantities of poisonous insecticides and chemical fertilizers since the 1960s has killed rice pests in large areas. However, at the same time, many other useful organisms have also been destroyed. The use of these chemicals has changed the characteristics of the natural ecosystem, brought about an imbalance in the ecology, and caused the gradual disappearance of ecological advantages. The current rice-fish culture system has reestablished the food chain of *fish eating insects and weeds* and made it possible to use little or no chemical herbicides to kill weeds and no insecticides to control insect pests.

Microbes and mosquito larvae

When rice and fish are raised together in ricefields, the plants need fertilizers and the fish need rich food. In fields where fish are being raised, organic manure should be used as the basal fertilizer. Only chemical fertilizers that are not poisonous to fish should be used for supplementary applications. Ammonium bicarbonate can be used as a top dressing. The ammonium bicarbonate (15–20 kg)

⁴⁸ Crop Cultivation Technical Station, Department of Agriculture and Forestry, Nanjing, Jiangsu Province.

should be shaped into balls and placed under the soil in fields covered with 6–7 mm of water.

When manure is applied to the ricefield, benthos and plankton reproduce rapidly and provide the fish with sufficient food. However, as the fish grow, their need for food increases, but the availability of food in the fields decreases. A field investigation showed that the amounts of benthos with fish and without fish were, respectively, 4.3 g and 12.9 g in mid-June, 8.0 g and 25.1 g in early July, and 5.4 g and 10.2 g in mid-July. The Jiangxi Aquatic Research Institute compared fish and nonfish ricefields in 1984. There are fewer phytoplankton (625 500/ml or 2.4 mg/L of water) and fewer zooplankton (18 730 000/ml and 3.6 mg/L) in the fields with fish compared with fields with rice only.

Fish culture in ricefields differs greatly from pond culture because there is a lot of plankton in the fields and the amount of life decreases gradually. Fewer fish are stocked in ricefields (30 000/ha) than in fish ponds (3 million/ha). A study by the Hubei Aquatic Institute demonstrated that there was as much as 119 g/m³ of benthos in ricefields, but only 39 g/m³ in ponds. Moreover, the amount of potential food increased after the fry had been added to the fields and reached its peak 6 days later. As the fish grow and their appetites increase, the amount of food that is available begins to decrease. However, in ponds, the benthos began to decrease sharply only 3 days after the fry were introduced. After 5 days, the amount had dropped to less than 10 g/m³, which is far too little to meet the needs of the fish.

Fish culture in ricefields also helps eliminate mosquito larvae. In these areas, the density of larvae in the ricefields was reduced by 50–90%, and in residential areas the number was reduced by more than 50%. The Chendu Municipal Health Station, Sichuan Province, surveyed three different areas severely affected by malaria. The incidence of malaria was 0.01% in 1981 when there was no rice-fish culture, but in 1982, the incidence dropped to 0.002% after rice-fish culture was started. Jiadian County Health Station, Shanghai Municipality, monitored the rice-fish fields of the Chuanjin Aquatic Production Farm from 2 July to 18 October. No larvae were found in the 18 samples from rice-fish fields, but in the nonfish fields, larvae were found in every sample. The average per sample was 2.2 larvae (1.7 in July, 3.3 in August, and 2.1 in September). The use of organic insecticides has killed large numbers of mosquitoes, but has also given rise to insecticide-resistant strains. Rice-fish culture is an effective control method for all types of mosquitoes, including the insecticide-resistant strains.

Weeds

Fish eat many of the weeds in ricefields. Some herbivorous fish loosen the soil by tilling and digging holes, which uproots the tender roots and stalks of the weeds. Weeding by fish is timely and frequent and superior to chemical weeding.

When the fry are first put into the ricefields, they feed on plankton. When the weeds begin to send out sprouts, the small fish eat these sprouts as well as small insects. As the fish grow, their ability to eat weeds increases. If there are sufficient

fish in the fields, they grow synchronously with the weeds, and control them. Even the withered rice leaves that fall into the water are eaten. A study by the Zhejiang Provincial Academy of Agronomical Sciences showed that on 22 August there were 8.0 kg of weeds in a rice-fish field, compared with 30.3 kg of weeds in fields without fish. On 11 November there were no weeds in the rice-fish field, but 3.07 million green duckweed in the field without fish.

Insect Pests

During the growth and development of rice, insects can be eliminated by fish if the proper measures are used and the habits of the insects are taken into consideration. For example, when rice planthoppers develop in the ricefields, they can be driven into the water if a rope is pulled over the rice plants. Because the planthoppers pretend to be dead when they fall from the rice plants, they are easily eaten by the fish.

During the incubation and developmental period for rice borers, a layer of water should be maintained in the ricefields. Because the rice borers transfer to a new rice plant after incubation, they will be forced to travel in the water where they can be eaten by the fish. If pest levels increase, the water level should be raised to drown part of the stalks and leaves and enable the fish to catch the insects. If the fish are close to the affected parts of the plant, they will jump to catch the insects.

Insect pests are normally not very serious and can be easily eliminated. Even during severe infestations, these methods can be used to reduce pest populations. According to materials published by the Rudong Botanic Protection Station in Jiangsu Province, in rice-fish fields there were 100 nest of rice planthopper with 984 eggs, compared with 4 468 eggs in fields without fish. An investigation in Rugao County showed that in rice-fish fields there were 30% fewer eggs of the yellow stemborer, *Tryporyza incertulas*, the rate of white ears was 50% lower, there were 50% fewer rice planthoppers, the rate of rice leafrollers was 30% lower, the rate of white leaves was decreased by 30%, and the number of rice leafhoppers was 30% lower.

Furthermore, in rice-fish fields, the rice plants are usually very strong and have good resistance to diseases. The possibility of rice diseases was also reduced because of the fertile water and good environment, improvements in varieties, reduction in density, good ventilation, and sufficient light. A study in Chenxian County, Zhejiang Province, demonstrated that under the same cultivation conditions, the indices of sheath and culm blight of rice were 11.8, 10.7, and 7.8 in fields without fish, rice-fish fields, and idle rice-fish fields, respectively,

Improvements in Soil and Water Conditions

Soil Fertility

In rice-fish fields, the activities of the fish help mix the manure with the soil. The fish swallow, digest, and assimilate 30–40% of the organisms living in the fields.

The rest of the organic matter is excreted into the fields and becomes manure. The fish faeces are a good quality manure that contains 42% phosphorus (a higher level than in pigs and cattle manure). Nutrient analysis has shown that there are 1.2 times more phosphates in rice-fish fields than in fields without fish, and ammonia levels are 1.3–6.1 times higher. The Soil Fertilization Station in the suburbs of Yancheng County, Jiangsu Province, made a comparison of rice-fish fields with fields without fish and found that in rice-fish fields where fish had been raised for 2 years, the organic matter level was 1.8% in both fields and the nitrogen content was 0.12%.⁴⁹ In ditches with fish, the organic matter content was 1.9% and the nitrogen content 0.142%, which was much higher than in ditches without fish.

Gases and Nutrients

Under normal conditions, the diffusion of oxygen in water is 10 000 times slower than that in air. This often results in anaerobic conditions at the soil–water interface. The activities of the fish increase the contact area of the water with air and profoundly change the gas structure of the water and soil and improve their physical properties and chemical composition. A gas determination of the soil has shown that in the fields where early rice is planted and fish are raised, oxygen is present to a depth of 5 mm in the soil, but not to 10 mm. In fields where late rice is planted and fish are raised, aerobic condition extends to 8 mm because the fish are larger and more active. In fields without fish, the surface of the soil–water interface is normally anaerobic.

Rice–fish culture helps raise rice production by:

- Increasing the oxidation of the soil and decreasing the reducing agents (e.g., H_2S , Fe^{++} , and Mn^{++}).
- Making it impossible for the medium matter (formed as a result of incomplete dissolution) to mineralize rapidly, to continuously release energy and produce various NH_4^+ and PHO_4^- ions, and to renew the humus in the soil.
- Allowing the highly concentrated nutrients to spread to the roots of the rice plants because of the activities of the fish.

Water Temperature and Oxygen Concentration

The water temperature and the conditions for oxygen solution in the ricefields are better than in fish ponds. The thin layer of water in ricefields puts large areas of water in contact with the air. There are also 100 times fewer fish in ricefields than in ponds. This is why fish do not come to the water surface as often in ricefields as in ponds.

⁴⁹ The author suggested that there was a difference between the two fields in both organic matter and nitrogen based on a difference of 0.03%. In the absence of confidence limits, the editors have assumed there was no significant difference and changed the text.

Fish Diseases

The water in ricefields is usually shallow and fresh and is replenished frequently. Rice plants absorb fertilizers and purify the water in the fields and, as a result, the water is continuously fresh and clear (much better than the water in ponds). The absolute number of pathogenic bacteria in pond water is 2.6 times higher than in ricefields. The number of bacteria in the water has a direct effect on the number of bacteria in fish gills. The number of bacteria on one side of the gills of fish in ponds was 160×10^6 ; whereas, in fish in ricefields there were only 18.5×10^6 . The change in the bacteria content of the water in ricefields clearly reflects the incidence of fish diseases. From February to September, the number of bacteria in ricefields remains stable, and the incidence of fish diseases is low. July, the month during which fish diseases increase, is the time when the number of bacteria in ponds is highest.

Because fish live in the water, it is difficult to make any accurate diagnoses of diseases. Generally, sick fish have no appetite, and medicine cannot be applied or mixed with fish food. The significance of rice-fish culture is low fish density and a health environment, which promote normal growth of the fish and prevent stress.

Biological Control of Rice Pests

Insecticides and herbicides are normally used to prevent and control insect pests and weeds. Part of the insecticide is absorbed by the rice and the rest drops into the water and soil. In fact, some insecticides are directly applied to water or soil and consequently contaminate them. For example, in the early 1980s, 9.6 kg/ha of BHC were used. Some of the BHC entered the soil and water, but most was dissolved and flowed away. The part that was absorbed as a residue in the crops was consumed by humans in the rice, and the by-products (bran and straw) were used as fodder for livestock or fish, whose eggs, meat, and milk were eaten by people. The residue of the insecticide is being transferred from one organism into another and in the end accumulates and concentrates in the human body. The Scientific Experiment Base, Taihu Lake Area, determined that insecticide residues are highest in rice stalks (4.3 mg) and leaves (5.1 mg) followed by rice husks and roots (both 3.8 mg). In the rice grain, the highest concentration was found in the husks and rice bran (3.4 mg). In crude rice, the level is 0.7 mg; in refined rice 0.3 mg.

Tests were carried out in 13 counties of Jiangsu Province in 1983 on the residues of organochloride insecticides in rice. In samples of middle rice (which accounts for 31% of the total rice output of the province), the BHC content ranged from 0.01 to 1.06 mg/kg (average of 0.16 mg/kg). Of the samples, 99.1% contained BHC and 13.7% exceeded the allowable limit. The highest content (1.06 mg/kg) was 2.5 times more than the allowable limit. In samples of late rice (which accounts for 49% of total rice production), the BHC content ranged from 0.07 to 1.21 mg/kg (average 0.34 mg/kg). All samples contained residues, and 54% exceeded the allowable limit.

The human body absorbs 34.4% of the insecticide residues in the grain. An investigation by the Scientific Experiment Base, Taihu Lake Area, found that the amount of BHC residue a person absorbs each day through grains, edible oil, meat, fish, and vegetables was 0.58 mg, which was 15 times higher than the maximum allowable limit suggested by the World Health Organization (0.039 mg per 65-kg person or 0.0006 mg/kg body weight). The insecticide remains in the fatty tissues and other organs and causes damage to human health.

Rice-fish culture reestablishes a symbiotic ecosystem, prevents environmental pollution, and preserves an ecological balance in agriculture. Farmers have made great achievements in irrigation, rice-strain selection, planting techniques, and fish culture. Consequently, rice-fish symbiosis has been further developed. At least, three advantages have been confirmed.

- The ecological benefits of rice-fish symbiosis are becoming more obvious. The elimination of insects and weeds by the fish directly protects large quantities of living organisms from pesticide use. Therefore, other useful organisms, natural enemies of insect pest in particular, survive and reproduce. This extends the possibility of biological pest control and consolidates the ecological benefits of rice-fish symbiosis.
- Rice-fish culture ensures production of fine-quality fish strains and market-size fish and increases the income of farmers. Despite the decrease of planting area, rice unit output increases. The income from rice-fish culture has increased, and in some cases doubled, the income from traditional ricefields. This fact can be used to popularize rice-fish culture.
- Rice-fish culture has also reduced soil and water pollution. Polluted areas become less contaminated or completely unpolluted through the process of self-purification.