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Kenneth T. MacKay

International Development Research Centre

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Ecological Effects of Rice–Fish Culture

Pan Yinhe[50]

Rice–fish culture is a traditional farming system. Since 1978, the area devoted to rice–fish culture has been expanded several fold, fish production has increased rapidly, and fish-farming technology has been improved. In many areas, good harvests of both rice and fish have been achieved (7500 kg of rice and 750 kg of fish per hectare).

Ni Dashu developed the theory of rice–fish mutualism, in which ricefields are used for fish culture and fish farming increases rice production. This paper discusses the ecological effects of rice–fish culture and its economic, social, and ecological efficiencies.

Effects on the Ecosystem

Abiotic factors (e.g., water, soil, light, heat, and air) and biotic factors (e.g., crops, animals, and microorganisms) are closely interrelated and interdependent and form an ecosystem in the ricefield. In this ecosystem, the biotic community is transfers and cycles energy and materials.

The ricefield is a typical anthropogenic ecosystem in which rice production is the main activity. The rice absorbs solar energy, carbon dioxide (CO_2), water, and various nutrients and through photosynthesis produces organic matter and energy, which are stored and converted into rice and straw. At the same time, wild grasses and other weeds, phytoplankton, and some photosynthetic bacteria grow in the ricefields. However, these products are not as useful and complete with the rice. In the ricefield, zooplankton, herbivorous animals, some insects, and pathogenic bacteria are the primary consumers. The carnivorous animals are the secondary consumers, and both bacteria and fungi in the soil decompose organic matter into inorganic matter.

In ricefields without fish, farmers must carry out regular and labour-intensive weeding. As a result, there is a heavy loss of soil fertility and solar energy and an increase of production cost. Because most of the bacteria, phytoplankton, and aquatic animals in the ricefield cannot be used by the rice, they are lost with the irrigation water. Moreover, insects, pests, and mosquitoes can reproduce rapidly and adversely affect both rice and human health.

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When fish are introduced into ricefield ecosystem, the population and composition of aquatic organisms, and the relationships among them, change. Population numbers change. Fish, the largest consumers, eat weeds, phytoplankton, zooplankton, aquatic insects, and other animals. Fish have the greatest effect on population density and mortality. Because they are primary consumers, grass carp, common carp, and crucian carp feed heavily on weeds. In China, more than 100 varieties of weeds grow in ricefields. Of these, *Hydrilla verticillata*, *Ptamogeton crispus*, *Vallisneriaa spiraalis*, *Potamogeton matainus*, and *Lemna* spp. are considered to be good feed for grass carp.

The Biological Department of Southwest Teachers College, Chongqing, Sichuan Province, stocked fish in ricefields at a rate of 3 000 fish/ha (grass carp 30%, common carp or crucian carp 60%, and silver carp 10%). After 75 days, the fish had consumed 12 465 kg/ha of weeds and only 360 kg/ha remained. If 50% of the weeds growing in ricefields were consumed by the fish, this would produce 78 kg/ha of grass carp based on a food conversion rate of 1:80. Therefore, rice-fish culture can effectively eradicate weeds and control the loss of energy from ricefields.

Rice-fish culture can change the direction of energy flow in the ecosystem. In the ricefield, the stocked fish transform *stagnant* energy (e.g., weeds) and *possibly lost* energy (e.g., phytoplankton, zooplankton, and aquatic insects) into useable products (fish and rice). Rice-fish culture also coordinates the interrelationship between the biotic and abiotic environments. In ricefield ecosystem, rice requires light, heat, air, water, and nutrients for its growth. Air, water, and nutrients have the greatest impact on rice production. Because the ricefield is usually flooded, the normal water requirements of rice can be ensured. However, an inundated field does not favour root development of the rice. Under inundated conditions, dissolved oxygen (DO) from the surface water can only be supplied to soil through diffusion and transpiration. In general, the level of dissolved oxygen in the surface water varies diurnally with algal photosynthesis during the day. Dissolved oxygen usually reaches a maximum (12-14 mg/L) when light is adequate. However, more than 95% of the DO is taken up by various organisms in the surface water and little of the DO diffuses and permeates into the soil.

Under these circumstances, as temperature rises, soil reduction increases and reducing substances (e.g., methane, organic acid, and hydrogen sulphate) increase and decay rice roots. This problem is normally solved by sun-drying the ricefield. However, as fish move about in the ricefield, they increase contact between the air and water. This increases oxygen content throughout the field. In addition, the fish disturb the soil, which accelerates decomposition of organic matter and reduces the concentration of reducing substances.

Although sun-drying and weeding are sometimes not practiced in rice-fish fields, rice production is higher than in fields without fish culture. From the viewpoint of aquaculture, the total dissolved oxygen level is low in rice-fish fields (less than 4 mg/L in the early morning). However, fish mortality due to the oxygen depletion has not been reported.

Table 1. Nutritional composition of four types of fish excreta (percentage dry weight).

Fish Excreta	N (%)	P (%)
Grass carp	1.102	0.426
Common carp	0.824	0.671
Crucian carp	0.760	0.403
Silver carp	1.900	0.581

Generally, the ricefield has a pH of about 7.0, which is optimal not only for the growth of rice and fish, but also for the reproduction of natural food organisms. Fish also have a positive effect on soil fertility because of the accumulation of fish excreta, which has a high nutritive value (Table 1). Silver carp excreta was the best, grass carp and common carp excreta second best, and crucian carp excreta the poorest. The concentrations of N and P in the fish excreta were higher than in pig and cow manure, similar to those of night soil and sheep manure, but lower than those of chicken and rabbit manure.

The daily manure production of one fish has been estimated to be about 2 g. If the average stocking density was 3 000 fish/ha (stocking size about 100 g), 6 000 g of fish manure would be produced every day. This would amount to 450 kg/ha of fish manure if the fish were reared for 75 days. The N content of the soil was reduced at the end of the production season by 1.1% in the ricefield with fish and 12% in the field without fish. The fish are able to transform the energy in the ricefield ecosystem and enrich the soil.

Fish can also minimize outbreaks of diseases and insect pests and reduce the application rate of pesticides, which can pollute water, soil, rice, and fish. When fish are cultured with rice, the main primary producer (rice) and consumer (fish) are combined to form a symbiotic rice–fish ecosystem.

In rice–fish fields, the rice reduces sudden changes in water temperature caused by sunlight, adjusts and stabilizes water temperature and quality, and, therefore, provides an environment that is conducive to the reproduction of natural organisms. Because the fish consume phytoplankton, zooplankton, and weeds that compete with rice, they play an important role in increasing and stabilizing soil fertility, eradicating harmful insects and pests, recovering lost energy, and adjusting energy flow. In the symbiotic rice–fish ecosystem, the mutualism between rice and fish is fully exploited to provide high-quality products and good environmental conditions.

Efficiency of Rice-Fish Culture

Economic Efficiency

Rice production is increased by 5-15% in rice-fish culture. Experiments in many locations have demonstrated that rice growth is improved in rice-fish fields. In particular, the rice developed evenly, tillering is improved, more rice grains are produced, ears are heavier, and the rate of false grains is lowered.

Rice-fish culture can also increase the production value of ricefields. Based on the collection of nation-wide information, net profit can be increased by CNY300-750/ha. Profits can be even higher (CNY1 500-15 000/ha) if fry are reared in the ricefields. The economic efficiency is increased because the fish have a high value.

Fish can also help eradicate weeds, minimize the loss of fertilizer, and reduce outbreaks of insects and pests. Therefore, fertilizers, pesticides, and labour can be saved. In experiments in Taoyuan County, Hunan Province, the concentration of quick-acting N and P in rice-fish fields was increased by 10% and 124%, respectively, compared with fields without fish. Fish are able to reduce populations of rice hoppers and rice leafrollers 2-6 times. As a result, the application frequency and quantity of pesticides can be decreased. Moreover, based on investigations in Jiangxi, Guizhou, and other provinces, about 120-180 labour units per hectare can be saved with integrated fish culture. In some places, farmers do not plough the field when rice-fish culture is practiced. This further reduces the inputs needed for rice planting, and therefore, reduces production cost and increases the economic efficiency of rice cultivation.

Social Efficiency

Rice-fish culture expands the area for fish culture and produces more fish products. Rice-fish culture also produces (with less input) increased numbers of large-size fingerlings for the development of fisheries in ponds, reservoirs, and rivers. If the ricefield is used to culture food fish, average production is 300-750 kg/ha (maximum 750-2 250 kg/ha). This practice is an effective way to increase fish production in hilly areas. At the same time, rice-fish culture effectively increases the income and living standard of farmers, particularly those living in hilly, rural areas.

Rice-fish culture also increases rice production. It makes multiple use of the ricefield to maximize the utilization of land and water resources. The proper combination of crop production and aquaculture will effectively promote the transformation of the structure of rice production.

Ecological Efficiency

In rice-fish culture, harmful insects and pests are greatly reduced. Therefore, pesticide application can be reduced or eliminated, and toxicity accumulation is minimized. This is beneficial to human health and the ecological balance of the environment. For example, the number of predators of rice pests is higher in rice–fish fields without pesticides than in fields without fish and with pesticides. Rice–fish culture also improves the environment and reduces infectious diseases of livestock and humans. In ricefields, mosquito larval, maggots, snails, and leeches, which are the intermediate host of malaria, encephalitis, dysentery, blood fluke, and filaria, reproduce rapidly. Fish, particularly common carp, crucian carp, tilapia, and other omnivorous fish, consume and eradicate these pathogenic parasites and minimize the infestation rate of human beings, thereby creating an improved living standard and a better level of health for the farmers.