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## Part I: Review and Outlook

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Rice–Fish Culture in Ricefield Ditchponds

Luo Guang-Ang

Rice–fish culture has been traditionally practiced in rural areas. Modern rice cultivation techniques such as intercropping, fertilizers, and chemical sprays often conflict with fish growth. In addition, other problems such as monoculture of fish, delays in putting fish into the pond, short growing periods, and lower output and economic profits have arrested the development of rice–fish farming. Recent reforms in the economic system have sparked new initiatives in agricultural production.

Renewed interest in rice–fish culture has prompted scientists to study different patterns of rice–fish culture (e.g., ditch-and-pit, wide ditches, and ditchponds). Research suggests that rice–fish culture in ditchponds can eliminate the conflicts between fish and rice and take full advantage of the symbiosis between rice and fish.

Rice–fish culture in a ditchpond is a three-dimensional agricultural production system. The artificial ecosystem simulates the biostructure of the natural ecological system and consists of an economic crop (rice) and a commercial animal (fish). The system provides the high output of an intensive fishpond farming system and makes full use of the ecological conditions in the ricefield. Fish feed on the abundant aquatic organisms and coexist with the rice. Both fish and rice develop harmoniously, each promoting the growth of the other, and problems between fish-rearing and field care can be reasonably handled. Both crops can achieve their full productive potential. At the same time, liana can be grown on an awning above the pond, taro and beans can be grown on the bank, duckweed can be cultivated with the fish in the water, and loach can be grown in the mud. This integrated and intensive farming system produces higher yields of rice, fish, and vegetables.

Management Techniques

The pond, which takes up 5% of the field area, is dug to a depth of 1–1.5 m on one side of the ricefield. On a third of the pond, a shed with an awning is built. Ditches are dug 40–60 cm wide and 20–30 cm deep. The ditches are dug according to the size of the field: if the field is less than 0.07 ha, ditches are dug in a straight line; if the field is about 0.07 ha, ditches are dug in the shape of a cross; and if the field is larger than 0.14 ha, parallel ditches are dug in both directions (in the shape of a double cross).

39 Bureau of Agriculture, Animal Husbandry, and Fisheries, Shangyou, Shangyou County, Jiangxi Province.
Engineering Construction and Management

Five basic steps are undertaken.

- Select a suitable field. The soil must be fertile, have moderate texture, and hold water well. The water supply must be adequate and drainage and irrigation must be available to ensure stable yields during droughts or excessive rain.
- Construct a bank around the field. The bank is raised to a height of 50–70 cm and a width of 30–40 cm. The bank must be solid enough to withstand heavy rains.
- Install fish screens. A semicircle of fish screens about 0.8-m high and 1-m wide are installed in the water inlets and outlets. The gaps between fish-screen bars should be 0.3–0.4 cm. A screen with a gap of 1.5–2.5 cm is placed at the juncture of the ditch and pond to prevent large fish from damaging rice seedlings. This screen is removed after the rice heads.
- Monitor water and fertilizer. Water and fertilizer have a significant effect on the growth of fish and rice. Excess nitrogen makes rice seedlings spindly and results in the closing of crop rows too early and densely, which is fit for neither fish nor rice growth. Therefore, the amount of base manure, potassium, and phosphorus fertilizer should be raised but nitrogen should be controlled to prevent the rice from becoming spindly. Water management is also important. Irrigation and drainage should be controlled separately. The water level should be kept at a depth of 1–1.2 m in the pond; however, the water in the ricefield should be 5–10 cm deep before rice tillering and 10–16 cm deep after rice tillering. When pesticides and fertilizers are needed, the water level in the field should be lowered slowly and the fish should be driven into the ditch and pond to separate the fish and rice for a short period.
- Patrol fields. Care is required to identify and deal with problems such as drought, waterlogging of the fields, diseases, insect pests, escapes of fish, and theft.

Improvements in Culture Techniques

To improve rice–fish culture ditch ponds, several changes are needed in traditional techniques.

- Transform monoculture into polyculture. Traditionally, common carp are the only fish grown in the ricefields. However, now many other species are available, e.g., local carp, wuyuan pouch red carp, wang-an glass red carp, xingguo red carp, feng carp, mirror carp, grass carp, black carp, silver carp, big-head carp, nile tilapia, and crucian carp.
- Change from single-cropping to double cropping of fish. Traditional systems of rice–fish production raised fish once a year However,
new techniques now mean that fish can be grown in ricefields throughout the year.

- Institute earlier stocking of fish. In traditional systems, the fish are stocked after the rice heads. New techniques allow the fish to be stocked after the rice is transplanted because of the ponds and ditches in the ricefield.

- Increase stocking density of fish. In the past, less than 1,500 fish were stocked per hectare of rice–fish field. Currently, 15,000–30,000 fish per hectare are used. The density depends on the objective of the rice–fish system. For fish fry, the density of summer fry is usually 19,500–30,000 fish/ha; for food fish, 6,000–9,000 spring fish fingerlings per hectare are recommended. In both cases, grass carp, common carp, and Nile tilapia make up about 90% of the total and black carp, silver carp, bighead carp, and crucian carp make up about 10%.

- Introduce feeding of fish. Water plants, plankton, and aquatic animals in the ricefield were the traditional sources of food for the fish. Green grass, duckweed, algae, rice bran, bean residue, distillers' grains, and manure are now added to supplement the feed for the fish.

Integrated Management

In addition to fish and rice, diverse agricultural products can be obtained from ricefields. For example, soybean, peppers, tomatoes, sorghum, corn, taro, mustard can be grown on the banks; vine crops such as musky pumpkin, wax gourd, balsam pear, Lagenaria vulgaris, and cow gram can be grown on the awning of the shed; and duckweed can be grown under the shed awning as pig feed.

Impact of Rice–Fish Culture

Production experience has demonstrated that fish farming in ditchpond makes good use of the land, water, and biotic and abiotic resources of ricefields. The rate of use and conversion efficiency of material and energy in the rice–fish ecosystem are higher than in rice-only fields. The system is a desirable production model that combines fish with rice.

Economic Benefits

Fish rearing in ditchponds has a low cost of investment but yields diverse products, which in turn increase total agricultural income. This is demonstrated by some examples from Shangyou County, Jiangxi Province.

In 1984, fish were raised in ditchponds on 86.5 ha of ricefields. The output of fresh fish averaged 760.5 kg/ha, and the yield of rice increased by over 2,900 kg/ha. The value of the total output increased by CNY5,780/ha. Zhong Linying, a farmer in Qixing, practiced monoculture of Nile tilapia in a late ricefield and produced 3,200 kg of fish per hectare. Cai Yunging, in Henglin, adopted
polyculture of grass carp, silver carp, bighead carp, and common carp and produced an output of CNY15 860/ha (net income CNY14 700/ha).

In 1985-1987, experiments in various parts of Shangyou County produced positive results. For example, a test of fish-rearing was undertaken by Kong Quingrong in a 0.08-ha double-cropped ricefield (area of pond 0.01 ha). The rice harvest was 976.7 kg (9% more than from the same field planted to rice the previous year). In addition, by using the field-bank ridge and shed awning to grow crops, he produced 5 kg of soybean, 5 kg of balsam pears, 15 kg of tomatoes, 30 kg of white gourds, 40 kg of musky pumpkins, 53 kg of kidney beans, and some other vegetables and livestock feeds. The net income, including CNY264 from the fish, was 3.6 times as much as in the previous year (an increase of CNY4 590/ha).

In 1986, this production system was extended in Dongshang Township. Results from a 0.9-ha field distributed into 23 pieces of land were 40.2 kg (603 kg/ha) of fish and a rice yield that averaged 11 063 kg/ha (1.8% higher than in the previous year). In addition, average income was CNY304/ha and total value reached CNY5 680/ha.

In 1987, results were obtained from five households in Dongshan Township. Kang Renhai obtained 15 018 kg of rice, 975 kg of fresh fish per hectare, and CNY294 from other interplanted crops (e.g., taro, soybean, and pumpkin) for a total output of CNY20 400/ha. In contrast, an adjacent field that was the same size but had no fish had an output that was 3.15 times lower in value.

**Ecological Effects**

The rice–fish system is an artificially controlled ecosystem in which rice and fish coexist, depend on, and promote each other. Fish play several roles in the system.

*Weed control and preservation of soil fertility.* In the ricefield, weeds compete with rice for nutrients, land, water, space, and sunlight. As a result they greatly affect the growth of the rice plants. Experiments have shown that 1 kg of grass-carp fingerlings in a ricefield consume about 40–60 kg of weeds, which would absorb about 1.25 kg of nitrogen as they grow. In the rice–fish system, weeds are eaten by grass-eating fish and their waste becomes a field manure that helps conserve and enrich soil fertility.

Huang Xinlian, a farmer of Shuiyan Township in Shangyou County, adopted the rice–fish system with a ditchpond for 3 years. In 1983, from a 0.06-ha field, she obtained 1 083 kg of grain (138 kg more than the previous year) and 38 kg of food fish, 1 109 large fingerlings of grass carp, silver carp, and common carp, and 32 Japanese crucian carp. She obtained a total income of CNY652 and a net income of CNY451 (CNY7 114/ha). In addition, she saved CNY12 for chemical fertilizers and pesticides and no tillage or weeding were needed for 3 years. Soil fertility and yields have increased each year.
Control of rice diseases and insect pests. Insects that are harmful to rice are a good food for fish. For example, when they fall into the water, rice borers, rice hoppers, and rice weevils are quickly eaten by the fish. Observations in experiment plots have indicated that densities of pest populations were lower, as was the damage to rice plants, when fish were present in the field. For example, for the third and fourth generations of rice borer the density of the third generation was 1305/ha and the rate of dead hearts in the rice was only 0.4% in the rice–fish field. In the fourth generation, pest density was 1380/ha and the rate of white heads was only 0.9% in the rice–fish field, but in a rice-only field the density was 1650/ha and the rate of white heads was 1.4%.

The vegetable and other crops grown on the field bunds also provide habitat for natural predators. The crops on the bunds and shed awning also enhance fish growth because they shade the water and lower water temperature.

The fish also reduces rice diseases by oxygenating the soil and speeding the decomposition of manure and the release of available nutrients. Large grass carp and common carp remove the basal leaves of the rice plant and diseased leaves, which allows air and sunlight to pass through easily. This promotes rice growth and reduces the incidence of rice diseases.

Early rice sheath-blight disease was investigated in Wangzai County. The incidence of diseased hills was 17.1% and rate of diseased plants was 2.7% in the rice–fish field, compared with 42% diseased hills and a rate of 6.1% for diseased plants in the ricefield without fish.

Social Effects

Making multiple uses of the same field is an important advantage of this system. Large fish fingerlings and commercial fish for market are produced without additional land. For example, five farm households in Shanyou County produced, from an area of 0.2 ha, an average yield of rice of 13 760 kg/ha, 568.5 kg/ha of fish, and an income of CNY1310/ha from vegetables. Total income reached CNY9 635/ha.

Fish consume weeds and pests, prevent disease, conserve and increase fertilize, reduce or eliminate chemical pesticides, and as a result, also save farm labour. Experiments have demonstrated that 8–10 units of labour power are saved when fish are present. The decrease in the amount of agricultural chemicals also reduces chemical poisoning and environmental pollution. At the same time, natural pest predators such as praying mantis, spiders, and frogs correspondingly increase. In addition, because fish are predators of mosquito larvae and snails, they help prevent malaria, flariasis, and snail fever.

Conclusion

Agricultural production is being changed in Shanyou County. Farmers now know how to use the limited arable land for multiple purposes. There are several
advantages to the new production system. First, the rice–fish system increases economic benefits two or three times compared with a single rice crop. Second, the production system integrates the main crop (rice) with fish and vegetables and improves agricultural production. Third, the principles of a natural ecosystem are borrowed to promote ecological balance and ecological cycles. Fourth, cropping and fish-rearing are linked in a simple way that uses land, water, and biotic and abiotic resources efficiently and features low inputs, quick effects, and excellent benefits.

Because fish-rearing in the ditch pond of a ricefield is a new production system, many items require further research. For example, the proportion of different fishes and the proportion of pond and ditch area must be tested and studied. To further improve the use of ricefield resources, cooperation is required between scientists working in the departments of agriculture, protection, and health.

Rice–fish culture in the ditch ponds of ricefields has great potential. There are 1.3 million ha of ricefields that are suitable for fish-rearing in Jianxi Province. If 25% of these fields were used for rice–fish culture and the unit output of fish was 750 kg/ha, then 250,000 tonnes of fish could be produced. This is 148,000 tonnes more than the total output of fish in 1984. At a market price of CNY3/kg, the output of fish would increase income by CNY750 million. If CNY250 million were produced from interplanted vegetables (CNY750/ha), the additional amount of revenue would be CNY1,000 million.