Rice–Fish Culture in China

Edited by
Kenneth T. MacKay

International Development Research Centre
Ottawa • Cairo • Dakar • Johannesburg • Montevideo
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Contents

Preface .......................................................... vii

Introduction  Wang Hongxi ..................................... ix

Part I: Review and Outlook

Rice–Fish Culture in China: The Past, Present, and Future
Cai Renkui, Ni Dashu, and Wang Jianguo  ...................... 3

Rice–Fish Culture in China: Present and Future
Chen Defu and Shui Maoxing  .................................. 15

Scientific and Technological Development of Rice–Fish Culture in China
Zhang Rongquan ...................................................... 23

Development of Rice–Fish Farming in Guizhou Province
Shi Songfa ............................................................ 31

Reforming Rice–Fish Culture Technology in the Wuling Mountains of Eastern Guizhou Province
Chen Guangcheng ..................................................... 37

The Development of Rice–Fish Farming in Chongqing City
Xu Shunzhi ............................................................. 43

Development of Rice–Fish Farming in Jiangsu Province
Xu Guozhen .......................................................... 49

Rice–Fish Culture and its Macrodevelopment in Ecological Agriculture
Yang Jintong ......................................................... 55

Value of the Rice–Fish Production in High-Yielding Areas of Yuyao City, Zhejiang Province
Cao Zenghao .......................................................... 63

Developing Rice–Fish Culture in Shallow Waters of Lakes
Wan Qianlin, Li Kangmin, Li Peizhen, Gu Huiying, and Zhou Xin 67
<table>
<thead>
<tr>
<th>Title</th>
<th>Authors</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Different Methods of Rice-Fish Farming</td>
<td>Nie Dashu and Wang Jianguo</td>
<td>77</td>
</tr>
<tr>
<td>New Techniques for Raising Fish in Flooded Ricefields</td>
<td>Wan Banghuai and Zhang Qianlong</td>
<td>85</td>
</tr>
<tr>
<td>Methods of Rice-Fish Culture and their Ecological Efficiency</td>
<td>Wu Langhu</td>
<td>91</td>
</tr>
<tr>
<td>Ridge-Cultured Rice Integrated with Fish Farming in Trenches, Anhui Province</td>
<td>Yan Dejuan, Jiang Ping, Zhu Wenliang, Zhang Chuanlu, and Wang Yingduo</td>
<td>97</td>
</tr>
<tr>
<td>Development of Rice-Fish Culture with Fish Pits</td>
<td>Feng Kaimao</td>
<td>103</td>
</tr>
<tr>
<td>Techniques Adopted in the Rice-Azolla-Fish System with Ridge Culture</td>
<td>Yang Guangli, Xiao Qingyuan, and He Tiecheng</td>
<td>107</td>
</tr>
<tr>
<td>Semisubmerged Cropping in Rice-Fish Culture in Jiangxi Province</td>
<td>Liu Kaishu, Zhang Ningzhen, Zeng Heng, Shi Guoan, and Wu Haixiang</td>
<td>117</td>
</tr>
<tr>
<td>Rice-Azolla-Fish Symbiosis</td>
<td>Wang Zaide, Wang Pu, and Jie Zengshun</td>
<td>125</td>
</tr>
<tr>
<td>Economic and Ecological Benefits of Rice-Fish Culture</td>
<td>Li Xieping, Wu Huaixun, and Zhang Yongtai</td>
<td>129</td>
</tr>
<tr>
<td>Cultivating Different Breeds of Fish in Ricefields</td>
<td>Wang Banghuai and Zhang Qianlong</td>
<td>139</td>
</tr>
<tr>
<td>Rice-Fish Culture in Ricefield Ditchponds</td>
<td>Luo Guang-Ang</td>
<td>147</td>
</tr>
<tr>
<td>Techniques for Rice-Catfish Culture in Zero-Tillage Ricefields</td>
<td>Chen Huarong</td>
<td>153</td>
</tr>
<tr>
<td>Demonstration of High-Yield Fish Farming in Ricefields</td>
<td>Cai Guanghui, Ying Yuguang, Wu Baogan, He Zhangxiong, and Lai Shengyong</td>
<td>163</td>
</tr>
<tr>
<td>Rice-Azolla-Fish in Ricefields</td>
<td>Chen Defu, Ying Hanquing, and Shui Maoxing</td>
<td>169</td>
</tr>
</tbody>
</table>
Part III: Interactions

Material Cycles and Economic Returns in a Rice–Fish Ecosystem
Ni Dashu and Wang Jianguo .................................................. 177

Fish Culture in Ricefields: Rice–Fish Symbiosis
Xiao Fan ............................................................................. 183

Ecological Effects of Rice–Fish Culture
Pan Yinhe ............................................................................. 189

Ecological Mechanisms for Increasing Rice and Fish Production
Pan Shugen, Huang Zhechun, and Zheng Jicheng ................. 195

Rice–Azolla–Fish Cropping System
Liu Chung Chu ..................................................................... 201

Effect of Fish on the Growth and Development of Rice
Li Duanfu, Wu Neng, and Zhou Tisansheng ......................... 209

The Role of Fish in Controlling Mosquitoes in Ricefields
Wu Neng, Liao Guohou, Lou Yulin, and Zhong Gemei ......... 213

A Comparative Study of the Ability of Fish to Catch Mosquito Larva
Wang Jianguo and Ni Dashu .................................................. 217

Ability of Fish to Control Rice Diseases, Pests, and Weeds
Yu Shui Yan, Wu Wen Shang, Wei Hai Fu, Ke Dao An, Wu Jian Rong, and Wu Quing Zhai ............................... 223

Distribution and Residue of Methamidophos in a Rice–Azolla–Fish Ecosystem
Xu Yinliang, Xu Yong, and Chen Defu ................................... 229

Residue and Application of Fenitrothion in a Rice–Fish Culture System
Lou Genlin, Zhang Zhongjun, Wu Gan, Gao Jin, Shen Yuejuan, Xie Zewan, and Deng Hongbing .................. 237

Part IV: Economic Effects

Economic Analysis of Rice–Fish Culture
Lin Xuegui, Zhang Linxiu, and He Guiting ............................... 247

Economic Research on Rice–Fish Farming
Jiang Ci Mao and Dai Ge ....................................................... 253

Ecology and Economics of Rice–Fish Culture
Quing Daozhu and Gao Jusheng .......................................... 259
Rice–Azolla–Fish in Ricefields

Chen Defu, Ying Hanquing, and Shui Maoxing

The yield per hectare of traditional fish-raising methods is only 75–150 kg in China. In Zhejiang Province, a high-yield rice-azolla–fish system was developed and extended to farmers. The technique has now been adopted in many regions in Zhejiang Province, and rice production and fish yields have both increased. In 1987, a demonstrative farmer, Shao Shousheng in Yuhang County, tested the high yield rice-azolla–fish system. The Zhejiang Academy of Agricultural Sciences, Yuhang Agricultural Committee, and Yuhang Science and Technology Society conducted the experiments. The techniques used to simultaneously raise rice, azolla, and fish are discussed.

Test Methods

The test field was located in Xingqiao Village, Yuhang County, 2 km from Hangzhou City. The field was 0.3 ha and had been used in 1986 as a test field for high-yield fish culture. Therefore, the farmer, Shao Shousheng, had practical experience. The fish ditch was 3 m in width, 1 m in depth, and occupied 21% of the total ricefield. Fine feed was used as the main fish food, and organic manure and fertilizers were used as supplements. Omnivorous, carp and crucian carp were raised. In 1986, the yield of rice was 9 730 kg/ha and the net yield of adult fish was 3 426 kg/ha. A comprehensive experiment on rice-azolla–fish was started in 1987 and several changes were made in rearing techniques:

- Instead of using fine feed for the fish, the fine feed was first fed to pigs and the pig manure was fed to the fish.
- Rice–azolla–fish were grown together in 1987, and the azolla were used as the main feed for the herbivorous fishes.
- Herbivorous fishes were chiefly raised in 1987 (silver carps, common carp, and crucian carp).

Test Results

Yield of Rice and Fish

The rice yield was 9 786 kg/ha in 1986. The early japonica rice (Biyuzaonuo) grew well in 1987 and produced an additional 980 kg/ha. However, transplanting of the late rice was delayed to nearly the beginning of Autumn because the early rice was...
late to mature. It was also difficult to keep the grass carp in the fish ditches away from the rice on the sides of the ditches. Because the fish eat some of the rice, rice yield decreased to 1233 kg/ha, but the yield of adult fish increased greatly (Table 1). In 1987, the yield of adult fish from the rice-azolla-fish system was 6990 kg/ha, an increase of 71% over the 4200 kg/ha in the rice-fish system in 1986. If the yield of fish fry is excluded, the net yield of adult fish was 5500 kg in the rice-azolla-fish system, an increase of 60% over the 3444 kg/ha in the rice-fish system.

Feed Consumption and Cost

Fine feed was the main food source for the fish in 1986, and 7300 kg/ha of feed were consumed. Therefore, the cost of fish raising was rather high. Major modifications were made in 1987. The fine feed was first used to feed pigs. The pig manure was then fed to the fish and used to fertilize the azolla. This modification made full use of material inputs and added four pigs to the output with limited input. The cost of feed for fish raising was also reduced. The unit cost of feed in the rice-azolla-fish system was only 47% of the cost in the rice-fish system, and the feed cost of fish per kilogram was 29% of the cost in 1986 (Table 2).

Economic Efficiency

The cost of fish raising was almost equal both years. The output value and net profit in the rice-azolla-fish field increased significantly because the adult fish yield in the rice-azolla-fish field was higher than that in the rice-fish field. The output value was CNY17100/ha and net profit was CNY9278/ha in the rice-fish field in 1986; whereas, in 1987, the output value was CNY25404/ha and the net profit was CNY17528/ha in the rice-azolla-fish field (an increase of 89%, Table 3).

Analysis and Discussion

There were several reasons for the yield increase and the cost decrease in the rice-azolla-fish fields.

Use of Herbivorous Fishes

Herbivorous fishes (grass carp and bream), especially grass carp, are fond of azolla and grow quickly. When there is a sufficient supply of azolla there is great potential for yield increase. The omnivorous fishes (carp and crucian carp) require high-quality fine feed, but grow slowly. These omnivorous fishes were the most numerous in 1986 (79% of the fish and 72% of the total weight). Herbivorous fishes comprised 14% of the fish and 15% of the total weight. Among the herbivorous fishes, grass carp accounted for 5% of the fish and 4% of the weight. In 1987, azolla was grown in the ricefields and herbivorous fish were the main species raised (48% of the fish and 31% of the weight). Grass carp accounted for
Table 1. Yields of rice and fish in rice-azolla-fish and rice-fish systems.

<table>
<thead>
<tr>
<th></th>
<th>Early Rice Yield (kg/ha)</th>
<th>Late Rice Yield (kg/ha)</th>
<th>Annual Fish Yield (kg/ha)</th>
<th>Fingerling Fish Yield (kg/ha)</th>
<th>Adult Fish Yield (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice-fish</td>
<td>4208</td>
<td>5579</td>
<td>9786</td>
<td>4119</td>
<td>678</td>
</tr>
<tr>
<td>Rice-azolla-fish</td>
<td>5190</td>
<td>4347</td>
<td>9537</td>
<td>7038</td>
<td>1535</td>
</tr>
</tbody>
</table>

Table 2. Fine feed consumption and cost of rice-azolla-fish and rice-fish systems.

<table>
<thead>
<tr>
<th></th>
<th>Fine Feed (kg/ha)</th>
<th>Beer Leftovers (kg/ha)</th>
<th>Pig Manure (kg/ha)</th>
<th>Fertilizer (kg/ha)</th>
<th>Azolla (kg/ha)</th>
<th>Cost (CNY/ha)</th>
<th>Cost/kg of Fish (CNY)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice-fish</td>
<td>7301</td>
<td>—</td>
<td>11243</td>
<td>543</td>
<td>—</td>
<td>3206</td>
<td>0.93</td>
</tr>
<tr>
<td>Rice-azolla-fish</td>
<td>1023</td>
<td>575</td>
<td>34110</td>
<td>506</td>
<td>2471</td>
<td>1494</td>
<td>0.27</td>
</tr>
</tbody>
</table>

Table 3. Economic efficiency of rice-azolla-fish and rice-fish systems.

<table>
<thead>
<tr>
<th></th>
<th>Rice-Fish (CNY/ha)</th>
<th>Rice-Azolla-Fish (CNY/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output value</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rice</td>
<td>3579</td>
<td>3503</td>
</tr>
<tr>
<td>Fish</td>
<td>13515</td>
<td>21902</td>
</tr>
<tr>
<td>Total</td>
<td>17094</td>
<td>25397</td>
</tr>
<tr>
<td>Cost</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rice</td>
<td>414</td>
<td>414</td>
</tr>
<tr>
<td>Fish</td>
<td>7402</td>
<td>7468</td>
</tr>
<tr>
<td>Total</td>
<td>7816</td>
<td>7882</td>
</tr>
<tr>
<td>Profit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rice</td>
<td>3165</td>
<td>3089</td>
</tr>
<tr>
<td>Fish</td>
<td>6113</td>
<td>14434</td>
</tr>
<tr>
<td>Total</td>
<td>9278</td>
<td>17522</td>
</tr>
</tbody>
</table>

32% of the herbivorous fish and 29% of the weight, and bream 16% of the fish and 1% of the weight. Omnivorous fishes comprised 7% of the fish and 11% of the weight. Oligophagous fish (silver carp) accounted for 45% of the fish and 58% of the weight (Table 4). The azolla were consumed by the herbivorous fish, and the manure from the grass carp increased the amount of plankton, which raised the yield of silver carp.
Proportions and Harvest of Fish

In 1986, too few fish were raised early in the year and too many were raised later. At high densities, all fish were almost the same size, which made batch harvesting impossible. The market size of the fish harvested at the end of a year was also low. In 1987, the density of the fish was reduced in rice-azolla-fish system. In addition, 983 larger fish (3760/ha) were stocked, which accounted for 27% of the total number of fish raised (1,123 kg). Of these larger fish, 188 were the grass carp (719/ha), 300 were the common carp (1,148/ha), and 495 were silver carp (1,757/ha), with the mean weight of 0.42 kg, 0.15 kg, and 0.38 kg, respectively (Table 5). In this way, the fish-holding capacity early in the year increased to 102 kg in 1987 from 45 kg in 1986. Grass carp and common carp fed on azolla in mid-March; whereas, the larger grass carp fed heavily on azolla during April to June. Grass carp and silver carp were caught in batches to supply the market. During April to October, 851 kg of large fish were harvested.

Azolla

The growth of fish and azolla in rice-azolla-fish system were different. Azolla grows quickly in the spring when the fish are small, grow slowly, and eat little. At this time, the azolla supply exceeds demand. In July and August, azolla grows slowly and the fish grow quickly; therefore, the demand for azolla exceeds supply. Three methods were used to mitigate this problem.

Harvest adult fish. At the end of June, adult fish were caught for market to decrease the fish-holding capacity of the field when the azolla were growing slowly. The grass carp grow very quickly during September, which is the second peak of azolla growth.

Supplement supply of azolla. The azolla supply in rice-azolla-fish fields could not satisfy the demand during July to August. Azolla from nearby ricefields, ditches, and ponds were used to supplement the supply. Green-stored azolla and dried azolla were also used.

Adjust feed. Less fine feed was used when azolla were plentiful, and more fine feed or grass was fed when azolla levels were insufficient.

Stopping Fish From Eating Rice

Two methods were used to stop the fish from eating the rice. The fish were kept in the fish pits with dikes and nets after the rice was transplanted. In addition, a grass field and feed platform were established in the fish pit for the omnivorous fish. Tender grass was placed in the grass field. Fine feed was placed on the feed platform when the tender grass was almost completely eaten.
### Table 4. Effects of use of different fish on yields from rice-azolla-fish and rice-fish systems.

<table>
<thead>
<tr>
<th>Fish Raised per ha</th>
<th>Fish Breed Ratio (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(No.) (kg)</td>
<td>(No.) (Wt.)</td>
</tr>
</tbody>
</table>

**Herbivorous fish**

<table>
<thead>
<tr>
<th>Fish Raised per ha</th>
<th>Fish Breed Ratio (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(No.) (kg)</td>
<td>(No.) (Wt.)</td>
</tr>
</tbody>
</table>

**Omnivorous fish**

<table>
<thead>
<tr>
<th>Fish Raised per ha</th>
<th>Fish Breed Ratio (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(No.) (kg)</td>
<td>(No.) (Wt.)</td>
</tr>
</tbody>
</table>

**Oligophagous fish**

<table>
<thead>
<tr>
<th>Fish Raised per ha</th>
<th>Fish Breed Ratio (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(No.) (kg)</td>
<td>(No.) (Wt.)</td>
</tr>
</tbody>
</table>

### Table 5. The proportion of species and larger fish in rice-azolla-fish and rice-fish systems (0.26-ha ricefield).

<table>
<thead>
<tr>
<th>Old Winter Fish Proportion of Larger Fish (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size (g/fish)</td>
</tr>
</tbody>
</table>

Grass carp

<table>
<thead>
<tr>
<th>Size (g/fish)</th>
<th>No. Fish</th>
<th>Size (g/fish)</th>
<th>No. Fish</th>
<th>Size (g/fish)</th>
<th>No. Fish</th>
<th>Proportion of Larger Fish (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>21.4</td>
<td>350</td>
<td>417.5</td>
<td>188</td>
<td>36.1</td>
<td>1445</td>
<td>4.6</td>
</tr>
</tbody>
</table>

Bream

<table>
<thead>
<tr>
<th>Size (g/fish)</th>
<th>No. Fish</th>
<th>Size (g/fish)</th>
<th>No. Fish</th>
<th>Size (g/fish)</th>
<th>No. Fish</th>
<th>Proportion of Larger Fish (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>29.2</td>
<td>669</td>
<td>-</td>
<td>-</td>
<td>6.3</td>
<td>614</td>
<td>-</td>
</tr>
</tbody>
</table>

Common carp

<table>
<thead>
<tr>
<th>Size (g/fish)</th>
<th>No. Fish</th>
<th>Size (g/fish)</th>
<th>No. Fish</th>
<th>Size (g/fish)</th>
<th>No. Fish</th>
<th>Proportion of Larger Fish (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>24.9</td>
<td>1845</td>
<td>150.0</td>
<td>300</td>
<td>-</td>
<td>-</td>
<td>7.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Size (g/fish)</th>
<th>No. Fish</th>
<th>Size (g/fish)</th>
<th>No. Fish</th>
<th>Size (g/fish)</th>
<th>No. Fish</th>
<th>Proportion of Larger Fish (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>16.6</td>
<td>1900</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Crucian carp

<table>
<thead>
<tr>
<th>Size (g/fish)</th>
<th>No. Fish</th>
<th>Size (g/fish)</th>
<th>No. Fish</th>
<th>Size (g/fish)</th>
<th>No. Fish</th>
<th>Proportion of Larger Fish (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>21.4</td>
<td>2500</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Silver carp

<table>
<thead>
<tr>
<th>Size (g/fish)</th>
<th>No. Fish</th>
<th>Size (g/fish)</th>
<th>No. Fish</th>
<th>Size (g/fish)</th>
<th>No. Fish</th>
<th>Proportion of Larger Fish (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>41.1</td>
<td>556</td>
<td>375.6</td>
<td>495</td>
<td>42.6</td>
<td>1310</td>
<td>12.2</td>
</tr>
</tbody>
</table>

Total

<table>
<thead>
<tr>
<th>Size (g/fish)</th>
<th>No. Fish</th>
<th>Size (g/fish)</th>
<th>No. Fish</th>
<th>Size (g/fish)</th>
<th>No. Fish</th>
<th>Proportion of Larger Fish (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>23.1</td>
<td>7659</td>
<td>305.7</td>
<td>983</td>
<td>32.9</td>
<td>3068</td>
<td>24.3</td>
</tr>
</tbody>
</table>
Raising Fish in Flowing Water

Flowing water has a high oxygen content, which favours fish growth. New irrigation water was added at regular intervals. During cloudy, muggy weather, when the fish lacked oxygen, a submersible pump was used to make the water flow and increase the oxygen content. Once a month, 75 kg/ha of quick lime were diluted in water and sprayed over the field to decrease the concentration of acid in the water. This treatment promotes the breakdown of organic materials and helps sterilize the water and prevent fish diseases.

Pig–Azolla–Fish–Rice System

This system reduced the cost of raising fish. Pigs were fed with fine feed. Fish and azolla were fed with pig manure. Azolla were used to feed the pigs. Fish manure also enriched the field. In this way, costs were reduced while net profit was increased.

Conclusion

Experiments in 1987 indicated that the high-yield rice–azolla–fish system was a success. Fish yields and net profit were increased and rice yields were maintained. This system can improve the economic efficiency of the ricefield; nevertheless, there are still some problems that require further study.

• Grass carp quickly grow to a large size. Silver carps are smaller and have a lower commercial value. The appropriate proportion of silver carp to grass carp must be studied. Bream grow slowly and should be raised in small proportions in rice–fish–azolla fields.
• In 1987, dikes and fish nets were used to prevent the fish from eating rice. This was expensive in both capital and labour. Many late rice seedlings were eaten by the fish in 1987, which resulted in a decrease in rice yield. Changes to the design of the fish ditch are proposed to allow the farmers to block the fish with one dike and one net. This would make the operation easier and more convenient.
• Azolla continue to grow in the winter and spring. This potential should be developed to build up resources that can be used as fish feed.
• The rice yield might be improved by transplanting the rice seedlings earlier. In 1987, rice seedlings were transplanted during the second 10 days of May. This caused the ripening stage to be postponed. The rice yield might be increased if seedlings were transplanted during the first 10 days of May.
• The harvesting method for the fish should be changed. Fish should be raised and harvested on a rotational basis. This means that different species should be raised in different proportions. The appropriate size and time of harvest also needs to be established for each species.