Rice–Fish Culture in China

Edited by
Kenneth T. MacKay

International Development Research Centre
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
Part II: Patterns and Technology

Different Methods of Rice–Fish Farming
Nie Dashu and Wang Jianguo ........................................ 77

New Techniques for Raising Fish in Flooded Ricefields
Wan Banghuai and Zhang Qianlong ............................... 85

Methods of Rice–Fish Culture and their Ecological Efficiency
Wu Langhu ................................................................. 91

Ridge-Cultured Rice Integrated with Fish Farming in Trenches, Anhui Province
Yan Dejuan, Jiang Ping, Zhu Wenliang, Zhang Chuanlu,
and Wang Yingduo ..................................................... 97

Development of Rice–Fish Culture with Fish Pits
Feng Kaimao .............................................................. 103

Techniques Adopted in the Rice–Azolla–Fish System with Ridge Culture
Yang Guangli, Xiao Qingyuan, and He Tiecheng ................. 107

Semisubmerged Cropping in Rice–Fish Culture in Jiangxi Province
Liu Kaishu, Zhang Ningzhen, Zeng Heng, Shi Guoan,
and Wu Haixiang ....................................................... 117

Rice–Azolla–Fish Symbiosis
Wang Zaide, Wang Pu, and Jie Zengshun ........................ 125

Economic and Ecological Benefits of Rice–Fish Culture
Li Xieping, Wu Huaixun, and Zhang Yongtai ..................... 129

Cultivating Different Breeds of Fish in Ricefields
Wang Banghuai and Zhang Qianlong .............................. 139

Rice–Fish Culture in Ricefield Ditchponds
Luo Guang-Ang .......................................................... 147

Techniques for Rice–Catfish Culture in Zero-Tillage Ricefields
Chen Huarong ............................................................ 153

Demonstration of High-Yield Fish Farming in Ricefields
Cai Guanghui, Ying Yuguang, Wu Baogan, He Zhangxiong,
and Lai Shengyong .................................................... 163

Rice–Azolla–Fish in Ricefields
Chen Defu, Ying Hanqing, and Shui Maoxing .................... 169
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 Tisanheng ....................... 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,
Xu 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
Techniques for Rice–Catfish Culture in Zero-Tillage Ricefields

Chen Huarong

Yunnan is situated on a low-latitude plateau that has a variety of physical features and many variations in climate. Agricultural production differs dramatically between regions and seasons. Ricefields in Yunnan cover 1 million ha, and more than 132,000 ha are suitable for rice–fish cultivation. The rice-growing regions vary from warm and sunny with plenty of rainfall and good soils to areas with low temperature and poor water-holding capacity.

The ricefields are not efficiently used and economic returns could be improved. Rice–fish fields only cover about 13,300 ha, which is only 10% of the area suitable for rice–fish culture. Average output is also rather low (45 kg/ha in 1982, 62 kg/ha in 1985, and 101 kg/ha in 1987) compared with the national average of 140 kg/ha.

Full exploitation of the potential productivity of the ricefields could remarkably increase economic benefits. Rice–fish cultivation is an important way to increase productivity. Experiments were conducted in Kunming, a rice-growing region of Yunnan Province, at an elevation of 1,900 m and with an annual average temperature of 14.5°C.

Fish Species

The choice of species greatly affects fish harvests, the value of the output, and the economic benefits gained from ricefields. The characteristics of the rice-growing regions in the Yunnan plateau are low temperatures, low water temperatures, shallowly flooded ricefields. The traditional fish species grow slowly and the growing period is short. Given these conditions, it was important to find fish species that grew quickly (reached market size in 120 days), tolerated low-oxygen conditions, were of high quality, and produced high outputs. Experiments were conducted in 1986–1988 to compare different species.

Vigour and Production

Different species were raised for 120 days in the ditches and beds of zero-tillage ricefields. Growth rates and yields varied greatly (Table 1). *Clarias leather* grew the fastest. Individual weights increased 168-fold and their average weights were four times that of nile tilapia and 10 times that of the carp. The length of the cat-

---

40 Yunnan Academy of Agricultural Sciences, Kunming, Yunnan Province.
Table 1. Growth rate and yield of different fish species.

<table>
<thead>
<tr>
<th>Year</th>
<th>Pattern</th>
<th>Species</th>
<th>Stocked Population*</th>
<th>Harvest Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fish per ha</td>
<td>Total Wt. (kg/ha)</td>
</tr>
<tr>
<td>1986</td>
<td>Mixed*</td>
<td>C. leather</td>
<td>7 500</td>
<td>9.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Nile tilapia</td>
<td>7 500</td>
<td>87.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Carp</td>
<td>15 000</td>
<td>9.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td>30 000</td>
<td>105.0</td>
</tr>
<tr>
<td>1987</td>
<td>Mixed*</td>
<td>C. leather</td>
<td>12 000</td>
<td>21.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Carp+ crucian carp</td>
<td>12 000</td>
<td>276.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td>24 000</td>
<td>297.0</td>
</tr>
<tr>
<td></td>
<td>Pure*</td>
<td>C. leather</td>
<td>15 000</td>
<td>16.5</td>
</tr>
<tr>
<td>1988</td>
<td>Pure†  (C. leather)</td>
<td>OYF</td>
<td>9 000</td>
<td>531.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>YF hatched in 1988</td>
<td>12 000</td>
<td>72.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td>21 000</td>
<td>603.0</td>
</tr>
</tbody>
</table>

* Wt. weight; OYF overwintered young fish; YF young fish. † Fish cultured from 4 June to 5 October. ‡ Fish cultured from 29 May to 20 September. § C. leather cultured from 27 May to 28 September; OYF from 29 April to 22 September. † Fish cultured from 13 May to 22 September.
Table 2. Economic benefits of different fish species stocked in ricefields.

<table>
<thead>
<tr>
<th>Year</th>
<th>Stocking pattern</th>
<th>Species*</th>
<th>Young fish</th>
<th>Feed</th>
<th>Total</th>
<th>Output (t/ha)</th>
<th>Value (CNY)</th>
<th>Value (%)</th>
<th>Net income (CNY/ha)</th>
<th>%</th>
<th>Benefit ratio</th>
<th>Input/total input (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1986</td>
<td>Mixed</td>
<td>C. leather</td>
<td>1050</td>
<td>555</td>
<td>1605</td>
<td>1.2</td>
<td>7245</td>
<td>73.5</td>
<td>5640</td>
<td>92.7</td>
<td>1:4.5</td>
<td>42.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Nile tilapia</td>
<td>600</td>
<td>555</td>
<td>1155</td>
<td>0.3</td>
<td>1522</td>
<td>15.5</td>
<td>367</td>
<td>6.0</td>
<td>1:1.3</td>
<td>30.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Carp</td>
<td>450</td>
<td>555</td>
<td>1005</td>
<td>0.2</td>
<td>1080</td>
<td>11.0</td>
<td>75</td>
<td>1.3</td>
<td>1:1.1</td>
<td>26.7</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
<td>2100</td>
<td>1665</td>
<td>3765</td>
<td>1.7</td>
<td>9847</td>
<td>100</td>
<td>6082</td>
<td>100</td>
<td>1:2.6</td>
<td>100</td>
</tr>
<tr>
<td>1987</td>
<td>Mixed</td>
<td>C. leather</td>
<td>1680</td>
<td>525</td>
<td>2205</td>
<td>1.1</td>
<td>6849</td>
<td>68.8</td>
<td>4644</td>
<td>77.1</td>
<td>1:3.1</td>
<td>56.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Carp+ Crucian carp</td>
<td>1200</td>
<td>525</td>
<td>1725</td>
<td>0.5</td>
<td>3105</td>
<td>31.2</td>
<td>1380</td>
<td>22.9</td>
<td>1:1.8</td>
<td>43.9</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
<td>2880</td>
<td>1665</td>
<td>4545</td>
<td>1.7</td>
<td>9847</td>
<td>100</td>
<td>6082</td>
<td>100</td>
<td>1:2.6</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Pure</td>
<td>C. leather</td>
<td>2100</td>
<td>1950</td>
<td>4050</td>
<td>2.0</td>
<td>11898</td>
<td>100</td>
<td>7848</td>
<td>100</td>
<td>1:2.9</td>
<td>100</td>
</tr>
<tr>
<td>1988</td>
<td>OYF</td>
<td></td>
<td>4140</td>
<td>2490</td>
<td>6630</td>
<td>2.0</td>
<td>17415</td>
<td>70.9</td>
<td>10785</td>
<td>71.8</td>
<td>1:2.6</td>
<td>69.5</td>
</tr>
<tr>
<td>Pure (C. leather)</td>
<td>YF hatched in 1988</td>
<td></td>
<td>1950</td>
<td>960</td>
<td>2910</td>
<td>1.1</td>
<td>7137</td>
<td>29.1</td>
<td>4227</td>
<td>28.2</td>
<td>1:2.4</td>
<td>30.5</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>6090</td>
<td>3450</td>
<td>9540</td>
<td>3.1</td>
<td>24552</td>
<td>100</td>
<td>15012</td>
<td>100</td>
<td>1:2.6</td>
<td>100</td>
</tr>
</tbody>
</table>

* OYF overwintered young fish; YF young fish.
fish increased 4.2-fold. Yields of *C. leather* were the highest. When stocked at 25% of the population *C. leather* yielded 71.4% of the harvest.

Yields of *C. leather* were twice as high in monoculture than in polyculture (average 3.1 t/ha in 1988; largest individuals weighed 450–600 g). The size of the young fish used for stocking influenced yield and economic return. Overwintered large-size young fish produced higher yields than smaller-size fish hatched the same year. The survival rate of overwintered fish to food fish was 90%, and the harvest increased significantly when larger-size young fish were used. Fish that were 15–20 cm in length constituted 63% of the average yield; whereas, fish less than 10 cm in length constituted 37% of the yield.

**Economic Benefits**

Economic benefits were closely related to the species (Table 2). *C. leather* produced the best economic returns. In mixed culture, *C. leather* constituted 43% of the total input and produced 74% of the total output value. Net income from *C. leather* was CNY5 640/ha (93% of total net income) and the benefit ratio was 1:4.5. The output value of nile tilapia and carp was 15–21% of the total output, net income was CNY75–367.5/ha, and the benefit ratio was between 1:1.1 and 1:1.3. In monoculture, the output of *C. leather* amounted to CNY24 552/ha, net income was CNY15 000, and the benefit ratio was between 1:2.6 and 1:2.9.

Experiments and demonstrations in ricefields over 3 years showed that *C. leather* grows quickly, produces high yields, and is of good quality. *C. leather* is considered to have 10 advantages. They grow exceptionally fast, individual fish are large, they are omnivorous and capable of eating coarse food materials, they tolerate "humble" living conditions, they are resistant to diseases, they have a high survival rate, they tolerate of low oxygen levels, they are suitable for cultivation in dense populations, they produce excellent output, and they produce good economic benefits for farmers.

**Rice–Fish Cultivation**

The techniques for rice–fish cultivation have been improved. Different fish species have been used and economic benefits have been increased by better integrating the use of the ricefields. Two patterns of the cultivation are currently used.

**Traditional Method**

This is the main method used in Yunnan. Although the method does produce some economic benefits, yields are limited because of deep ploughing, close planting of the rice, the use of shallow-flooded fields with few ditches, the stocking of small numbers of small fry, and no additional feeding and management. This pattern of production yields on average less than 150 kg/ha (maximum 300–450 kg/ha). It is important to improve the techniques and gradually encourage farmers to change from low-yield, extensive cultivation to the high-yield, intensive methods of cultivation.
Improved Method

This method combines the culture of fish in ditches and beds in the ricefield with zero-tillage of the fields. This method has been successful in Kunming, a rice-growing region with an annual average temperature of 14.5°C (monthly averages from May to September are 18.9°C, 19.4°C, 19.7°C, 18.9°C, and 17.4°C). Corresponding water temperatures in the ditches are 21.6°C, 22.1°C, 23.3°C, 22.2°C, and 20.3°C. Several steps are involved in establishing this type of rice–fish system. First, choose a ricefield with good water supply and a convenient irrigation and drainage system, good water-retaining properties, and little shade. Second, dig ditches and divide the field into beds (zero-tillage) — ditches should be 0.4–0.6 m in depth and 0.4–0.5 m in width, the beds 2–3 m wide, and the ditch area should be 10–15% of the total area of the ricefield. Third, spread manure over the field before the ditches are dug, pulverize and level the top soil, and dig out the ditches to cover the manure before the rice seedlings are planted. Fourth, raise and reinforce the surrounding small dikes with the subsoil dug from the ditches. The ditches should be straight, level, and have a flat bottom. Tillage should not be needed for 5 years.

The main features of this cropping pattern are: zero-tillage fields with deep ditches and wide beds; rice planted in shallow water and rice and fish grown together; symbiosis of rice and fish, which reduces stress on both; intensive management and multiple use of water; and increased income from both rice and fish. Additional ditches can be added without reducing yield, the ricefield can be dried without damaging the fish, and chemicals can be applied to the rice without killing the fish.

Income generation. Rice–fish yields increased each year. Rice yields were 7–12% higher in the zero-tillage rice–fish system than in ploughed fields without fish. Fish yields were more than 3 000 kg/ha, which was over 10 times the yield of fish from ricefields cultivated in the traditional way. The value of rice plus fish was CNY275 525/ha and net income was CNY16 815/ha (an increase of 8.6- to 19-fold, Table 3).

Ecological benefits. Increases in yields of rice and fish were closely related to the patterns of zero-tillage, bed division in the ricefield, rice and fish being grown together, and the selection of specific fish species. The rice and fish derived mutual benefit from the system, and ecological conditions in the ricefield were improved in several ways (Table 4).

- Improved habitat. A mutually beneficially habitat was provided for the rice and the fish. Circulation of air and penetration of light were improved between beds and rows. Light penetration in fields with bed divisions was 12.6% higher than in fields without divisions. Water temperatures were 0.7°C higher, there were 6–10 more rice grains per panicle, and the rate of empty, shrunken grains was 5–10% lower. These changes in light and water conditions favoured growth of both fish and rice.
<table>
<thead>
<tr>
<th>Year</th>
<th>Pattern</th>
<th>Input (CNY/ha)</th>
<th>Output (t/ha)</th>
<th>Output Value (CNY/ha)</th>
<th>Economic Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Rice</td>
<td>Fish</td>
<td>Total</td>
<td>Rice</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1986</td>
<td>Rice + mixed fish species</td>
<td>1425</td>
<td>3510</td>
<td>4935</td>
<td>6.5</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>1560</td>
<td>0</td>
<td>1560</td>
<td>5.8</td>
</tr>
<tr>
<td>1987</td>
<td>Rice + pure fish species</td>
<td>1425</td>
<td>3900</td>
<td>5325</td>
<td>7.1</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>1725</td>
<td>0</td>
<td>1725</td>
<td>6.4</td>
</tr>
<tr>
<td>1988</td>
<td>Rice + pure fish species</td>
<td>1170</td>
<td>9540</td>
<td>10710</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>1875</td>
<td>0</td>
<td>1875</td>
<td>6.5</td>
</tr>
</tbody>
</table>

* Values used in calculations were: CNY 3 for 1 labour-day input; CNY0.42 for 1 kg of rice output; CNY6 for 1 kg of fish output (CNY8 in 1988).
Table 4. Edge effect on rice in ditch-bed and zero-tillage rice–fish cultivation.*

<table>
<thead>
<tr>
<th>Cult.</th>
<th>Treat.</th>
<th>No. Grains</th>
<th>No. Full Grains</th>
<th>ES (%)</th>
<th>Tillers/Plant</th>
<th>Prod. Tillers (%)</th>
<th>Pan. wt. (g)</th>
<th>Wt./Row (g)</th>
<th>Yield (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>80-2</td>
<td>Edge 1-3</td>
<td>121.6</td>
<td>96.2</td>
<td>21.0</td>
<td>1.67</td>
<td>376.5</td>
<td>52.0</td>
<td>2.50</td>
<td>2.275</td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td>115.4</td>
<td>83.6</td>
<td>27.5</td>
<td>1.60</td>
<td>330.0</td>
<td>45.5</td>
<td>2.17</td>
<td>2.015</td>
</tr>
<tr>
<td>79-635</td>
<td>Edge 1-3</td>
<td>84.8</td>
<td>70.4</td>
<td>17.0</td>
<td>2.24</td>
<td>684.0</td>
<td>60.5</td>
<td>1.54</td>
<td>2.125</td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td>74.3</td>
<td>54.0</td>
<td>27.2</td>
<td>2.11</td>
<td>618.0</td>
<td>56.3</td>
<td>1.24</td>
<td>1.900</td>
</tr>
</tbody>
</table>

*Plant population: single-row strip, 3 x 5, 600,000 stands per hectare; Control: edge 6 rows; weight per row: total weight of 108 stands in a row.

- Higher yields of rice. Experiments have shown that in zero-tillage fields, shallow-planted plants constitute 94.6% of the population. In ploughed fields, deep-planted plants make up 77.2% of the population. (Shallow-planting less than 6.7 cm, deep planting more than 10 cm). Shallow-planted plants recover more readily, tiller earlier, and more vigorous, have a larger number of productive tillers, a higher percentage of ear-bearing tillers, a lower percentage of empty, shrunken grains, and have heavier panicles with less diseases (Table 5). Zero-tillage is a new practice that solves the problem of plants being planted too deep and also saves energy and labour.

- Improved soil fertility. Rice–fish culture is an efficient way to accelerate soil enrichment. Ricefields provide fish with a rich source of natural food, and the fish excrete manure, loosen the soil, and eradicate weeds. Soil analysis (Table 6) shows that rice–fish cultivation with successive zero-tillage increased organic matter and active nitrogen, but reduced phosphorus in the soil. It is necessary to apply large amounts of manure and smaller amounts of fertilizers. With successive rice–fish cultivation, it is particularly important to control nitrogen and increase phosphorus to maintain steady rice growth during the entire crop cycle.

Because the fish loosen the soil, the soil has higher permeability, which promotes decomposition of complex soil nutrients, manure, and fertilizer and improves rice growth. Root systems are also better developed (25.5% increase) and more widely and deeply distributed. Large amounts of weeds were eaten by C. leather, which has a good appetite and also devours insects. As a result, the ricefields were nearly free of weeds without cultivation or weeding.
Table 5. Effects of ditch-beds, zero-tillage rice–fish culture, and ploughing on planting depth of rice seedlings.

<table>
<thead>
<tr>
<th>Cult.</th>
<th>Till. Pat.</th>
<th>Less than 6.7 cm</th>
<th>6.7 cm</th>
<th>More than 10 cm</th>
<th>Full Grains (%)</th>
<th>ES Grains (%)</th>
<th>Prod. Ears (%)</th>
<th>EB Tillers (%)</th>
<th>Pan. Wt. (g)</th>
<th>Dis. Plants (%)</th>
<th>Yield (%)</th>
<th>Yield (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dianyu</td>
<td>Plow</td>
<td>29.0</td>
<td>30.4</td>
<td>71.0</td>
<td>69.9</td>
<td>0</td>
<td>0</td>
<td>87.2</td>
<td>70.4</td>
<td>19.3</td>
<td>529.5</td>
<td>75.4</td>
</tr>
<tr>
<td></td>
<td>Zero-tillage</td>
<td>4.7</td>
<td>7.1</td>
<td>18.1</td>
<td>49.6</td>
<td>77.2</td>
<td>43.3</td>
<td>87.8</td>
<td>61.0</td>
<td>30.5</td>
<td>480.0</td>
<td>60.8</td>
</tr>
<tr>
<td>80-2</td>
<td>Plow</td>
<td>30.8</td>
<td>56.5</td>
<td>63.8</td>
<td>34.8</td>
<td>5.4</td>
<td>8.7</td>
<td>112.0</td>
<td>91.8</td>
<td>18.0</td>
<td>313.5</td>
<td>78.6</td>
</tr>
<tr>
<td></td>
<td>Zero-tillage</td>
<td>9.5</td>
<td>32.7</td>
<td>14.3</td>
<td>49.0</td>
<td>76.2</td>
<td>18.3</td>
<td>108.5</td>
<td>84.2</td>
<td>22.4</td>
<td>313.5</td>
<td>70.1</td>
</tr>
</tbody>
</table>

* Cult. cultivar; Till. Pat. Tillage pattern; ES Empty-shrunken; Prod. productive; EB ear-bearing; Pan. Wt. panicle weight; Dis. diseased.

b Values in this column x 10,000.

c Planting depth sampled at tillering peak (on 30 June). S = seedlings; T = tillers.
Table 6. Soil nutrients in experimental rice–fish cultivation fields
(zero-tillage practiced in successive years).

<table>
<thead>
<tr>
<th>Year</th>
<th>Treatment</th>
<th>pH</th>
<th>Organic Matter</th>
<th>Active N (ppm)</th>
<th>Active P (ppm)</th>
<th>Active K</th>
<th>Total N (%)</th>
<th>Total P (%)</th>
<th>Total K (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1984</td>
<td>Control (before fish stocking)</td>
<td>6.73</td>
<td>4.101</td>
<td>161.2</td>
<td>94.50</td>
<td>61.69</td>
<td>0.208</td>
<td>0.160</td>
<td>2.055</td>
</tr>
<tr>
<td>1985</td>
<td>1st year of rice–fish cultivation</td>
<td>6.38</td>
<td>4.848</td>
<td>167.3</td>
<td>74.10</td>
<td>—</td>
<td>0.228</td>
<td>0.111</td>
<td>2.454</td>
</tr>
<tr>
<td>1986</td>
<td>2nd year of rice–fish cultivation</td>
<td>6.41</td>
<td>5.014</td>
<td>233.8</td>
<td>12.18</td>
<td>172.19</td>
<td>0.231</td>
<td>0.110</td>
<td>2.659</td>
</tr>
<tr>
<td>1987</td>
<td>3rd year of rice–fish cultivation</td>
<td>6.24</td>
<td>5.269</td>
<td>—</td>
<td>10.46</td>
<td>84.9</td>
<td>0.245</td>
<td>0.122</td>
<td>2.643</td>
</tr>
</tbody>
</table>

In contrast, fields planted to rice, but not stocked with fish, require weeding twice during the growing season and still contained 2,000 kg of weeds per hectare at harvest. Oriental army worms and rice planthoppers were eaten by the fish; therefore, no pesticides were needed and labour for spraying was saved. The percentage of diseased rice plants decreased by 7–14% compared with fields without fish.

Conclusion

The most desirable fish species for rice–fish cultivation in the Yunnan plateau is *C. leather*. It grows quickly, is of good quality, tolerates low oxygen, and can be stocked at high densities. The use of ditches and beds, combined with zero-tillage, produced the best economic returns from rice–fish cultivation in Yunnan. This system produces increased outputs and income from both rice and fish and imparts additional ecological benefits to the ricefield.