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Contribution of Stocked and Wild Fish in Ricefields to Fish Production and Farmer Nutrition in Northeast Thailand

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Abstract

Fingerlings of common carp (*Cyprinus carpio*), Thai silver carp or tawes (*Puntius gonionotus*), Nile tilapia (*Oreochromis niloticus*) and mrigal (*Cirrhinus mrigala*) were stocked in rainfed lowland ricefields in Northeast Thailand in 1986 and 1987. In both years, farmers harvested on average 50 $kg \cdot ha^{-1}$ of stocked fish species. Farmed fish yields were correlated with stocking densities. Feeding practices did not contribute to fish yields. Average recovery rates in both years were about 16%, but recovery of tawes was much better than of the other species. Nursery-paddies to increase recovery rates were not successful. The fingerling costs exceeded the market value of the farmed fish with 40% of the farmers.

The average wild fish yield over both years was 209 $kg \cdot ha^{-1}$, mostly snakehead (*Channa striata*) and catfish (*Clarias batrachus* and *C. macrocephalus*), with some climbing perch (*Anabas testudineus*). Wild fish yields in both years were correlated with water depths in the field. The market value of the wild fish equalled the market value of the rice crop. Wild fish caught by household members from ricefields were the most important source of animal produce consumed during the rice-growing season (68%).

Introduction

Ricefields as artificial swamps are very productive habitats (Heckman 1979). Northeast Thailand, where nearly all farm land is used for growing rice, becomes one vast wetland during the rainy season.

Common wild species found in flooded ricefields are snakehead (*Channa striata*), catfish (*Clarias batrachus* and *C. macrocephalus*) and climbing perch (*Anabas testudineus*). These predatory fish feed on small barbs such as *Danio* spp. and *Rasbora* spp., that are numerous in the flooded fields. All three predators may crawl over land and successfully invade newly flooded ponds and ricefields, or retreat at the end of the season to remaining water bodies, called catch ponds. The catch pond should be pumped dry in time, otherwise the fish will again try to leave for less crowded places, or the big fish will eat the smaller ones. Attempts by farmers to "store" the wild fish in the catch pond into the dry season generally were not successful (Middendorp and Verreth 1986).

In Northeast Thailand, contrary to popular belief, no tradition of stocking fingerlings in flooded ricefields exists. The area under rice-fish culture was only 2,500 ha in Northeast Thailand in 1986, or about 1% (Anon. 1988). However, the prevailing extensive rice cultivation methods do favor rice-fish culture (Leelapatra and Sollows, in press; Thongpan et al., in press).

Rice-fish culture in Kho Wang district (CARE International, Thailand) was initiated in response to farmers' requests (Middendorp and Waters 1988). Farmers' activities were monitored during two consecutive rainy seasons. Importantly, rice-fish culture was seen as an extension "point-of-entry" to interest farmers in other fish farming activities, notably pond and hapa culture (Middendorp and Verreth, in press).

The two main objectives were: (1) to investigate the contribution of stocked fingerlings to fish yields from ricefields, and the influence of feeding, stocking density and water level on stocked and wild fish; and (2) to establish the contribution of fish in the diet of the farmers.

Materials and Methods

Project Outline

Participating farmers from all eight project villages were visited weekly by the field officers. Progress was discussed and data were recorded on preprinted forms. Forms were more detailed in 1987. Data of 20 farmers in 1986 and 16 farmers in 1987 were considered reliable for analysis.

All fields in the Kho Wang district are rainfed. Lowland rice is the only field crop. The area is reasonably fertile and usually receives sufficient precipitation, compared to other regions in Northeast Thailand. All rice-fish fields had 150-500 m^2 catch ponds, 3-4 m deep.

Direct project support consisted only of free transport to a private fingerling station. Farmers bought their own fingerlings more or less according to project guidelines.

Stocking of Fingerlings

In both years, fingerlings were stocked in the ricefields during the third week of July. Farmers were advised to stock 3,750 fingerlings per hectare, following recommendations from a nearby rice-fish project (Thongpan et al., in press). Average stocking density was 2,855$\cdot$ha^{-1} (SD = 1,680) in 1986, and 3,819$\cdot$ha^{-1} (SD = 2,439) in 1987. Nominal costs were 15-20 Baht (B) per 100 fingerlings of 2-3 cm (US $1 = B25).

In 1986, species stocked were: common carp (*Cyprinus carpio*), tawes (*Puntius gonionotus*) and tilapia (*Oreochromis niloticus*), at a recommended stocking ratio of 2:1:1. Fingerlings were released directly into the catch ponds. Often fingerlings of predatory fish such as snakehead and catfish, with some climbing perch, were already present.

In 1987, species stocked were: common carp, tawes and mrigal (*Cirrhinus mrigala*). Recommended stocking ratio was 4:4:1; but only eight of the 16 farmers stocked mrigal. In view of the low recovery rates obtained in 1986, farmers were asked to release the fingerlings in "nursery-paddies" of about 40-80 m^2 constructed in a corner of the field. Recommended nursing time was one month, and recommended water depth was 40+ cm. The dike of the nursery-paddy was screened against frogs, snakes and predatory fish with blue nylon mosquito netting (50-cm high). One roll of nylon netting was provided per farmer. Most nurseries were heavily manured, and sometimes rice was transplanted in them as well.

Data Collection and Statistics

The water depth was measured weekly at the deepest part of the field ("bottom-to-surface") at a fixed spot, and mean monthly water levels per field were calculated. The cumulated sums of these mean water levels (3-4 months) were then used as an estimate of flooding.

Feed inputs were calculated over the rice cultivation period (August-November: 120 days). Farmers could provide realistic estimates of rice yields only for the total of their fields, based on the number of sacks harvested.

Farmers recorded by size all fish taken from the rice-fish field during the rice-growing period. Fish that were caught from catch ponds at the end of the season were counted and weighed by the field officers. Fish production was divided into four categories: farmed species versus wild species, and fish harvested during the rice growing season versus fish harvested when the catch pond was emptied.

The household was defined as the group of persons living in a farmer's house during the rice season. Animal produce consumption by the household was calculated over the mentioned cultivation period of 120 days. The annual per capita consumption of rice (1 kg paddy = 0.67 kg milled rice) was calculated by deducting 20% from the farmer's estimate to correct for feed, seed and waste (Palacpac 1982).

In 1987, the number of fish harvested was recorded to calculate recovery rates. For 1986, the number of fingerlings recovered was approximated by dividing the total harvest weight per species by the mean harvest weights of common carp and tawes observed in 1987, and using an arbitrary harvest weight of 100 g for tilapia (tilapia was not stocked in 1987 due to its low recovery in 1986).

Growth rate ($g \cdot day^{-1}$) was calculated per farmer as harvest weight divided by total rearing time.

Regression coefficients (m) were calculated between fish yields ($kg \cdot ha^{-1}$) and total feed ($kg \cdot ha^{-1}$); between yields and stocking density; and between yields and the sums of the mean monthly water levels (equations 1-3). The multiple regression on farmed fish yields with stocking density and the sum of water levels as covariables was also computed (equation 4):

$$\text{Yield} = m1 \cdot (\text{total feed}) + b1 \quad ...1)$$
$$\text{Yield} = m2 \cdot (\text{stocking density}) + b2 \quad ...2)$$
$$\text{Yield} = m3 \cdot (\text{sum water level}) + b3 \quad ...3)$$
$$\text{Yield} = m4 \cdot (\text{stocking density}) + m5 \cdot (\text{sum water level}) + b4 \quad ...4)$$

where b1-b4 are yield coefficients.

The relative margin of stocking 100 fingerlings in 1987 was calculated per species by multiplying fingerling recovery rate (Rec), the mean harvest weight of an individual fish (HW) and fish market prices (MPr); and subtracting fingerling costs (Fing Cost)(equation 5). The gross margin (Grs. Mar.) of rice-fish culture was defined as the difference between fingerling costs and the calculated market value (total weight times the market price) of the harvested farmed fish species (TotFF) (equation 6). The return of ricefield fisheries was defined as the market value of both wild (TotWF) and farmed species, minus fingerling costs (equation 7). Other costs, e.g., feed, fingerling transport and labor, were not considered.

$$\text{Rel. Mar.} = 100 \cdot \text{Rec} \cdot \text{HW (kg)} \cdot \text{MPr(B/kg)} - \text{FingCost (B)} \quad ...5)$$
$$\text{Grs. Mar.} = \text{TotFF(kg)} \cdot \text{MPr(B/kg)} - \text{FingCost (B)} \quad ...6)$$
$$\text{Return} = \text{TotWF(kg)} \cdot \text{MPr(B/kg)} + \text{Grs. Mar. (B)} \quad ...7)$$

Results

Household Consumption and Rice Cultivation

Table 1 presents a summary of data on households and rice cultivation. In 1987, only five farmers (31%) from the previous year participated, the others having no experience with rice-fish culture. The average age of the farmers was 46.5 years.

Total area planted to rice per household was about 4 ha. The mean rice-fish field measured 6% of the total rice area in 1986 and 18% in 1987. Most farmers applied chemical fertilizer only once, shortly after transplanting. The amount of fertilizer per rice-fish field could not be estimated correctly, but was very small.

Mean paddy yield was $1.6 t \cdot ha^{-1}$. Per capita consumption was 218 kg paddy per year (SD = 58), which equals 400 g milled rice per day. Excluding small children (0-5 years of age), 252 kg paddy per household member per year was consumed.

Animal produce consumption per household (Table 2) averaged 55 kg in 120 days in 1986 (82 g/person/day), and 60 kg in 1987 (99 g/person/day). Fish was 72% (1986) and 82% (1987) of the animal produce consumed. Calculated over both seasons, fish obtained by the household members from all ricefields surrounding the village, contributed 88% to total fish consumption, or 68% to total animal produce consumption. All meat was bought in the market. Average market prices (1987) reported by the farmers were: fish: 16.2 $B \cdot kg^{-1}$; poultry: 20.9 $B \cdot kg^{-1}$; meat: 51.1 $B \cdot kg^{-1}$; and 1.1 B per egg.

Fish Yields from Ricefields

A summary of fish yields is given in Table 3, with yields per species shown in Table 4. Calculated over both seasons, farmed fish

Table 1. Average household and rice cultivation data. Standard deviation in brackets.

	1986; 20 farms		1987; 16 farms	
Household (persons)	6.7	(2.2)	5.8	(2.5)
Adults (16+)	4.5	(1.8)	3.8	(1.4)
Buffaloes	2.5	(2.4)	2.6	(2.6)
Total rice area (ha)	4.4	(3.7)	3.7	(2.6)
Glutinous rice (ha)	1.4	(1.1)	2.1	(1.9)
Rice-fish area (m^2)	2,687	(1,109)	3,659	(1,824)
Paddy yields ($kg \cdot ha^{-1}$)				
ordinary	-		1,587	(992)
glutinous	-		1,660	(1,000)
Paddy consumption per household ($kg \cdot year^{-1}$)	-		1,492	(558)

Table 2. Animal produce consumption per household (August-November, 120 days), the percentage bought in the market and daily consumption per household member.

	1986; 20 farms					
Animal produce*	Fis	Pou	Mea	Cra		
Household consumption (kg)	40	7	4	4		
Standard deviation	14	4	2	6		
Market bought (%)	7	0	100	0		
Daily consumption (g/person/day)	56	10	5	11		
	1987; 16 farms					
Animal produce*	Fis	Pou	Mea	Cra	Egg	Fro
Household consumption (kg)	49	7	3	1	40	3
Standard deviation	33	5	3	1	39	4
Market bought (%)	16	32	100	0	31	0
Daily consumption (g/person/day)	77	14	6	2	-	6

*Fish; poultry; meat; crabs and shrimps, eggs (no.) and frogs.

Table 3. Summary of fish yields (kg·ha^{-1}) from ricefields. Standard deviation in brackets.

		1986; 20 farms				
Concurrent yield	14	(20)				
Final harvest	290	(267)				
Farmed fish (FF)	49	(49)				
Wild fish (WF)	255	(254)				
Maximum observed yield						
Farmed fish	163	-				
Wild fish	825	-				
Total fish yield	303	(266)				
Total fish per farmer (kg)	76	(71)				
		1987; 16 farms				
Concurrent yield	FF:	3	(7)	WF:	35	(113)
Final harvest	FF:	48	(46)	WF:	127	(180)
Farmed fish (FF)		51	(45)			
Wild fish (WF)		162	(286)			
Maximum observed yield						
Farmed fish		148	-			
Wild fish		1,199	-			
Total fish yield		214	(316)			
Total fish per farmer (kg)		56	(46)			

yield averaged 50 kg·ha^{-1}, and wild fish yield averaged 209 kg·ha^{-1}. Concurrent fish harvest (i.e., during the rice-growing season) was 4.5% of total fish yield in 1986, and 18.0% in 1987. Wild species contributed 84% to total fish yield in 1986, and 76% in 1987. Snakehead and catfish were the most important wild species by weight: 90% of all wild fish in 1986, and 83% in 1987.

Most of the feeding was done during the first two months. Farmers fed about the same quantities of feed per rice-fish field in both years, but fields were larger in 1987 (Table 5). Correlations between total amount of feed and yields of stocked and wild fish, were not significant.

Average fingerling recovery over 1986 and 1987 was 513 fish·ha^{-1} or 16% (Table 6). Mean rearing time in 1987 was 161 days (Table 7). Harvest weights and growth rates differed markedly per species (Table 8) (it was not possible with every farmer to count the final fish harvest). Average yield per 100 fingerlings stocked in 1987 was calculated at 1.6 kg for common carp; 2.7 kg for tawes; and 3.1 kg for mrigal.

Table 4. Average fish yields per species per farm.

	Fish species*							
	CC	TW	TI	MR	SH	CF	CP	Misc. spp.
1986: $kg \cdot ha^{-1}$	35	22	7	-	120	128	39	38
Standard deviation	39	24	6	-	109	135	49	32
No. farms	13	20	9	-	19	18	6	7
1987: $kg \cdot ha^{-1}$	15	37	-	6	77	59	20	7
Standard deviation	18	41	-	8	103	127	43	11
No. farms	16	14	-	8	16	16	16	16

*Farmed species: *C. carpio* (CC); *P. gonionotus* (TW); *O. niloticus* (TI); *C. mrigala* (MR). Wild species: *Ch. striata* (SH); *Clarias* sp. (CF); *A. testudineus* (CP).

Table 5. Mean feed inputs and feed costs in rice-fish culture (120 days).

	1986; 20 farms		
	RB	BR	TF
No. farms	20	11	20
Total feed ($kg \cdot ha^{-1}$)	150	30	167
Total feed (SD)	100	26	116
Feed cost ($B \cdot kg^{-1}$)	1.2	1.6	-
Mean feed cost per farmer			49
Mean feed cost ($B \cdot ha^{-1}$)			180

	1987; 16 farms			
	RB	BR	PL	TF
No. farms	15	2	7	16
Total feed ($kg \cdot ha^{-1}$)	82	13	31	97
Total feed (SD)	57	3	30	171
Feed cost ($B \cdot kg^{-1}$)	1.8	1.8	11	-
Mean feed cost per farmer				98
Mean feed cost ($B \cdot ha^{-1}$)				266

RB = Rice bran; BR = Broken rice; PL = Comm. pellet; TF = Total feed.

Table 6. Summary of fish recovery rates from ricefields and as percentage of stocking density. No standard deviations (SD) available for 1986.

	1986; 20 farms (fish·ha^{-1})	(%)
Common carp	153	11
Tawes	275	39
Tilapia	67	9
Mrigal	-	-
Total stocked fish	495	17
Total wild fish	-	-

	1987 (16 farms) (fish·ha^{-1})	(SD)	(%)
Common carp	124	217	7
Tawes	453	413	33
Tilapia	-	-	-
Mrigal	18	24	11
Total stocked fish	530	444	15
Total wild fish	1,545	-	-

Table 7. Rearing periods, 1987.

	Days	SD
Time in nursery paddy	50	(21)
Time in ricefield	74	(17)
Time in catch pond	37	(26)
Mean rearing time	161	(34)

Table 8. Mean harvest weight and growth rate per species, with standard deviation (SD) (1987; 16 farms).

	Harvest weight (g)	(SD)	Growth rate (g·day^{-1})	(SD)	Farms (no.)
Common carp	231	187	1.38	0.91	13
Tawes	81	57	0.52	0.34	14
Mrigal	286	112	2.19	1.00	6
Snakehead	168	57	1.09	0.43	16
Catfish	127	56	0.84	0.51	15
Climbing perch	43	29	0.27	0.16	14

Stocking Density and Water Level

The number of fingerlings per farmer was fairly constant, but stocking densities varied widely due to differences in field size. Yields of stocked species were correlated with stocking densities in 1987 (=0.10), but not in 1986 (Table 10). The combined data of both years were significantly correlated (=0.05) with the extrapolated yields of farmed species, increasing from 41 kg•ha^{-1} at 2,000 fingerlings per ha, to 95 kg•ha^{-1} at 10,000 ha^{-1}. Wild fish yields were not correlated with densities of stocked fish.

Mean monthly water levels (Table 9) in the rice-fish fields were highest in September. The correlation between wild fish yields and cumulated sums of the mean monthly water levels was significant in both years. Farmed fish yields and water levels were only significantly correlated in 1987 (Table 10). Regression coefficients with the sum of water levels calculated over three months (August-October) were similar to those calculated over four months (including November).

The multiple regression on farmed fish yields, with both the sum of mean water level (August-October) and the stocking density as co-variables, was not significant for 1986, but highly significant for 1987 (R^2=0.624). The regression over both years combined was also significant (Table 10).

Rice-Fish Economics

The mean rice yield of 1987 was valued at 4,000 B•ha^{-1} ($160•ha^{-1}) at a farmgate price of 2,500 B per tonne, which corresponds to 15,063 B per household or 1,468 B per average rice-fish field. For comparison, the mean market value over both seasons of the wild fish per rice-fish field was 1,461 B (Table 11).

Fingerling costs per farmer averaged only 120 B in 1986, and 225 B in 1987. Still, eight farmers (40%) had a negative gross margin in 1986, and six farmers (38%) in 1987. The general return on ricefield fisheries over both seasons was 5,461 B•ha^{-1} ($218•ha^{-1}). The gross margin of stocking fingerlings was only 11% of the general return on ricefield fisheries (Table 11).

Average market prices per kg, as reported by the farmers (1987) and used in the calculations, were: common carp 27.5 B; tawes 24.9 B; snakehead 27.1 B; catfish 33.5 B; climbing perch

Table 9. Mean monthly water levels in rice-fish fields measured weekly at the deepest part (fixed spot).

	1986; 16 farms					
	J*	A	S	O	N	Sum ASON
Depth (cm)	n.a.	36	42	32	9	120
Standard deviation	-	22	24	31	13	77

	1987; 20 farms					
	J	A	S	O	N	Sum ASON
Depth (cm)	18	28	35	25	14	102
Standard deviation	15	11	11	9	17	39

*J = July, A = August, S = September, O = October, N = November.

Table 10. Regression analysis of stocking density and water level on fish yield. 1986: n = 20; 1987: n = 16; 1986+87: n = 36.

Yield = m2 · (St. Dens.) + b2

1986: FF/ha	= 0.0049 · St. Dens. + 34.7		(r = 0.19 NS)
1987: FF/ha	= 0.0085 · St. Dens. + 18.7		(r = 0.49 *)
86/87: FF/ha	= 0.0067 · St. Dens. + 27.8		(r = 0.33 **)

Yield = m3 · (sum Water Level) + b3

1986: FF/ha	= 0.10 · WL (ASO) + 37.3	(r = 0.15 NS)
1986: WF/ha	= 2.40 · WL (ASO) - 13.0	(r = 0.66 ***)
1987: FF/ha	= 1.14 · WL (ASO) - 49.0	(r = 0.73 ***)
1987: WF/ha	= 6.74 · WL (ASO) - 429.6	(r = 0.67 ***)

Farmed Yield = m4 · (St. Dens.) + m5 · (sum Wat. Lev.) + b4

1986: FF/ha	= 0.0056 · St. Dens. + 0.13 WL(ASO) +16.2	(r = 0.27 NS)
1987: FF/ha	= 0.0056 · St. Dens. + 1.01 WL(ASO) - 61.8	(r = 0.79 ***)
86/87: FF/ha	= 0.0072 · St. Dens. + 0.23 WL(ASO) - 0.2	(r = 0.43 ***)

Level of significance: * = 0.10; ** = 0.05; *** = 0.01

FF/ha = Total farmed fish species (kg·ha^{-1}); WF/ha = Total wild fish species (kg·ha^{-1}); WL(ASO) = Sum of the average monthly water levels of August, September and October; St. Dens. = Stocking density.

Table 11. Costs of fingerlings, calculated market value of fish yield, gross margin of rice-fish culture, and return on ricefield fisheries. Average values per farm, and per ha. Standard deviation in brackets.

	1986 (B/farm)		1987 (B/farm)		1986 (B·ha^{-1})	1987 (B·ha^{-1})
Fingerling cost	120	(52)	225	(114)	448	615
Market value farmed species	301	(314)	390	(323)	1,120	1,065
Market value wild species	1,838	(2,044)	1,083	(1,144)	6,839	2,960
Gross margin rice-fish	180	(315)	165	(296)	672	450
Return ricefield fisheries	2,018	(2,110)	1,248	(1,263)	7,511	3,411

13.8 B. The relative margin per 100 fingerlings in 1987 was 30 B (common carp); 52 B (tawes); and 67 B (mrigal).

Based on the obtained regression of farmed fish yields on stocking density, at an approximated cost of 16 B per 100 fingerlings (ignoring differences between species), a market value of 25 B·kg^{-1}, and ignoring all other costs, then a gross margin for rice-fish of 710 B·ha^{-1} is calculated at a stocking density of 2,000 ha^{-1} (fingerling costs: 320 B·ha^{-1}), while at 10,000/ha, a gross margin of 778 B·ha^{-1} is calculated (fingerling costs: 1,600 B·ha^{-1}).

Discussion

Household Consumption and Rice Cultivation

Households and their farm lands did not differ from others in the district. Per capita consumption of rice in the nearby Lam Pao irrigation area was 396 kg of paddy per year (Middendorp and Verreth 1986), nearly twice the quantity found in this study.

Total animal produce consumption per household was comparable in both years. Mean household size was slightly smaller in 1987 than in 1986, and so daily consumption per person was slightly higher. The importance of fish to the diet of the participating households was evident.

Farmed fish harvested during the rice-growing season were negligible. The mean concurrent harvest of wild fish of 35 kg·ha^{-1} in 120 days (1987) indicates that the average household would need the fish production of about 2 ha to cover its fish consumption.

Fish Yields from Ricefields

The average fish yield over both years was 259 kg•ha^{-1}, of which 81% was wild fish. The maximum observed yields of both wild and farmed fish were about 3-4 times higher than the average yields, indicating some scope for yield improvement.

Middendorp and Verreth (1986) reported from Lam Pao, to the north of Kho Wang, an average stocked fish yield of 263 kg•ha^{-1} in 1983, and no correlation between stocking density and farmed fish yield. Wild fish yields were not included in the survey. Possibly yields were overstated in their one-time survey, compared to the weekly monitoring in this study.

In Ubon, to the east of Kho Wang (Thongpan et al., in press), common carp, tawes and tilapia fingerlings were stocked at a ratio of 2:2:1, and at a density of 3,750 ha^{-1}. Fingerling size was 5-7 cm in 1987, but only 2-3 cm in 1988. At the lowland site comparable to Kho Wang, the average yield of farmed species was 147 kg•ha^{-1} in 1987 (three farmers) and 88 kg•ha^{-1} in 1988 (nine farmers). Wild fish yields were not mentioned.

Mang-umphan et al. (1990) monitored 60 farmers during the 1987 rice season in Surin, west of Kho Wang. Common carp, tawes and tilapia were stocked at a ratio of 2:1:1 at 3,125-5,000 fish per ha. On average 88 kg•ha^{-1} of stocked species were harvested, and 33 kg•ha^{-1} of wild fish. As in Ubon, final fish harvest took place only in May. In Kho Wang, most fish were harvested in December. It is hypothesized that while a prolonged rearing time apparently results in higher yields of farmed species, the standing crop of wild fish diminishes in an isolated catch pond, in the midst of dried-out fields. Snakehead and catfish are voracious predators and cannibalistic when prey becomes scarce.

Fish Recovery and Growth Rates

Recovery of tawes was markedly better than of common carp, mrigal and tilapia, but common carp and mrigal reached much higher average harvest weights. Yields per 100 fingerlings stocked were highest for mrigal and tawes.

Recovery and growth rates reported by Mang-umphan et al. (1990) were comparable to those found in this study. Sollows and Thongpan (1986) also reported a superior growth rate of common carp compared to tawes or tilapia. Poor tilapia growth rates of less than 0.4 $g{\cdot}day^{-1}$ in rice-fish culture in the Philippines were reported by Dela Cruz (1980) and Mang-umphan and Arce (1988).

Stocking Density and Water Level

The results indicated that farmed fish production may be increased by stocking more fingerlings. The recommended fingerling density of 3,750 $fingerlings{\cdot}ha^{-1}$ was clearly too low. It was concluded that wild fish yields were not influenced by stocking fingerlings, because stocking densities were not correlated to wild fish yields.

In 1987, 62% of all variance in farmed fish yields was explained by stocking density and water level. The difference in mean wild fish yields of 1986 and 1987 was tentatively attributed to the general difference in water levels in the fields between both years. Unfortunately, analysis of variance to take into account the effects of time (two seasons) and place (eight villages in four districts) was not possible due to limitations in the dataset. Only five farmers from various villages participated both years, while within years the number of farmers per village varied from one to five.

It is inferred that the catch ponds improve wild fish yields. Because these ponds fill up with the first rains, when the ricefields are still dry, they may help by advancing wild fish reproduction. In view of the difference between wild and farmed fish yields, farmers understandably are not interested in fencing off their catch ponds against invading wild fish in order to improve the recovery of released fingerlings. Little and Muir (1987), referring to Northeast Thailand, reported that stocking of fingerlings was only acceptable to certain farmers when one-way screens were placed in their paddies, allowing entrance of wild fish.

Stocking fingerlings in nursery paddies in 1987 did not result in improved recovery rates, compared to releasing them directly into the catch ponds in 1986. Either the presence of wild fish in the catch ponds did not seriously affect the farmed species, at least not in the first month, or the nursery paddies were not well set up. Rice-fish yields generally were lower than in the previous year.

The idea of providing a predator-free rearing area for small fingerlings in Northeast Thailand (Little et al. 1987) merits further study because: (1) it is one of the few management possibilities open to the farmers since large fingerlings are not available commercially;

and (2) from an extensionist's point of view, fingerling nursing may be an effective introduction to fish farming in general.

Economics

The extrapolated yields of farmed species would only double if stocking densities and hence stocking costs were increased five times, with the approximated margin on stocking costs increasing by only 68 B•ha^{-1}. Consequently, lower stocking densities gave higher relative margins (as percentages of fingerling costs). Feed costs were not included in these calculations, because feeding did not significantly increase yields. Note that in both years about 40% of the farmers did not even recover the costs of fingerlings from the market value of farmed species, even though farmers spent only very small amounts of money on fingerlings.

Unfortunately, a direct economic comparison with our earlier study was not meaningful because the fish yields in the two studies do not correspond well (Middendorp and Verreth 1986). Mangumphan et al. (1990) found a comparable average margin on stocking fingerlings of $17.35 per ha (434 B•ha^{-1}), but a lower market value of wild fish, $48.85 per ha (1,221 B•ha^{-1}).

Policy

Given the economic appraisal of rice-fish culture in this study, it must be concluded that stocking fingerlings in rainfed ricefields where wild fish are common is not an economically relevant alternative to intensify ricefield production in Northeast Thailand, at least under the present circumstances. The importance of fish in the diet of these rice farmers has been shown in this study; but stocked fish are nearly all harvested at the end of the culture period and of no importance to household nutrition during the rice season. Also, the quantity of farmed fish is small compared to that of the wild fish harvested from the rice-fish field.

Improvement of rice yields is almost invariably quoted in support of rice-fish projects. Lightfoot et al. (in press) in their review, reported both increases and decreases in rice yields due to stocking fish, although the rice increases often exceeded the decreases. In Northeast Thailand, Middendorp and Verreth (1986) reported a mean increase in rice yield of 15% due to rice-fish culture.

Thongpan et al. (in press) found a significant mean increase of 14.8% in rice yields, compared to unstocked control fields. These articles focused on the positive effects of introduced (farmed) species, implying that "stocking fingerlings" is being compared to an empty ricefield. However, at least in this study, the wild fish outnumbered the farmed fish, and their possible influence on the rice crop should not be overlooked. Farmers often remarked that higher rice yields depended not so much upon the fish stocked, as on the extra care provided by the farmer to his rice-fish field.

Fingerling availability is another constraint to the large-scale introduction of rice-fish culture. Farmer's travelling costs are often as high as one or two bags of fingerlings. With the low margin on stocking costs, certainly not much effort will be put into obtaining fingerlings for rice-fish culture.

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