The next stock transfer will therefore occur in 106 + 29 = 135[th] day.

Here a fractional refers to time, not an activity (of stock transfers in 3 above) so we round-off rather than ignore it.

d. How many harvests would we have had in 120 days?

Using equation 4.2

T = 120-7 = 113

$$k_5 = \frac{113-(3-1)30}{30+15} = \frac{60}{45} = 1.18$$

We would have had one harvest, with (1-0.18) (15 + 30) (using equation 5.1) = 36.9 or approximately 37 days to the next harvest, which therefore will be due on

113 + 37 = 150[th] day

6. Further Development of the Approach

It has been shown in 3 above that for m = 2, total number of stock transfers = $T/(\bar{n}+\bar{p})$, and for m = 3, total number of stock transfers = $(2T-\bar{n})/(\bar{n}+\bar{p})$. The denominator is the same for all values of m, but the numerator changes and an attempt is made here to make the numerator a function of m. Consider the following:

m	Numerator of 'k'
2	T
3	$2T - \bar{n}$
4	$3T - 3\bar{n}$
5	$4T - 6\bar{n}$
6	$5T - 10\bar{n}$
7	$6T - 15\bar{n}$

It is obvious that T, with respect to m, carries a coefficient of (m - 1). Considered as a series, the coefficient n increases as the sum of an arithmetic progression whose common difference (d) is 1, the first term (a), 1, and the final term (n), (m - 2).

Taking the general equation for the sum of an arithmetic series:

$$S_n = \frac{n}{2}[2a+(n-1)d] \qquad ...6.1)$$

and substituting our own terms we have

$$S_{m-2} = \frac{m-2}{2}[2+(m-2-1)]$$
$$= \frac{m-2}{2}(2+m-3)$$
$$= \frac{m-2}{2}(m-1)$$
$$= \frac{(m-2)(m-1)}{2} \qquad ...6.2)$$

i.e., the coefficient of $n = \frac{(m-2)(m-1)}{2}$

A general relationship for the number of stock transfers can therefore be written as

$$TST = \frac{(m-1)T - \frac{1}{2}\bar{n}(m-2)(m-1)}{\bar{n}+\bar{p}}$$
$$= \frac{(m-1)T - 0.5\bar{n}(m^2-3m-2)}{\bar{n}+\bar{p}} \qquad ...6.3)$$

Neat as this equation is, however, it is incapable of discriminating against the fractional residuals, which it compounds for each compartment to give a value of TST which is larger than the actual value.

Concluding Remarks

The author hopes that this paper will stimulate readers to think further about the development and use of such production planning aids. Comments from other NTAS members would be most welcome.

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Rice-Freshwater Prawn (*Macrobrachium rosenbergii*) Farms in the Mekong Delta, Vietnam

NGUYEN QUANG TUYEN

Introduction

The Mekong Delta of Vietnam covers 4 million ha, of which 2.3 million ha are under rice cultivation. The delta floods annually. Water depth in the ricefields is around 0.3-3.0 m during the wet season and brackishwaters cover about 1.6 million ha in the dry season. Aquaculture in ricelands has been practised here for a long time and integrated rice-freshwater prawn farming has become more and more popular.

The giant freshwater prawn (*Macrobrachium rosenbergii*) occurs in the two main river systems of the Mekong Delta: "song Tien" and "song Hau" in parts of Hau Giang, Cuu Long, Tien Giang, An Giang and Dong Thap provinces.

The total annual freshwater prawn production in Vietnam during 1985-90 was reported to vary from 5,000 to 6,000 t, most of it from natural fisheries (Kwei Lin and Lee 1992).

Farming Systems

These integrated farming systems were developed by farmers of the Mekong Delta to produce more food and more cash crops.

The farmers have improved their rice varieties and culture techniques to increase their rice production and have also learned how to raise prawns simultaneously to get extra income. Prawns are grown in ricefield peripheral trenches. Trees of high economic value are grown on the surrounding dikes that prevent the prawns from escaping.

The farmers practise different rice-freshwater prawn systems. For example, in freshwater ricelands, they can grow *M. rosenbergii* with two rice crops a year. The most attractive systems are: summer-autumn high-yielding rice (HYR) - main season HYR + prawn; winter-spring HYR - summer-autumn HYR - main season HYR + prawn; and main season HYR - sugarcane + prawn. In brackishwater areas, farmers can raise freshwater prawns mixcropped with the main season HYR because there is enough freshwater for this during rainy season. In saline water-intruded areas of the Mekong Delta, farmers have found that lands cleared of bushes produce acid substances in dry periods. These can kill their subsequent rice crops. However, if kept flooded, these lands can produce a shrimp catch in addition to being able to grow a crop of rice (wet season) (Vo-Tong Xuan 1983).

Constraints and Potential

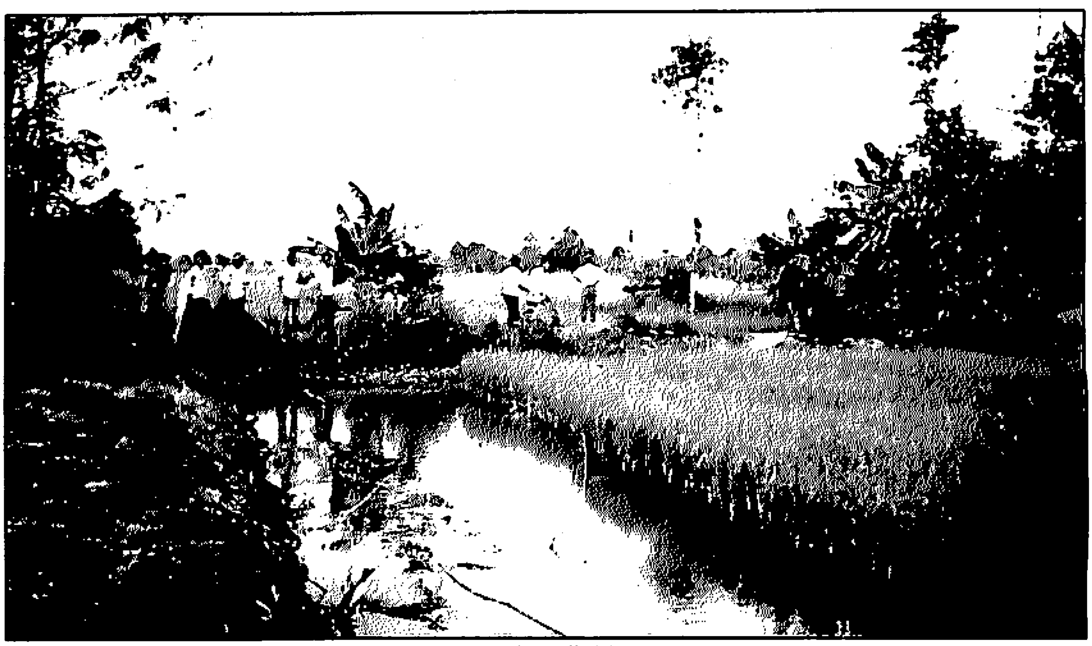
There are abundant sources of prawn seed in the delta but not enough to supply all the needs of farmers now that prawn farming is expanding. Generally, the farmers are poor and practise extensive culture, mainly exploiting natural feed resources. However, some farmers who raise prawns in semi-intensive systems invest regularly in feeds. Farmers need more capital to develop and improve these systems.

Prawns command a high price; the sales value of 1 kg of prawn at size 1 (>70 g/prawn) is equivalent to about 70 kg of paddy rice. However, farmgate prices are often unstable and may decrease a little at harvesting peaks.

Current Research

Recent research on rice-freshwater prawn farming systems has given the following results:

- Young prawns (4-10 kg) can be grown in ponds and harvested after three to four months with 60% having individual weights 30-50 kg (STCCL 1988).
- In ricelands that were gravity-fed with water, the average yields from mixcropping of rice and prawns with two rice crops in the year were 3.9 t/ha of rice and was 70 kg/ha of prawns (Nguyen Quang Tuyen et al. 1991).
- Another case study in an irrigated area revealed that *M. rosenbergii* and silver barb (*Puntius gonionotus*) mixcropped with two rice crops gave rice yields of more than 5 t/ha, 187 kg/ha of prawns and 214 kg/ha of fish (Le Thanh Duong et al. 1990).
- If the trench to rice growing area ratio is increased, prawn survival improves. Prawn survival was 30-51% with a 15% trench area ratio.
- A daily feeding rate of 3% prawn biomass was inadequate for prawns stocked in ricefields at 2.0-1.8/m^2 and the food conversion ratio was 4.5 for compounded feeds (Cong Danh Tran et al. 1989); in ricefields, a daily feeding rate at 2-3% of prawn biomass was recommended by STCCL (1988).
- A case study in the Mekong Delta showed the economic viability (net returns and rate of return) of the various rice-prawn culture systems as follows: a) 4.9 t/ha of rice, 2.1, respectively, for early wet season of HYR + prawn + main wet season HYR pattern; b) 3.1 t/ha rice, 1.6 for wet season HYR + prawn and dry season HYR pattern; and c) 1.7 t/ha rice, 1.5 for rice monoculture (Nguyen Quang Tuyen et al. 1991).
- Prawns and fish eat large quantities of grassy weeds and can reduce weeding expenses by about one-third; similarly, NPK fertilizer application can be reduced by about 28%, without reducing rice yield, because prawns and fish assist fertility (Lightfoot and Nguyen Anh Tuan 1990).
- In a study monitoring 119 farm families to compare the relative economic returns from various systems and to determine the degree of adoption of the new technology, about 62% of the farmers used fertilizer correctly, rice yields were more than 4 t/ha per crop and the maximum prawn yield obtained 364 kg/ha per crop. The marginal benefit-cost ratio was 0.96 for summer-autumn HYR - main season HYR + prawn; 0.77 for main season HYR - sugarcane + prawn; and 1.0 for winter-spring HYR - summer-autumn HYR - main season HYR + prawn (Nguyen Van Sanh 1991).
- Nguyen The Huy studied a number of popular farming systems involving rice, upland cash crops, fish and prawn and perennial trees; in each system, the average area reserved



Farmers and researchers monitoring rice-shrimp fields.

for rice was about 56-71% of the total, trenches occupied 14-23% and surrounding dikes 14-25% of the total area.

- Studies on the toxicity of insecticides (Source, Vietnam Pesticides Company) to prawns, using rice plots in concrete tanks, showed extreme toxicity for Decis, moderate toxicity for Sherpa, Methyl Parathion, Bassa, DDVP and Sumithion and less toxicity for Azodrin and Monitor (Nguyen Anh Tuan and Nguyen Phu Tam 1990).
- In integrated rice-prawn culture, the prawn production ranges from 200 to 400 kg/ha/year with a gross income of US$600-1,200, which far exceeds the income from the rice crops generated from a shared ricefield. The popularity of rice-prawn farming in certain areas of the delta suggests that farmers have accepted the concept and are confident of the economic viability of the system (Kwei Lin and Lee 1992).
- Juvenile prawns are stocked 15-20 days after rice transplanting. They are harvested one month after the rice harvest. Due to dependence on natural seed, several stockings may be needed to reach the desired density: 10,000-20,000 of 4-5 g juveniles/ha. Although prawns are fed occasionally, natural food is very important to compensate for the low stocking density and irregular feeding regime. Farmers apply little or no pesticides. Rice losses due to the brown planthopper (*Nilaparvata lugens*) are minimized by keeping young ducklings and high water levels. Farmers with prawn yields lower than 100 kg/ha had net benefits less than US$400/ha/crop. Those with yields higher than 300 kg/ha/ had net benefits higher than US$1,000/ha/crop. The return from prawns was the decisive factor determining the net benefit (Le Thanh Hung 1992).
- Integrated rice-prawn farming at Phung Hiep district, Cantho province, yields on average 8.5 t/ha of rice from two crops per year and 354 kg/ha of prawns (one crop). The contribution to farm net income from rice is 42% versus 32% from prawns. Rice is consumed at home, but prawns are sold as a high value cash crop for export, yielding 43% of the cash income compared with only 20% from rice.

The introduction of a cash crop, such as prawns, does not have to be synonymous with unsustainable practices such as reducing diversity, putting increased stress on the natural resources, or relying less on integration and more on external chemical inputs. On the contrary, it can help promote ecologically sound and economically attractive farming practices (Nguyen Van Sanh et al. 1993).

Merchants inspecting shrimp harvest at farm households.

The Future

Rice is always the basic food for humans and animals in the delta. Modern rice varieties are needed for improved yields, pest resistance and stress tolerance. Ricefields are a good environment for aquaculture because of their diverse natural feeds. Prawns can act as insect predators and can also improve soil fertility. The high economic value of prawns has attracted farmers to develop this system in the Mekong Delta but constraints are slowing its expansion. More research is needed on these rice-fish/prawn systems.

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