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Technical Manual for Integrated Rice-Freshwater Prawn farming, Cambodia

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Technical Manual for Integrated Rice-Freshwater Prawn farming, Cambodia

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List of abbreviations

$CaCO_3$	Calcium carbonate
cm	Centimeter
CO_2	Carbon dioxide
DAP	Diammonium phosphate
DO	Dissolved Oxygen
FAO	Food and Agriculture Organization
FCR	Feed conversion ratio
GH	Hardness
H_2S	Hydrogen sulfide
Ha	Hectares
Kg	Kilograms
KH	Alkalinity
NH_3	Ammonia
NO_2	Nitrite
NPK	Nitrogen (N), phosphorus (P) and potassium (K)
O_2	Dioxygen
pH	potential of Hydrogen
PVC	Polyvinyl chloride
ROI	Return on investment
IRRI	The International Rice Research Institute

Foreword

The freshwater prawn (*Macrobrachium rosenbergii*), belonging to the family Palaemonidae, is found in Cambodia, particularly along the Mekong River and its tributaries in the provinces of Prey Veng, Kandal and Takeo. Because of the market demand and its high economic value, this species has become a significant source of income and a vital resource for sustaining rural livelihoods, both in terms of nutrition and economic stability (Chea 2012).

Integrating rice–prawn culture into rice fields offers a successful and sustainable integrated farming system. This technique not only helps farmers increase their income but also contributes positively to the environment by reducing chemical inputs, improving soil and water quality, increasing biodiversity and promoting the efficient use of natural resources–regenerative agriculture (Halwart and Gupta 2004).

Recognizing these benefits, WorldFish, the International Rice Research Institute (IRRI), the General Directorate of Fisheries, the General Directorate of Agriculture, the Royal University of Agriculture, the Prek Leap National Institute of Agriculture and various research institutions, together with other partner institutions, developed this technical manual to support farmers and aquaculture practitioners. The objective is to promote the integrated rice–prawn farming system, which diversifies production, reduces dependence on a single crop and meets growing market demand.

This manual was discussed and verified through a workshop called Technical Handbook on Prawn Farming in Rice Fields and Value Chain Production Analysis. It was implemented under the Scaling Regenerative Agri-food System Innovations in the ASEAN–CGIAR.

The workshop was attended by specialized institutions, including the Fisheries Administration of the Ministry of Agriculture, Forestry, and Fisheries, as well as various research institutes, national agricultural universities and model farmers. They reviewed and provided feedback to ensure that the content of this book is technically accurate and easy to implement for small-scale, family-run prawn farming operations.

We would like to express our deepest gratitude to all relevant institutions, experts and partners who contributed technical input and support in preparing this technical manual. In particular, we wish to thank the Department of Aquaculture Development of the Fisheries Administration, the General Directorate of Agriculture, the Kampong Thom and Takeo Provincial Department of Agriculture, Forestry, and Fisheries for their effective cooperation, technical support and facilitation in implementing various activities.

This manual is intended to serve as practical reference for farmers, agricultural extension workers and other relevant stakeholders on how to implement the integrated rice-prawn farming system effectively and sustainably.

Introduction

Freshwater prawns belong to the family Palaemonidae, specifically the species *Macrobrachium rosenbergii* and the genus Macrobrachium. Although these prawns can live and grow in freshwater, their reproduction requires brackish or saline water with a salt concentration of 10–12 parts per thousand (ppt). In Cambodia, prawns are abundant along the Mekong River and in riverine areas within the provinces of Prey Veng, Kandal and Takeo, as well as in coastal estuaries in the provinces of Kampot, Preah Sihanouk, and Koh Kong. Prawns are an aquatic species in high demand with a premium market value across the entire country (Chea 2012).

Integrating freshwater prawn farming into rice fields (integrated rice–prawn farming systems) not only boosts farmers' incomes but also contributes significantly to environmental health. This practice reduces chemical use in paddy fields, enhances biodiversity within the agricultural system, improves soil and water quality and ensures the efficient use of natural resources. Given the high market value of prawns and the environmental benefits of this system (Halwart and Gupta 2004), WorldFish, the IRRI and the Department of Aquaculture Development of the Fisheries Administration, along with various relevant institutions, developed this technical manual. Its goal is to encourage farmers and aquaculturists to scale up freshwater prawn farming, helping them diversify away from monoculture, meet market demand and increase household income. The manual is designed to provide practical, technical insights for farmers, technicians, staff from non-governmental organizations, and relevant institutions to implement this production system correctly and effectively.

The main objectives of the manual are as follows:

- Provide knowledge on freshwater prawn farming techniques in rice fields.
- Introduce methods for managing rice and prawns to achieve high yields.
- Help farmers increase productivity and household income on the same land.
- Reduce risks and losses in production.
- Support extension officers and organizations in disseminating techniques to communities.
- Promote the sustainable use of land and water resources.

This manual is written in clear, accessible language, drawing on farmers' practical experiences and relevant references to ensure ease of understanding and effective application.

What is rice-prawn culture?

Rice–prawn culture is an integrated agricultural practice where farmers broadcast or transplant rice and raise prawns simultaneously within the same paddy field. This system uses the rice crop as shelter and a natural food source for the prawns. Meanwhile, the prawns help reduce pests by feeding on them and can enhance biodiversity within the field by creating habitats for various aquatic organisms such as plankton, snails, apple snails and small fish. Reducing the use of chemical inputs in the paddy field also helps these beneficial aquatic plants and animals thrive. Furthermore, prawns help loosen the bottom soil of the rice field and decompose organic matter, allowing nutrients to be recycled back into the system while increasing biodiversity (Halwart and Gupta 2004). Generally, the rice field is modified by digging a canal system around or in a specific section, occupying about 20%–30% of the total field area, to serve as a habitat for the prawns to live and move around to forage. This canal also provides a space for prawns to hide within artificial shelters, especially during their molting period.

In this system, rice and prawns mutually benefit each other in the following ways:

- Rice fields serve as a habitat for prawns while providing them with natural food sources, such as insects, snails, bivalves, aquatic plants, fallen rice grains and other aquatic fauna.
- Prawns help control pests and weeds by consuming insects, aquatic plants and organic residues.
- Prawn waste enriches the soil, acting as a natural fertilizer for rice crops.

Rice–prawn culture can be practiced at both household and commercial scales, depending on the size of the rice field, availability of water and the farmers' investment capacity. This system is increasingly recognized as an important option for farmers to diversify income, reduce risks and make efficient use of land and water resources.



Figure 1. The freshwater prawn farming system in rice fields.

Benefits of rice–prawn culture

Rice–prawn culture can be implemented on both a small-scale subsistence and a commercial basis, depending on land availability, water sources, labor capacity and the investment potential of the farmer. This integrated system is emerging as a highly viable option for farmers to maximize their income while optimizing land and water resource efficiency.

The rice–prawn co-culture technique is an integrated agricultural system that yields multifaceted economic, environmental and social benefits for farmers. Beyond enhancing land and water productivity, this approach significantly boosts household income, generates local employment opportunities and mitigates overall production risks.

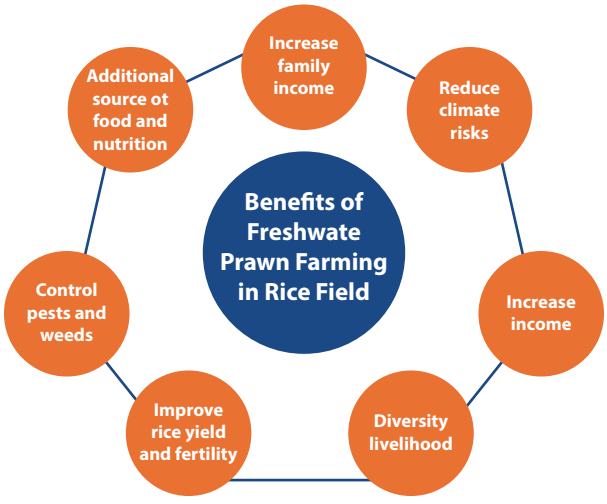


Figure 2. Benefits of freshwater prawn farming in rice fields.

Step 1. Site and farmer selection

Selecting an optimal site and establishing a technically sound freshwater prawn farming system are the most critical steps for achieving success in rice–prawn cultivation.

1.1. Site selection

- The site must be located near a water source of adequate quality to support both rice growth and prawn survival. Water source availability includes groundwater, rivers, streams, lakes, canals and other irrigation systems.
- The rice fields should be located near the farmer's home to ensure convenient daily management, monitoring and maintenance.
- Prawn rice fields should not be situated in areas prone to severe flooding or heavy inundation during the rainy season.
- Sites must be located away from areas using chemical pesticides or insecticides, as well as waste discharge zones. Such runoff severely compromises water quality and the surrounding environment and is highly lethal to prawns.
- The field dimensions must be appropriate to facilitate efficient water management, feeding and general maintenance.
- The rice field should ideally have a minimum surface area of 0.5 ha or larger.

Additionally, for rice–prawn culture, the following two points should be considered:

1. Good water-retaining soil quality:
    - The rice field should be located in a lowland area that can retain water year-round, especially during the dry season.
    - The soil should preferably be loamy to retain water for a long period without excessive seepage; this is a good choice for prawn farming.
2. Water source:
    - Farmers should consider water sources that are safe and not contaminated.
    - Farmers should have their own water pump, such as one that is solar-powered, to ensure water supply throughout the production cycle.
    - Water should be managed appropriately to facilitate the growth conditions for prawns and rice crops, especially during the tillering stage.
    - Generally, most farmers rely on rainwater for rice cultivation. Therefore, rice–prawn culture in rice fields requires dikes or a deepened pond (water reservoir or sedimentation pond) of suitable size to retain water for a medium-term period of at least 6-12 months during the prawn rearing period.
    - A freshwater prawn farm must be equipped with two separate water storage ponds: one dedicated to holding high-quality water and the other for managing wastewater. Additionally, it must feature a structured drainage or canal system to facilitate efficient water intake and discharge



Figure 3. The canal system as a water source for rice-prawn farming.

Step 2. Preparation of the rice–prawn culture system

Before starting the preparation of the freshwater prawn culture system in rice fields, a clear plan must be developed to ensure successful prawn cultivation. A set of guiding questions can be helpful for the development of prawn culture techniques (Appendix).

2.1. Layout design for rice–prawn culture

When preparing the rice–prawn culture system, we need to consider allocating land usage: 50% for rice cultivation, 30% for digging dikes and 20% for making dikes for planting vegetables.

2.1.1. Land for rice cultivation

- Allocate at least 50% of the total land area for rice and 20% vegetable cultivation.
- Determine the appropriate height for the rice field bunds. The inner bunds should be lower and smaller than the dike system bunds.

2.1.2. Dike system

- Dig the dike system according to the condition of the rice field to serve as a habitat for prawns and as a water inlet/outlet system.
- Dike should have a depth of about 1.2–1.5 m to allow sufficient sunlight to reach the bottom, which helps promote the growth of plankton (New 2002).

2.1.3. Water inlet and outlet systems

- Install water inlet and outlet systems for ease of water management.
- Install protective nets to prevent predators from entering.

2.2. Protective netting/plastics

- Install netting/plastics around the prawn farming system to protect prawns from various predators.



Figure 4. Protective barriers for prawn farming systems.

2.3. Techniques for constructing the dike system

Building a dike system for prawn farming in rice fields is essential to provide a secure refuge for prawns during periods of shallow water, extreme heat or when draining the field, particularly in the month before rice matures. Well-designed dikes improve prawn survival rates and facilitate their movement and foraging for food.

The following techniques are important for building dikes:

- Dikes can be dug in square, L or U shapes, depending on the rice field conditions, to store water and serve as a habitat for prawns.
- Dikes should have a depth of 1.2–1.5 m to retain water for a long period and allow sunlight to reach the bottom (New 2002; Chea 2011).



Figure 5. Canal layouts in L shapes.



Figure 6. Canal layouts in U shape for Rice-Prawn Farming.

- The top width of the dike should be approximately 4–5 m, depending on the size of the field and the farmer's capacity.
- The dike slope should have a low angle, not too steep (approximately 1:1.51:2) to prevent soil erosion and make it easy for prawns to move up and down for feeding.
- The dike bottom should slope toward the drainage point to facilitate draining and cleaning (New 2002; Chea 2012).
- The dikes should be connected to the drainage system for easy water management in the field.
- Plant aquatic plants (algae) or place bamboo or (dry) branches into the dike to create shelter and increase natural food sources for the prawns.
- Ensure that the dikes can retain water for at least 5–6 months during the prawn rearing season.

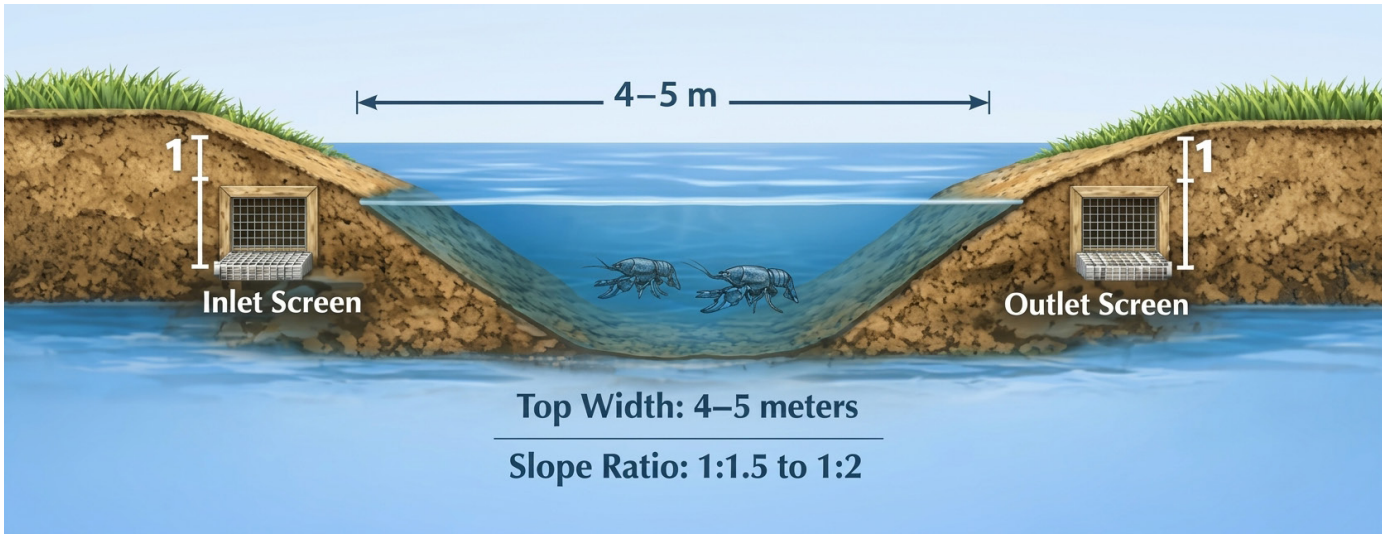


Figure 7. Methods of digging canals for prawn farming.

2.4. Preparing the water inlet and outlet system

In freshwater prawn farming within rice fields, it is essential to establish an effective water inlet–outlet system to ensure proper water management and protect the field from flooding during the rainy season. The dikes should be designed to allow controlled water inflow and outflow according to seasonal conditions, maintaining good water quality and supporting prawn health.



Figure 8. Water inlet–outlet arrangements in prawn farming.

Tips for preparing the water inlet–outlet system:

- Inlet and outlet pipes (PVC) must be suitably installed along the canal system bunds.
- The end of the water inlet pipe must be fitted with netting or a screen filter.
- Use bamboo pipes or PVC pipes, depending on the materials and availability in the local area.
- Regularly inspect and clean the water pipes to prevent water blockages.

2.5. Water and soil quality testing

2.5.1. Water quality testing before stocking

Before starting to raise freshwater prawns, the quality of the water to be used in the dikes or fields must be tested to ensure it is suitable for farming. This testing can be done by taking water samples for testing or using aqua-tool kits.

Key parameters to monitor include total hardness, total alkalinity, the pH level and dissolved oxygen (DO). These parameters directly impact the growth and health of the prawns.

2.5.2. Soil quality testing

Testing soil quality is important for digging and managing the prawn farming field:

- If the soil is very sandy, the dikes will not retain water for long, so the dike bottom needs restoration, and bunds must be made stronger.
- Soil containing about 15% clay is considered good for dikes, as it retains water well, but the soil must be compacted firmly.
- If there is too much clay, it can cause problems, such as the soil easily becoming muddy and flowing into the dikes during rainfall.
- Some types of clay can crack or cause water leakage from the dikes. Therefore, mixing different soil types can help make the soil more suitable for digging dikes. Generally, the soil should have a clay content of approximately 15%–50%.

Before digging the dikes, test the soil using a simple two-step method as follows:

1. Take some soil and roll it into a ball.
2. Let it dry for 2 or 3 days.

If the soil retains its shape without cracking, this indicates that the soil is suitable for digging dikes.

Soil samples are collected from rice fields by digging at different locations (at least five distinct sites) and placing the soil into a bottle. Water is then added, and the bottle is shaken thoroughly to mix the soil with the water. Afterward, the mixture is left to settle for 24 hours.

The soil particles will separate into layers according to their size. Heavier particles (e.g. sand) will settle first, followed by finer particles (e.g. silt and clay), while lighter organic matter may float or remain on the surface of the water. This simple method helps to observe the soil texture (structure) and composition of the rice field soil.



Figure 9. Simple method for soil profile inspection before canal digging.

Step 3. Preparation of the rearing system before prawn stocking

Preparing the rearing dike system before stocking prawns is one of the most critical technical steps to ensure success, prawn health and high yields. Proper preparation ensures that prawns grow quickly and remain healthy. It also helps reduce predators and diseases in the field.

3.1. Cleaning dikes before stocking prawns

Cleaning and preparing the refuge dikes for prawns in rice fields is an important step to ensure good water quality, increase survival rates and promote good prawn growth. Clean and prepare dikes as follows:

- Remove weeds, grass and rubbish, and inspect holes and clear plants growing around the dikes and rice field bunds.
- Remove predatory fish and other animals from the dikes.
- For old dikes, restore the bottom by removing the old sludge layer, leaving a layer of approximately 10–15 cm to eliminate pathogens and toxic gases.
- After cleaning, dry the dikes in the sun for 7–10 days to eliminate toxic gases (H_2S, NH_3, CH_4). However, do not let them dry for too long if the soil is highly acidic, as prolonged drying can cause the soil to release more acid. When water is added again, the water pH will be low, affecting prawns, fish and natural food sources.
- Spread quick lime over the bottom, dike edges and rice field to disinfect them, eliminate predatory fish and adjust water pH levels.

3.2. Quick lime application

Lime is used to disinfect the dikes and adjust pH levels or reduce the acidity of the water in the dikes (Chea 2012).

- For new dikes, use quick lime ($Ca\ CO_3$) at a rate of 7–10 kg per 100 m^2.
- For old dikes, use quick lime at a rate of 3–5 kg per 100 m^2.

3.3. Fertilizer application and nutrient supply

After preparing the dike system and rice field bunds, apply fertilizer to promote the growth of phytoplankton and zooplankton. Suitable fertilizers include animal manure from cows, buffalos, chickens, ducks or pigs, at a rate of 25–30 kg/100 m^2. Farmers can apply natural fertilizers and liquid compost by mixing them with water (10 L of liquid compost per dike area) to promote the growth of rice crops, plankton and benthic organisms such as snails and bivalves. Farmers can use either chemical fertilizers and organic fertilizers (Chea 2012):

- Chemical fertilizers include urea and diammonium phosphate (DAP).
- Organic fertilizers include animal manure and compost (solid compost and liquid compost).

If animal manure is not available, NPK chemical fertilizer can be used at a rate of 2–4 g/m^2. The fertilizer should be dissolved in water first, then sprayed or broadcast evenly in the dikes (New 2002).

Soil pH	Amount of quick lime to use (kg/100 m^2)	Remarks
4–5	20	Highly acidic soil
5–6.5	10	Moderately acidic soil
6.5–7.5	5	Optimal for prawn farming
7.5–8.5	2	Slightly alkaline
8.5–9.5	0	Highly alkaline

Source: Chea 2012.

Table 1. Quick lime application rates based on the pH of the soil.



Figure 10. Producing liquid compost fertilizer.

3.4. Water quality testing before stocking

After applying fertilizer, wait 1 day, then fill the dikes with water to a depth of approximately 30–40 cm. After 2–3 days of fertilization, algae and other aquatic plants will appear, turning the water a light-green color. At this point, add more water to fill the dikes to prepare for farming. When filling the dikes with water, use netting with a mesh size of approximately 0.5 mm to prevent predators from entering the prepared dikes (New 2002).

Shelters for prawns, such as bundles of tree branches, bamboo or dry branches, should be placed in the canal and positioned 30–50 cm above the canal bottom. Alternatively, artificial shelters, such as PVC pipes, bamboo mats, etc., may be used to provide refuge for prawns during the molting stage.

In addition, aquatic plants such as algae can be introduced to serve both as supplementary feed and as natural shelters for the prawns.

Suitable water conditions for healthy freshwater prawns are as follows:

- Temperature: The suitable range is 22°C–32°C, with an optimal range of 28°C–31°C. If the water temperature drops below 16°C, prawns will reduce feeding; if it exceeds 40°C for a prolonged period, it can cause prawn mortality.
- pH: The suitable range is 6.5–8.5. Prawns cannot survive in water with a pH below 5.
- Salinity: A suitable level for prawn growth cannot exceed 5 ppt. Generally, prawns can tolerate and survive in water with salinity up to 20 ppt, but the level must be increased gradually to avoid causing mortality.
- DO: Prawns prefer to live in open water areas with DO levels above 5 mg/L. The minimum level for prawns is 3 mg/L. If DO drops below 1.5 mg/L, prawns will come to the water surface; if it falls below 1–2 mg/L, it can cause prawn mortality.
- Water hardness: Water with a hardness level of 50–100 mg/L is suitable for prawns.
- Minerals and heavy metals: The suitable iron level is 0.1–0.2 mg/L, but if it exceeds 4 mg/L, it can be harmful to prawns (Chea 2012: FAO).

3.5. Techniques for monitoring water quality

Good water quality promotes rapid growth and ensures healthy prawns. Figure 11 shows techniques for monitoring water quality both before and during the stocking of prawns for culture (Appendix).



Figure 11. Monitoring water quality.

Step 4. Rice production

Implementing proper rice production techniques is essential in the integrated rice–prawn farming system. Good cultivation and management of the rice crop help ensure high productivity and reduce impacts from pests and diseases.

4.1. Selection of suitable rice varieties

- Select rice high quality varieties that are suitable for the agroecological conditions (soil and water conditions in the field).
- Use medium-duration rice varieties (100–105 days) with a growth period that is compatible with the growth cycle of the prawns (Chou 2014).
- Choose varieties that are disease-resistant, good quality, come from a clear source and have high market value.
- Select varieties similar to those grown by surrounding farmers to protect against damage from pests.
- Consider using local rice varieties released by the Cambodian Agricultural Research and Development Institute.

Note: Good land preparation helps the rice crop grow uniformly, making it easier to manage weeds and apply fertilizers.

4.2. Land preparation

Plow and dry the field for 20–30 days before cultivation.

- Add water to the field to moisten it adequately before the first plowing, then plow to a depth of 10–20 cm.
- Harrow twice, 1 week after plowing, and level the field thoroughly 2 weeks after plowing.
- If there is excess water in the field, drain it before planting to prevent the soil from becoming too wet (Chou 2014).

4.3. Seed preparation and cultivation

- Use a medium seed rate of 60–80 kg/ha.
- Soak rice seeds for 12 hours, then incubate them for 24–36 hours.
- Dry the seeds in the shade for approximately 10–15 minutes before planting to prevent them from sticking together, which would make it difficult to use seeding equipment.
- Plant the rice using a seeder or transplant in rows, with row spacing approximately 20–25 cm. Planting or transplanting in rows facilitates easy movement for prawns within the rice field (WorldFish and IRRI 2024).



Figure 12. Preparing the rice field before planting rice.

4.4. Water management

- Monitor the water level in the field before and after adding water. Install water level gauges with marked indicators for the required water depth in both the field and the dikes.
- After planting or transplanting for 20 days, add more water to reach a depth of 10–15 cm.
- After planting or transplanting for 45 days, increase the water depth to 20–25 cm (approximately one-fifth of the height of the rice plant).
- Draining water from the field during mid-season is important for rice growth, disease management and reducing gas emissions. When rice is flowering, it is essential to maintain water continuously in the field. Water should be drained about 1 week before harvesting to allow the harvesting machine to operate effectively (Chou 2014).

Note: An appropriate water level in the rice field helps increase rice yield, while deeper water supports successful prawn farming.

4.5. Fertilizer application

To achieve high rice yields, organic fertilizer must be applied correctly according to technical standards. Farmyard manure should be incorporated into the soil at a rate of 1000 kg/ha to improve soil fertility and enhance biodiversity in the field (Chou 2014).

Supplementary fertilizer should be applied 10–20 days after transplanting or direct seeding, before prawns are released into the rice field.

Agricultural chemicals, such as herbicides, must not be used. Instead, the use of organic fertilizers, such as animal manure and Siam weed (Chromolaena odorata), should be promoted for compost and prawn feed residues (Chou 2014).

4.6. Weed management

Proper plowing, harrowing and soil leveling according to technical recommendations help reduce the presence of weeds during rice growth.

The most effective method of weed control, however, is mechanical control (hand weeding). Hand weeding remains an important practice in agriculture, whether for household-level cultivation or small-scale farming.

Key benefits of manual weed control include the following:

- High safety: No use of toxic chemicals that could harm the health of farmers and consumers.
- Environmental friendliness: It helps protect the environment by avoiding soil or water pollution, which is a crucial factor for sustainable agriculture, including prawn farming.
- Deep effectiveness: Hand weeding removes entire root systems and tubers, preventing weeds from re-growing quickly.
- Improved soil quality: Weeding enhances soil aeration and reduces competition for nutrients with the main crop.
- In summary, manual weed control is a cost-effective method (saving on herbicide expenses) and the safest approach.



Figure 13. Removing weeds from the rice field.

Step 5. Freshwater prawn production in rice fields

Selecting, transporting and stocking juvenile prawns are crucial stages for ensuring prawn growth and health. Proper implementation of rearing practices will help reduce mortality rates and ensure the efficiency of the integrated rice–prawn farming system.

5.1. Selection of juvenile prawns (post-larvae)

To achieve good quality prawn production, attention must be paid to the following key points:

- Juvenile prawns should be purchased from reputable hatcheries with a clear source. If possible, select only male juvenile prawns for stocking, as they exhibit faster growth rates.
- Additionally, select male juvenile prawns aged 45–60 days, with a body length of 3–5 cm and a weight of 5–7 g (uniform in size) that are healthy and have no wounds or missing appendages (Chea 2012).

Characteristics of healthy juvenile prawns:

- Generally, their antennae are symmetrical. Antennae shaped like a "V" indicate that the juvenile prawns are weak.
- Healthy juvenile prawns are active and swim swiftly; when oxygen is deficient, they will swim up to the water surface.
- Healthy juvenile prawns have translucent bodies.
- In contrast, diseased juvenile prawns have opaque bodies, and their head or shell may appear black.

5.2. Transportation of juvenile prawns

- Juvenile prawns should be placed in plastic bags or clean water containers filled to approximately one-third of their total capacity. Air or oxygen (O_2) must be supplied, and the containers should be kept in a cool environment.
- Transportation must be carried out with care to prevent stress and maintain adequate oxygen levels.
- The stocking density in each bag depends on the size of the juveniles and the duration of transportation. For prawns measuring 3–5 cm in length, 300–500 individuals can be packed per bag, depending on the size of the bag (Chea 2012).

5.3. Stocking procedure for juvenile prawns

- Before stocking juvenile prawns, check the water quality of the dikes first. If it is good and the dike is fully prepared, the juvenile prawns can be stocked into the dikes.
- For juvenile prawns transported in plastic bags with oxygen, float the bags in the dike water for approximately 10–15 minutes before releasing them into the dikes to allow the water temperature in the bags to equalize with the dike water. Then, open the mouth of the bag and allow the juvenile prawns to swim out into the dike water.
- Stocking should be done in the morning (06:30–08:30) (Chea 2012).

5.4. Carrying capacity and stocking density

Carrying capacity in a prawn farming system ensures high survival rates, good growth and productivity without negative environmental impacts. Carrying capacity is the maximum number or biomass of prawns that the farming system can support without causing deterioration in water quality.

Key term	Definition
Carrying capacity	The maximum number or biomass of prawns that the system can support without adverse environmental effects.
Stocking density	The number of prawns per square meter (prawns/m^2). Example: For family-scale farming in rice fields, 1–2 juvenile prawns per square meter can be stocked relative to the water surface area (or field + water area).
Water quality	Parameters such as DO, temperature and pH that influence growth and survival rates.
Productivity	The amount of prawn product (kilograms per hectare) that can be obtained under safe conditions.

Source: Auburn University and American Soybean Association 2022. CAST Project, Cambodia.

Table 2. Key terms and definitions related to carrying capacity.

5.5. Prawn sampling and measurement

Sampling or monitoring is a fundamental practice in managing prawn farming in rice fields. This practice aims to evaluate prawn growth as follows:

- Growth rate: Monitor the average weight of prawns over time.
- Feed efficiency: Optimize feeding practices to enhance growth and reduce waste.
- Health status: Identify potential diseases or abnormalities on time.
- Density: Ensure optimal stocking density for healthy growth.

Use the following methods for prawn sampling:

- Prepare sampling materials, such as a data recording book, electronic scale, ruler and either a bucket or metal tray.
- Conduct sampling once a month (e.g. sample 6 times for a 6-month rearing cycle), setting a specific date, except during molting periods.
- Collect prawns for sampling from the feeding trays or baskets used for feeding.
- Measure, weigh and count the juvenile prawns, then record the data in the book.
- Calculate the average bodyweight to determine the amount of feed for subsequent days.



Figure 14. Monthly Sampling by weighting.

Feeding tray	Prawn #	Weight (g)	Length (cm)	Remarks
1	Prawn#1			
	Prawn#2			
	Prawn#3			
2	Prawn#1			
	Prawn#2			
	Prawn#3			
3	Prawn#1			
	Prawn#2			
	Prawn#3			
Total				

Table 3. Prawn sampling record.

$$\textbf{Average Weight of Prawn (g/head)} = \frac{\text{Total Weight}}{\text{Number of the Sampling Prawns}}$$

$$\textbf{Average Length of Prawn (cm/head)} = \frac{\text{Total Length}}{\text{Number of the Sampling Prawns}}$$

Step 6. Feed and feeding techniques

Feed should be provided in adequate amounts, avoiding overfeeding. Excess leftover feed in the dike water can decompose into harmful substances, promote excessive growth of aquatic plants and create unfavorable conditions for prawn survival and growth. Therefore, it is generally safer to slightly underfeed prawns than to risk overfeeding them.

6.1. Feed type, size and nutrients

To ensure prawns remain healthy and grow quickly, attention must be paid to the following key points for feed:

- Balanced nutrition: Pelleted feed provides essential nutrients for the growth and health of prawns.
- Protein: Feed should be 40% protein for post-larvae and juveniles, reduced to 36% for sub-adults or larger prawns. Appropriate fat levels are also important for prawn growth.
- Size: Feeds come in various pellet sizes suitable for the mouth size and growth stage of juvenile and adult prawns (Chea 2012).



Figure 15. Feed (pellets and snails) for prawns.

No.	Prawn culture period	Feed pellet size (diameter × length)	Protein (%)	Fat (%)
1	First month after stocking	Diameter 1.2 mm, length 0.8–1.2 mm	36	5
2	2–4 months after stocking	Diameter 1.4 mm, length 2.0–4.0 mm	36	5
3	5–6 months after stocking	Diameter 1.6 mm, length 2.5–4.5 mm	30	5

SourceTechniques for raising prawns in ponds. Prey Veng Province, Cambodia. By Chea T (2014)

Table 4. Type, size and nutrients for feed.

6.2. Feeding methods

Commercial feed and natural food should be provided to prawns regularly from the first month onward. Fresh feed, such as crabs, golden apple snails, bivalves, etc., which are low-cost during the rainy season, can also be used as prawn feed, mixed with commercial feed.

Mixing natural food with pelleted feed helps prawns grow faster and can reduce the cost of purchasing external feed. However, it can degrade dike water quality if provided in excess.

6.2.1. Using feeding trays

To facilitate monitoring and management of feed quantity, farmers should place feeding trays in approximately 15 to 25 different locations within the dike (the space of each tray should be 5–6 m). Each feeding tray should be positioned 10–20 cm above the dike bottom and have an area of approximately 0.6–0.8 m^2. During the first month, when juvenile prawns are small, simply broadcast a small amount of pellets along the dike edges or field bunds (Chea 20212).

Approximately 2 hours after feeding, check the feeding trays as follows:

- If the feed is completely consumed, the quantity is appropriate.
- If a large amount remains, reduce the feed amount for the next feeding.
- If the feed is consumed quickly, increase the feed amount for the next feeding.
- Leftover feed should not remain in the trays in the water for more than 24 hours.

6.2.2. Feeding time and rate

Feed the prawns twice daily as per the following schedule:

- Feed prawns at 07:00 AM and 17:00 PM.
- In the morning, provide approximately 30% of the total daily feed amount.
- In the evening, provide approximately 70% of the total daily feed amount.

Before placing new feed in the trays, clean them thoroughly first, then add the new feed to avoid water pollution and disease transmission to the prawns. Collected feed waste should be placed at the base of coconut or banana trees or kept in a compost pit for use as fertilizer for other crops.

Note on feeding safety
When providing feed to prawns, farmers should wear protective gloves and boots to prevent transmission of infectious agents (parasites) from predatory snails.



Figure 16. Feeding tray for prawn farming.

6.3. Feeding rate for freshwater prawns

Generally, the feeding percentage for prawns decreases from 8% to 7% rather than increasing from 7% to 8%. This is because the feed requirements and growth rates change as prawns grow larger. Smaller prawns require a higher percentage of feed relative to their bodyweight (e.g. 8% to 7%) because of higher energy use and greater growth demands. As prawns grow larger, their energy consumption rate relative to their bodyweight decreases, so the feeding percentage based on bodyweight should also be reduced accordingly (e.g. 7% to 5.5%, then to 6% to 4.5%).

Therefore, feeding rates are expressed as ranges such as 8% to 7%, 6% to 5%, 4% to 3% and below 3% to reflect different prawn sizes and appropriate feeding levels for optimal growth and feed efficiency. Thus, smaller prawns require a higher percentage of feed relative to their bodyweight, and this percentage decreases as they grow larger to ensure feed efficiency and good growth performance (Chea 2012).

The daily feed amount is determined based on the prawn growth stage and calculated based on the total prawn biomass in the rearing system.

Rearing period (days)	Average weight (g/prawn)	Survival rate (%)	Feed rate (% of bodyweight/day)
1–20	4	100	20
21–40	7	95	15
41–60	13	90	10
61–80	22	85	8
81–100	31	80	5
101–120	40	75	4
121+	50+	70	3

Source:Techniques for raising prawns in ponds, 2014,. Prey Veng Province, Cambodia.

Table 5. Feeding rate relative to total prawn biomass.

Note: Juvenile prawns should be fed frequently, three or four times per day. As the prawns grow larger, the feeding frequency can be reduced to two or three times per day. Avoid overfeeding, as excess feed can pollute the water, harm the prawns and result in wasted expenditure.

6.4. Formula for calculating feed quantity based on bodyweight

Feed Quantity (g) = (Percentage of Feed Rate × Prawn Weight) 100%

Example:
- Prawn weight: 4 g
- Feed rate: 20%

Feed quantity required per prawn per day = (20 × 4) 100% = 0.8 g

6.5. Formula for calculating feed conversion ratio for prawns

The feed conversion ratio (FCR) is the amount of feed used in production divided by the weight gain of the prawns. Feed represents the highest cost among production inputs. A clear understanding of the FCR is essential for proper management and decision-making for using feeding properly.

$$\textbf{FCR formula} = \frac{\text{Total Weight of Feed Used}}{\text{Total Weight Gain of Prawns}}$$

Example of FCR calculation:

- Number of juvenile prawns stocked: 6800 individuals
- Average weight of juveniles: 5 g
- Total weight at stocking: 3400 g or 34 kg
- Total weight at harvest: 247 kg
- Total weight gain of prawns: 213 kg
- Total weight of commercial pelleted feed used: 160 kg
- Total weight of snail feed used: 3000 kg
    - Pelleted feed FCR = 160 ÷ 213 = 0.75
    - Snail feed FCR = 3000 ÷ 213 = 14.08

The FCR depends on the following three key factors:

1. high-quality prawn strain/variety
2. type of feed used
3. feeding method (management)

Feed management and feed quality are important, as they result in a good FCR. Therefore, farmers need to clearly understand quality feed and should use feed according to proper technical practices.

6.6. Preparing prawn shelters in dikes and rice fields

Preparing prawn shelters is a key technical point in the integrated rice–prawn farming system to ensure good survival and growth of the prawns. Shelters help prevent losses, reduce competition and provide safe spaces for prawns to rest and forage. Especially during the molting stage (soft-shell prawns), they need hiding places to avoid attacks from other prawns or aquatic predators.

In the prawn farming field, perimeter dikes should be prepared to serve as refuges for prawns to survive well when water levels in the field drop or during weather changes, especially during harvesting period.

6.6.1. Importance of prawn shelters

- Protect against cannibalism during molting.
- Protect against poaching (theft via nets or traps).
- Reduce high water temperatures.
- Promote the growth of periphyton, which is a live food source for prawns.

6.6.2. Types of prawn shelters

- Natural refuge: This type of shelter uses aquatic plants, rice crops or grasses present in the field to create quiet areas for the prawns. Aquatic plants can help reduce sunlight and provide hiding places for the prawns. However, management is needed to prevent these plants from growing too densely, which could affect water quality. Also, inspect for predators such as snakes, frogs and predatory fish to prevent them from preying on the prawns.
- Constructed refuge: This type of shelter is prepared using materials such as tree branches, dry grass, bamboo or other materials that do not negatively affect water. quality. Shelters should be placed in areas that are easy to monitor and feed, allowing prawns to congregate and facilitating management. Avoid using fresh leaves or branches (these should be sun-dried first).

Step 7. Management of the system during prawn rearing

Effective management of the rice–prawn culture system is a critical technical factor for ensuring healthy growth, high survival rates and overall success. Consistent monitoring of water levels, water quality, field conditions and pest control practices helps minimize losses and ensures that the production system operates efficiently.

7.1. Water quality management

Water quality is a crucial factor for rice–prawn culture in rice fields. Farmers must understand and manage key water quality parameters that support good prawn growth and high yields. (Refer to the Appendix for water quality parameters and their importance as well as water quality monitoring.)

7.1.1. Temperature

Water temperature affects the metabolism of prawns and DO levels in the water. A suitable water temperature is 26°C–30°C.

7.1.2. pH

The pH level in water can fluctuate constantly because of the growth of aquatic plants and the decomposition of organic matter at the dike bottom, which can cause pH to rise or fall. Sometimes, water can become acidic or highly alkaline from various water sources entering the dikes. Therefore, maintain the pH of dike and field water between 6.5 and 8.5, which is suitable for prawns and aquatic life. If the pH falls below 7 or rises above 9, it will negatively affect the prawns.

Use the following methods to improve the pH of the water:

- Exchange with new water into the dike.
- Use lime to improve water quality.
- If excessive aquatic plants are causing high pH, exchange with new water and remove some aquatic plants from the dike.
- Before the rainy season, spread lime around the dike to help prevent pH drops.
- Address acid runoff entering the dike and manage pH levels in the water.

After rainfall, measure the water pH again. If the level is below 7, use lime at a rate of 1–1.5 kg/100 m^2. Mix the lime or dolomite with water to dissolve it first, then broadcast it evenly over the surface of the dike to increase and stabilize the water pH level.

7.1.3. Dissolved oxygen

A lack of dissolved oxygen in dike water can cause prawns to come to the water surface and can lead to mortality. This problem often occurs in prawn farming dikes.

Causes of oxygen deficiency include the following:

- The content of organic matter in the dike becomes high.
- Feed residue in the dike becomes excessive.
- There is an overgrowth of aquatic plants or algae.
- The suitable dissolved oxygen level in dikes is 35 mg/L. If DO falls below 2 mg/L, it can cause prawn mortality (Chea 2012).

To increase DO in water, use aerators in the dikes and exchange the water with new water into the dikes:

- Water transparency: This affects light penetration and can serve as a source of infection. Maintain a water transparency of 25–40 cm. If transparency is less than 25 cm, meaning the dike water is too turbid, water exchange is needed. If transparency exceeds 40 cm, add organic fertilizer to increase natural food in the water. Dike water with a light-green color is of the best quality. If the water is dark green, turbid or reddish, water exchange is required (Chea 2012).
- Water hardness and alkalinity: Dike water with a total hardness of 50–100 mg/L is suitable for prawn farming. If water hardness falls below 50 mg/L, add lime or crushed snail shells to increase it, which helps prawns grow well and facilitates molting.
- Ammonia, nitrite, nitrate, black sludge and carbon dioxide: These are all toxic to prawns, especially at high concentrations.

Factors that cause water quality deterioration include the following:

- Use of poor-quality feed.
- Overfeeding or feed residue left in the dikes.
- Prawn stocking density being too high.
- Poor preparation of the dike bottom.
- Decomposition of various plants.
- Inflow of waste from the surrounding environment.
- Prawn mortality and waste release from disease outbreaks.

Maintaining balanced water quality

- Monitor and observe: Regularly test water parameters (temperature, DO, pH, ammonia, nitrite, etc.). Inspect the condition of the prawns and promptly remove any dead prawns from the canals or fields.
- Feed management: Provide good quality feed, avoid overfeeding, monitor feeding activity and distribute feed properly.
- Density and dike management: Avoid overstocking and perform water exchange correctly.
- Solutions: Reduce or stop feeding during periods of problems. Take corrective measures such as aeration, water exchange, applying lime and identifying the root cause of the issue to address it effectively.

7.2. Monitoring and following up prawn activity

Farmers should regularly observe prawn behavior, as this helps detect problems early. If prawns rise to the water surface or swim sluggishly, it may indicate water quality issues. Timely intervention can reduce losses. In the morning, if prawns are seen gathering at the corners of canals, this is a sign of oxygen deficiency. Immediate action is required by adding or replacing water to restore proper oxygen levels.

After 3 months of stocking juveniles, prawn growth should be assessed. Prawns with old, dark-blue or black claws covered with algae should have their claws removed. This practice promotes growth, facilitates molting and helps to prevent disease.

Constraints caused by old blue or black claws with algae growth

- Prawns are unable to molt properly.
- They become highly susceptible to shell disease (black shell).
- They remain stunted, fail to grow to market size and lack flesh.

7.3. Water exchange management

Water exchange is an important practice in managing, nurturing and raising prawns. Exchanging a portion (20%–30%) of the dike water with good quality fresh water helps neutralize toxins, increases DO, reduces waste accumulation in the dikes and facilitates prawn molting. Water exchange should be performed every 1–2 weeks (Chea 2012).

Step 8. Harvesting

Harvesting rice and prawns is highly significant from both economic and livelihood perspectives, as well as for food security, especially within the context of integrated farming. Timely and technically correct harvesting helps ensure high product quality and reduces losses. Harvesting is divided into two parts: (1) rice harvesting and (2) prawn harvesting.

8.1. Rice harvesting

Harvesting rice in the integrated prawn farming system is an important step that must be carried out carefully to maintain rice quality and avoid impacting the living environment of the prawns in the field. Proper harvest planning can help achieve a good yield while allowing the prawns to continue growing well in the dikes surrounding the field.

Before harvesting, drain the water from the rice field into the dikes to allow the prawns to move into the dikes and to facilitate mechanical harvesting (using combined harvesters or hands for smallholder farmers).

- Rice harvesting: For medium-duration seasonal rice varieties (flowering stage), harvesting should be carried out around mid-November when the crop reaches about 85% maturity. Avoid harvesting at excessive maturity (up to 95%), as this increases grain shattering and results in significant yield loss. Harvesting at the recommended stage ensures good grain weight and high quality for storage or marketing. Farmers should avoid harvesting when fields are too deeply flooded, as this makes operations difficult and disrupts prawn movement. Harvesting should also be avoided during heavy rain or strong winds, which can cause lodging and reduce grain quality. For farmers with large rice fields, mechanical harvesters are recommended to improve efficiency.
- Rice harvesting method: Farmers should harvest the rice using a method suitable for the field conditions to reduce crop damage and ensure smooth harvesting operations. After cutting, the rice should be threshed and dried on the same day or within a short period to prevent fungal growth and grain spoilage. Properly managing the harvesting process will help maintain rice quality, reduce losses and ensure a good selling price.

8.2. Prawn harvesting

After a rearing period of approximately 5–6 months, when prawns reach market weight (e.g. 80–100 g each), harvesting can begin. Generally, there are two main prawn harvesting methods: (1) selective harvesting, also known as gradual harvesting and (2) total harvesting, which farmers can choose based on field conditions and market demand:

- Selective harvesting is a method of catching prawns gradually by selecting only those of suitable size for sale, while smaller prawns are left to continue growing in the dike until the end of the rearing season. This method helps increase total yield, as the remaining prawns have more space and can grow faster in the final stage.
- Total harvesting is carried out when the majority of the prawns have reached suitable marketable size. To facilitate capture, drain approximately half of the dike water first, then drag a net or seine three or four times to catch the prawns. Afterward, when only a few prawns remain, drain all the water and collect the remaining prawns.

8.3. Post-harvest handling of prawns

After harvesting, the prawns should be kept in basins, hapas (net cages) or tanks with clean water and aeration to keep them alive and fresh. Before selling, small prawns or any mixed fish should be sorted out. During transportation, oxygen should be supplied in the tank or bag to keep the prawns alive longer, allowing them to be sold at a higher price. Typically, farmers prefer to pack prawns in Styrofoam boxes with ice, which can maintain prawn quality for about 4–5 hours.

The following are some key steps to ensure successful harvesting:

- Select the correct net: Choose a net with an appropriate mesh size to avoid injuring the juvenile prawns.
- Timing: Drag the net when the water temperature is cool and DO levels are high, at least 3 mg/L.
- Gentle method: Move the net slowly and calmly to avoid startling or agitating the prawns excessively.
- Remove debris: Quickly remove debris, aquatic plants, branches or bottles from the net and discard them outside the dike system to prevent injury to the prawns when they are agitated.



Figure 17. Harvesting prawns.

Step 9. Prawn disease prevention and treatment

Good disease management in the integrated rice–prawn farming system helps ensure prawn health, high yields and marketability. It helps suppress bacteria that cause disease in prawns, maintain a fresh and attractive prawn color and reduce stress in prawns.

9.1. Causes of disease in prawns

- Poor water quality: Low DO, increased waste, pH issues and elevated toxic substances in the water beyond safe levels all lower water quality.
- Overfeeding: Uneaten feed pollutes the water and disrupts the oxygen balance in the dikes.
- Pollution: Inflow of toxic or contaminated substances into the dikes can pollute the water.
- Overcrowding: This causes stress in prawns and facilitates faster disease transmission.
- Nutrient deficiency: This leads to poor health and weakened physical condition in prawns.
- Pathogens: Bacteria, viruses, parasites and fungi can all lead to disease.

9.2. Common signs of diseased prawns

1. Prawns eat less or stop eating entirely.
2. Prawns exhibit sluggish movement, abnormal swimming or often swim to the water surface.
3. Prawns gather at the dike edges, gasping for air.
4. Prawn shells are abnormally soft.
5. Gills become brownish-red or black.
6. The body color becomes dull or loses its blue hue.
7. Other body parts, such as body curvature, broken claws or legs, deteriorate or become immobile.

9.3. Disease prevention and treatment

There are four key strategies for preventing disease transmission:

1. Proper dike preparation:
- Clean and eliminate disease-causing agents correctly.
- Maintain appropriate water depth and good water circulation.
- Create a healthy dike environment.

2. Appropriate stocking density and feed:
- Avoid overcrowding and intense competition.
- Use the correct amount of feed/fertilizer to avoid overfeeding and overfertilizing.

3. Good water quality:
- Regularly monitor key parameters (pH, alkalinity, DO, temperature, ammonia and nitrite).
- Resolve water quality issues timely.
- Implement water exchange and aeration techniques.

4. Proper handling practices
- Reduce stress from handling.
- Use correct prawn capture techniques to avoid injury.
- Use sterilized equipment to prevent disease transmission..

Step 10. Production recordkeeping and cost analysis

It is necessary to record production cost data, including system preparation costs, expenses, income, farm activities, labor, etc. This recordkeeping should also include monitoring growth, mortality and problems encountered, which helps farmers evaluate results and improve subsequent rearing cycles.

10.1. Data recording for freshwater prawn farming

Purchase date	Prawn type	Number of prawns (individuals)	Prawn size (cm)	Source of prawns

Table 6. Record of system preparation and prawn stocking data.

Date	Description of cost item	Quantity of rice seed (kg)	Unit price (KHR)	Total price (KHR)

Table 7. Record of rice field preparation and sowing data.

Date	Description of cost item	Unit	Quantity	Unit price (KHR)	Total price (KHR)	Remarks
	Dike system Preparation					
	Lime					
	Juvenile prawns					
	Netting for field Perimeter					
	Rice field land preparation					

Table 8. Record of initial costs for prawn rearing system preparation and rice cultivation.

Date	Feed type (commercial or supplementary)	Daily quantity (kg/day)	Number of times daily	Protein (%)	Notes on feeding time

Table 9. Feed and prawn feeding records.

Date	Type	Total quantity	Total weight (kg)	Unit price (KHR)	Total price (KHR)	Use (sold, consumed, etc.)

Table 10. Prawn harvest record.

No.	Date	Description of expense item	Unit	Quantity	Unit price (KHR)	Total price (KHR)
Total expenses (I)						

Table 11. Expense record (for final harvest date = prawns + rice).

No.	Date	Description of income item	Unit	Quantity	Unit price (KHR)	Total price (KHR)
Total income (II)						

Table 12. Income record (for final harvest date = prawns + rice).

Profit from prawn farming

Profit = Total Income (II) – Total Expenses (I)

Remarks:

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Appendix. Key considerations for planning freshwater prawn farming

Before constructing the canal system, farmers should develop a clear plan to ensure effective management and successful prawn cultivation. Important points to consider include the following:

- Land size and allocation: What is the total area of your land? How much should be allocated for rice cultivation and prawn farming? Is there a plan to expand canals in the future?
- Purpose of canal construction: What is the main objective of digging the canals?
- Water management: How frequently will water need to be pumped in and out? What canal depth is most suitable for prawn culture?
- Soil characteristics: What type of soil is present (sandy, clay, low or high-water retention)?
- Water source: Where will the canal water come from (river, lake, stream, canal or groundwater)?
- Flood and drainage system: During heavy rainfall or flooding, where will excess water flow? Is there a drainage system to release water from the prawn farming area?
- Flood risk: Is the site prone to flooding? If so, how high can water levels rise, and can they be managed effectively?
- Bund reinforcement: Consider placing topsoil on the upper part of canal bunds to facilitate grass growth for erosion control and to allow planting of mixed vegetables.

No.	Water parameter	Optimal level	Acceptable level	Dangerous level	Monitoring frequency	Impact factors
1	Temperature (°C)	25-32	22-37	<25 or >32	Daily	Extremely low or high temperatures can cause stress and high mortality in prawns.
2	DO (mg/L)	>5-<12	>5-10	<4->12	Daily	Low or excessively high DO levels can cause mortality, stress and reduce prawn growth.
3	pH	7-8	7.5-8.5	<7->9	Weekly	Very high or low pH levels cause prawn stress and disrupt metabolism.
4	Ammonia (mg/L)	<0.02	0–<0.01	>0.05	Weekly	High ammonia levels can be toxic and affect prawn survival.
5	Nitrite (mg/L)	<0.1	<0.05	>0.1	Weekly	High nitrite levels cause stress and affect respiration.
6	Nitrate (mg/L)	<10	<5	>20	Weekly	High nitrate levels can affect water quality and prawn health.
7	Black sludge (mg/L)	<0.1	<0.05	>0.1	Weekly	High levels affect respiration and prawn survival.
8	Carbon dioxide (mg/L)	<20	<10	>20	Weekly	High CO_2 lowers pH, causes stress, reduces organ function and inhibits respiration.
9	Water hardness (mg/L)	50-200	80-150	<50->200	Weekly	Low hardness causes mineral deficiency; high or low levels affect molting and slow growth.
10	Alkalinity (mg/L)	50-200	80-150	<50->200	Weekly	Low alkalinity leads to pH fluctuations; very high alkalinity makes ammonia more toxic, negatively affecting prawn growth.
11	Water transparency (cm)	>20	>30	<20	Daily	Highly turbid water blocks light, causes stress, affects feeding and degrades water quality.
12	Water color	Green or light brown	Light green	Clear, dark green, or dark brown	Daily	Clear water = nutrient/food deficiency; dark green = algal bloom (low DO/pH fluctuations); brown = high organic matter (low DO, high black sludge).

Source: Chea T. 2011. Techniques for raising prawns in ponds. Prey Veng Province, Country: Cambodia

Table 13. Water quality parameters and their importance.

Date	pH	Temperature (°C)	DO (mg/L)	Hardness (KH) (°d KH)	Nitrite (mg/L) NO_2	Nitrate (mg/L) NO_3	Ammonia/Ammonium (mg/L) NH_3/NH_4	Water transparency (cm)
Suitable level	6.5-8.5	28-31	5-7	80-120	0-0.02			

Source: Chea T. 2011. Techniques for raising prawns in ponds. Prey Veng Province, Country: Cambodia

Table 14. Weekly water quality monitoring (between 09:00 and 11:00)



About WorldFish

WorldFish is a leading international research organization working to transform aquatic food systems to reduce hunger, malnutrition, and poverty. It collaborates with international, regional and national partners to co-develop and deliver scientific innovations, evidence for policy, and knowledge to enable equitable and inclusive impact for millions who depend on fish for their livelihoods. As a member of CGIAR, WorldFish contributes to building a food- and nutrition-secure future and restoring natural resources. Headquartered in Penang, Malaysia, with country offices across Africa, Asia and the Pacific, WorldFish strives to create resilient and inclusive food systems for shared prosperity.

For more information, please visit www.worldfishcenter.org