Ricefield Fisheries Handbook

Cambodia-IRRI-Australia Project

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Preface

The Ricefield Fisheries Handbook is intended as a reference document on fisheries issues for agronomists and fisheries specialists working in rice growing areas of Cambodia. Both traditional capture fisheries and contemporary culture fisheries are discussed for each of the rice ecosystems found in Cambodia. Potentials for development are also presented. Attention is given to lowland rainfed ricefield capture fisheries which remains the system most commonly exploited by farmers and generally the most significant in terms of ricefield fish production. The handbook also includes chapters on common management themes and suggests ways to monitor ricefield fisheries development. The final chapter answers twenty-two questions to further explain broad ricefield fisheries issues.

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Chapter

1

RICE ECOSYSTEMS AND THEIR CAPTURE/CULTURED FISH PRODUCTION POTENTIALS:

This section will examine the 5 main rice ecosystems in Cambodia from a culture and capture fisheries perspective.

1.1 Rainfed Upland Ricefields

Capture Fisheries

True upland ricefields do not have bunds to retain water and so water is not maintained in the field for long. (Nesbitt 1996). Furthermore, they are normally totally dependent upon local rainfall so that little opportunity exists for fish to migrate into these areas from local swamps and rivers. Significant amounts of fish are therefore not normally collected from upland rice growing areas, although they may be caught from local streams, ponds and canals. Meusch, (1996) in his study of ricefield fisheries in Laos, found fish, (frogs, snails and shrimps) to be the most important animal protein sources in three upland villages in Laos, although it is unclear how much of this originates from upland ricefields. Patterson *(pers comm)* claims that frogs, (and rats) caught from rice fields are important sources of animal protein for upland communities in Rattanakiri. Baird, (1996) has documented the importance of fish to the Kavet and Keung upland communities in Rattanakiri Province but claims that most of this fish originates in small streams. No mention is made of foraged foods from rice fields. Data collected from Kus Commune in Takeo, an area close to hills, suggest that the local ricefield fishery is inadequate to fully support the communities living there. Helmers, (*pers comm*) suggests that more than half the average household cash expenditure over a year is the purchase of fish. Data collected by the Department of Fisheries in this commune, suggests that the most common fish species in ricefields and adjacent ponds in this area are Climbing Perch and Catfish with few Snakehead. Typically, ponds would produce between 2-10 kg of wild fish when pumped during the dry season.

Cultured Fisheries

Households in upland rice growing areas are likely to have inadequate supplies of natural fish for their requirements. If the physical conditions allow aquaculture to be practised, then farmers will likely be receptive to fish culture, (as long as animal protein from forest animals is not in abundant supply).

The water constraints that limit natural fisheries in upland rice rowing areas also reduce the potential for rice fields' being used for fish culture, although, household ponds in these areas will have potential for fish culture. Interestingly, one of the oldest fish culture systems in SE Asia can be found in the rice growing valleys of Northern

Laos and Northern Vietnam, where farmers have been growing Common Carp, originally introduced from China hundreds of years ago. Feral populations of this species exist in the rivers and perennial water bodies of this area and enter the ricefields, (before transplanting) to breed in May of each year. Fish are harvested in September. Yields of around 50 kg/ha are the norm. Hundreds of years of this management have produced a thin variety of Common Carp more suited to shallow local ricefield conditions, (Luu *et al* 1995).

The area of Takeo, studied by Helmers, whilst not a true upland rice area, (fields are bunded and have standing water for extended periods) provides some pointers to issues which would likely affect true upland rice growing areas. The area has recently received attention from the Department of Fisheries Aquaculture Office and trials have begun with 50 farmers culturing fish in household ponds and ricefields. Initial results look very promising. Whether water will remain in the ricefields for long enough to make rice fish culture a viable option remains to be seen. Constraints include the threat of flash flooding caused by heavy rain and made worse by severe deforestation of the hill slopes and poor maintenance of drainage canals. There is also a conflict over pond water use as many of the ponds are used as drinking water sources and these cannot be managed for fish culture unless an alternative water supply is available.

1.2 Rainfed Lowland Ricefields

Capture Fisheries

The fish which inhabit the lowland rice fields of Cambodia and other rice growing areas of Asia are extremely prolific. These fish and other aquatic animals, such as crabs, shrimps, edible insects and frogs form important sources of animal protein for lowland rice farming families in Cambodia. Despite the obvious importance of these foods to rice farming families, (Ovensen, Trankel and Ojendal 1996) they have rarely been the attention of researchers and are usually ignored by rural development projects. Studies by the AIT Aquaculture Outreach Programme in NE Thailand have estimated household fish collection from ricefields was in the order of 300-400 kg/household/year in a "good year" and 100 kg/household in a "bad year". Leenanond *et al* (1989) found an average family fish production from ricefields of 310 kg/family/year in the Tung Kula Ronghai area of NE Thailand.

Estimates of fish production per unit area of ricefield are notoriously difficult to estimate. Ali 1990 suggests values of between 88 - 174 kg/ha/season in his studies of Malaysian ricefield fisheries. Extrapolating the figures from Gregory's study of Svay Theap suggests a value of around 100 kg/ha/year. Gum (1996) estimates the total production from the ricefield fishery in Battambang to be 1,140 tonnes fish per year but considers this is an under-estimate. Spiller, (1985) suggests a lower value of 25 kg/ha(/year) while in other Asian countries the range is thought to be from 1.5 - 84 kg. Taking the lowest estimate of 25 kg/ha/year as an average value for Cambodian lowland ricefields would suggest a total ricefield catch of around 43,500 tonnes capable of meeting the annual animal protein requirements, (=88g fish/day[1]) of a population of 1.35 million people[2].

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[1] Based on Mekong Secretariat (1992) figures and assumes 30% of total protein requirement is from animal sources and 75% of this animal protein is from fish.

[2] Lowland ricefield area estimates 1.746 million ha is taken from Nesbitt 1996.

Data collected in Svay Rieng suggest that virtually all rice farming households in the province regularly collect fish and other aquatic produce from their fields. For example, a study of 15 households in three communities of Svay Theap District has shown that over a seven month period, (August 95 - February 96) the households studied collected an average of 681 kg of fish and other aquatic animals, (making up 18% of the total by weight), (Gregory 1996). Average per capita consumption of wild fish and other aquatic animals caught from ricefields and adjacent canal and swamp areas was 31.6 kg/capita. In addition to this fish sold to middlemen and other villagers fetched an average income of $241 per household. During the 8 month period studied virtually no fish or other aquatic products were purchased, fish (ave. < 0.5% of total fish consumed). In the area studied, rice yields were extremely low; averaging 650 kg/ha. Those households that were short of rice used money generated from fish sales to purchase rice. It was concluded that in many cases, the families were not so much rice farmers who caught some fish but rather fishermen who grew some rice.

The collection of ricefield foods is time consuming. The 15 households studied in Svay Theap spent on average 972 hours foraging for ricefield foods during the eight months studied. However, estimation of this labour demand is difficult due to multi-tasking by the families studied, e.g. children might be tending buffaloes and fishing simultaneously.

Indigenous Fish Species Found in Lowland Ricefields

A wide range of fish species can be found in lowland ricefields in SE Asia. Heckman,(1979) in his study of lowland ricefield ecology in NE Thailand records 18 fish and aquatic animal species regularly consumed by rice farming families. In Cambodia, Gregory reports 19 species of fish and 6 other animal species caught from ricefields in Svay Rieng, whilst Gum, (1996) accounts for a total of 38 fish species. The more diverse ricefield fishery studied by Gum, in Battambang may be a result of fish from the Great Lake mixing freely with the swamp fishes which normally dominate ricefield fisheries. Table 1 details the more common fish species and does not include lacustrine and riverine fish species which can be caught from ricefields following high river water levels.

Table 1: Common indigenous fish species from lowland ricefields in Cambodia

Common Name	Genus	Khmer Name	Feeding Habit
White Fishes			
Danio	Rasbora.	trey changvar	Plantivorous
Barb	Puntius	trey chupin	Herbivorous
Snakeskin Gourami	Trichogaster	trey cantor	Herbivorous
Gourami	Trichogaster	trey kumpleang	Herbivorous
Half-beaks	Xenentodon	trey phtong	Insectivorous
Black Fishes			
Snakehead	Channa	trey phtuwa/trey roch	Carnivorous
Sheatfish	Ompok	da'om	Carnivorous/Omnivorous
Catfishes	Clarias	trey undaing	Carnivorous/Omnivorous
Spiny Eel	Mastacembelus	trey chloing	Omnivorous
Climbing Perch	Anabas	trey greyng	Insectivorous
Swamp Eel	Fluta	unthong	Carnivorous

Dominant Fish Species

Snakehead tend to predominate in lowland areas with large numbers of perennial refuges. In higher areas, away from perennial water bodies, Clarias catfish often make up the highest proportion of the total catch. In the highest areas studied so far, it seems that Anabas predominate, perhaps because of their incredible mobility, (known by foreigners as the climbing perch, there are even tales of this species being found in the branches of trees). Ali (1990) found in Malaysia that Snakeskin Gourami were the dominant fish species, accounting for an average of 55% of the total catch by weight. Snakehead averaged 28.8% and Clarias catfish, 10.5% respectively. This is odd in that the Snakeskin Gourami is an introduced fish species which appears to have managed to establish successful feral populations.

The Exploitation of Lowland Ricefield Fisheries

Ricefield fish and other aquatic animals are caught by many different and ingenious methods employed by rice farmers. These include netting, hooking, trapping, harpooning, cutting by knife, throwing nets and gaffing. A study in Battambang identified a total of 22 gears used by rice farmers to collect fish and other aquatic animals, (Gum 1996). Gregory and Guttman, (1996) recorded 23 types of gear used by rice farmers in Svay Rieng. Farmers apply different methods and gears during each of the three seasons:

With the first heavy rains of the **wet season**, fish are caught leaving dry season refuge areas or moving between rice fields. Thai rice farmers report that fish caught at this time of year are often carrying spawn and this ensures a higher market price for the fish. Following periods of heavy rain, farmers will go out at night to spear fish and frogs, using lights to immobilise the prey. In Cambodia, there appears to be no ownership of the fish by individual land owners during this time and people are free to take fish from any ricefield that they choose. If there is a pronounced short dry season during the monsoon this may result in large numbers of immature or maturing fish being caught from the drying rice fields. Farmers sometimes collect these immature fish for stocking into their ponds. Fish typically caught at this time of year are *Rasbora sp.*, small catfish and snakeheads, climbing perch and *Puntius spp.*. Nearer to river systems, other species such as Halfbeaks, *Mystus spp.*, *Mastocembelus spp.* and riverine cyprinids may also be caught from the ricefields.

During the **cool season**, when the paddy fields begin to dry, fish are caught as they start to migrate from the ricefields, back to deeper water areas. This back migration appears to be stimulated by the onset of the northerly winds which characterise the cool season in Cambodia. The catch usually consists of medium sized *Clariads* and Snakeheads, *Rasbora spp.*, Spiny Eels and Anabantids. Shallow trap ponds and depressions dug in the rice fields are drained manually and the fish caught by hand. Children are often seen carrying out this activity. Again it appears that in Cambodia open access exists for anyone wishing to catch fish in this situation. Dry jump traps also are prepared at this time of year. This technique uses a bamboo screen to block the fish's migration and fish, especially snakeheads are caught in the dry pit once they have attempted to jump over or around the bamboo obstruction. Those fish which escape entrapment at this time of year move to deeper locations where they can survive until the next rains. Deeper ponds dug by farmers exploit this instinct, persuading the fish that they have reached a safe area where they can survive throughout the dry season. These trap ponds are usually > 3 m deep and will have one embankment broken, linking the pond to the surrounding paddy field or a canal.

Many of the ponds dug through the Family Food Production Programme, (FFP) and other rural development projects in Cambodia have been converted to this purpose.

Although few ricefield fish are usually available during the **dry season,** fish which did most of their growing during the wet season in the ricefields and had moved to deeper ponds or perennial swamps are now collected by rice farmers for household consumption and sale. Modern pumps make the pumping of these water bodies relatively easy and inexpensive; the remaining fish caught by hand from the mud. At this point in time, the fish are considered the property of the owner of the water resource or in the case of a swamp, the person or village with fishing rights. In Svay Rieng villagers will police their dry season swamp areas to prevent outsiders taking their fish, Guttman (*pers comm*). The final catch is usually only black fish; i.e. snakeheads and catfish with occasional Anabantids and eels. Most white fish will have been eaten by the predatory fish in the confined conditions and are usually not present in any numbers in the catch at this time of year. Other water bodies, including the refuge areas are fished very intensely at this time of year, usually by manually drying shallow sections of any remaining water bodies in the ricefield or, in deeper water, repeated netting. At this time of year, frogs and crabs are dug up or hooked from their burrows in the ricefield bunds. Children are often charged with collecting these foods.

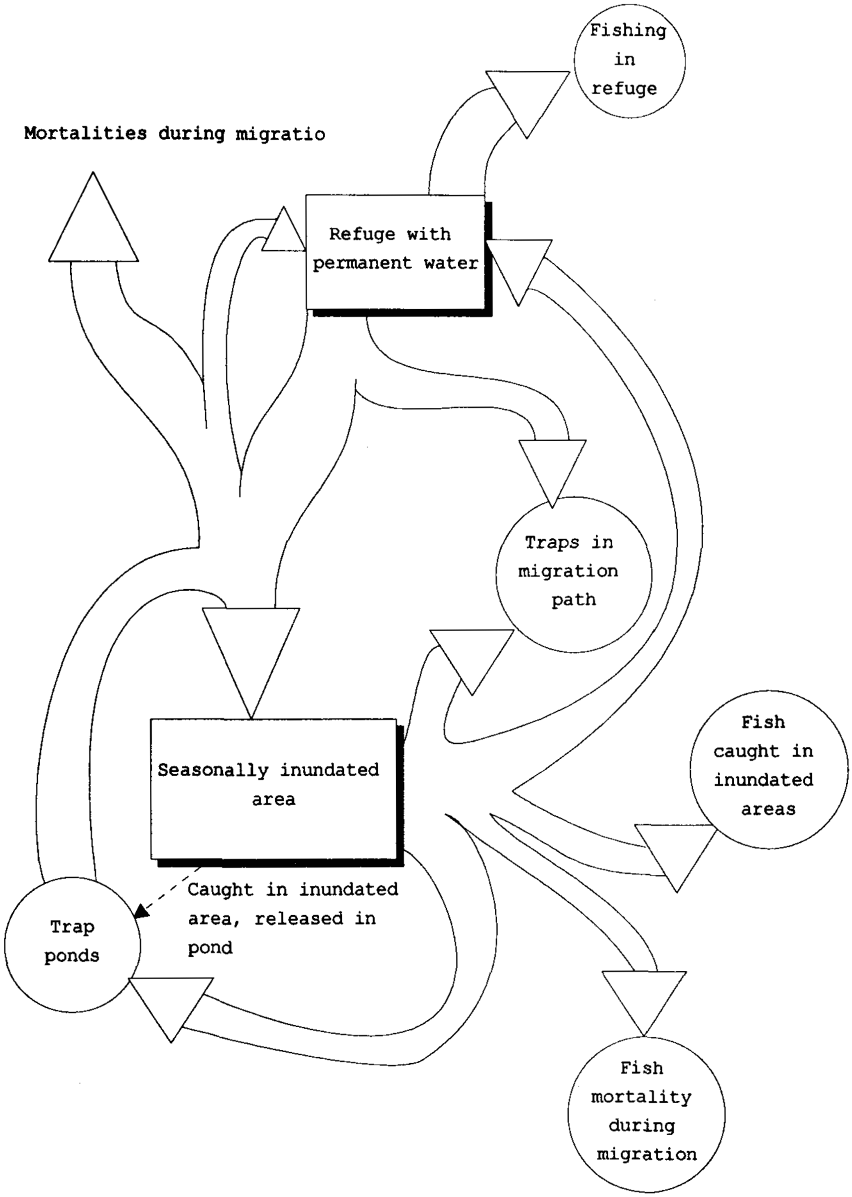
This exploitation can be shown in the schematic diagram (Figure 1) developed by Guttman, (Gregory and Guttman, in Nesbitt 1996) on the following page.

Fish Production from Trap Ponds

Annual catch rates from trap ponds vary considerably from area to area and from year to year. In drier years, lower catches from ricefields and trap ponds are to be expected. In a wetter year or a year with early and late rains, then ricefields and trap ponds will likely produce more fish. Farmers in NE Thailand report that early rains are the single most important factor in determining subsequent wild fish production.

There is thought to be very limited fish production from the trap ponds or dry season refuges themselves. Fish catches from small trap ponds, ($80m^2$) in Svay Rieng range from 2 kg in higher areas to 75 kg in lower areas. Research in Kompong Ro District of Svay Rieng suggests that trap pond catches are related to land topography with most fish being trapped in basin areas receiving drainage from extensive rice growing areas. Proximity to swamp areas also appears to have a positive influence on trap pond catches. Larger trap ponds in Kompong Ro District of Svay Rieng have been shown to yield in excess of 300 kg of fish. The trend of increasing numbers of new trap ponds in many areas is likely to result in declining fish yields from individual trap ponds although their effect on overall ricefield fish production is uncertain. This trend seems likely to continue as an on-farm dry season water resource remains one of the best investments a farm family can make. The siting of trap ponds is an important factor which determines how many fish will be attracted to the pond. Little *et al* (1996), suggests that farmers in NE Thailand have to compromise between the best site on their land and the proximity to the home which ensures security. The wide range in trap pond production from FFP ponds may be a consequence of farmers being instructed to dig their pond next to the homestead.

Figure 1: Schematic outline of the exploitation of fish in ricefield fisheries



Trap Pond Management

Despite the limitations on fish productivity from trap ponds imposed by location, Cambodian farmers are able to increase the numbers of fish that they trap through simple management methods. Examples of this include putting in branches which attract and provide shelter for the fish. Mud from perennial swampy areas can also be introduced to the trap pond to try and persuade the fish that they have indeed reached a safe refuge area. Buffalo or cow skins introduced to the pond are used by many farmers to attract catfish and eels and feeding of rice bran to the fish is carried out by some Cambodian farmers. Household latrines are sometimes found over trap ponds. Older trap ponds in NE Thailand often have large trees growing on the raised embankment which farmers believe help attract fish through offering shade. In Svay Rieng trap ponds are often surrounded by cashew trees. In drier years, or during the mini dry season, farmers may collect immature fish from drying ricefields and release them to the trap pond as a compensatory measure. This has also been reported in NE Thailand, (Setboonsarng 1993).

In the Svay Theap and Kompong Ro Districts in Svay Rieng, broodstock catfish and snakeheads are retained in the pond following the harvest and encouraged to spawn with the first rains. This practice has also been noted in NE Thailand where farmers paid respect to the pond spirit by releasing a few pairs of fish back into the pond, (Little *et al* 1996). Some farmers induce these fish to breed through the manipulation of water levels and the digging of burrows for the fish. Many farmers believe that the young of the fish which spawn in a pond, will return to that exact same pond as adults. Whilst the homing instinct in some species of fish is very precise but it is not known whether this is the case for catfishes and snakeheads.

The species composition of trap pond catches has been shown to be quite consistent in Svay Rieng with Snakehead typically accounting for 25 - 40% of the total catch weight, Clarias catfish, (35 - 40%) Climbing Perch, (10-15%) and *Rasbora spp.* (10-15%).

The predominantly black fish are very easily marketed as they can be carried to, (and back from, if necessary) the market place live and fetch a considerably higher price than cyprinids. Many Cambodian farmers try and keep on to their trap pond fish until Khmer New Year when they can be sold at a higher price or when the family might like to celebrate.

In NE Thailand, groups of up to 10 rice farmers operate in fish catching teams which pump other farmers trap ponds, offering them a price based on a pre-catch estimate. These fish catching teams often co-own vehicles and pumps to enable them to work effectively. Through experience the catching team members are able to develop skills in being able to estimate fish production from trap ponds by watching the number of times fish break the surface over a period of time. Other team members assess the quantity of fish in the trap pond by walking into it and feeling for places that the fish like to rest on. This and an overall assessment of the pond location, water conditions and the history of fish production from the pond contributed to an estimate and a price being offered. The final agreed price for the pond results from a complex negotiation between the fish catching team and the trap pond owner which can take up to 2 hours. In some years, this business is severely affected by the ulcerative fish disease as fish showing symptom of the disease; red spots, ulcers etc. fetch low prices in local markets.

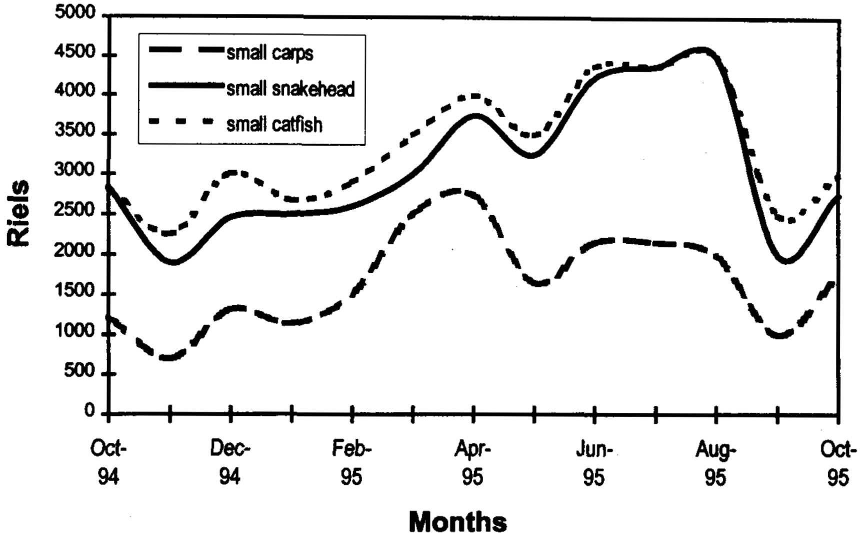
Market Prices of Ricefield Fish

The Figure 2 shows Svay Rieng market prices for three categories of fish during 1994/95. It should be stressed that this is a town market and rural markets may show different trends.

The Figure is interesting not for the values but the general trends. Prices are lowest in November when ricefields are drying and it is easy to catch ricefield fish. the dip in January results from large numbers of fish being exported from north of Phnom Penh on the Tonle Sap, when the incredible fish migrations from the Great Lake are exploited by the Dai nets set on the Tonle Sap River. Prices peak at Khmer New Year

(April 13-15) before declining, presumably because of falling demand. During the peak wet season prices increase as it is difficult for farmers to catch enough fish to interest middlemen. The steep decline in prices in August in the year studied was due to a prolonged "mini dry season" which dried many ricefields and enabled immature fish to be harvested in great numbers.

Figure 2: Svay Rieng Market Prices; October 94 - October 95



From Gregory and Guttman in Nesbitt 1996

The Future of Lowland Ricefield Capture Fisheries

The ricefield fisheries of Cambodia and other countries in Asia appear to be extremely robust, i.e. they are able to stay productive despite the enormous fishing pressure on them. Even in the most populous countries such as Bangladesh, it is possible for farmers to catch ricefield fish and trap fish in ponds in many areas. In Cambodia, with its relatively small population and extensive natural resources, ricefield areas should be able to produce ample wild fish for consumption and sale for the foreseeable future. However, there are pressures on the ricefield fisheries which may well result in declining fish production and these include the following:

The reclamation of swamplands for dry season agriculture will most likely reduce the numbers of fish surviving in dry season refuges each year. Associated pesticide use with dry season rice in these areas may either kill the fish in nearby swamps or effect the fishes ability to grow or reproduce. In many parts of Asia, such as in central Thailand, increased rice production has almost certainly been paid for by the loss of wild fish and other aquatic animals from the farmers fields.

Any increase in fishing pressure on the dry season fish refuge is likely to result in lower ricefield fish catches, the following wet season. Ricefield fisheries conservation measures should firstly concentrate on protecting dry season refuge areas.

The use of fine mesh nets during the early wet season to catch immature fish as they migrate between rice fields is probably detrimental to the fishery as a whole. If these nets are static then they may constrain the free movement of fish on the floodplain even if they do not catch and this will also be detrimental. Roads, built without culverts affect the migration of wild fish onto the floodplain and thus reduce the distribution of seed. If culverts exist then they are very popular places for fishing!

The move towards selling trap pond fish and the availability of pump sets will put increased pressure on fish stocks as farmers look to harvest their trap ponds more efficiently and earn money. This is becoming the case in SE Cambodia where there is now a trend to sell trap pond fish to middlemen for the Phnom Penh market.

Culture Fisheries

The culture of fish in lowland ricefields is a well established practice in some SE Asian countries such as Indonesia, (particularly West Java) and NE Thailand. In others, farmers have not adopted the practice in any numbers despite considerable development effort. The Philippines is an example of this. Time will tell whether Cambodian farmers adopt and sustain this practice in any numbers.

In areas where naturally occurring fish are inadequate to meet the Cambodian farmers needs, fish can be introduced to the ricefield for simultaneous or alternate culture. Under these conditions the farmer is able to exert more control over the fish production system than in the wild capture systems described earlier. Fish deficit areas where aquaculture is appropriate are usually at a higher elevation than the main floodplain and where wild fish are not able to reach the fields or ponds in any numbers. Such areas are often not ideal for fish culture, often having poorer soils and drying out early. The methodology used to develop fish availability zones based on mapping of trap pond production figure is a useful approach to determining where culture as opposed to capture fisheries should be promoted, (Gregory and Guttman in press).

The AIT, Department of Fisheries field research project in Svay Rieng has shown that fish can be cultured successfully in lowland rice fields during the wet season. The major findings from this work follow.

The Design of Rice/Fish Culture Systems in Cambodia

In many ways the culture system copies the traditional system except that seed is introduced by the farmer. Due to the uncertainty of the rains in the Svay Rieng region, rice/fish farmers usually create a refuge area in or close to the ricefield, where the fish can move to if the field starts to dry up. Many farmers use old trap ponds for this purpose, enabling them to toggle between capture and culture fisheries as they like. The pond can also be used for nursing fingerlings prior to the field being transplanted and before the fish are allowed access to the ricefield. A deep water refuge is particularly important if the short dry season, which typically occurs from late July - early August in Svay Rieng persists. Allowances must also be made for too much water during the monsoon and bunds surrounding the ricefield fish system must be high enough to avoid even temporary inundation. This has the disadvantage of offering better shelter to rodents that may later damage the rice. Most farmers construct simple bamboo screens to allow water level regulation. As with the wild fish system, at the start of the cool season, the fish start to return to the refuge pond as the fields dry out and the rice ripens. Here they can be held until harvesting.

Fish Species for Rice Fish Culture

A variety of indigenous and exotic fish are cultured in rice fields by farmers in Svay Rieng. Success has been achieved with stocking various ratios of the following species as shown in Table 2:

Table 2: Fish Species for Rice Fish Culture

Common Name	Species	Khmer Name	Native	Feeding Habit
Silver Barb	Puntius gonionotus	trey chapin	Indigenous	Herbivorous
Snakeskin Gourami	Trichogaster pectoralis	trey cantor	Indigenous	Herbivorous
Common Carp	Cyprinus carpio	trey carp samunh	Exotic	Omnivorous
Tilapia	Oreochromis niloticus	trey tilapia	Exotic	Planktivorous
Tilapia	O. mossambicus	carophee	Exotic	Planktivorous
Silver Carp	Hypophthalmichthys molitrix	trey carp sor	Exotic	Planktivorous

Fingerlings of the above species can be stocked individually or in a composite culture. Stocking ratios used by Svay Rieng farmers are in the range of 0.25 - 1 fish per m^2 of total rice field area. In Svay Rieng farmers have identified two peak periods when they need fish but have no time to catch them nor money to buy them; these being at transplanting time and at rice harvest, when they often have to feed additional labour. farmers should therefore stock fish with this in mind

Management of Fish Culture in Ricefields

Farmers in Svay Rieng usually purchase fish seed for rice fish culture in June/July or as soon as their refuge ponds have enough water. This is a particularly busy time for the rice farmer, who will be preparing ricefields and setting seed. Fish seed is slowly becoming more easily available through private fish seed producers in the rural areas, government hatcheries and Vietnamese traders, who bring fish seed from Vietnam. At the moment fish seed in most areas of Cambodia are still too expensive for rice fish culture to develop fast. At 30 riels a head, poor survival rates of say 30% mean that a fish cost 90 riels to establish in the ricefield. Only when fish seed is available for 15 riels or less are farmers likely to adopt rice fish culture in numbers. (Pond aquaculture with its higher fingerling survival rates is less affected by expensive seed). Some informal short term credit is offered by some traders allowing rice fish farmers to pay for their seed a few weeks after receiving them. Following purchase, the fingerlings are often reared in the small trap pond refuge until the rice has been transplanted for about 10 days. Rice varieties which tiller well in deeper water, (20-30 cm) should be planted. The bund separating the trap pond from the field is then broken and the fish allowed access to the ricefield as they choose. Farmers have observed a diurnal migration of fish taking place, with fish leaving the pond area in the evening and returning the following morning.

It is extremely important that large predatory fish species such as Snakehead, (Channa striatus) are not present in the pond or the field when fingerlings are first introduced as they will drastically reduce survival rates. AIT/CIAP rice fish trials in 1996 were seriously affected through stocking small fingerlings late in the season, when Snakehead were already established in the fields. However, farmers often have difficulty in removing such fish from the system. If farmers suspect that such predators are present then larger fingerlings should be purchased or small fingerlings raised in an inverted mosquito net, (happa) until they are large enough to escape predation, (AIT Aqua Outreach 1997). The presence of Snakehead can often be noted by the trained observer due to the tendency of the fish to come up to the surface to look at people who have just walked up to the pond. Predators entering the ricefield system after the cultured fish are established are less of a problem. Farmers in Svay Rieng have reported that rats will take fish from the ricefields at night. The rats tend to advertise their presence through discarding the head of the fish which can be found on the ricefield bund. The most evasive of the three common fish species used in rice fish culture is the Silver barb which is able to avoid predation, fairly successfully, if a small number of Snakehead are present. Survival rates of over 40% are possible. Tilapia and Common carp are less able to avoid predation by Snakehead.

Some additional ricefield management is necessary for successful rice fish culture. Water levels must be regulated to ensure that the field does not dry up or flood. Usual fertilisation regimes can be followed by the farmer. In the authors experience there is no danger in broadcasting urea or DAP whilst fish are in the field although fish mortalities have been observed by others, (Kamp *pers comm*) who suggest that fish may eat the granules, mistaking them for food.

Although the fish present will control some of the softer weeds which grow in the field, some others will have to be removed by hand in the usual way. The fish will derive most of their growth from naturally occurring organisms in the field and these include benthic and epiphytic organisms such as worms, snails, insect larvae and algae. Many farmers supplement the naturally occurring field by providing a variety of feeds, including, duckweed, termites, earthworms, and rice bran.

Several successful rice fish farmers in Svay Rieng have continued to develop their fish culture systems and several integrated pond ricefields have been converted to fishponds. Several instances are also recorded of farmers converting rice seed beds to shallow fish ponds. Often the seed bed is in a place which has good early wet season water. The excavation of these areas for fish culture can also benefit rice seedbed management as the new area chosen for the seed bed can then be irrigated from the fish pond if the fields start to dry out.

Pesticides and Integrated Pest Management

Until recently few farmers applied pesticides on wet season rice. In these cases, the dilution effect of rain and outside water entering the system may be enough to prevent fish mortality resulting. In irrigated rice where pesticides are often used as a prophylactic and calendar spraying is common, culturing fish in ricefields really means that the farmer has to forgo the spraying of pesticides while fish are present in the field.

The extent to which fish can control rice pests is inconclusive. As many of the pests conceal themselves within the rice plant, it is unlikely that fish can feed on them. It could be argued that beneficial insects such as spiders and wasps, being more mobile, will be more prone to predation by fish. Svay Rieng rice/fish farmers seem to accept some rice pest damage as the fish produced are usually more than enough to compensate for pest damage to the rice fields. In some instances, rice yields have been shown to increase in the presence of cultured fish possibly due to the better rice and water management applied by farmers if they have fish present in their fields. In Sway Rieng two farmers growing fish in ricefields in 1996 suffered sever crop damage through black bug. These foul smelling pests are probably bad tasting to the fish which leave them alone.

Fish culture can therefore be used as a tool for those IPM programs that discourage any use of pesticides in irrigated rice in Cambodia. With the growing concern regarding the Golden Snail becoming a rice pest in Cambodia, cultured fish may play a role in helping to control this animal. Common carp especially will eat large numbers of juvenile snails.

Harvesting of Cultured Fish from Ricefields.

After three months in the ricefield the fish should have reached an edible size of around 50 - 100g. They can then be caught from the ricefield or the refuge by hooking or gill netting. Total harvests are usually done through pumping the refuge dry and catching the fish by hand. Fish culture in the ricefield can continue after the rice harvest, if enough water is available.

Cultured fish produced in wet season ricefields have to compete with considerable numbers of wild fish in the Cambodian marketplace in December - February. Prices for cultured fish, at this time are often low, typically 1200-1500 riels/kg, (which will be similar to the 'small carps' category in Figure 2). Due to water shortages many farmers are forced to sell their fish earlier than they would wish and for less money. Other farmers process their fish as Ba'Ork, or eat them fresh.

In addition to cultured fish harvested, up to 80% of the total fish catch can be from wild fish which invaded the system, (Little *et al* 1996). In Svay Rieng a figure of 10-20% from successful fish culture systems is common. (In unsuccessful plots this will be 100%).

Cultured Rice/Fish Yields

From the limited data available from Cambodia, cultured fish production in wet season lowland rice is usually in the range of 200-400 kg/ha. Fish harvested are normally in the 100 - 300g size. Survival rates of fish are generally low, (ave. 20-40%) even in well managed situations. This is mainly due to aquatic and terrestrial predators and fish escaping over the bund. This contrasts with pond aquaculture where survival rates of 80% are not unusual. Cheap fish seed is therefore desirable if farmers are going to adopt this activity in any numbers. Due to seasonal price differentials, the fish produced will have a seasonal value of 300,000 - 600,000 riels/ha. This compares favourably with rice production on the poorer soil areas of Svay Rieng where farmers expect rice yields of around 800 kg/ha, worth 400,000 riels at 500 riels/kg. In many instances the value of fish produced will actually exceed the value of the rice production.

1.3 Irrigated Ricefields

Capture Fisheries

Capture fisheries activities are limited in irrigated ricefields as farmers will often screen the water pumped to the field for fish, so that no fish fry reach the field. Eggs of fish may pass through the nets placed to screen the inlet water and some of the more mobile fish species may find their way into the fields. The sources of water for irrigation such as canals, will usually be fully exploited for fish by local people. In pumped systems, nets are usually arranged so that water passing through the pump is screened and small fish and shrimp can be harvested. These irrigation waters are often extremely turbid due at least in part by the intensive fishing that they attract in the dry season. The high incidence of pesticide use in the shallow water of irrigated rice fields will often kill those fish and other aquatic animals present in the field. A recent study of 482 dry season rice farmers by CIAP found that 385 used pesticides. Of those that applied pesticides, 150, (39%) had observed dead fish in their fields as a result. Of some concern was the finding that 11, (7%) of these farmers admitted that they ate the fish which had been killed. Farmers in Svay Rieng have been observed catching dying fish in ricefields where pesticides had been applied, and then transferring the fish to buckets of clean water where some then recover. These fish were then eaten or sold. However, where pesticide use is light, irrigated ricefields may offer dry season refuges for wild fish and so may contribute to the productivity of the following wet season ricefield fishery. Irrigated systems that operate to help overcome gaps in wet season rainfall should benefit natural fisheries as they prevent drought conditions occurring in the fields.

Cultured Fisheries

Irrigated ricefield fish culture has considerable potential in Asia as it allows fish to be produced at peak demand times and the farmer's control over water levels in the field reduces much of the risk associated with rice fish culture systems dependent on rainfall.

In some Asian countries, sophisticated, irrigated rice/fish systems have developed to produce fish seed prior to wet season demand for fingerlings. Examples of this can be found from Bangladesh, (Gregory and Kamp 1992) and NE Thailand, (Little, *et al* 1996). The production of fingerlings from rice fields for wet season fish culture has several advantages over attempting to grow market sized fish under these conditions. Reasons for this compatibility include the high price of early wet season fingerlings in areas with developed fish culture; the shallow water being suitable for fingerling production; and the short rice growing cycle being more suited to fingerling production than market fish production. Gregory and Kamp recorded average fingerling production by Bengali farmers of around 15,000 fingerlings/ha/crop. Due to the low cost of hatchlings and the high demand for fingerlings, survival rates of over 3% were profitable.

Only one case of dry season irrigated rice fish culture in Cambodia is known by the author. This was in Svay Rieng where an experienced fish farmer was encouraged by the Department of Fisheries to attempt fish culture in his 1 ha dry season irrigated field. Water for the field was pumped from a long irrigation canal dug during the Pol Pot years. Fish were stocked 10 days after transplanting. About one week later the rice was seriously affected by stem borer. The farmer could not spray the field as the fish were present but he managed to kill many of the stem borer larvae by flooding the plants in the field for a few hours. The rice recovered but yielded around 1.5 tonnes (the farmer claimed this was only half the yield that would have been attained if he could have sprayed pesticides). To compensate for the low rice yield, 140 kg of cultured fish, (no wild fish at all!) were harvested. In this case the fish harvest was worth 500,000 riels or the equivalent of one tonne of rice. Unfortunately further experimentation was not possible as farmers have not carried out dry season rice in that area since, due to prohibitive water costs.

The development of irrigated rice/fish systems in some areas of Cambodia where water availability and soil quality are conducive to this activity can be expected. One of the inducements to this development is that market fish can be produced at a time when few fish from the natural fisheries are available and market prices are at their highest.

1.4 Recession Ricefields

Capture Fisheries

Recession ricefield areas are usually not important for wild fish production whilst they are under rice cultivation. However, recession rice cultivation has grown remarkably in recent years, in many areas, replacing deepwater rice cultivation as the preferred rice production technique, (Nesbitt 1996) and this has implications for local fisheries. Of concern is the clearing of seasonally flooded forests for recession rice cultivation. The unique flooded forest environment is considered to be of great importance to the nations fisheries and the clearing of these forests may reduce fish species diversity and/or production.

Pesticide use in dry season rice growing areas is usually high ranging from 50-100%, (Jahn *et al* 1996). Recession rice areas encroaching on small water bodies such as swamps may seriously compromise the capacity of these water bodies to act as fish refuge areas. It may not be coincidental that the decline of the giant freshwater prawn, (*Macrobrachium rosenbergii*) fishery in Takeo Province has occurred as recession rice farming has boomed and pesticides, some targeting crabs have become common place.

Cultured Fisheries

The comments in the preceding section on irrigated rice fish systems mostly apply to recession rice. Generally, it is thought that recession rice areas have less potential for fish culture than more conventional irrigated systems. Trials are planned by the Department of Fisheries in Takeo Province early in 1998 to assess this potential. As with irrigated rice, the farmer's dependence on pesticides for control of pests is one issue to be addressed. A second issue will be that of water supply. Recession rice farmers typically transplant seedlings when water levels are adequate for fish but the farmer may not supplementary irrigate the field until the soil is exposed. Maintaining adequate water levels in the field may be labour intensive and/or add costs to the production system. Refuge areas will almost certainly have to be made by the farmers if water levels cannot be maintained in the field.

1.5 Deep Water Ricefields

Capture Fisheries

Fish have long been harvested from and around deepwater rice areas in Cambodia by traps and nets or by creating ditches or sumps which collect fish as the water recedes. Fish will of course move freely from the open water areas to the rice growing areas as they choose. Whether the deepwater rice area is any more productive than the surrounding waters is open to debate. The rice is likely to offer shelter to several fish species and in effect creates a refuge area which is difficult to systematically fish through netting. Brush parks, called *samra* which act as fish attractants are also used close to deepwater rice growing areas. These brush parks are periodically netted, following the removal of branches and water hyacinth from the area enclosed. A more diverse fishery is found in deepwater rice areas as large numbers of riverine fish species are found. It is difficult to estimate fish production from deep water rice areas but in West Bengal, fish yields of 50-100 kg/ha/year are estimated, (Mukhopadhyay 1992). The general trend away from deep water low yielding rice cultivation towards higher yielding recession rice is thought likely to continue and increasingly deepwater rice areas will revert to open water fisheries activities.

Cultured Fisheries

Deep water areas have been used for fish culture by Cambodians for generations. Using traditional floating wooden cages, carnivorous fish species such as *Pangasius spp.* and Snakehead, (*Channa micropeltus*) are grown. In recent years farmers have begun to experiment with the cage culture of indigenous cyprinids and tilapia.

The variation in water depth presents difficulties for impounded fish culture. Areas can be cordoned off by using bamboo fencing. Large fingerlings of carps and tilapias could then be introduced and the fish fed supplementary feeds to encourage growth. To the author's knowledge, this has not yet been attempted in Cambodia. One issue of interest is that in other countries waste feeds tend to attract crabs which may then damage the rice crop. Regular trapping of crabs is required.

It is likely that deep water rice areas already have significant stocks of wild fish and the need for fish culture is questioned. It is doubtful then that deep water rice fish culture will develop in the near future, as it has in West Bengal, where high human population densities and severely depleted natural fisheries make these systems viable.

1.6 Conclusions of Ricefield Ecosystems Potential

The greatest potential for improvement appears to lie in the **rainfed lowland** and **irrigated** rice ecosystems. The former offers scope for community based ricefield capture fisheries development, in lowland areas where wild fish are plentiful, (or have been plentiful in the recent past). Ricefield culture fisheries can be expected to develop in slightly higher areas where wild fish stocks are low, as long as water levels can be controlled adequately by the farmers.

Table 3 illustrates the relative importance (or potential importance) of the various rice ecosystems during each of the seasons.

Table 3: Potential for improving fish production from rice ecosystems.

	Wet Season		Cold Season		Dry Season	
Rice ecosystem	Capture Fishery	Culture Fishery	Capture Fishery	Culture Fishery	Capture Fishery	Culture Fishery
Rainfed Upland						
Rainfed Lowland						
Irrigated						
Recession	N/A	N/A				
Deep Water					N/A	N/A

Key

no potential
little potential
some potential
major potential

Table 3 leads on to Table 4 which summarises where effort might be expended to increase fish availability in and around ricefields.

Table 4: Recommended techniques for improving fish production in rice ecosystems

	Wet Season		Cold Season		Dry Season	
Rice Ecosystem	Capture Fishery	Culture Fishery	Capture Fishery	Culture Fishery	Capture Fishery	Culture Fishery
Rainfed Upland	-	Fish culture in on farm ponds	-	Fish culture in on farm ponds	-	-
Rainfed Lowland	Community protection of fish out-migration	Fish culture in ricefields	-	Fish culture in ricefields/ refuge ponds	Community protection of dry season refuges	Fish culture in refuge ponds
Irrigated	-	Fish culture in ricefields	-	Fish culture in ricefields as part of IPM	-	Fish culture (fingerling production?) in ricefields
Recession	N/A	N/A	-	Fish culture in ricefields as part of IPM	-	-
Deep Water	-	cage or pen aquaculture	-	cage or pen aquaculture	N/A	N/A

The irrigated rice areas will favour the development of culture based ricefield fisheries due to the reliability of water supplies. This should allow "off season" fish production which can take advantage of high market prices. It is strongly recommended that any attempt to introduce fish culture to irrigated rice farmers do so under the umbrella provided by IPM programmes aimed at reducing or even preventing pesticide use by farmers. Fish can then be used to compensate for some pest damage.

The three other rice ecosystems are unlikely to develop serious ricefield fisheries systems. In **upland** rice, fish culture may be required to supplement poor fish availability in highland areas. This may develop in bunded ricefields situated in valleys and/or in on farm ponds. There appears to be no scope for true upland rice growing areas. In **recession** rice, fish culture is considered less likely to develop due to the regular drying out of fields and heavy pesticide levels currently used. **Deep water** rice growing areas offer scope for fish culture in pens and cages but any cultured fish production would have to compete the large amounts of wild fish commonly found around large receding water bodies.

In conclusion it can be said that the more control the farmer has over water levels, the more appropriate culture systems become. In systems where farmers have less control and water levels can fluctuate to a large extent, capture fisheries will probably remain the primary source of fish supply.

Chapter

2

MANAGEMENT THEMES

This section looks at land, water and crop management of ricefields in Cambodia from a fisheries perspective. Examples from other Asian countries are used.

2.1 Land Management

Swamp Reclamation

One threat to the natural ricefield fishery appears to come from the development of dry season irrigated or recession rice around swamps. It has already been explained that these swamps are important refuges for fish which will breed and thus restart the wet season fishery each year. The planting of recession rice and the use of pesticides will be likely to affect the fish which survive in these dry season refuges. The de-watering of these swamplands for irrigated rice or to hasten drainage from them to improve wet season rice cultivation locally, are also likely to have negative effects on the natural fishery. Unfortunately, it remains unknown how much refuge is required to repopulate a given area of ricefield fishery each year.

Land Levelling

Although there is no data yet to support this idea, in theory the recommendation that farmers pay more attention to levelling their rice fields should also benefit fish either cultured or naturally occurring. Fish can be expected to use the more regular water depth better. In an unlevelled field near drought conditions would result in the fish being crowded in the lowest parts of the ricefield where they would be too crowded to grow well and more vulnerable to predation. No negative effects of farmers levelling fields are therefore thought likely.

Increased Use of Fertilisers

Improvement of soil conditions through the application of organic matter is also likely to have positive effects on both the culture and capture ricefield fisheries. The most important feeding pathway for fish in this environment is detrital; the productivity of which is often limited by carbon and nitrogen availability. No doubt application of organic manures will benefit fish production. The use of inorganic fertilisers is also likely to be a positive influence on the fisheries. Although the speed with which the rice plant takes up these nutrients may mean little actual increase in the natural food for the fish results.

Soil Types

The most productive ricefield capture fisheries in SE Cambodia seem to occur in areas where the soils are black and the pH is low. In Svay Rieng this is certainly true of the black Koktrop soils, (White *et al* 1997). This may be due to the fact that these soils develop in low swampy areas and these are preferred by fish or that the clear water conditions which are usually found in these areas are better for the predominant fish species. For fish culture more neutral clay soils such as Bakan soils are preferred as plankton and other natural foods are easier to establish under these conditions. However, the dispersive clay soils often result in highly turbid condition in the ricefield which may limit light penetration, reduce primary productivity and affect fish feeding behaviour and growth.

The water retention capacity of the soils will also determine the scope for ricefield fisheries; waterlogged soils being usually more productive for fish. In Bangladesh, irrigated rice plots nearest to the main irrigation canals were often the best for fish production due to the seepage from the canal water logging those plots, (Kamp *pers comm*). Soils which retain water long after precipitation has ended will prolong the time fish have access to the field and result in higher fish yields.

2.2 Water Management

Rainfall/Drought Patterns

Fluctuating rainfall is one of the most serious variables in ricefield fisheries. Cambodia suffers particularly erratic rainfall patterns and the 20 year average is unrepresentative if not positively misleading, (CIAP 1997). The common mini-drought which occurs in July/August over much of the country can result in many juvenile wild fish being caught in the drying fields. Early and/or late rains are beneficial to the natural ricefield fishery; the longer the wet season the better for wild fisheries.

The situation is completely different for ricefield culture fisheries. As mentioned before, fish culture becomes a more attractive option in dry years when the natural ricefield fishery is expected to produce inadequate numbers of fish for local communities. Low rainfall and short wet seasons can therefore be considered good for culture ricefield fisheries. The preceding wet season should also be considered as a factor in determining the scope for culture ricefield fisheries in any year. i.e. If the wet season ended early during the previous year, then the scope for fish culture will be increased as more refuges will dry out and heavier fishing pressure will be exerted on the stocks trying to survive the wet season. This is also true if the rains are late starting. Cambodian farmers with a few years of fish culture experience seem to understand these issues quite quickly. As their understanding grows, it is likely that many farmers will do fish culture when they predict the following years wild fishery will be poor. A key factor in this decision making will be recent rainfall patterns.

Flood Control

Heavy rain over a short period of time can result in ricefields flooding. Whilst this is of no concern, (probably beneficial) to the natural ricefield fishery, it can spell disaster for the culture fishery. Once the bund is breached then most of the cultured fish will leave as they seem very sensitive to water currents and will queue up to leave once they sense water is flowing out of or into the field. Farmers may use bamboo screens to try and reduce water levels in the fields if water levels are too high, assuming they can drain the field to lower areas. Fish culture trials in mountainous areas are at particular risk to flash flooding from the hills. The slower threat from rising rivers and floodplains are much easier contained by farmers who have time to raise bunds to beat the rising water, if they wish.

2.3 Crop Management

Integrated Pest Management and Fish

There is some evidence to suggest that fish play a role in controlling insect pests in rice, (Chapman *et al* 1987). Xiao, (1992) also reports that fish were able to reduce numbers of rice planthoppers significantly and that Grass Carp (*Ctenopharygodon idella*) were able to effectively control sheath blight disease. It can be argued that fish will be more likely to prey upon the mobile beneficial insects such as spiders and wasps which will control pest numbers if undisturbed. Certain insect species, including the ones that emit a strong smell when disturbed, such as 'black bug' are distasteful to fish and they cannot be expected to reduce populations of these pests at all. Whether fish can be classified as beneficial to overall pest predator ratios in Cambodian rice fields requires further work but the main role of fish in IPM is that the economic threshold at which a farmer must spray is raised if income from fish sales is considered, (Waibel 1988). This does not include the positive effects on health and the environment if fish are used instead of pesticides. IPM programmes might benefit from replacing a non action extension message, "Do not spray"! with an active one, "Stock fish"!

Pesticide Use by Farmers

Generally, toxicity of major groups of pesticides to fish ranked from the most toxic to the least toxic are insecticides, molluscicides and herbicides. There are six main groups of insecticide compounds used on rice. These are carbamates, organophosphates, organochlorines, synthetic pyrethroids, and biological and botanical pesticides. Herbicides, (phenoxy-aliphatic compounds and substituted amines) can also effect fish and other aquatic life in the ricefield.

Carbamates are the least toxic of group of pesticides to fish. Organophospates are generally less toxic than organochlorines, which tend to break down slowly after application. Synthetic pyrethroids have a high toxicity to fish but also a high mammalian safety factor and so could possibly be used where pesticide residues in fish are of concern. Biological pesticides can be expected to be non-toxic to fish although some botanical pesticides, (such as Derris) are toxic.

The use of pesticides in ricefields can have negative effects on fish populations in them. Fish kills arising from pesticide application may occur although less visible effects may also occur. The effects on fish and other aquatic life can be split up into acute toxicity and sub lethal toxicity.

Acute toxicity is determined by measuring the concentration lethal to 50% of the population (LC50) or the tolerance level for 50% survival (TL50) in aquaria over 24, 48 and 96 hours exposure. These tests are often inadequate to determine the effects of field use of the same chemicals as some compounds may be more toxic in the presence of sunlight, at different temperatures, pH, hardness, salinity, turbidity and dissolved oxygen levels. Different fish species and even stages of a single fish species may be more sensitive to a certain pesticide than others. Several field tests have shown that the toxic levels of pesticides obtained from laboratory experiments have proved non-toxic to fish in field situations, (Cagaun and Arce 1992). Still these tests are crude indicators of relative toxicity.

Table 5 details the toxicity of specific pesticides on a single fish species. This can be used as a guide to relative toxicity of the pesticides listed.

Table 5: Toxicity of insecticides expressed as 48-96 hour LC_{50} to Oreochromis niloticus

Insecticide	48 hour LC_{50} ppm of Formulated Product	96 hour LC_{50} ppm of Formulated Product	Toxicity
Carbamate			
BMPC	5.6- 6.7	5.4 - 6.12	high
Carbyl	3.1	2.93	high
Carbofuran	2.27	1.97	high
MTMC	68	50	medium
MTMC with Phenthoate	0.56	0.47	extreme
PMC	6.05[a]	-	high
PMP	59	47.1	medium
Organophosphate			
Azinphos ethyl	0.028	-	extreme
Chlorpyrites	2	1.3	high
Diazinon	45	2.2	medium
Methyl parathian	25.7	19	medium
Monocrotophos	1.2	-	high
Triazophos	5.6	-	high
Synthetic pyrethroid			
Permethrin	0.75	0.75	extreme
Cypermethrin	0.63	0.63	extreme

[a] 24 hour LC_{50}. Table adapted from Cagaun and Arce (1992).

Sub lethal effects are more difficult to determine. Although the fish does not die as a result of exposure to a pesticide its performance may be affected. This can manifest itself in poorer growth rates, delayed development, abnormalities in appearance, lower resistance to disease and behavioural changes. Pesticide residues can end up as residues in fish and the aquatic food chain such as the plankton on which they feed. These residues will tend to accumulate in more carnivorous species such as Snakehead, or man.

Rice Varieties

Different rice varieties are more suited to different fish management regimes than others. For example, for simultaneous fish culture, rice varieties that tiller well in deeper water should be used. This may make some traditional rice varieties more suitable for rice fish culture than some of the shorter stemmed, short duration HYVs, now being more popular in Cambodia. Varieties which tend to lodge should be avoided in fish culture systems as the fish will eat a considerable portion of the grain if the panicles fall into the water. Varieties that are easily uprooted should not be used if large Common Carp are stocked as the digging habit of these fish may uproot them.

Rice Fish Culture Farming Systems

To date, Cambodia's rice fish culture systems are in their infancy. As farmers perceive the benefits from diversifying into fish culture then novel ways of management will probably emerge. To an extent this has already started in Svay Rieng, where farmers have started to modify rice seed beds into simple pond aquaculture systems. The most sophisticated management of rice fields for fish culture can be found in Indonesia, where due to reliable year round water availability, three management strategies are possible; *palawija, penyalang* and *minapadi* (Koesoemadinata and

Costa-Pierce 1992). All three of these systems concentrate on producing fingerling fish for other inland fish culture systems, such as cage aquaculture.

Palawija is a form of rotational cropping where a single crop of fish is stocked in ricefields after a single annual crop of rice has been harvested. This system is dependent on a dry season water source.

The *penyelang* system is an intermediate cropping system used to produce fingerling fish. It is used in areas where two crops of rice are possible fish can be grown for 1 - 1.5 months. The recent change to HYV shorter duration varieties has allowed farmers to abandon the *penyalang* system in favour of multi-cropping rice

The *minapadi* system is a concurrent rice fish culture system and is now the most popular and widely used in Indonesia. Rearing of fish in this system are carefully synchronised with rice cultivation. An initial fish rearing period is conducted between rice transplanting and first weeding (21-28 days). A second fish rearing period is between second and third weeding (40-45 days). A third fish rearing period, (50 days) is carried out following third weeding. The *minapadi* system is possible through trenching of the ricefield which allows all the fish to be accommodated in trenches 40-50 cm wide, during drying and weeding of the ricefields. Indonesian farmers often combine these rice fish farming systems; the most popular sequence now being; *minapadi-penyaleng-minapadi-palawija*.

Rice or Fish

The conversion of rice fields to fish ponds looks favourable in economic terms. A 100 m^2 area of ricefield can typically produce 16 kg of paddy worth 4,800 riels over a 3 month period. Following conversion of this area to a fish pond, the same area can produce 30 kg of fish worth 75,000 riels over a 6 month period, although half of this amount would be spent on pond and stock management. Rice farmers in some areas in Cambodia can expect to convert some of their ricefields to fish ponds. This diversification can be encouraged as it would not seem to expose the farmer to a great degree of risk.

On-farm Inputs Verses Purchased Inputs

There are many on farm wastes and materials that can be used as inputs to enhance fish production. Materials for pond fertilisation and fish feeding can be found around the farm. Table 6 lists the on-farm materials commonly found in Svay Rieng. It also details alternative uses of these materials and the relative labour effort needed to collect them.

Table 6 shows the limitations of on-farm feeds for fish culture. Several of the inputs are already in short supply for basic crop production and those that are not, are labour intensive to collect. Rice farmers diversifying into fish culture often initially commit a disproportionate amount of on-farm resources to fish culture and may suffer reductions in rice and vegetable production as a result of this diversification. To an extent this competition does not exist in integrated rice fish culture systems where much of the food needed for the fish to grow occurs naturally in the field. The difference between pond fish culture and ricefield fish culture can be compared with the difference between raising pigs in confined pens, where all feed must be supplied and allowing them to forage for food around the village.

Pond fish culture systems can be viably fuelled by purchased inputs. Lime, (Calcium oxide) and inorganic fertilisers such as DAP and Urea can create pond water conditions conducive for fish growth, without the need for the provision of feeds. A 100 m^2 pond can be kept productive through the weekly application of 200 g of inorganic fertiliser, (approx. 5 kg over a 6 month period). This is probably the best option for farmers, (even poorer households) to take.

Table 6: On farm inputs vs. purchased inputs

On-farm Material	Use for Fish Culture	Labour Requirement	Alternative Use
Cow/Buffalo Manure	Pond Fertilisation	Low	Rice
Pig/chicken Manure	Pond Fertilisation/Feeding	Low	Vegetables
Green Manure	Clearing Water/Fertilisation	Medium	None Recorded
Compost	Pond Fertilisation	Medium	Vegetables
Termites	Pond Fertilisation	High (Seasonal)	Chickens
Duckweed	Fish Feed	Medium/High (Seasonal)	Pigs
Earthworms	Fish Feed	High (Seasonal)	Pigs/Chickens
Waste Vegetables	Fish Feed	Low	Pigs
Rice Bran	Fish Feed	Low (Can be Purchased)	Pigs

Harvesting and Marketing of Ricefield Fish

Fish prices show a marked differentiation according to the different seasons in Cambodia. Prices are usually lowest in December/January when ricefield fish are abundant. They start to peak at Khmer New Year and will remain high until July, when the ricefield fish begin to make an appearance. This differentiation can be as high as 100%, i.e. a kilogram of Snakehead worth 1500 riels in January can be worth 3,000 riels in April/May. Farmers managing trap ponds and fish culture ponds try and maintain stock in their systems until prices are high(est). To do this they must overcome deteriorating water quality conditions and increasing temperatures which create difficulties in keeping cultured fish alive. Wild ricefield fish have evolved to withstand these poor conditions and so represent less of a risk to the farmer holding them until prices increase.

This issue is of particular importance to the ricefield fish farmer. The hydrology affecting of these systems is no different from the natural ricefield fishery which means that cultured fish, if they are not to have to compete with wild ricefield fish must be held in ponds/refuges until the price increases. Little or no growth can be expected from the fish in their confined conditions during this time, although farmers have to feed a maintenance diet, (usually rice bran) to prevent the fish losing weight. It also means that fish refuges must be big enough to maintain the fish. For example a 1 ha rice fish field might produce 150 kg of fish, requiring a refuge pond of at least 100 m^2 and 1.5 m deep.(150 m^3 of water).

There are distinct advantages to be had by stocking fish as early as possible each year. Farmers can use the fish refuge part of the rice fish systems as a nursery area and grow their fish to a good size well in advance of the field being transplanted and the fish allowed access to it. Farmers who are able to do this often use some of the fish to feed labour involved in rice transplanting. The capacity to do this for most farmers will depend on the amount of water they have been able to maintain in their refuges over the dry season and the amount of early rain that falls. The release of larger fish into the ricefield should ensure that the survival rate of fish is higher and that larger fish, worth more per kilogramme, are eventually harvested.

Chapter

3

MONITORING OF RICEFIELD FISHERIES

This section will examine ways to determine the needs of farmers and recommend approaches for research, development and monitoring.

3.1 Recommended Monitoring for Surveys on Ricefield Fisheries

Human Nutritional Requirements

In assessing the food security situation of lowland rice farming households it is important to include fish and other aquatic products in the equation. The following guidelines can be used to assess nutritional standards from fish consumption. In lowland rice farming areas in SE Asia it can be assumed that approximately 75% of the animal protein requirements come from fish. In these cases < 88 g/kaput/day, (<31 kg/kaput/year) is considered deficient to an individual's requirements. A figure of 133g/kaput/day, (48.5 kg/kaput/year) is considered optimum, (Mekong Secretariat 1992).

Assessing the Importance of Ricefield Foods

The following approach to monitoring has been used by the AIT Aquaculture Outreach Programme for assessing the importance of ricefield foods to farming communities in Cambodia.

Regular Monitoring Visits

By far the most accurate way to assess the importance of a ricefield fishery is to conduct long term studies which collect household fish consumption data on a regular basis over a year or a fishing season. This can be done on a weekly, bi-weekly or monthly basis; the catch on the day of the visit, or the last time fish were caught is taken as typical and is multiplied by the fishing effort since the last monitoring visit to arrive at a total fish catch for that period. An advantage of regular monitoring visits is that good data results once the household are fully relaxed with and not suspicious of the researcher.

Seasonal Studies

If human resources do not allow the time consuming longitudinal studies then seasonal studies can be conducted. Exploiting ricefield fisheries tends to differ markedly with the seasons. The overall value off the fishery can therefore be assessed through a wet season, cool season, and hot season interview with the households to be studied. Care must be taken to ensure that the households understand that the researcher is not only interested in the large fish species but also the very small fish and shrimp which are eaten regularly by many rice farming households.

One-off Interviews

If resources do not allow regular or seasonal studies then a one-off interview can yield useful information to assess whether the ricefield fishery is important or not. Studies which rely on a single interview tend to produce gross under-estimates of the actual situation. This may be because farmers tend to under-estimate the importance of these foods themselves, even though they may be seemingly dependent on them for their survival. One complication is that farmers tend not to think of their fish catch in kilogramme terms unless the fish are sold. In such cases indicators of previous fishing activity can prove useful. These include the number of fishing traps or other fishing gears per household and the number of Brahok jars found in the homestead. In both cases, the more that can be seen in the homestead, the better the fishing in that area is likely to be poor. A casual look in the day's cooking pot or fish holding basket can also inform and serve as a point of discussion. The general appearance of children is also an indicator. Children living in areas with poor fish supplies may have brownish hair, caused through inadequate nutrition. In order to assess the general fish availability, it is sometimes better to ask how many times the family have to purchase fish over a given period, rather than ask them how much fish they are catching. This carries the assumption that if the household is not buying fish, they probably have enough from the wild, for their own needs. However it is difficult to accurately quantify the importance of fish to the household from a one-off interview.

Trap Pond Studies

The AIT Aquaculture Programme is continuing to assess how indicative of the overall situation of ricefield fish productivity, the production from trap ponds is. Results to date suggest a crude zoning of areas is possible using a fish production (kg/m^2) figure.

3.2 Recommended Approach to Ricefield Fish Culture Research and Development

Having assessed that the ricefield fishery is poor enough to offer the potential development of ricefield culture fisheries. There are two ways of monitoring culture fisheries developments in ricefields.

On-farm Trials

In Cambodia, rice fish culture technology is not yet fully aligned to local conditions to a point where it can be extended as a "proven package." To the author's knowledge rice fish culture in Cambodia has only begun to emerge over the last 5 years. It has yet to be adopted by farmers on a large scale and it is strongly recommended that agencies promoting rice fish culture in any of the rice ecosystems do so on an on-farm trial basis where they can closely monitor fish and rice production and the farmers attitude to this new activity. These initially should be researcher managed; field preparation and stocking of fish being closely supervised by the researcher.

Comparative On-farm Trials

Comparative trials can be done by dividing the field by a bund or bamboo screen. Plastic netting does not seem robust enough to use. In comparative trials, two pond refuges of a similar size are required. Results from even closely monitored on-farm trials are likely to be erratic as it is difficult to remove variation. For example, the part of the field furthest from human activity will be visited more often by fishing birds and rodents and fish survival rates may be lower. It is also difficult to convince farmers to treat each part of the field similarly. For example, they may remove fish for food from wherever they can catch them more easily or they may feed the fish closest to the homestead more often.

Data Collection

For both types of trial, data should be collected on the following:

Fish Harvests

Data on both cultured fish and wild fish production should be collected on a species basis. In addition to the main harvest(s) which will occur at the end of the growing season, data should also be collected on small fish harvests used for household consumption.

Fish Mortalities

Dead fish found floating in the rice field should be removed from the field and accounted for. It is rare to see this, unless pesticides have been used near to or in the rice fish field. Heads of fish predated by rodents should also be recorded by farmers.

Fish Feed Inputs

Data should be collected on fish feeds put into the field or trap ponds by the farmer. The amount of labour used in the collection of farm feeds should also be estimated.

Rice Production

If possible, rice production from rice fish culture fields should be compared to adjacent fields without fish, to establish if the presence of fish has any positive or negative effects on rice production.

Pest and Beneficial Insect Populations

Regular sampling of rice fields for both beneficial insects and pests should be carried out to establish whether fish are assisting in pest control or otherwise affecting pest predator ratios.

Labour Issues

Additional labour required for the management of rice fish systems should be looked for as these can be significant, particularly in respect of pond/field preparation, guarding of the stock, irrigation and the collection of on farm feeds.

Field Hydrology

Water depth in the ricefield should be collected over the culture period. Shallow waters can be expected to cause slow/no fish growth, so periods of near drought conditions should be identified and used in the analysis of results. Water depth can also used to explain water quality fluctuations.

Natural Foods for Fish

Regular sampling of zooplankton and benthic organisms can be done throughout the fish culture cycle. Populations of these invertebrates tend to fluctuate wildly at different times during the culture period. Shading by the plant allows little phytoplankton to develop. Epiphytes growing on the stems of rice plants may also be important sources of fish feed.

Field Fertilisation

Both organic and inorganic fertiliser use by the farmer should be recorded as this may have an affect on fish culture. Some feeds fed to fish, such as rice bran may act as fertilisers once they have been partially digested by the fish. Quantifying organic fertiliser use is difficult on a kg basis and should be extrapolated from the number of baskets used, once a basket has been weighed.

Weeding

Cultured fish have a role in controlling the softer weeds found in the ricefield. This can result in reduced labour, required for weeding. Whilst difficult to quantify, a lower than normal number of times the farmer has to weed a plot is an indicator of the degree that fish are suppressing weeds.

Water Quality

Water quality will greatly affect the performance of the fish. Table 7 suggests acceptable ranges for Common Carp.

Table 7: Water Quality Parameters for Cultured Fish in Ricefields

Parameter	Minimum	Maximum	Optimum	Comments
pH	5	10	7	pH can be corrected by lime when fish are not in the field.
Susp. Solids (mg/l)	0	10,000	0	Water tends to clear as rice plant becomes established.
Temperature ^{0}C	12	35	25	Rice plants provide good shading when well established.
Oxygen (mg/l)	1.5	5	9	High organic matter content will result in deoxygenation.
Ammonia (mg/l)	0	30	0	General low pH in ricefields results in little toxic UIA[3].
Hardness (mg/l $CaCo_3$)	20	500	250	Liming will increase hardness levels.
Alkalinity (mg/l $CaCo_3$	20	500	250	Liming will increase alkalinity.

Table adapted from BAFRU, 1990.

Farmers Observations

Farmers co-operating with trials should be encouraged to make their own observations and record them. Such observations are often behavioural; e.g. the fish move out of the refuge into the field at night; or socio-economic, e.g. we don't have to buy fish at the moment like we usually do.

UIA Un-ionised Ammonia

3.3 The Adoption of Rice Fish Culture

It is difficult to determine farmer adoption rates unless one looks over a long period of time. Farmers may choose to do rice fish culture in some years when hydrological conditions are suitable, when they predict that wild ricefield fish populations may be poor, or when they have the money to invest.

Once rice fish culture begins to develop in an area. It may be desirable to measure the extent that the new technology spreads and how farmers change the technology originally extended or used in the on-farm trials. This is difficult to achieve as rice fish culture plots are difficult to distinguish from plots without fish. One of the simplest ways to achieve this is to visit the producers or transporters of fish seed for the area studied as these informants may have intimate knowledge of where their fish have gone. Farmers who co-operate with researchers in on-farm trials should be watched closely to see how they modify the researchers ideas. Experience from Svay Rieng have shown that some farmers will dis-integrate their rice fish systems and turn the whole area over to shallow pond aquaculture.

Chapter

4

QUESTIONS ON RICEFIELD FISH IN CAMBODIA

This section attempts to answer twenty-two common questions raised about fish and other aquatic animals in ricefields in Cambodia. More detailed information can be found in the previous chapters.

1) What exactly do we mean by capture and culture ricefield fisheries?

The table below highlights the major management differences between capture and culture ricefield fisheries.

Table 8: Major differences between capture and culture ricefield fisheries

Management	Capture Fisheries	Culture Fisheries
Ricefield prepared before fish arrive	No	Yes
Fish fingerlings stocked	No	Yes
Feed provided to the fish	Rare	Yes
Materials used to attract fish	Yes	No
Water impounded by high bunds	No	Yes
Cash Investment required	No	Yes

2) What wild animal products do farmers collect from ricefields?

In Cambodia, 39 species of wild fish have so far been recorded as being collected by farmers from ricefields for food, making it one of the most diverse ricefield fisheries in Asia. The five most common fish species found in ricefields are Snakehead, (*Channa striatus*) Catfish, (*Clarias macrocephalus*) Climbing Perch, (*Anabas testudineus*) Spiny Eels, (*Mastacembelus spp.)* and Danios, (*Rasbora spp.)* In addition to fish, other aquatic and semi-aquatic animals such as shrimps, frogs, crabs, snakes, wading birds, insects and field rats are also collected for food or sale.

3) What are black fish and white fish?

The fish which inhabit Cambodia's ricefields can be broadly classified by two types; **white fishes**, which are small herbivorous or planktivorous cyprinid species and **black fishes** which are mostly carnivorous, air breathers able to survive in low, (no) dissolved oxygen situations. All black fish species have dark coloration and small scales. Examples include Snakehead and Catfish. Many of the black fishes exhibit parental care by both or one of the parents and so produce fewer, larger eggs. Under confined conditions black fish juveniles will often exhibit cannibalistic tendencies. White fishes tend to show no parental care after egg laying and the females produce vast numbers of eggs relative to their body weight. The white fishes usually have larger plate like scales usually giving them a shiny appearance. In natural ricefield fisheries, the black fishes are the most desirable and usually the most economically important. They are usually considered more tasty than herbivorous and omnivorous fish species. In addition, the black fishes can stay alive under market conditions for extended periods, (>1 week) so their fresh market price can be maintained for a long time. In culture fisheries, white fishes are raised due to their good utilisation of low grade feeds and their inability to traverse over-land.

4) How important are these products to the nutrition of rice farming families?

Quantitative data on this issue is extremely limited. One study carried out in a fish rich area of Svay Rieng suggests that animal products gathered from in and around ricefields were far more nutritionally important to the communities than the rice itself. Families monitored were selling fish to buy rice in this poor rice growing area and sales of fish were the biggest cash earner for the families concerned. The relative value of fish in more productive rice growing areas is likely to be less; although that said, it is hard to find a lowland rice farmer in Cambodia who does not collect fish and/or other aquatic products from ricefields at some time of the year. In 1993 and 1994 a survey of 5 provinces, (585 households) by UNICEF found that 87.5% of households interviewed, foraged for fish, crabs, shrimp, snails, frogs or green leaves. It is likely that much of this gathering would have occurred in and around ricefields.

5) Which is the most important type of rice growing area for fish?

The lowland rainfed ricefield is probably the most important of the five rice ecosystems although less is known about fish production from deep water rice areas. Heavy pesticide use in irrigated and recession rice areas in Cambodia lessens the importance of the natural ricefield fishery although the more reliable water sources do offer scope for fish culture development in these areas. IPM programmes aimed at reducing pesticide use by farmers, can promote fish culture as a way to wean farmers away from pesticide use and abuse. In these cases a fish harvest can compensate for decreased rice production through pest damage. True upland ricefields would seem to offer little scope for a ricefield fishery, as water is not impounded by bunds, however other animals such as frogs may be collected from the fields by farmers.

6) What lessons on management can be learned from other Asian countries?

Unfortunately, (in the authors experience) there appear to be no examples, of agriculture policy taking into account natural ricefield fisheries in other areas of Asia. The general trend of intensification of rice production with associated chemical use and encroachment on swamplands tends to result in the decline of the productivity of natural ricefield fisheries. A good example of this is occurred in the Central Plains of Thailand in the 1970's where a prolific ricefield fishery declined drastically in the wake of efforts to intensify rice productivity. Aquaculture was able to make up for this but not equitably, as it tended to favour better off farmers who could afford the on-farm investment required to dig ponds and the associated risks. Most Governments appear to have waited until the ricefield fisheries have been badly damaged and then promoted aquaculture as a compensatory measure. Cambodia presents, perhaps the last opportunity in Asia to approach this problem in a more holistic way as traditional rice farming practices still allow for healthy ricefield fisheries in many areas. As Cambodian agriculture develops and intensifies the chance does exist to make rice productivity gains and keep the ricefield fisheries largely intact.

The culture of fish in lowland ricefields is a well established practice in some SE Asian countries such as Indonesia and NE Thailand. In other countries, such as the Philippines, farmers have not adopted the practice in any numbers despite considerable development effort. Even within a country rice fish culture may take off in some areas and not others. For example, in Indonesia rice fish culture has developed considerably in West Java, but much less so in other areas. Little *et al* (1996) comment that in some cases, rice fish culture has been more favoured by researchers than by farmers. It remains to be seen on what scale, Cambodian farmers adopt this practice in the long term.

7) Where does the ricefield fishery start and where does it end?

This is difficult question to answer and depends on the nature of the wet season and local hydrological conditions. In wet years, migrations of riverine and lucustrine fish species onto the floodplain and thus the ricefields occurs, e.g. *Notopterus spp.*. Swamp fishes may move freely from swamp to ricefield and back as water conditions allow. The surprising mobility of these fish ensures their widest possible distribution. Fish which have done most of their growing in ricefields may end up in canals or ponds once the water has receded from the ricefields. These more permanent water bodies must therefore also be considered part of the ricefield fishery. Guttman's conceptualised diagram on page 7 illustrates this.

With ricefield culture fisheries, the culture system usually includes a pond or a deeper refuge area where no rice is grown. This is necessary to safeguard the stock in case of low water conditions in the ricefield. Cultured fish species will move freely from the deeper refuge to the ricefield as they choose.

8) Why do ricefields make good fish environments?

The conditions created to enhance rice production can be well exploited by a number of fish species, in particular the swamp fish species, sometimes referred to as the black fishes. These fish have evolved to proliferate in environments with severe hydrological extremes and periodic low dissolved oxygen. The alternative flooding and drought conditions which typify rainfed lowland rice ecosystems are an easy adjustment for them to make. The shallow waters and substrate areas of ricefields also provide important food niches, (detritus, epiphytes, zooplankton, small fish, insects), for a wide range of natural and cultured fish.

9) Where do natural ricefield fish come from?

It is quite remarkable how quickly ricefield fish can repopulate areas following inundation. As mentioned earlier, many fish or their young originate in nearby perennial water bodies and invade the ricefields when water conditions allow. Many of the fish species have evolved for their spawning to be triggered by meteorological or hydrological conditions, as the first fish to get on the new floodplain have an advantage over their peers. The small cyprinids such as *Rasbora spp.* seem to arrive first but the more predatory species such as Snakehead, Clarias Catfish and Anabantids will never be far behind. The Cambodian name for one of the most common *Rasbora spp.*, (Changva Pleaung) found in ricefields, describes their nature well. With the first rains, swarms of Snakehead fry, protected by the male Snakehead can often be seen in ponds where they are nursed until they leave the pond and invade the ricefields when hydrological conditions allow. This race onto the floodplain and into the ricefields is an on-going evolutionary contest.

10) When do farmers collect fish and other aquatic animals from ricefields?

The collection of fish and aquatic animals takes place throughout the year in lowland rice growing areas but some seasons are more important than others. With the first rains, fish leaving dry season refuges and moving onto the floodplain are trapped by rice farmers. Small frogs can also be collected in abundance as soon as there is any standing water in the ricefields. During the peak of the rains, fish are caught in bamboo or net traps as they move from field to field. Hunting at night with torches and spears also produces large fish and frogs at this time of year. The most important fishing time for ricefield fish is at the end of the wet season when the wind changes and air and water temperatures drop. This seems to be a signal for the fish to start to migrate back to find dry season refuges. At this time they can be caught in large numbers in traps, shallow depressions, nets etc. This back migration seems clearly linked to wind strength. A trap which will be full of fish on a windy night/morning will be virtually empty of fish on a calm morning. Children are often involved in catching the last fish from the small depressions left in the ricefields before the fields dry up completely. The dry season refuges such as canals, trap ponds and swamps are then targeted and the water pumped out and the fish harvested. Surprisingly the fields at their driest can still yield frogs, crabs and eels for farmers who dig them out from their burrows.

11) So should farmers capture or culture fish in ricefields?

In Cambodia this appears to depend on local topography and hydrology. If the ricefield fishery is a productive one then there would seem to be nothing to be gained by farmers switching to fish culture. Wild fish are a low input, high priced output. There is also little doubt that Cambodian people prefer wild fish such as Snakehead to cultured fish, such as Tilapia. Traditional cooking, and preserving methods have developed by using these fish and may not be fully suited to the preparation of cultured fish for food. If farmers cannot collect enough fish from around the farm then taking up fish culture may be worthwhile for them. For agencies involved with promoting fish culture it is important to focus effort in areas where the ricefield fisheries are inadequate to meet local demand. This handbook explains ways that the productivity of the ricefield can be assessed and how to determine whether farmers are likely to adopt fish culture if promoted. See chapter 3.

12) What do pesticides do to fish in ricefields?

Pesticides tend to have negative effects on fish in ricefields. The extent of these effects vary with fish type, pesticide type method of application, hydrological conditions and meteorological conditions. Generally speaking granular pesticides are more toxic than liquid pesticides; organochlorines and more damaging than organophosphates and cultured fish are more susceptible to pesticides than indigenous ricefield fishes. If rainfall or hydrology allows for a large dilution, then the effects of pesticides may be reduced. There is no evidence to suggest that there is any connection between the common ricefield fish disease, Epizootic Ulcerative Syndrome and pesticides.

13) What is the biggest factor affecting the productivity of wild ricefield fish?

The single most important factor affecting wild ricefield fish productivity appears to be rainfall. Long wet seasons with regular rains tend to result in greater amounts of ricefield fish being caught once the waters recede. Prolonged dry spells during the wet season can result in fish being collected at a smaller size and significant lost production potential. Short dry seasons between the two rainy seasons should mean that more fish survive in their refuges and can more quickly and thoroughly repopulate the floodplain once the rains arrive. It is also thought likely that rainfall patterns have a cumulative effect, i.e. that two very dry years are much worse than a single poor ricefield fish year whilst two or three wet years would yield increasingly higher amounts of fish.

14) Is the natural ricefield fishery over-exploited by rice farmers?

This is difficult to answer. By its nature the ricefield fishery can withstand significant fishing pressure especially on the back migration of fish at the end of the wet season. However, dry season fishing or de-watering of fish refuges and heavy pressure on the out migration from these refuges to the floodplain probably result in retarded repopulating of the ricefields and subsequently lower yields.

15) How can the ricefield fishery be conserved?

The problem facing attempts to conserve natural ricefield fisheries are two fold. Firstly, any conservation efforts make no sense if they are made on the individual farmer basis, as ricefield fisheries are a common resource. It would not benefit individuals then to manage their part of the fishery in a more considerate manner. Efforts to sustain or even improve ricefield fisheries must then be made at the community level, where self policing of activities is possible. The second problem is how to measure the effects of any conservation measures. As mentioned above, the biggest variable affecting ricefield fisheries is probably the extent of the wet season inundation. Sensible ricefield fisheries management by a community in a dry year would probably yield less fish than poor or no management by the same community in a wet year. It is in drier years though that ricefield fisheries management is most required so that fish stocks which will restart the fishery the following year are not over exploited.

16) What destructive fishing gears are used to catch ricefield fish?

Most of the traditional gears, made from bamboo or hand made nets are not considered destructive to the ricefield fishery. There are problems with some modern techniques however. The widespread availability of machined micromesh nets allows farmers to catch the young of fish which would pass freely through the spacing in traditional gears. The catching of Snakehead and Clarias fry by these gears early in the wet season is likely to be destructive. Similarly, electro-fishing of shallow water areas during the dry season may kill the fry of fish which are waiting to move on to the floodplain. Finally, the availability of water pumps have made the de-watering of water bodies less labour intensive. This is offset by the gradual change from a subsistence based activity to an income generating activity. The costs of fuel can therefore be paid for by some of the catch. Obviously, these destructive practices cannot be controlled by local fisheries authorities and restrictions on their use must come from the communities using them.

17) Do fish help control rice pests?

It would be nice to imagine fish actively hunting insect pests in the rice field and thus helping keep pest numbers down. There are many papers which suggest that this is the case. However, it can be argued that the insects that fish will come into the most frequent contact with will be the mobile ones and these are often the predatory, beneficial insect species, such as spiders, wasps. Often pests are well concealed above the water line, in and around the plant and it is difficult to see how the fish might feed on them. Whilst eggs of the golden apple snail are laid above the water line, once they hatch, the young snails will be readily consumed by a range of fish including Clarias catfish and Common Carp.

18) How do modern farming technologies affect ricefield fisheries?

Negative implications of modern rice farming include the trend of increasing pesticide use of short stemmed HYV which require less water. Practices which are unlikely to effect or may influence in a positive way include land levelling and increased fertilisation regimes. Fish culture can be a useful spin off from farmers ditching and dyking their fields as they diversify crop production away from rice; the raised bunds allowing water impoundment and reducing flooding risk.

19) Does the culture of fish increase rice yields?

Farmers culturing fish in their ricefields often get higher yields than in previous years without fish. Some scientists have suggested that this synergism is a result of improved nutrient recycling, fish controlling weeds or pests, and better soil aeration through the digging habits of some fish. Another possibility is that the farmer that has cultured fish in his fields will tend to visit that field more and may take more notice of the rice and take necessary action earlier. In addition the farmer may add more inputs in the form of fish feeds and ensure better water levels in the field. The changed management regime that results when fish are present is likely to result in higher than "normal "rice yields.

20) Should farmers culture Indigenous or Exotic Fish Species in ricefields?

Ideally, indigenous fish should be used for fish culture in ricefields. The transfer of exotic fish species for aquaculture carries serious risk for local ecosystems, through the threat of bringing new diseases, which indigenous fish may have no resistance against. There is evidence to suggest that the serious swamp fish disease, (see Q.21) spread through SE Asia as a result of the transfer of fish for aquaculture, (Lilley *et al.*) 1992. Exotic fish species may also establish feral populations which may threaten indigenous fish populations or even cause the extinction of some local fish species. As understanding grows on these issues, it is becoming increasingly difficult to justify the introduction of exotic fish species for aquaculture. However, two of the three most commonly cultured fish in ricefields; Common Carp, (*Cyprinus carpio*) and Tilapia, (*Oreochromis mossambicus* and *O. niloticus*) are not native to Cambodia, the latter being introduced in 1953, (Bardach 1959). These two species are easy to breed and raise in ricefields by small-scale farmers. No obvious indigenous fish alternatives exist although Puntius, (*Puntius gonionotus*) and Snakehead Gourami, (*Trichogastar pectoralis*), both indigenous to Cambodia, can also be grown in ricefields.

21) How serious is disease of natural ricefield fishes in Cambodia?

In 1983/84, widespread mortality of ricefield fish occurred in Cambodia. The disease which came to be known as Epizootic Ulcerative Syndrome, quickly spread throughout SE Asia and caused catastrophic losses of ricefield fish, in particular Snakehead. The causative agent appears to be the fungus Aphanomyces invaderis (Lilley *et al* 1997). Sporadic outbreaks still occur and 1997 was a particularly bad year in parts of S and SE Cambodia. The classic symptoms are red ulcers found on the head and back of the fish later developing into patches of fungus which cover large parts of the dying fish. Snakehead will often be found lying lethargically near the water surface or in shallow water areas and will be slow to move away when disturbed. No effective treatment for diseased fish is known, although the chances of fish becoming infected seem to be reduced through the addition of lime, (1 kg/m^2) to the water body. This, of course is not practical in most ricefield situations. It is now thought that the pathogenic fungus invades the muscle of fish after the fish's protective mucus has been damaged through a rapid decrease in pH, which often occurs in freshly flooded ricefields. The disease tends to come and go over the years and is not thought to have much long term effect on ricefield fish stocks. Cultured fish species, with the exception of Silver Barb do not seem to be affected by the disease.

22) How many fish can be cultured in a ricefield?

Recommended stocking rates are for three species polycultures totalling 5,000/ha or 1 fish for every 2m^2. The bias should be towards Common Carp, a bottom feeding fish which grows well in ricefields. A ratio of 2:1:1 for Common carp, Puntius and Tilapia is generally considered appropriate, (i.e. 2,500 Common Carp; 1,250 Silver Barb; 1,250 Tilapia per hectare). Large fingerlings >5 cm should be stocked to ensure adequate survival if predators are present or likely to be present.

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