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Reservoir Fishery Management and Development in Asia

Proceedings of a workshop held in Kathmandu, Nepal, 23–28 November 1987

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Proceedings of a workshop held in Kathmandu, Nepal, 23–28 November 1987

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ABSTRACT

This publication presents the results of an IDRC-funded workshop held in Kathmandu, Nepal, 23-28 November 1987. Representatives from 15 countries reviewed the status of reservoir fishery research in Asia under the following topics: existing fisheries, limnological aspects, biological and resource aspects, management aspects, and culture. Papers were presented on these topics, but the discussion sessions were the main element of the workshop. Summaries of these discussions as well as a series of general recommendations that were generated during the final discussion are presented in this book. The potential for increased fish production in reservoirs and the need for early involvement of fisheries scientists in the planning and preimpoundment studies before dam construction are emphasized.

RÉSUMÉ

Cet ouvrage présente les résultats d'un atelier financé par le CRDI à Katmandou, au Nepal, du 23 au 28 novembre 1987. Des représentants de 15 pays ont examiné l'etat de la recherche sur l'élevage du poisson en étangs en Asie, en particulier les aspects suivants : les systèmes actuels, les aspects limnologiques et biologiques, les ressources, la gestion et l'élevage. Des exposés ont été présentés sur ces sujets, mais les discussions ont été l'élément le plus important de l'atelier. L'ouvrage présente également un résumé des discussions ainsi que les recommendations générales issues de ces discussions. On met l'accent sur la possibilité d'augmenter la production de poissons en étangs et la nécessité pour les ichtyologistes de participer trés tôt aux études de planification, notament de la mise en étangs du poisson, qui précèdent la construction d'un barrage.

RESUMEN

Esta publicación presenta los resultados de un taller auspiciado por el CIID en Kathmandu, Nepal, del 23 al 28 noviembre de 1987. Representantes de 15 países analizaron el estado de la investigación sobre pesquería asiática en embalses desde los siguientes ángulos: pesquería existente, aspectos lomnológicos, aspectos biológicos y de recurso, aspectos de manejo y cultivo. Las ponencias versaron sobre estos temas, pero las sesiones de discusión fueron el principal elemento del taller. Este libro ofrece los resúmenes de estas discusiones, así como una serie de recomendaciones generales emanadas de ls discusión final. Se subraya el potencial para incrementar la producción pesquera en embalses y la necesidad de una participación temprana de los científicos del área en la planificación y los estudios de apropiación que anteceden a la construcción de represas.

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INTEGRATED AQUACULTURE SYSTEMS IN THE SAGULING RESERVOIR, WEST JAVA, INDONESIA

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Abstract *The use of reservoir floating net aquaculture as a planned means of resettlement for 3000 families from the Saguling and Cirata reservoirs in West Java, Indonesia, is described. Over 600 floating net units (7 m by 7 m) were operating commercially by July 1986 in the Saguling Reservoir, producing 1800 t of fish. Research with a 7 m by 7 m unit stocking common carp (Cyprinus carpio) at 71.8 g mean size and 2.4 kg/m^3 produced 1070 ± 151 kg/net in 90 days, with a net profit of IDR 270,000 and a benefit-cost ratio (BCR) of 1.1 (in January 1986, 1 United States dollar (USD) = 1130 Indonesian rupiah (IDR); in September 1986, IDR devalued from 1130 to 1640 per 1 USD). It was noted that the growth rates of common carp slowed toward the end of the culture period; this likely was due to overstocking the unit. A 9 m by 9 m unit was tested at 0.5 kg/m^3 and produced 975.6 kg in 90 days, with a net profit of IDR 655,200 and a BCR of 2.2. Mean food-conversion ratios were 2.3 for the 7 m by 7 m unit and 1.2 for the 9 m by 9 m unit. Large savings in seed and feed costs, the two largest operating costs in floating net aquaculture were realized. Low-cost cages 17-17.5 m^3 in size were developed to stimulate subsistence protein production. Cages stocked with common carp at a mean size of 70.8 g produced 147.3 ± 20.5 kg in 90 days. It is calculated that the protein production of a single cage is sufficient to supply 61% of the protein needs of a family of five persons for 1 year.*

A planned program of aquaculture and fisheries development at the reservoir-engineering phase can assist in meeting the goal of large-scale resettlement, which is an inevitable consequence of impoundment. The potential importance of using reservoirs for expanding food production and employment opportunities is particularly apparent in Asia where the rate of new reservoir development is increasing dramatically (Fernando 1984) and fish is the major source of animal protein (Edwards 1983).

Two new reservoirs in West Java, Indonesia, are the subject of a comprehensive program to develop agriaquaculture and fisheries

activities as a planned means of large-scale resettlement for 3000 families from the innundated areas. The resettlement scheme is the direct result of recommendations and research from 1979 to 1986. The reports from the Institute of Ecology (IOE), Padjadjaran University, Bandung, Indonesia (IOE 1979, 1980) detail criteria for a reservoir resettlement program whose primary target group is the displaced peasants and whose aim is to reduce population pressure on the land by making full use of the new water resource through a planned program of agriaquaculture and fisheries development. IOE also developed a plan for an integrated aquaculture and fisheries industry that could provide employment to the displaced population (IOE 1981, 1982).

In 1986, a program was initiated by IOE and the International Centre for Living Aquatic Resources Management (ICLARM) to assist the West Java Fisheries Agency (Dinas Perikanan Propinsi Jawa Barat) in the rapid development of agriaquaculture and fisheries as a resettlement option for displaced families from the Saguling Reservoir and from another downstream Citarum River reservoir (to be filled by February 1988), the Cirata Reservoir (Costa-Pierce and Soemarwoto 1987). This program is funded entirely by the Indonesian State Electric Company (PLN) as part of the loan package from the World Bank for dam construction at Cirata. The IOE/ICLARM program, in cooperation with the West Java Fisheries Agency and directed by PLN, is training 3000 families in low-cost fisheries and aquaculture methods using pilot demonstration projects, conducting research to improve existing systems, and developing a comprehensive management plan in fisheries and agriaquaculture for the Saguling and Cirata reservoirs. In addition, using the previous studies of IOE as a basis, the project is conducting marketing, sociocultural, economic, and environmental studies to support the objective of employing 3000 families in fisheries and aquaculture by 1990.

Reservoir Aquaculture Development in West Java

On the recommendations of IOE, the potential of floating nets as a support system for large-scale resettlement was evaluated at Lido Lake near Bogor in 1982 (Djajadiredja et al. 1982) and at the Jatiluhur Reservoir (Lake Juanda) in 1983. Experiments at Jatiluhur by the Research Institute for Inland Fisheries (RIIF) concluded that a "family unit" consisting of 75-m^2 grow-out and 27-m^2 nursery floating nets could produce an average of 1071 kg of common carp in 4 months. The annual income of such a family unit was estimated at USD 1200 and the internal rate of return was estimated at 36%, for a payback period of approximately 3 years (RIIF 1983). During the experiments at Jatiluhur, 20 residents of the Saguling Reservoir region were trained in aquaculture by RIIF. Some of these first trainees became the pioneers of aquaculture in Saguling when the reservoir was filled in 1985.

Research and training was also conducted by a team of Indonesian scientists from the Lembaga Penelitian (Research Institute) of Padjadjaran University (LPPU) from October 1985 to January 1986. In the research, 1.0-1.3 t/net of common carp was harvested in 3 months, for a net monthly profit of IDR 178,612/net (LPPU 1986) (in January 1986, 1 United States dollar [USD] = 1,130 Indonesian rupiah [IDR]). The LPPU team estimated total capital costs (including labour) for a 7 x 7 x 3 m floating net at IDR 402,200 and operating costs for a

3-month grow-out period at IDR 1,152,000. Furthermore, successful experiments with floating nets were conducted at the Saguling Reservoir after innundation by the West Java Fisheries Agency. These results were directly transferred to prospective and new fish farmers through a new fisheries extension service created by the West Java Fisheries Agency especially for Saguling and Cirata, the Unit Pelaksanaan Teknis (UPT).

Saguling reached its mean high water level in February 1985. By July 1987, over 700 producing aquaculture units were present in the reservoir, consisting of floating net cages, pen systems, and small-scale hatcheries (Fig. 1). Over 300 families are now employed in reservoir aquaculture at Saguling. The number of pen and small hatchery units has remained relatively stable over the past year; however, the number of bamboo cage systems has declined because of the increased popularity of the floating net systems. Although a wide range of systems, unit sizes, and culture practices occur, the most popular system to date is the 7 x 7 m floating net (Fig. 2). In a 1986 survey, 79% of Saguling fish farmers had only one 49-m^2 net that produced a median yield in 75 days of 755 kg (Table 1). The number of floating net systems has been steadily increasing in Saguling, and fish production has now reached an annual capacity of over 1800 t (assuming an annual production of 3 t/net). Fish farmers in Saguling currently culture common carp (Cyprinus carpio) exclusively because it is the most preferred fish of the Sundanese people of West Java.

With the assistance of UPT, fish farmers have formed an association to deal with their common problems of access to credit, problems of marketing, and costs and availabilities of seedstock and feed. With respect to credit availability, two innovative credit schemes now exist. The UPT-initiated scheme has groups of farmers investing 25% of their profits, through the village bank, to assist new fish farmers. The IOE/ICLARM-initiated scheme is derived from the highly successful "Trickle-Up Program" (TUP, 54 Riverside Drive, New York, NY, USA). In addition to these credit programs, Bank Rakyat Indonesia (BRI) provides loans to new fish farmers. BRI initiated its program after the repayment of initial loans made to Saguling fish farmers in 1985 and after a favourable analysis of the profit potential of future aquaculture development in Saguling.

Reservoir Aquaculture Research

The cooperative IOE/ICLARM project has conducted a series of controlled yield trials that first used conventional stocking densities, feeding rates, and fish sizes to replicate the results of the commercial farmers. In one trial using the current commercial model, four replicate 7 x 7 m floating nets were stocked at 2.4 kg/m^3 with common carp averaging 71.8 g. Fish were fed a commercial 24% protein feed (Comfeed, Cirebon, Indonesia) at 3% body weight three times daily. Feeding rates were adjusted biweekly when samplings to determine fish growth rates were accomplished. The floating nets produced 1070 ± 151 kg/net (mean ± SD) after 90 days (Table 2).

Fish growth rates dropped markedly toward the end of the culture periods in all the unites. This was believed to be due to excessive stocking. Therefore, a preliminary yield trial was conducted in one floating net using a lower stocking density. A stocking density of

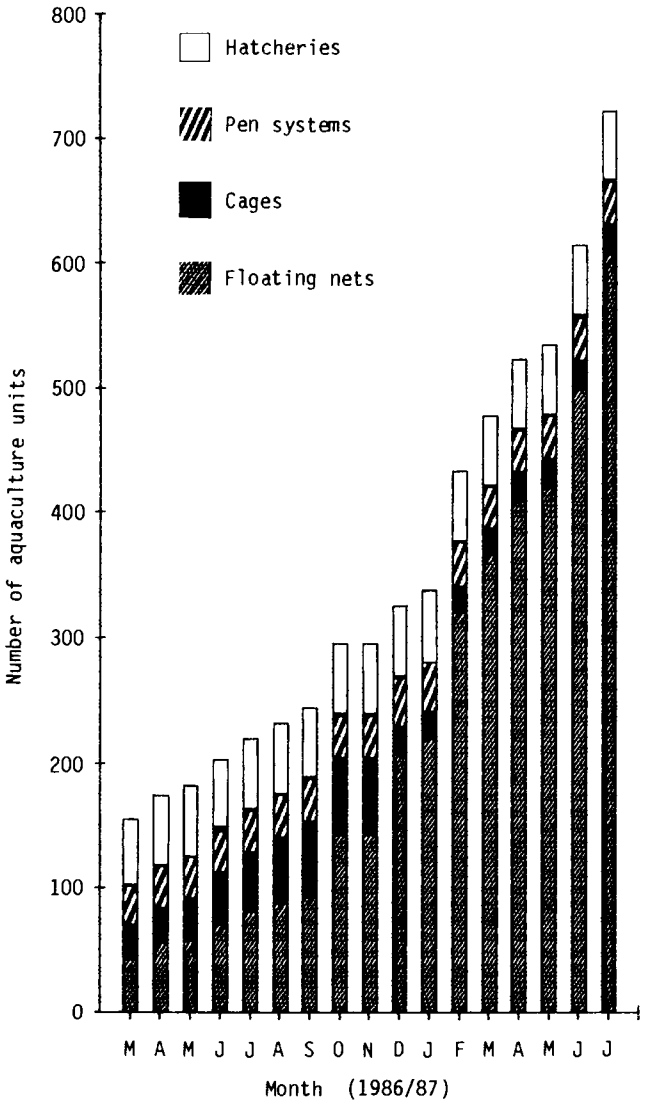

Fig. 1. Aquaculture development in the Saguling Reservoir during 1986/87.

0.5 kg/m^3 of common carp averaging 63 g was used in a 9 x 9 m net; this is 1/3 to 1/16 lower than the density now used by fish farmers in Saguling (see Table 1). After 90 days, the total yield was 976 kg/net (Table 2). This yield is not significantly different (t-test, $p > 0.05$) from the mean yield obtained with 7 x 7 m nets (Table 2). With the 9 x 9 m nets, however, there was a 67% savings in the amount of seed fish and a 50% savings in the amount feed used.

The total cost of the 9 x 9 m net was IDR 486,600 (in September 1986, IDR devalued from 1,130 to 1,640 per 1 USD). For the 7 x 7 m

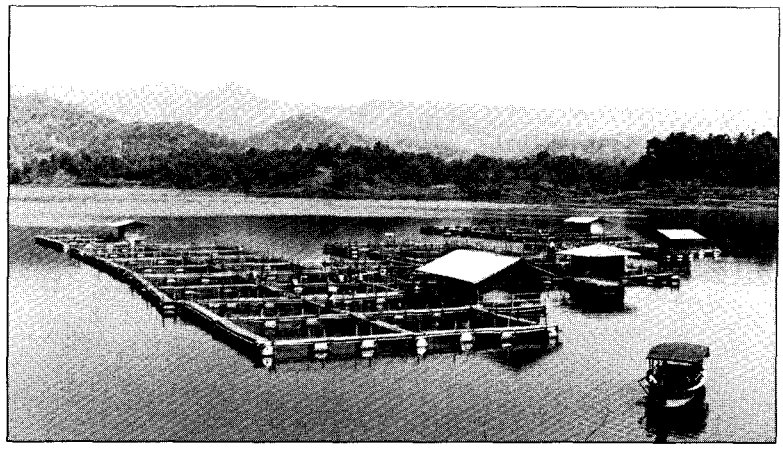

Fig. 2. Floating net aquaculture system used in the Saguling Reservoir, West Java, Indonesia.

Table 1. Biotechnical survey of floating net aquaculture systems in the Saguling Reservoir.

Parameter	Range	Median
Unit size (m^2)	16-2227	49
Stocking rate (kg/m^3)	1.8-8.2	5.8
Culture period (d)	30-150	75
Fish yield (kg/net per culture period)	180-1800	755
Fish growth (kg/net per day)	5-22	11
Total FCR[a]	0.5-2.6	1.5

Source: Kusnadi (1986).

[a]Total food-conversion ratio (FCR) equals the total dry weight (kilograms) of commercial fish feed (Comfeed) given during the culture period divided by the total wet weight (kilograms) of fish harvested. Not included in the ratio are the weights of noncommercial feeds such as rice bran, cassava leaf, vegetable leaves, and kitchen wastes (primarily cooked rice) given to the fish during the culture period.

floating net, the total cost was IDR 331,000. A preliminary economic analysis of the large floating net stocked at 0.5 kg/m^3 showed a net profit of IDR 655,200 and a benefit-cost ratio (BCR) of 2.2. For the conventionally sized (7 x 7 m) and stocked (2.4 kg/m^3) over the same 90-day culture period, there was a net profit of IDR 270,000 and a BCR of 1.1. These preliminary results clearly indicate that further research on optimizing the carrying capacity of fish in the floating nets in the Saguling Reservoir is important. Large savings in seed and feed costs, the two largest operating costs in floating net aquaculture, are possible.

Table 2. Results of yield trials using floating nets in the Saguling Reservoir.

Parameter	9 x 9 m net	7 x 7 m nets				
		1	2	3	4	Mean ± SD
Net size (m^3)	202.5	122.5	122.5	122.5	122.5	
Trial (d)	83	90	90	90	90	
Stocking no.	1576	4170	4425	4122	4006	4181±177
Mean stocking size (g)	63.4	71.9	67.8	72.8	74.9	71.8±3.0
Total stocking weight (kg)	100.0	300.0	300.0	300.0	300.0	300.0
Initial biomass (kg/m^3)	0.5	2.4	2.4	2.4	2.4	2.4
Harvest no.	1540	4162	4316	4062	3978	4129±145
Mortality (%)	2	< 1	2	< 1	< 1	1
Mean harvest size (g)	633.5	217.4	290.6	241.7	293.6	260.8±37.5
Total yield (g)	975.6	905.0	1225.0	982.0	1168.0	1070.01±151.2
Final biomass (kg/m^3)	4.8	7.4	10.0	8.0	9.5	8.7±1.2
Total feed given (kg)	1086.4	1328.2	1806.4	2138.6	1676.3	1737.4±335.1
Net FCR[a]	1.2	2.2	1.9	3.1	1.9	2.3±0.6

[a]FCR, food-conversion ratio.

Subsistence aquaculture systems have also been tested in Saguling by the cooperative IOE/ICLARM project. Floating cages were constructed using a variety of materials (bamboo, wire, net) and stocked with common carp. Cages were located in three villages in the northern part of the Saguling Reservoir where no previous aquaculture activities existed. A trial using seven 17.0-17.5 m^3 floating cages stocked at 2.1-2.5 kg/m^3 with common carp averaging 70.8 g yielded 147.3 ± 20.5 kg/cage after approximately 90 days (Table 3).

Reservoir Fisheries Development

High reservoir aquaculture production through a program of low cost intensification can be realized of it is compared with the potential output of reservoir capture fisheries, e.g., evaluating the capture fisheries potential of the whole of the Saguling Reservoir balanced with its productive potential for aquaculture. In Indonesian reservoirs, annual fish yields range from 22 to 353 kg/ha, with a mean of 177 kg/ha (Baluyut 1983). This average annual yield would likely be the maximum that could be expected from the Saguling Reservoir and translates into a maximum productin of 991 t/year. One 7 x 7 m floating net yields approximately 1000 kg common carp in 90 days (Table 2). With three crops of common carp per year, each net has an annual productive capacity of 3 t. Therefore, the maximum annual fish yield of 991 t could be produced by just 330 7 x 7 m floating nets.

Table 3. Results of yield trials using cages in the Saguling Reservoir.

Parameter	Net			Bamboo				Mean ± SD
	Wire	1	2	1	2	3	4	
Cage size (m^3)	17.5	17.0	17.5	17.5	17.5	17.5	17.5	
Trial (d)	90	90	90	86	86	86	86	
Stocking no.	608	500	583	537	530	517	547	546±38
Mean stocking size (g)	60.8	82.0	75.0	68.9	69.8	71.6	67.6	70.8±6.6
Total weight stocked (kg)	37.0	41.0	44.0	37.0	37.0	37.0	37.0	38.6±2.8
Initial biomass (kg/m^3)	2.1	2.4	2.5	2.1	2.1	2.1	2.1	2.2±0.2
Harvest no.	586	494	565	527	510	490	522	528±36
Mortality (%)	4	1	3	2	4	5	5	3±1
Mean harvest size (g)	309.7	276.3	300.0	280.8	263.7	259.2	256.7	278.1±20.5
Total yield (kg)	181.5	136.5	169.5	148.0	134.5	127.0	134.0	147.3±20.5
Final biomass (kg/m^3)	10.4	7.8	10.0	8.5	7.7	7.3	7.6	8.5±1.2
Total feed given (kg)	262.5	215.7	250.8	192.4	188.3	190.5	201.0	214.5±30.4
Net FCR[a]	1.8	2.2	2.0	1.7	1.9	2.1	2.0	2.0±0.2

[a]FCR, food-conversion ratio.

There are now well over 600 7 x 7 m nets in the Saguling Reservoir. The IOE/ICLARM project is now assessing the available area and the carrying capacity for floating net aquaculture in the reservoir. Before innundation, it was estimated that 1% of the total area (56 ha) of Saguling would be suitable for year-round floating net aquaculture with no environmental deterioration (RIIF 1983). From water-quality data obtained by the IOE/ICLARM project (unpublished), no measurable environmental deterioration in diurnal oxygen, ammonia, nitrite, or hydrogen sulfide occur if a 7 x 7 m or 9 x 9 m net is used over a reservoir surface area of 400 m^2. Therefore, at least 1400 nets are possible in the 5600 ha Saguling Reservoir. This estimate is very close to that obtained in a recent extensive survey by Lembaga Penelitian, Padjadjaran University (LPPU 1987). With an annual fish production of 3 t/net, the annual aquaculture production of Saguling could reach over 4200 t. At present fish market prices (IDR 1500/kg), this production level would mean a gross annual income from the Saguling Reservoir of USD 3.84 million.

Production from Saguling is already having a major impact on the fish markets and the traditional aquaculture production network of West Java. IOE (1982) predicted a total annual fish demand in the Bandung Regency of 14,400 t, rising to over 16,000 t by 1985. Large fish markets exist throughout heavily populated West Java (IOE 1986) and the ability of these markets to absorb the production from Saguling is

unquestioned. In addition, the State Electric Company (PLN) and the West Java Provincial Fisheries Agency are planning to fully develop the aquaculture potentials of the new Cirata Reservoir from 1988 to 1990 and the older Jatiluhur Reservoir. If the number of floating nets in the Cirata Reservoir approaches the number forecast for the Saguling Reservoir, a minimum of 10,000 t of fish could be coming from reservoir aquaculture in West Java by the early 1990's. The Fisheries Agency and UPT are now planning to develop a fish-holding and marketing centre at the edge of the new Cirata Reservoir, which skirts the heavily traveled Bandung-Jakarta highway. This centre will assist reservoir fish farmers to directly market their products and will hopefully prevent drastic fluctuations in fish prices.

Before Saguling, the most popular, rapidly growing aquaculture production systems in the region were the running-water systems (RWS) of common carp. Some 5000 units now exist in West Java (Dinas Perikanan Propinsi, personal communication). However, because of the high capital and operating costs of this system and the advent of the floating net system in Saguling, nearly 50% of these RWS are now unstocked, understocked, or going out of business. A completely new aquaculture production network has been created in West Java (Fig. 3). Before floating nets, RWS absorbed most of the seed fish coming from rice-fish culture systems; pond aquaculture absorbed the remainder. Because the initial capital and operating costs of the floating net system are much lower than those for RWS, the floating net system is able to produce fish more cheaply. RWS fish are now selling wholesale in Bandung at IDR 1800/kg; floating net fish sell for IDR 1400-1500/kg.

The impact of reservoir aquaculture development can also be appreciated from a subsistence viewpoint. Project studies showed that seven cages (17.0-17.5 m^3) produced a mean (±SD) yield of common carp of 174.3 ± 20.5 kg/cage in 86-90 days (Table 3). Because fish are 18%

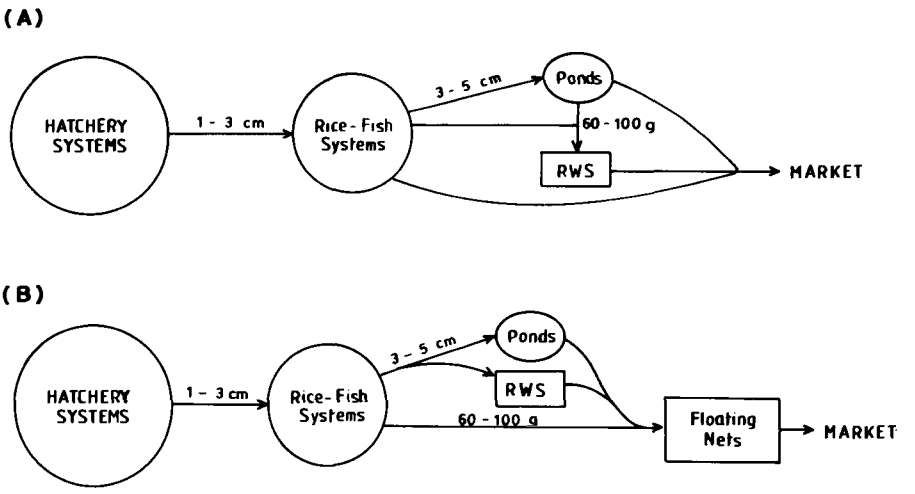

Fig. 3. Changes in freshwater aquaculture production networks in West Java: (A) network before 1985; (B) new, evolving network since 1986. RWS, running-water system.

protein and 70% edible matter (Edwards 1983) and assuming three fish crops per year, one cage produced 79.5 kg protein/year. If we assume a daily protein need of 50 g/person (Edwards 1983) and five persons per family, the total annual protein requirement of a family is 91.2 kg. Therefore, one cage can produce 61% of the total annual protein need for an average five-person family. The development of low-cost, intensive, cage systems could also play a major role in supplying protein to the rural poor displaced by dam construction.

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