Kagoshima Univ. Res. Center S. Pac. ,Occasional Papers, No. 2, 1983

A Reevaluation of Extensive Aquaculture Systems in Madura Island, East Java, Indonesia*

Hachiro HIRATA

(Faculty of Fisheries, Kagoshima University, Kagoshima, Japan 890)

Introduction

In recent years, the shift from extensive to intensive application of aquaculture methods in fish production had been advocated by many aquaculturists. Such trend is most evident in countries where production areas are severely limited or where population has tremendously increased. Many workers have utilized such intensive methods as pond aeration, supplemental feeding and multiple cropping. In Red China, the average production of 15,000 $kg \cdot ha^{-1} yr^{-1}$ was obtained utilizing aeration and the so-called multigrade conveyor system[4)]. Comparable rates have been achieved in Israel using intensive techniques as high stocking densities, automatic feeders, and pond aeration[7)].

These methods, although proven effective, may create serious problems during culture. In Japan, for example, the intensive yellowtail cage culture, employing a density of 10 ~ 15 $kg \cdot m^{-3}$, depends to a large extent on the amount of feeds being supplied daily. Certain problems such as eutrophication, resulting from accumulation of faeces and remaining feeds, induce outbreak of "red tide bloom" and disease[3)].

On the other hand, extensive methods of fish production have been widely practiced in developing countries particularly Southeast Asia. In Laguna de Bay, Philippines, the culture of milkfish in pens has adopted the traditional method since 1972. Throughout the culture period, no fertilization and supplemental feeding are done. Recently, a total net production of 25.55 $tons \cdot ha^{-1}$ was obtained from polyculture of milkfish, carps and tilapia at an initial stocking density of 66,000 $fish \cdot ha^{-1}$[(5)]. The stocking of fish was coincided with phytoplankton and zooplankton bloom which naturally occurs in Laguna de Bay yearly.

Extensive aquaculture in marsh ponds in East Java, Indonesia, has a long history and can be traced back 600 years ago. The maximization of fish production by harnessing

---

* This work was financed by the Overseas Scientific Survey No. 5641062 from the Ministry of Education, Japan, in 1981.

these inland waters holds much promise considering the vast areas that remain untouched. According to fishery statistics, distribution rate of aquaculture yield among the total fisheries products is about 20% in weight and 50% in prices and is gradually increasing in recent years. A survey of such traditional methods have been conducted in Madura Island, Indonesia. The methods have been reevaluated from the viewpoint of aquaculture physiology and ecology.

Statistical Features of Aquaculture Products

Fisheries statistics from 1976 to 1979 in East Java Province are presented in Table 1. The average total fishery products in the province were 63,740 tons (range; 120,700 to 179,740 tons). Annual yield from aquaculture averaged 163,740 tons. Minimum and maximum yields in aquaculture were 27,262 tons and 37,114 tons in 1976 and 1979, respectively. Distribution rates of the yield were calculated at 16.1% in 1976 and 21.8% in 1979. The average rate by weight of aquaculture products among the total fisheries products was 19.6%.

In prices, the highest distribution rate of aquaculture products was 59.8% in 1978. The lowest rate was 27.9% in 1977. The average rate was calculated at 48.5%. These features only mean to show that aquaculture in East Java has played an important role in the fishing industry from the viewpoint of economics.

Table 1. Statistics of fish landing in East Java, Indonesia, from 1976 to 1979 (Data source: "Laporan Statistik Perikanan Jawa Timur" published by Dinas Perikanan Daerah Propinisi Daerah TK. I Jawa Timur, Surabaya)

Year	Weight(t) & prices (1.000 Rp)*	Fishing: Marine fish (%)	Fishing: Freshwater fish (%)	Aquaculture (%)	Total (%)
1976	Weight (t)	85,000 (70.4)	9,438 (7.8)	26,262 (21.8)	120,700 (100)
	Prices	8,159 (52.8)	849 (5.5)	6,434 (41.7)	15,442 (100)
1977	Weight	139,431 (78.9)	8,732 (4.9)	28,521 (16.1)	176,684 (100)
	Prices	16,035 (66.0)	1,464 (6.0)	6,780 (27.9)	24,279 (100)
1978	Weight	135,261 (75.4)	8,265 (4.6)	35,947 (20.0)	179,472 (100)
	Prices	18,956 (36.9)	1,680 (3.3)	30,673 (59.8)	51,309 (100)
1979	Weight	132,251 (74.3)	8,127 (4.6)	37.727 (21.2)	178,105 (100)
	Prices	23,084 (46.9)	1,977 (4.0)	24,177 (49.1)	49,238 (100)
Mean	Weight	122,986 (75.1)	8,641 (5.3)	32,114 (19.6)	163,740 (100)
	Prices	16,559 (47.2)	1,493 (4.3)	17,016 (48.5)	35,067 (100)

*1,000 Rp = 2.4 US$ in 1981

As a basis for comparison, statistical analyses were made to compare features common to both Java in Table 1 and Kagoshima in Table 2. The results are summarized in Table 3 and Fig. 1. In Kagoshima Prefecture, total fishery products during the period from 1976 to 1979 averaged 167,625 tons. The average yield in the prefecture resembles that in the East Java Province.

The average annual yield in aquaculture in Kagoshima Prefecture was 20,526 tons. The distribution rates in Kagoshima were estimated to be about half the rates in East Java.

Table 2. Statistics of fish landing in Kagoshima Prefecture, Japan, from 1976 to 1979 (Data source: "Norin–suisan Tokei" published by the Ministry of Agricultural–Forest–Fisheries, Tokyo)

Year	Weight(t) & prices (1,000 Yen)*	Fishing		Aquaculture	Total
		Marine fish (%)	Freshwater fish (%)	(%)	(%)
1976	Weight (t)	131,825 (87.5)	1,206 (0.8)	17,659 (11.7)	150,690 (100)
	Prices	42,245 (70.3)	365 (0.6)	17,514 (29.1)	60,124 (100)
1977	Weight	146,090 (87.2)	774 (0.5)	20,743 (12.4)	167,607 (100)
	Prices	48,776 (66.0)	323 (0.4)	24,796 (33.6)	73,895 (100)
1978	Weight	159,250 (87.6)	393 (0.2)	22,234 (12.2)	181,877 (100)
	Prices	46,652 (63.3)	331 (0.5)	26,738 (36.3)	73,721 (100)
1979	Weight	148,448 (87.2)	410 (0.2)	21,468 (12.6)	170,326 (100)
	Prices	52,328 (74.4)	- -	17,964 (25.6)	70,292 (100)
Mean	Weight	146,403 (87.3)	696 (0.4)	20,526 (12.2)	167,625 (100)
	Prices	47,500 (68.3)	340 (0.5)	21,753 (31.3)	69,508 (100)

*1,000 Yen = 4.35 US$ in 1981

Table 3. Average weight and prices of fish landing in East Java, Indonesia, and Kagoshima Prefecture, Japan, from 1976 to 1979 (Date source derived from Tables 1 and 2)

Area & (Country)	Weight(t) & Prices($)	Fishing products (%)	Aquaculture products (%)	Total products (%)
East Java (Indonesia)	Weight	131,627 (80.4)	32,114 (19.4)	163,740 (100)
	Prices	43,325 (51.5)	40,838 (48.5)	84,161 (100)
Kagoshima (Japan)	Weight	147,099 (87.8)	20,526 (12.2)	167,625 (100)
	Prices	208,104 (68.7)	94,696 (31.3)	302,730 (100)

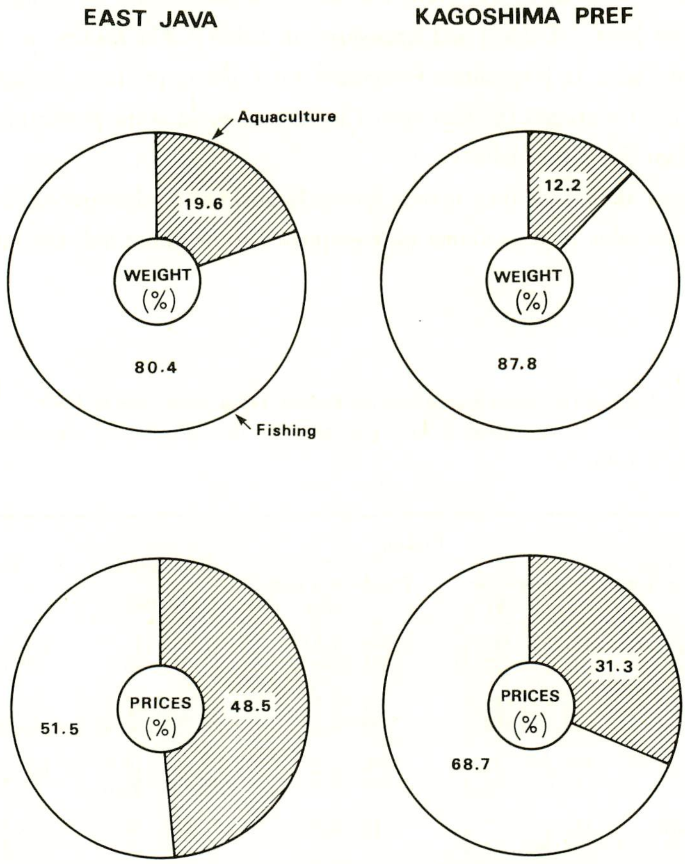

Fig. 1. Percentage of weight and price of fish landing in East Java and Kagoshima Pref.

Structure of Fish Ponds

The construction of a fish pond is typically shown in Fig. 2–a and b. Ponds are constructed along coastal area in the south coast of Madura Island. During high tides, seawater floods the water basin entrapments in between dikes or pathways. At low tides, water recedes, keeping the level of water at 1.0 ~ 1.5 m deep in the basins. Dikes are constructed by concaving the basins "A" and "B" as shown in Fig. 2–a. The size of the pond is generally 0.5 ~ 1.0 ha including the "halfway island" at the center of the pond (Fig. 2–b). The halfway island occupies more than 50% of total pond area. The islands are covered by the water during high tide and are exposed to the air during low tide.

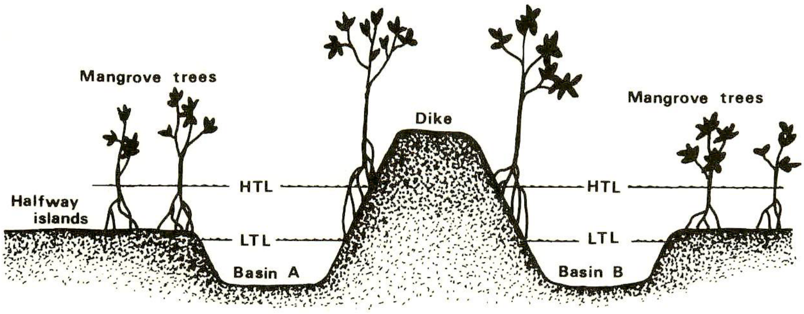

Fig. 2–a. Cross–sectional view of aquaculture pond.
(HTL: High tide level, LTL: Low tide level).

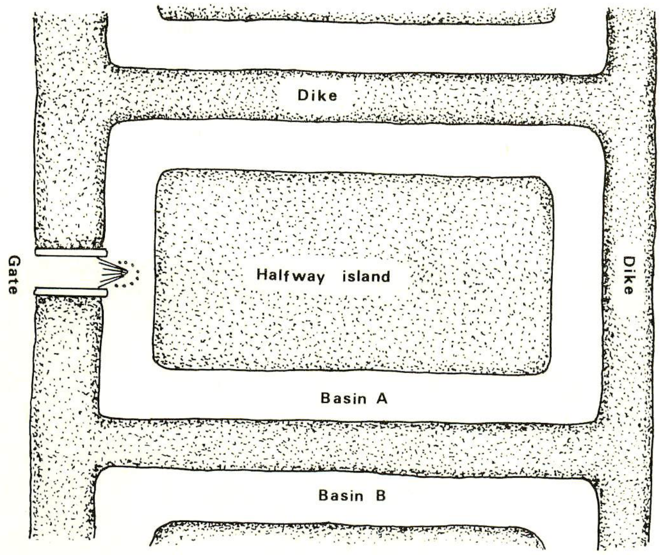

Fig. 2–b. Plane delineation of aquaculture pond.

Several types of mangroves are left growing in the halfway island, and are planted in the dikes. These trees serve three ways: 1) protection of dikes from erosion; 2) sanctuaries or "resting" area of cultured fish; and 3) source of pond nutrients from decaying leaves and seeds.

It is interesting to note that the gates of the ponds serve as one–way traps. The gates are constructed to allow water to intrude during high tide levels. The gates are protected by bamboo traps, so constructed that fish are able to enter but unable to go out. At low tides, when water recedes, entrapped fish are left in the basins. Typical examples of this gate were observed only in the west coast of Madura Island between Camplong and Bangkalan.

Biological Productivity

In a survey conducted by YAMAMOTO[7] in Southeast Asia, the average yield of milkfish in ponds varied greatly from 245 $kg \cdot ha^{-1}$ in Java, 694 $kg \cdot ha^{-1}$ in Philippines, to as high as 2,067 $kg \cdot ha^{-1}$ in Taiwan (Table 4). In this survey, however, the yield in Madura Island was estimated only at 100 ~ 120 $kg \cdot ha^{-1}$. Such variation in yield may be due to differences in culture methods adopted. In Taiwan, for example, intensive feeding using artificial diets is done. Supplemental feeding and pond fertilization are also being applied in the Philippines. In west coast of Madura Island, however, neither fertilization nor supplemental feeding is employed. Growth of fish depends entirely on the inflow of natural nutrient resources during high tides. In a study made by *SEAFDEC*[5] in a lake, Laguna de Bay, Philippines, no supplemental feeding and fertilization were done and yet a high production of 11.10 and 25.55 tons per hectare were obtained from polyculture of

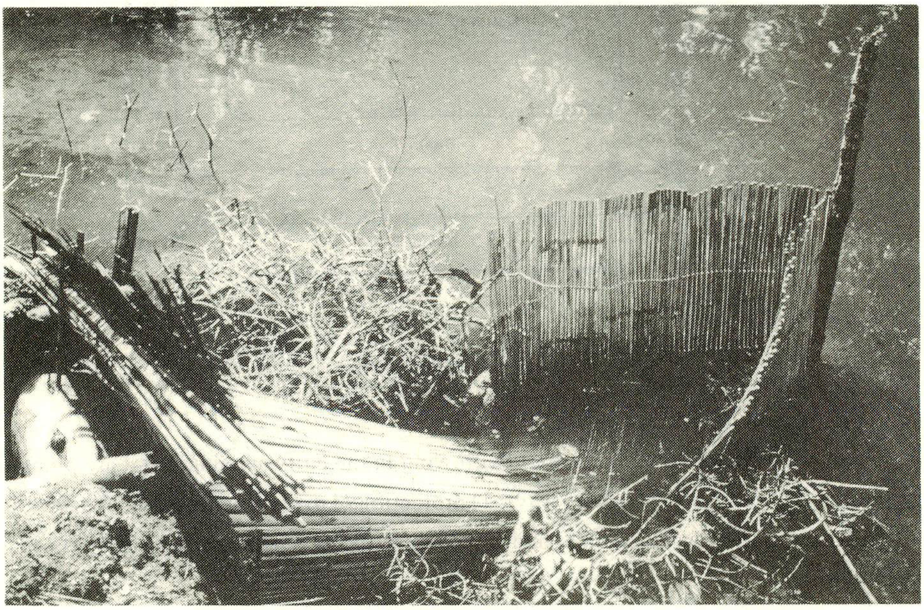

Fig. 3. Gate construction of aquaculture pond.
Fish are able to enter but unable to go out.

carps, tilapia and milkfish, and from polyculture of Chinese carps, common carp and tilapia, respectively. Such a high production was attributed to the continuous inflow of natural food through the nets, water current, and high primary and secondary productivities during the culture period.

Most aquaculture techniques in Madura Island were based on the utilization of the natural sources from the land and coastal waters. Seeds of cultured fish, *Chanos chanos*, were obtained twice a year from coastal waters. Fish larvae and plantonic diets were naturally supplied by tidal current. Several types of mangroves were left growing along dikes and halfway island as mentioned before. These trees serve as source of pond nutrients from decaying leaves and seeds. Supplemental feeds and fertilizer were not supplied into the pond in the rural areas. Predators such as crabs were trapped daily in the pond and were utilized for family and local consumption.

Table 4 presents a comparison of PO_4–P budgets in ponds employing extensive methods in Malaysia[2] and intensive methods in Norway[1]. A marked difference of -17.5 $\mu g \cdot l^{-1}$ and $+29.7$ $\mu g \cdot l^{-1}$ between the inlet and outlet of the ponds is obviously seen in extensive and intensive methods, respectively. These results are summarized in Fig. 4. Such features may well mean that in extensive methods, natural nutrients are fully utilized whereas in intensive methods, eutrophication of natural water results. Therefore, a reevaluation of extensive culture systems like those in Madura Island was deemed neccessary considering that such traditional methods have remained effective and unrivaled for nearly six centuries.

Table 4. Comparison of PO_4–P budgets in extensive and intensive culture methods which were observed in Malaysian ponds (HIRATA *et al.*, in print) and in Norwegian ponds (BERGHEIM *et al.*, 1982)

Ponds	PO_4–P (μg/l)			Cultured species (weight)
	Inlet	Outlet	Difference	
Extensive 1	16.0	3.0	−13.0	Giant Malaysian prawn
Extensive 2	24.0	2.0	−22.0	Grass carp
Mean	20.0	2.5	−17.5	
Intensive 1	10.0	21.0	+11.0	Trout (2, 260 kg)
Intensive 2	11.0	30.0	+19.0	Trout (7, 320 kg)
Intensive 3	10.0	42.0	+31.0	Trout (7, 320 kg)
Intensive 4	11.0	18.0	+ 7.0	Trout (2, 690 kg)
Intensive 5	10.0	51.0	+41.0	Trout (2, 690 kg)
Intensive 6	10.0	79.0	+69.0	Trout (5, 970 kg)
Mean	10.3	40.2	+29.7	

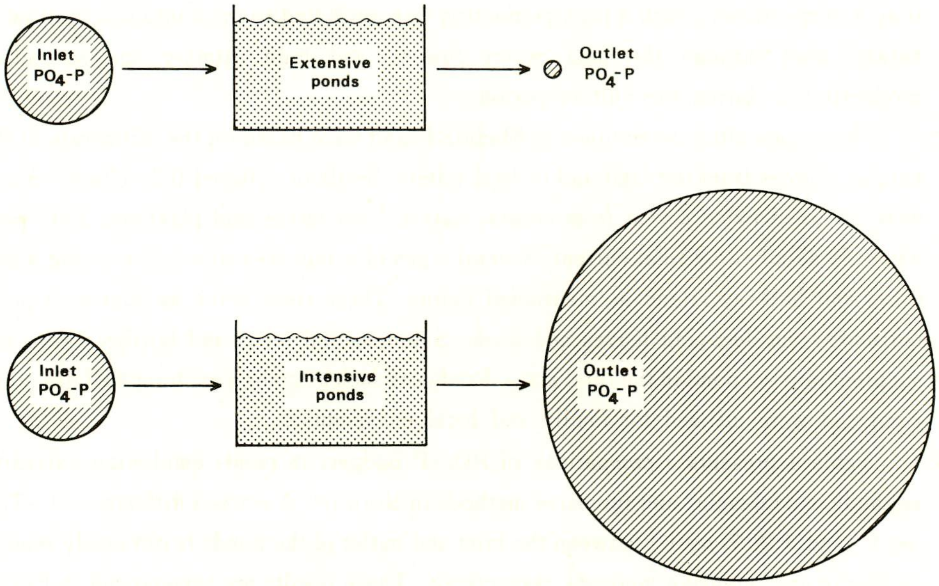

Fig. 4. Schematic diagram of PO_4–P budget in extensive and intensive ponds. (Data source: HIRATA *et al.* in print: BERGHEIM *et al.* 1982).

Summary

1) A survey of aquaculture systems in Madura Island, East Java, Indonesia, was conducted during the summer of 1981. The systems were reevaluated from the viewpoint of aquaculture physiology and were compared with other systems in world aquaculture.

2) According to fishery statistics, annual yield of aquaculture from 1976 to 1979 had an average of 163,740 tons. Distribution rate of this yield among the total fisheries products was calculated to be 19.4% in weight and 48.5% in prices, whereas in Kagoshima Prefecture the rates were 12.2% and 31.3%, respectively. These features show that aquaculture in East Java has continuously played an important role in the fisheries industry.

3) Most aquaculture techniques in Madura Island were based on the utilization of the natural sources from the land and coastal waters. Several types of mangroves serve as sources of pond nutrients from decaying leaves and their seeds. Fish larvae and planktonic diets were naturally supplied by tidal current. Predators such as crabs were trapped daily and were utilized for family and local consumption. Supplemental feeds and fertilizers were not supplied into the pond.

4) The fish ponds were constructed by digging and concaving the catchment basins. Dugged soil are then used for dike construction. The size of the ponds was generally 0.5 ~ 1.0 ha including the "halfway island" at the center of the pond. The halfway islands were submerged in water during high tides, and were exposed to the air at low tides. Mangrove trees also serve as protection of dikes from erosion and sanctuaries or "resting" area of cultured fish.

5) In Southeast Asia, the average yield of fish in ponds vary greatly from 245 $kg \cdot ha^{-1}$ in Java, 694 $kg \cdot ha^{-1}$ in Philippines, to as high as 2,067 $kg \cdot ha^{-1}$ in Taiwan. The yield in Madura Island, however, was estimated only at 100 ~ 120 $kg \cdot ha^{-1}$. Such variation may be due to differences in culture methods adopted. In Taiwan, intensive feeding using artificial diets is done. Supplemental feeding and pond fertilization are also being applied in the Philippines. In the west coast of Madura Island, however, neither fertilization nor supplemental feeding is employed.

Acknowledgements

The author wishes to thank Ir. K. MANGUNSUKARTO, Faculty of Fisheries, Bogor Agricultural University, for his help throughout the survey, and Ir. S. HARIJONO, Department of Fisheries of East Java Province, for providing the statistics data in East Java. The author also wishes to acknowledge Dr. G. KAWAMURA, Mr. S. YAMASAKI and Miss S. C. CASTRO, Faculty of Fisheries, Kagoshima University, for their assistance in the preparation of the manuscript.

References

1) BERGHEIM, A., SIVERTSEN, A. and SELMER–OLSEN, A. R. : Estimated pollution loadings from Norwegian fish farms. I. Investigations 1978 – 1979. *Aquaculture*, **28**, 347–361, (1982)

2) HIRATA, H., ORIHARA, T. and KURODA, M. : Phosphorus budget in a Malaysian fish culture ponds. *Min. Rev. Data File Fish. Res.*, **3**, (in print)

3) KUBOTA, T. : Water pollution by aquaculture in coastal farms. *Fish. Ser.*, **21**, 1–29, (Koseisha–Koseikaku, Tokyo), (1977) (in Japanese)

4) Pearl River Fisheries Research Institute : Pond fish culture in China, Guangzhou China National Bureau of Aquatic Products. 136 p. (1980)

5) SEAFDEC Binangonan Research Station: Polyculture of milkfish, carps and tilapia in pens in Laguna de Bay. *Ann. Rep.* SEAFDEC 11–18, (1980)

6) TAL, S. and ZIV. I. : Culture of exotic fishes in Israel. *Proc. Sympo. Culture. Exotic Fish., Atlanta*, 1–9, (1978)

7) YAMAMOTO, T. : A view of brackish water culture in Indonesia. *Sangyokeiei–Kenkyu*, 2, 33–57, (1982) (in Japanese)