Advances in Milkfish Biology and Culture

Aquaculture Department,
Southeast Asian Fisheries Development Center
International Development Research Centre

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PROCEEDINGS OF THE SECOND INTERNATIONAL MILKFISH AQUACULTURE CONFERENCE
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FOREWORD

Close to three quarters of a million hectares of ponds and inland waters are being utilized to culture milkfish *Chanos chanos* (Forsskal) in several Asian and Pacific countries where the milkfish industry employs over a million people. These enormous amounts of human, land, and water resources being devoted to milkfish culture underline the importance of this species to the nutrition and livelihood of many Asians and the need to understand its biological characteristics and ecological habits so that man may derive more benefits from this hardy fish. Recognizing this need, the Southeast Asian Fisheries Development Center, Aquaculture Department and the International Development Research Centre sponsored the First International Milkfish Aquaculture Conference in 1976 at Tigbauan, Iloilo, Philippines.

In 1982, the two institutions decided to make a renewed effort to summarize the state of milkfish research and to chart new research directions to solve the problems that might have emerged in the previous six years. As a consequence, the Second International Milkfish Aquaculture Conference was convened in Iloilo City, Philippines, 4-8 October 1983.

This multidisciplinary conference served as a medium for the exchange of knowledge among senior scientists and for stimulating interest in milkfish biology among younger researchers. The proceedings of this conference are a summary of the present knowledge and definition of future trends in milkfish research and culture.

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INTRODUCTION

Aquaculture has a long history in Asia, where fish and shellfish production account for about three-fourths of the world aquaculture total. A production of four million tons makes Asia the center of fish culture activities in the world. A five- to ten-fold increase over this already impressive figure is technically feasible if production technology can achieve a broader scientific base.

One species that contributes significantly to overall aquaculture fish production in Asia is the milkfish, *Chanos chanos* (Forsskal), easily one of the most productive brackishwater species in the world. Over a quarter of a million tons of milkfish are produced annually in Southeast Asia alone, primarily in Indonesia, the Philippines, and Taiwan. As with most fish species in Asia, production of milkfish in many areas can also be increased tremendously if advances in basic and applied research are achieved and brought to bear on nagging production problems. Furthermore, many untapped areas in the Pacific, South Asia, North Africa, the Middle East, and Central America are suitable for milkfish culture and can therefore be exploited to increase protein production to remedy rampant malnutrition.

BIOLOGY

Wild milkfish larvae are usually caught in coastal marine waters of tropical and subtropical countries when they are 18-21 days old. These are then placed in nursery ponds, where half, or about 1000 million, survive to be stocked in grow-out ponds or used as baitfish for tuna.

Milkfish meets many of the criteria for assessing the suitability of a species for aquaculture. First, it is an omnivore and does not compete with people for "trashfish," a valuable commodity in regions where protein malnutrition is widespread. Its digestive system can adapt to a variety of diets. *Second,* not only does one adult female spawn about 1-7 million eggs, but also milkfish fry are hardy and easy to collect. Thus, a few spawners can supply fry to a given collecting area, where fry can be stored and then transported with simple gear and distributed to fish farmers with minimal mortality. *Third,* because it is placed in ponds at the stage of its life when growth is geometric, milkfish grows much better than many herbivorous species. *Fourth,* because it is resistant to disease and not cannibalistic, milkfish can be stocked in relatively high densities. This suggests that, with additional inputs in terms of feed and fertilizer, the existing land areas devoted to extensive milkfish culture can support more fish by way of a semi-intensive culture system. Its tolerance of and adaptability to widely fluctuating salinities and temperatures allow milkfish culture under a wide variety of conditions. Hence, fish farmers can be assured of a reasonable harvest under conditions when other species fail to grow or even survive. *Fifth,* its hardy nature and rapid growth make milkfish an efficient feed converter.

PROBLEMS AND CONSTRAINTS

The organizers of the Second International Milkfish Aquaculture Conference (SIMAC) recognized that a thorough study of milkfish aquaculture technology involves more than the study of its biology. Problems relating to the economics of production and resource allocation as well as factors affecting demand, marketing infrastructure, marketing channels, and viability of new technology have to be considered.

To increase biological production, milkfish ponds and pens may be intensively stocked with more fingerlings, but the additional inputs (fertilizer, feeds, manpower, water, aeration) required for intensive production may not be economical because milkfish has a low market price relative to other fish species or aquaculture products. This problem is discussed in the papers describing the milkfish industry in Southeast Asia and in several countries representing the Region.

In order to solve what some perceive as a significant shortfall in the supply of wild fingerlings, especially during times of peak demand, milkfish biologists have been conducting intensive research on generating a new technology of milkfish seed production to supplement the supply of fry from the wild. One institution that has invested heavily in milkfish research, for example, maintains a sizeable number of broodstock; mature (5-year-old) milkfish are induced to spawn or spawn naturally in captivity. The fertilized eggs collected from such a spawn are then cultured to the fry stage (21 days old) in pilot hatcheries. Some of these attempts to generate a new technology are well described in two papers discussing milkfish reproduction.

The existing technologies of wild fry collection, storage, and transport, as well as that of grow-out, are in constant need of improvement. Present status and possible areas where refinement studies may be concentrated are described in succeeding papers. The behavior of milkfish fry and the problem of acid sulfate soils are given special consideration.

In practical terms, there is no major nutritional constraint to the present mode of production. Although pond fertilization is already an accepted practice and represents an advance from the more rudimentary types of pond management, the vast majority of milkfish farmers still relies mainly on natural food in ponds as the source of nutrition. This is probably the result of the twin problems of high feed cost relative to a low market price of the fish, as well as lack of a sustained and concerted effort toward feed development in the past. As long as there is a low market demand for artificial milkfish feeds, there will probably be low incentive, especially for the private sector, to develop diets specifically designed for this species. This is probably an area where research institutions are justified in taking the lead to develop diets or pursue nutritional studies in anticipation of future needs. Steps leading in this direction are summarized in the paper reviewing milkfish nutrition.

Because milkfish is cultured mainly in the tropics, it has at times been susceptible to parasites and diseases that have plagued the fish culture industry in these parts of the world. Since it can survive salinities ranging from 0 to over 100 ppt, it faces an interesting variety of disease problems, and sometimes a fish culturist can solve these problems merely by changing to a salinity that is tolerable by the host but not by the pathogenic organism. An area where pathology can help solve constraints in milkfish production is the generally low survival of fry to fingerlings during or after they have been subjected to stress due to collection, transport, and storage activities. Two papers give an overview of past studies on milkfish parasites and diseases.

The status of milkfish research in two countries with vastly difficult histories of milkfish culture is then presented. One review describes Sri Lanka's efforts to help a fledgling milkfish industry; another discusses research in the Philippines, a country where milkfish culture is centuries-old. The industries of two places that are fairly well advanced in milkfish culture, Taiwan and the Philippines, are then described.

Finally, future work in various areas of milkfish research is presented by the editors as a set of recommendations based on workshop discussions. It may be a lengthy list, but perhaps that is the status of milkfish research today: a modicum of achievements, a myriad of problems. Indeed, more investments in research are needed to increase fish seed supply, to improve growth rates, to ensure higher survival rates, and to lower production costs.

It is hoped that this volume will provide the readers with an interesting and informative overview of the biology and socio-economics of milkfish culture. Furthermore, the editors hope that these proceedings will provide avenues for regional cooperation and interdisciplinary collaboration among researchers in order to broaden the scientific base of milkfish aquaculture technology.

THE CONFERENCE

International conferences which are multidisciplinary in nature are difficult to organize. Not only do the organizers have to contend with language barriers but they also have to grapple with the problem of stimulating interest in several fields other than the participant's own. However, the distinct advantage of multidisciplinary approaches to single species problems is the plethora of views that are brought to bear on production constraints. If the conference is a success, what often emerges are recommendations that are not imprisoned in the language or conventions of one discipline.

Almost 300 scientists, administrators, farmers, and students attended the Second International Milkfish Aquaculture Conference held 4-8 October 1983 in Iloilo City, Philippines. The editors would like to think that the participants' overriding interests in milkfish biology and industry prevailed over their own personal and academic interests, and led them to participate actively in all aspects of the conference.

The Editors

SOUTHEAST ASIAN MILKFISH CULTURE: ECONOMIC STATUS AND PROSPECTS[1]

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Historically, milkfish (*Chanos chanos* Forsskal) has been the premier aquaculture product in Indonesia, the Philippines, and Taiwan. Approximately 480 000 ha of brackishwater and freshwater ponds and 30 000 ha of fishpens in these areas produce almost 285 000 t of milkfish annually. However, there are significant differences in the industry's performance among and within these places, especially in terms of yield. These differences can be explained by different factor (land, labor, capital) endowments and by the fact that producers have generally been responsive to these conditions.

In Taiwan and the Philippines, milkfish production is becoming less profitable over time. In Taiwan, per capita fish consumption has levelled off with rising per capita incomes; in the Philippines, declining real wages and inflation have reduced per capita fish consumption. In both places, brackishwater pond producers of milkfish are caught in a cost-price squeeze as input costs have increased more rapidly than market prices. Indonesian producers also face market constraints because high regional transport costs often isolate them from major market centers.

In response to declining profitability of milkfish, producers have been changing their production techniques (e. g., to polyculture with shrimps and to deep water systems) and

[1] ICLARM contribution no. 168.

shifting to the culture of other species such as tilapia that currently have greater domestic or export market potential. Although total milkfish production continues to increase, in the Philippines and Indonesia at least, milkfish's traditional share of total aquaculture production in all these places has declined quite dramatically over the last 10 years, and this trend is likely to continue.

While shifts to other more profitable techniques or species may bring higher profits to producers and lower cost protein to consumers, research and extension institutions that have been devoting much of their energies to milkfish may not be able to shift their focus quite so rapidly. The declining profitability of milkfish production in brackishwater ponds also has important implications for aquaculture development policy, because less efficient farms are likely to be driven out of the industry in the near future.

INTRODUCTION

While milkfish (*Chanos chanos* Forsskal) has for centuries been the premier aquaeulture commodity in Southeast Asia, its position is being eroded by the interplay of economic factors that are beginning to favor other species. Taiwan, the Philippines, and Indonesia have traditionally raised milkfish in brackishwater ponds, and the industry has grown over the past 400 years until the present time, when almost 500 000 ha produce almost 285 000 of milkfish annually (Table 1). In the last decade, this rearing area has also included freshwater pens in the Philippines, which have recently expanded to over 30 000 ha (Coronel 1983). While the historical growth of this substantial industry can be explained by a variety of technical, economic, institutional, and entrepreneurial dimensions that vary among the three locations, economic dimensions seem to be the prime determinants of the future prospects of the industry. Technologists may debate this point, but from our perspective as economists it appears that most of the basic technical procedures for managing brackishwater milkfish ponds have been worked out over the past few decades. Technical research, with the exception of that related to reproduction and stimulation of artificial breeding, appears to be in a refinement stage, where dramatic advances in knowledge and hence in industry growth are unlikely. Certainly there are large numbers of producers in Indonesia and the Philippines who lag behind the industry leaders in their respective countries in terms of output per hectare — we will return to this special problem of the industry later in this paper—but here we wish to draw attention to the fact that, for the most part, the industry leaders among private producers have "caught up" with the researchers and are already producing levels of output that maximize their profits, given the technology available to them. Consequently, future growth in total output from the milkfish industry, while theoretically possible from a variety of sources (e.g., technical breakthroughs, expansion in area under production, increased production from those existing producers who produce less than the economically efficient maximum), may be possible only through basic

Table 1. Milkfish production in Taiwan, the Philippines, and Indonesia.

	Total pond and pen culture[a] area (ha)	Pond and pen production (t)	Productivity of all species (kg/ha)	Milkfish as percent of total pond and pen production	Estimated milkfish production (t)
Taiwan, 1982[b]					
Brackishwater ponds	20 345	51 044	2 509	46	23 416
Freshwater ponds	17 652	117 531	6 658	5	6 104
Philippines, 1981[c]					
Brackishwater ponds	195 832	170 431	870	90[e]	153 388
Freshwater pens	25 000	56 299	2 252	99[e]	55 736
Indonesia, 1979[f]					
Brackishwater ponds	181 792	93 644	515	49	46 200
Freshwater ponds	41 300	69 359	1 679	0	0
Total/average	481 921	558 308	1 159	51	284 844

[a]Not including padi and cage culture, reservoirs, or mariculture.
[b]Source: Taiwan Fisheries Bureau (1983).
[c]Source: BFAR (1981) except where noted.
[d]Approximately 34 000 ha of fishpens were identified during an aerial survey conducted by the Laguna Lake Development Authority in 1983 (Coronel 1983). 25 000 ha is our estimate by 1981.
[e]Our estimate.
[f]Source: DGF (1981).

shifts in the economic environment in which producers or the milkfish transformation sector operate (Fig. 1). Significant economic constraints to future growth of the industry appear to be developing, however, in the form of increased competition from other species and changing consumer preferences.

Throughout these three areas of Southeast Asia, milkfish is produced almost exclusively by private producers who can be assumed to respond to the profit motive to varying degrees. Non-economic factors such as land ownership for security or social purposes may explain the behavior of some producers, but the majority seek to combine the inputs at their disposal — their land, labor, and capital — in such a way as to maximize their returns (Neal and Smith 1982). The more economically sophisticated producers, for example, will say that they are less interested in maximizing their physical yields than they are in maximizing their net economic yields. To achieve this objective, milkfish producers must take into account not only their production costs but also the likely prices that their produce will fetch in the market. The supply of inputs and the demand for the marketable product will thus influence producer decisions (Smith 1982).

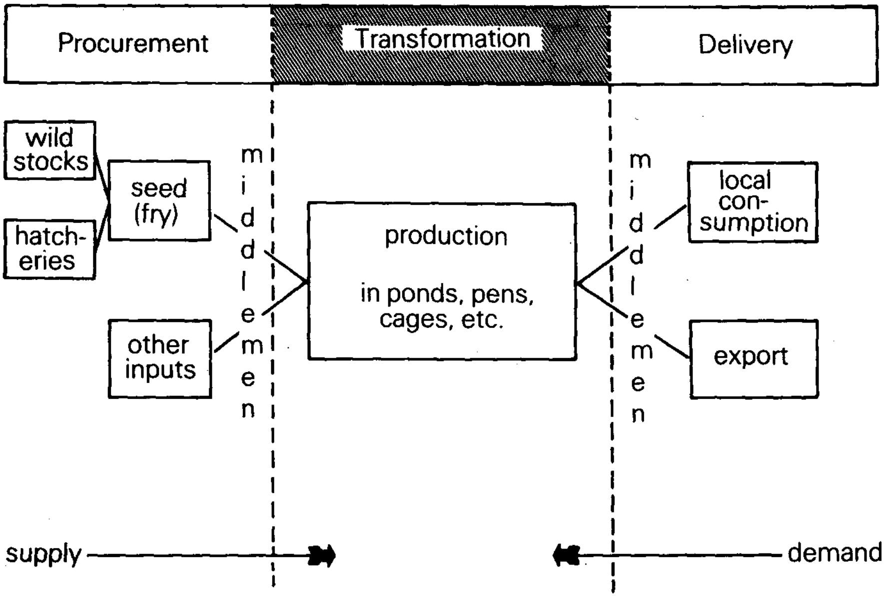

Fig. 1. The milkfish resource system (Smith 1982).

In addition to combining their inputs more efficiently, producers may also consider changing their product mix (e.g., raising *Penaeus monodon* in polyculture with milkfish) or they may switch to another species altogether. While there are certain technical constraints such as pond design, soil quality, and water salinity that circumscribe the producer's flexibility in this regard, even these can be overcome in the long term. The innovative entrepreneur can even sell his brackishwater ponds and embark on a totally new endeavor such as freshwater culture if economic conditions favor such a shift.

Traditionally, aquaculture systems, including that for milkfish, have been evaluated in terms of their production per unit area (i.e., the land input). Such evaluations can be misleading in the strictly economic sense, however, because society is primarily interested in the "value added" by any productive process. Moreover, if labor or capital is the scarce resource, and not land, it makes more sense to evaluate the milkfish industry in terms of production per labor or capital input, rather than per unit area. Relative factor (land, labor, capital) endowments will vary from one country to another and even within countries.

Ideally, then, an economic evaluation of the status and potential of the Southeast Asian milkfish industry should include an examination of (1) the availability and costs of various inputs used in milkfish production, (2) the prices of market-size milkfish, (3) the relative profitability of other activities that require the same inputs as those used by milkfish producers, (4) the supply and prices of other products with which milkfish competes in the marketplace, and (5) historical trends of milkfish output and area under production. From such information one could state with some confidence how the milkfish industry is likely to fare in the near future.

Such a comprehensive evaluation is not possible at the present time. There are two major limitations. First, reliable secondary data on inputs and output of the milkfish industry are not available in full in any of the three areas. The second impediment to adequate predictions of the potential of the milkfish industry is the paucity of sustained economic research. Most of the economic research conducted in the early and mid-1970s (Guerrero and Darrah 1974; Librero et al 1976,1977; Shang 1976a, b; Ramirez 1978; Wiratno 1978) is now out of date. More recent studies, while comprehensive, have not been followed up (Chong et al 1981, 1982; Lee 1983). There is not a single up-to-date costs and earnings study available. This is really quite shocking when one considers that the retail value of the milkfish produced in Southeast Asia probably exceeds US$200 million annually.

Nevertheless, despite the above limitations and data gaps, it is possible to draw some inferences from what information is available in each place. The data generally support our contention that the milkfish industry is likely to decline in importance relative to other aquaculture species in years to come. The following sections of this paper examine each locality in turn.

TAIWAN

The aquaculture sector in Taiwan is undergoing dynamic growth. By 1980, almost one ton in five of the total fisheries production of 936 000 t was contributed by aquaculture (Westbrook 1983, Taiwan Fisheries Bureau 1983). Despite this overall expansion, however, the relative contribution of milkfish has declined significantly (Table 2). While the aquaculture sector is thus growing rapidly, comparatively speaking the milkfish industry is not.

This decline is not due to lack of innovation on the part of Taiwanese milkfish producers. In fact, in response to declining profitability of milkfish production, producers have recently made three major shifts in brackishwater production techniques. However, in two of these cases, which continued a concentration on milk-

Table 2. Taiwan brackishwater milkfish area and production, 1965-1982[a].

	Total brackish-water and freshwater pond area (ha)	Brackish-water area (ha)	Brack-ishwater area as % of total pond area	Brackish-water pond area (ha) devoted to milkfish	Milkfish area as % of brack-ishwater area	Total pro-duction from brackish-water area (t)	Milkfish production (t)	Milkfish produc-tion as % of total produc-tion from brackish-water area
1965	20 956	15 612	74	15 612	100	29 812	27 562	92
1970	23 403	16 738	72	16 360	98	31 606	27 857	88
1975	30 124	18 115	60	16 800	93	44 652	33 490	75
1979	36 016	19 654	55	15 345	78	52 574	32 034	61
1982	37 997	20 345	54	14 563	72	51 044	23 416	46

[a]Does not include milkfish production from freshwater ponds, which was 6104 t from 651 ha in 1982.
Source: Taiwan Fisheries Bureau (1983) and earlier Fisheries Yearbooks as reported in Lee (1983).

fish, the economic "laws of supply and demand" have resulted in only short periods of increased profits. The third case, which involved shifts to species other than milkfish, has been somewhat more successful.

Lee (1983) reported that the rate of return on operating capital for the average Taiwanese milkfish farmer in 1980 was only 10%, less than the opportunity cost of capital. Shang (1976b) had reported a higher rate of 18% for 1972 but drew attention to the narrowing profit margin due to the fact that input costs were increasing faster than milkfish prices. Facing these reduced returns, three changes occurred in the industry:

(1) Many producers began raising other species such as crabs and shrimps (especially *P. monodon*) in the brackishwater ponds formerly used for milkfish.
(2) Some producers began specializing in the production of milkfish fingerlings to be used as baitfish by longliners based in Kaoshiung.
(3) Some producers began experimentation with the so-called deep water method of producing milkfish in 2-3 m deep ponds using commercial feeds and pond aeration. An increasing number of these ponds are in freshwater areas.

Certainly the first of these changes has resulted in increased profits for producers, but milkfish has not played a part in this particular change. Liu (1977), for example, reported that grass shrimp culture in Tainan and Pingtung gave considerably higher profits per hectare than did milkfish culture in the same areas.

The second of these changes provided an alternative outlet for milkfish farmers, and Lee (1983) reported that profits for these fingerling producers in 1979-80 were significantly higher than for those who continued to produce market size milkfish (Table 3). However, as Lee pointed out, due to increased fuel costs, the longliners that used the fingerlings as baitfish were reducing their fishing efforts and hence their demand for fingerlings. The market for fingerlings as baitfish was thus quickly saturated, with high profits being unsustainable over the long term.

The third and most recent change in Taiwanese milkfish farming is the most imaginative and the most expensive. By deepening brackishwater ponds from their traditional 10-30 cm depth to 2-3 m, and by using commercial feed, higher stocking rates (20 000 pieces/ha per year of 15-18 cm size), and pond aeration, average yields can be increased from the previous 2 t/ha per year to over 10 t (Chen 1981). Using this deep water method, profits could also be substantial, surpassing even those of shrimp farming (Table 4).

The potential farm income per hectare of US$770 reported by Chen (1981) is considerably higher than the US$240 reported by Lee (1983) for the traditional shallower ponds. Although published information on the deep water system of Taiwan is scanty, apparently large numbers of producers have deepened their ponds and increased their production markedly. Deep water ponds using fresh water have also been developed. Chen (1981) warned about the negative impact that increased production could have on prices, and, indeed, 2 years later, retail prices were reported to have fallen from US$4/kg in 1980 to less than US$2/kg (Westbrook 1983, Liao and Lei 1983). Based on Chen's 1981 data (Table 3), deep water milkfish producers would have experienced losses at these prices.

The inability of the Taiwanese domestic market to absorb increased production of milkfish is a major constraint to expansion of the milkfish industry. The problem

Table 3. Comparison of annual costs and returns (US$) per hectare for milkfish fingerling rearing (for baitfish) and market size rearing, 1979.

	Fingerling rearing	Market size rearing
Gross receipts	4304	2551
Variable costs		
Fry	2269	919
Feeds	69	617
Fuel	24	33
Materials	63	60
Labor	447	459
Water/electricity	27	16
Maintenance	33	—
Subtotal	2933	2104
Fixed costs		
Land rent	30	50
Interest	23	93
Taxes	18	2
Depreciation	12	66
Subtotal	83	211
Total costs	3016	2315
Residual return to owned inputs	1288	236
Rate of farm income	29.8%	9.3%

Source: Lee (1983).

of this cost-price squeeze on producers can best be shown through a comparison of prices of milkfish fry (one of the major inputs) and of market size milkfish adjusted for inflation. The real prices of fry have been increasing steadily since 1970; in comparison, the real wholesale price of market size milkfish (which closely approximates the ex-farm price) has changed little during the past decade (Fig. 2).

Why have real wholesale prices of milkfish in Taiwan not increased during the past decade? The answer appears to lie in the consumption patterns of the population. Between 1952 and 1980 there was a dramatic five-fold increase in real per capita income in Taiwan (Table 5). Until 1970, annual per capita fish consumption also increased, but since that time it has levelled off in the range of 37-39 kg. In contrast, consumption of other competing protein products such as meat, eggs, and vegetables has continued to increase. In 1977, meat consumption per capita passed fish consumption per capita for the first time. As disposable incomes have increased, total protein intake has also increased, but a consumer preference for meat over fish has emerged. Per capita consumption of fresh fatty fishes, in particular, has declined. Some experienced observers (Liao and Lei 1983) also believe that young Taiwanese do not care for bony fishes like milkfish.

During this period, Taiwanese fish exports also increased, leading to increases in producer prices for those products that were exportable in large quantities. Relatively speaking, however, milkfish is less exportable, and it appears that, as the limits of the domestic market have been reached and prices stabilized, many producers have shifted to other more profitable species.

Table 4. Comparison of financial return per annum (US$) between deep water milkfish farming and farming of shrimp *(Penaeus monodon)* from 0.1 ha in Taiwan (1981).

		Milkfish farming	
Operating costs		US$	%
Fingerlings	2000 (15-18 cm) at $0.20	400	22
Feeds	2160 kg at $0.45	972	53
Electricity		230	12
Labor		180	10
Others		63	3
	Subtotal	1845	100
Income			
Sale of fish	1176 kg (98% survival) at $2.50/kg	2940	
Gross profit		1095	
		Shrimp farming	
Operating costs		US$	%
Juveniles	12 000 at $0,015	430	28
Feeds	612 kg at $1.00	612	40
Electricity		230	15
Labor		180	12
Others		63	4
	Subtotal	1515	100
Income			
Sale of shrimp	306 kg (95% survival) at $7.75/kg	2372	
Gross profit		857	

Source: Chen (1981). Note: Although fixed costs also need to be deducted from the above gross profit figures to obtain a return to the owner's own inputs (capital, labor, and management), this table provides a useful comparison of the relative profitability of milkfish and shrimp farming, given the prices of inputs and output that prevailed at that time.

Table 5. Changes in per capita income, per capita fish consumption, and per capita consumption of other selected protein products in Taiwan, 195Z-80.

Year	Real per capita income (1976 US$)	Per capita consumption of selected protein products (kg): Fish	Meat	Eggs	Vegetables/fruits
1952	256	15.1			
1955	297	18.7	16.3	1.7	72.0
1958	324	20.7			
1960			16.2	1.6	83.0
1961	352	25.3			
1964	444	28.2			
1965			19.2	2.4	77.8
1967	533	28.7			
1970	665	34.2	25.3	4.1	130.1
1973	894	37.0			
1975			27.0	5.2	164.8
1976	987	35.3	31.6	5.9	180.5
1977	1054	35.1	35.3	6.3	179.8
1978	1157	36.5	36.1	7.6	169.3
1979	1223	38.1	40.3	7.8	194.1
1980	1252	38.7	39.6	8.0	199.7

Source: Taiwan Food Balance Sheet and Taiwan Statistical Data Book as reported in Lee (unpubl.).

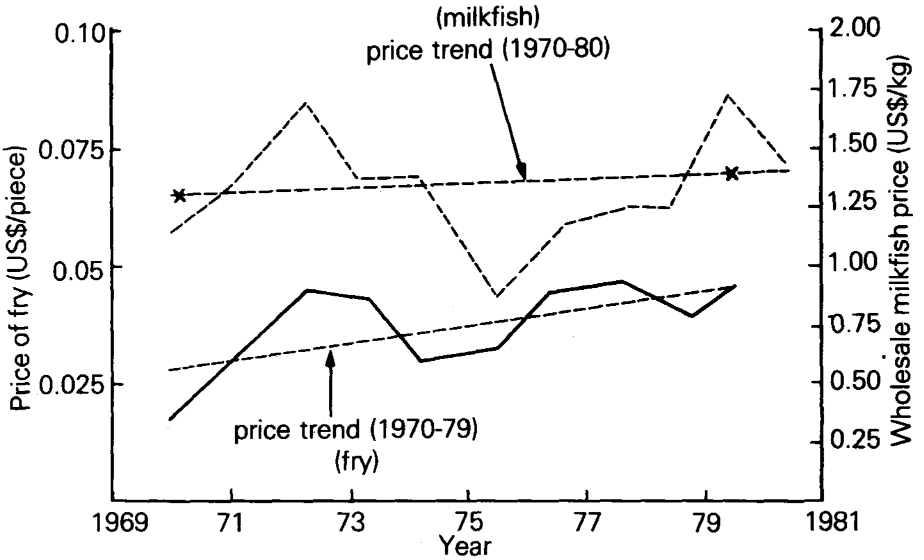

Fig. 2. Comparison of prices of milkfish fry and market size milkfish in Taiwan in constant US$ (i.e., adjusted for inflation using 1970 prices as the base year).

THE PHILIPPINES

As in Taiwan, the relative contribution of milkfish to total aquaculture production in the Philippines is declining, though in absolute terms it continues to increase. The major increases in milkfish production that have occurred in the past decade have come from the establishment of freshwater fishpens in the 90 000 ha Laguna de Bay near Manila. Steady increases in yields from brackishwater ponds are also apparent (Table 6).

Official statistics on Philippine aquaculture production and productive areas, however, are not rigorous, and industry observers are often reduced to conjecture based on qualitative assessments or, if funds are available, to expensive field surveys of producers. Several such economic surveys have been conducted during the past decade (Librero et al 1976; Chong et al 1982, 1983).

The absence of reliable secondary data on Philippine aquaculture certainly complicates research on the industry. Certain commonly held observations regarding Philippine aquaculture are worth mentioning here, however, before proceeding to an analysis of price data, which fortunately permit some assessment of the status and prospects of milkfish culture in the country.

For several centuries, milkfish was the only major cultured species in the Philippines (Herre and Mendoza 1929), and it remains the dominant species today. However, the recent rapid expansion of freshwater aquaculture, while significantly adding to the domestic fish supply, has produced competition for milkfish in local markets and has diminished milkfish's share of total production. In particular, tilapia (*Oreochromis niloticus*) has become increasingly popular with producers and consumers alike (Guerrero 1983).

Table 6. Aquaculture area, production, and yields in the Philippines, 1955-1980.

	Brackishwater			Freshwater production	
Year	Area (ha)	Production (t)	Average yield (kg/ha per yr)	Milkfish (t)	Other (t)
1955	104 952	36 734	350		
1960	123 252	60 119	488		
1965	137 251	63 198	461		
1970	168 118	96 461	574		
1973				19 204	
1975	176 032	106 461	605		
1976				47 020	
1980	176 230	135 951	771		
1982	195 832	170 431	870	55 736	17 514[a]

[a]We believe that this is almost certainly an underestimate.
Sources: BFAR (1981) and other annual fisheries statistics of the Philippines as reported in Chong et al (1982).

Philippine milkfish producers using brackishwater pond methods have for several years been complaining publicly that their profits have been declining. In the mid-1970s, Librero et al (1976) and Nicolas and Librero (1978) reported that brackishwater ponds and freshwater pens returned positive net revenues to operators (Table 7). A later study reporting on the 1978 crop year (Chong et al 1982) showed just slightly higher profits, but small farms less than 6 ha in size incurred losses in most provinces surveyed (Table 8). In the traditionally more advanced provinces (Iloilo, Pangasinan, and Bulacan) returns were still positive at that time. Unfortunately, more recent data on costs and returns are not available.

The problems of the Philippine milkfish industry are most apparent, however, in the trends of retail prices over the past decade. Market constraints have generally

Table 7. Annual costs and earnings per hectare (in pesos) of milkfish producers in the Philippines, 1974/1975 and 1978 crop years.

	Brackishwater ponds		Freshwater pens	
	1974°	1978[b]	1974[c]	1975[d]
Receipts				
Cash	2 241	4 772	19 307	18 444
Non cash	53	—	167	•3 481
Total	2 294	4 772	19 474	21 925
Expenses				
Cash	1 437	3 158	13 697	16 478
Non cash	21	236	966	4 288
Total	1 458	3 394	14 663	20 764
Net earnings (current pesos)	836	1 378	4 811	1 161
Net earnings (1974 pesos)	836	1 037	4 811	1 070

Sources: [a]Librero et al (1977).
[b]Chong et al (1982).
[c]Nicolas et al (1976).
[d]Guerrero (1975).

been ignored by researchers (e.g., PCARRD 1982). With capture fishery supplies in the country levelling off and population continuing to grow, one would expect milkfish prices to exhibit steady increases. In fact, Metro Manila retail prices for milkfish have not increased significantly since 1979 (Table 9). A similar pattern has occurred in other major market centers around the country. In real terms adjusted for inflation, Metro Manila prices in 1983 up to June were actually 21% lower than they were in 1974 and 30% lower than in 1977 and 1979. Milkfish fry and organic fertilizer prices have continued to increase, although in the absence of data their rates of increase cannot be compared with that for market size milkfish. Certainly, too, there are variations in economic viability of milkfish production in different parts of the country, but in general Philippine milkfish producers, in a manner similar to their Taiwanese counterparts, are caught in a cost-revenue squeeze with declining profits being the result.

In response to these pressures, brackishwater ponds are increasingly being used for polyculture with shrimp (*P. monodon)* and even for shrimp monoculture; shrimp, of course, have greater export market potential for Japan and, although no data are available to prove this, apparently produce higher returns for producers (but at somewhat higher risk).

There are two apparent reasons for the current decline in profits for brackishwater milkfish producers. The first has to do with increased availability of lower cost milkfish from the freshwater fishpens in Laguna de Bay and of other substitute species such as tilapia. Before Laguna de Bay became overcrowded with fishpens, yields approached 6-7 t/ha annually (Delmendo and Gedney 1974, Nicolas and Librero 1978). Growth rates, and hence annual yields, slowed as more and more of the lake was converted to fishpens (34 000 ha by 1983). But if one conservatively assumes annual yields of 1.5 t/ha, these fishpens may still have produced as much as 50 000 t of milkfish in 1982. This increased supply of milkfish and of tilapia as discussed earlier has undoubtedly contributed to the levelling off of milkfish prices in Metro Manila, with secondary effects on other regional producers, who traditionally supplied part of the Metro Manila market.

The second reason for declining profitability of brackishwater milkfish culture is related to the buying habits of consumers and their preferences. Milkfish has historically been a first-class fish in the Philippines, priced higher than many marine products. Unlike Taiwan, where per capita incomes (in real terms) have been steadily increasing, real per capita incomes in the Philippines have declined by almost 30% since 1972 (NEDA 1982) due to the high rate of inflation as measured by increases of the consumer price index (CPI). The annual per capita consumption of fish declined as a result from 38 kg in 1970 to just over 20 kg in 1980 (Fig. 3). These disturbing facts have had a special impact on the milkfish industry because demand for fish is more elastic at lower incomes than at higher incomes. In other words, a continuing fall in real per capita income will result in an even greater reduction in demand for fish, especially of the traditional first-class fish such as milkfish. Other cheaper species have and will become in greater relative demand.

Another aspect of this declining demand for milkfish is that many consumers appear to be shifting their preference toward other species, especially tilapia. In

Table 8. Annual costs and earnings per hectare (in pesos) of Philippine milkfish farms by farm size (1978).

	Small farms (<6ha)	Medium farms (6-50 ha)	Large farms (>50ha)	All farms
Revenues	3248	3757	6392	4772
Costs				
Stocking materials	444	375	712	520
Fertilizers	259	517	894	686
Pesticides	55	59	66	62
Supplementary feeds	141	52	218	167
Labor[a]	1954	1080	552	926
Miscellaneous	1101	1070	973	1033
Total	3956	3154	3415	3394
Returns[b]	(708)	603	2977	1378

[a]Hired and family labor.
[b]Return to owner inputs (land, labor, capital, and management).
Source: Chong et al (1982).

Table 9. Yearly average retail prices of milkfish (₱/kg) in Metro Manila, Philippines, 1974-1983.

	1974	1975	1976	1977[a]	1978	1979	1980	1981	1982	1983[b]	Percent change 1974-1983
Current pesos	6.45	7.14	7.26	8.97	8.84	11.46	11.98	12.90	12.92	12.25	+ 90%
Constant pesos[c]	6.45	6.60	6.32	7.24	6.63	7.23	6.42	6.39	5.58	5.09	-21%
CPI (1972=100)	152.2	164.6	174.8	188.6	202.9	241.1	284.1	335.2	352.2	366.2	

[a]January-June only.
[b]Average for first 6 months of the year.
[c]Constant peso price = current peso price deflated by the consumer price index (CPI) for all items (1972=100).
Sources: 1974-1977: Bureau of Agricultural Economics.
1978-1983: Philippine Fish Marketing Authority.

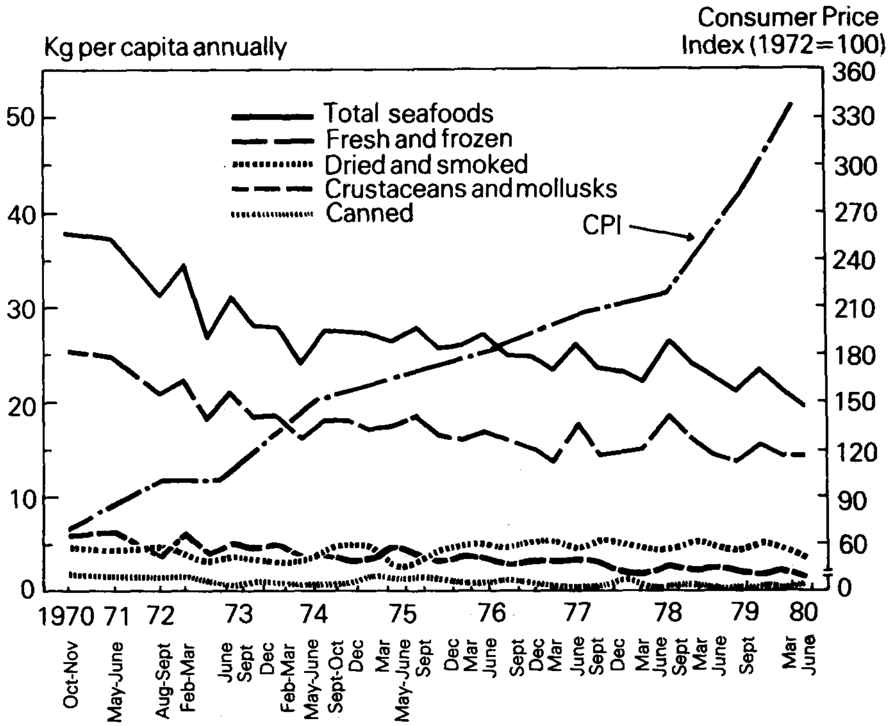

Fig. 3. Average annual per capita rates of use of seafoods and related products, 31 surveys, Philippines, 1970 to 1980. Source: Food Consumption Surveys, SSD, Ministry of Agriculture, reported in Regalado 1983.

part, this can be explained by the lower prevailing prices of tilapia (although currently tilapia sells for about the same price as milkfish in Metro Manila). Also, the recent introduction of the Nile tilapia (*O. niloticus*) has made available a fish that is increasingly attractive to consumers. Milkfish producers should be concerned that this attractiveness may result in a permanent shift in demand away from milkfish in the Philippines and a continuing constraint to further milkfish industry growth.

INDONESIA

Although Indonesia's brackishwater pond area is approximately the same as that of the Philippines, average yields (515 kg/ha per year in 1979) are only two-thirds those of the Philippines. Also, since brackishwater polyculture is more prevalent in Indonesia than elsewhere in Southeast Asia, total milkfish production is less than 50 000 t or only 40% that of the Philippines, which has an equal area of brackishwater ponds, and only 40% more than Taiwan, which has only 1/10 of the brackishwater pond area. Since 1973, the brackishwater area in Indonesia has stabilized at approximately 182 000 ha, while in contrast the freshwater area has increased by almost 37% to 42 300 ha (DGF 1981).

While milkfish production since 1973 has increased by 20%, tilapia and shrimp production have each increased at substantially higher rates (Table 10). Consequently, milkfish's share of brackishwater pond production declined from 64% in 1973 to 40% in 1979, while those of tilapia (primarily *O. mossambicus)* and crustaceans increased to 11% and 26%, respectively. As in Taiwan and the Philippines, these statistics imply a relative shift toward species other than milkfish. Despite this relative shift, however, it will be some time before these other species are able to supplant the role of milkfish in brackishwater fish culture in Indonesia.

Unlike Taiwan and the Philippines, where the changing industry pattern is already clear, the picture of the Indonesian brackishwater aquaculture industry is still emerging. Milkfish as a cultured species in brackishwater fishponds (*tambaks*) is being neglected by the *tambak* operators. Because the higher value shrimps are allowed to enter the *tambaks* to grow, *tambak* operators have not given the lower value milkfish the attention they have paid to shrimp.

This is not to say that the shrimp are given supplemental feeding or provided with other inputs to boost yield. For the naturally stocked shrimp, the major input cost is labor. Even though milkfish is artificially stocked, *tambak* operators do not generally apply the necessary production inputs such as organic and inorganic fertilizers and pesticides to increase production in spite of many government attempts to encourage them to do so.

The economic reasons for this behavior remain unclear to us (but perhaps not to the producers themselves), because there has been so little economic research on Indonesian aquaculture. We have been unable to locate a single complete costs and returns study based upon actual farm data, although some hypothetical projections have been made based upon experimental data (Cremer 1983). Partial data for 1974 and 1975 are perhaps indicative in that they show that increases in input prices such as milkfish fry, rice bran, and organic fertilizers were 100% or greater between the 2 years, while the price of market size milkfish increased by only 10% (Padlan 1979). Although no later data are available, perhaps Indonesian milkfish fanners are being caught in a cost-price squeeze similar to their Taiwanese and Philippine counterparts. More recent experience in Aceh and North Sumatra shows that farm yield and industry production increases are often accompanied by added marketing risks and falling prices due to marketing constraints (Sullivan 1981). Remote areas such as these perhaps face their biggest constraint in the marketing costs involved in shipping milkfish to major demand centers in Java.

Relative prices of the major aquaculture species give some evidence of consumer preferences. Unlike Taiwan and the Philippines, carp rather than milkfish is the favored species in Indonesia, as evidenced by its higher price (Directorate General of Fisheries, unpubl.). The milkfish retail price (Rp. 1169) was 72% of the carp retail price (Rp. 1619) in 1982. By contrast, tilapia prices were considerably lower (Table 11), especially for *O. mossambicus,* which is produced primarily in brackishwater ponds. Sullivan (1981) suggested that the primary market competition for milkfish, in Aceh at least, comes from higher priced marine species. Consequently, milkfish prices and marketability may depend upon the supply of these other species.

Table 10. Brackishwater and inland pond production (in tons) in Indonesia, 1973-1979 (milkfish and other major species).

	1973	1974	1975	1976	1977	1978	1979	Percent change 1973-1979
Brackish water ponds								
Milkfish	38 439	41 650	44 692	44 072	48 641	48 287	46 187	+ 20%
Tilapia	1 243	2 264	5 345	7 746	8 075	8 049	10 165	+ 718%
Crustaceans	9 576	11 616	9 994	14 621	21 462	21 797	24 426	+ 155%
Others	11 223	11 226	18 745	13 764	9 426	9 862	12 866	+ 15%
Subtotals	60 481	66 756	78 776	80 158	87 604	87 995	93 644	+ 55%
Inland								
Tilapia	6 491	6 128	2 616	3 115	10 327	15 477	16 441	+ 53%
Others	45 379	48 611	52 787	49 516	44 014	42 203	52 918	+ 17%
Subtotals	51 870	54 739	55 403	52 631	54 341	57 680	69 359	+ 34%

Source: DGF (1981).

Table 11. Prices (Rp/kg) for selected food items in Indonesia, 1973-1980.

Item	1973	1974	1975	1976	1977	1978	1979	1980	Average
Jakarta prices[a]									
Beef	561	812	964	1030	1179	1393	—		990
Tinned corned beef	562	786	813	885	1040	1195		—	880
Fish (*bawal*)	302	435	529	582	661	719			538
Milkfish	—	—	—	—	301	375			338
Imported sardines	439	634	650	665	787	941	—	—	686
All Indonesia prices[b]									
Brackishwater tilapia	176	88	196	147	167	176	216	304	184
Freshwater tilapia	235	255	196	265	304	265	343	559	303

[a]Statistics of Indonesia, Biro Pusat Statistik, 1977-1978 and Directorate General of Fisheries, Jakarta as cited in Sullivan (1981).
[b]DGF (1982). Freshwater tilapia consists of *Oreochromis mossambicus* and *O. nilotica,* while brackishwater tilapia is *O. mossambicus* only.

As in the Philippines and Taiwan, where changing economic forces have determined the pattern and direction milkfish producers have taken, in Indonesia until recently no major development occurred. However, with the 1981-82 ban on trawlers which exploit coastal shrimp resources, a stimulus was set in motion which may shape the future of brackishwater aquaculture in Indonesia. Already the Government has announced plans to build 200 shrimp hatcheries in various parts of the country. This government investment may encourage an even greater emphasis on shrimp over milkfish in Indonesian brackishwater farms.

Although the data are far from complete, some indications of milkfish marketability in Indonesia can be obtained from price and consumption data. Milkfish is priced lower than many other animal protein products (Table 11). Fish is also the major source of animal protein (Table 12), but the overall level of fish intake per capita (8.66 kg/yr) is well below intake levels in Taiwan and the Philippines. Though these data are only indicative, the market constraint for milkfish in Indonesia may be in the form of low effective demand, i.e., limited purchasing power of consumers. The extent of this potential problem could only be assessed if producer profitability and marketing costs were known. Certainly, too, it would vary from region to region in a country as large and diverse as Indonesia.

IMPLICATIONS FOR THE FUTURE

Based on available secondary data and previous economic studies, the preceding sections of this paper have sought to demonstrate the declining attractiveness of milkfish farming in Taiwan, the Philippines, and Indonesia relative to other species with which milkfish competes either in production or in marketing. Our emphasis on market constraints, in particular, is at variance with much previous research (including our own), which has tended to focus on production constraints (e.g., Chong et al 1983) and thus has identified credit, extension, and information dissemination bottlenecks as the primary impediments to expansion of the industry.

Milkfish is clearly no longer an infant industry in the early stages of dynamic growth. Expansion of the production area is unlikely in Southeast Asia; the pressure for alternative use of the resources required for milkfish is just too great. The fishpens in Laguna de Bay for example, have clearly overexpanded to the detriment of both milkfish growth rates and the capture fishermen who also use the lake. Fishpens are currently being dismantled by the Laguna Lake Development Authority to reduce the areas used substantially. Increased concern for conservation of remaining mangrove area holds promise of future restrictions on continued conversion of these areas to milkfish farming. Taiwan, of course, has faced high land and labor costs for many years, which explains the higher productivity per unit of land area there. With suitable milkfish producing areas becoming less readily available in the Philippines and Indonesia, consequent pressure will be put on producers in these two countries to intensify their milkfish production methods, i.e., to increase their use of non-land inputs such as fertilizer and supplementary feeds. Availability of these inputs will thus be a prime determinant of the ability of milkfish to remain the species of choice of producers.

Table 12. Per capita consumption of selected food items in Indonesia, 1977.

Item		Quantity (kg/yr)
Meat		
Cow		0.97
Buffalo		0.26
Goat		0.28
Sheep		0.09
Chicken		0.51
Pork		0.50
Other meat products		0.06
Offal		0.51
	Subtotal	3.18
Fish		
Inland freshwater fish		2.63
Marine fish		6.03
	Subtotal	8.66

Source: Food Balance Sheet in Indonesia, Agricultural Statistics, 1977 as cited in Sullivan (1981).

Milkfish production is not carried on in isolation from other sectors of national or Southeast Asian economics. The Philippines experiences highly variable availability of organic fertilizers (Chong et al 1983); the resulting high prices in some locations thus work against intensification of milkfish production methods: Another area of impact on milkfish farming comes from the recent bans on shrimp trawling in all of Indonesia (Sardjono 1981) and in the coastal waters of the Philippines. With expected reductions in the supply of shrimp from capture fishery and increased prices in the export market, shrimp farming in brackish water should become increasingly attractive. If tilapia can be successfully raised to market size in brackishwater ponds, milkfish may lose much of its current comparative advantages for the use of brackishwater rearing areas.

Certainly there is potential for making milkfish more competitive with other species through reductions in the average costs of production. For example, the Taiwanese deep water system is one way in which producers have been able to reduce their average production costs and thus increase their profits. Similar benefits to individual producers exist through increased use of supplementary inputs in the Philippines and Indonesia (Chong et al 1982, Wiratno 1978). However, market constraints apparently limit the extent to which reduction in production costs will produce marked growth in the industry.

Should this apparent levelling off of growth in the milkfish industry be of major concern? The primary interest of Southeast Asian planners and fisheries departments is to maintain or increase the supply of fish protein at reasonable return to producers. Consequently, at this level one should not expect any particular attachment to milkfish per se except perhaps as it pertains to issues of producing for domestic markets vis-à-vis export markets. Nor should the private fish fanner be expected to retain some emotional attachment to milkfish if alternative species can be raised for larger and more sustainable profits.

Institutional changes however, are likely to lag behind those changes in the production sector brought about by changing economic conditions. Large investments have been made in all three areas to support the milkfish industry. Indonesia, for example, is developing a milkfish hatchery at Gondol, Bali, while at the same time planning 200 shrimp hatcheries. If successful in supplying seed at prices competitive with naturally caught seed, each approach offers hope of benefitting brackishwater producers. At some point, however, careful assessments must be made of aquaculture investments and research projects (including artificial breeding programs) in light of current economic conditions. In particular, research institutions that have invested much in milkfish research are faced with the choice of intensifying their milkfish research so as to recover milkfish's competitive edge or of diversifying their programs to include other species. The task of transferring research results to the private sector through extension and information programs is made more difficult, too, by diversity in production systems and rapid changes in the private sector. The current situation thus presents a substantial challenge to governments and to the research community.

There are, of course, numerous courses of action. Because the declining profitability of milkfish production seems to emanate primarily from market constraints, market diversification becomes increasingly important. The Taiwanese benefits from using milkfish as baitfish have been previously mentioned; further development and promotion of "boneless *bangus*" and canned milkfish (sardine-style) in the Philippines perhaps offer similar benefits. The economic potential of these options remains to be documented, though the availability of these products in the market indicates some private sector interest.

In all three milkfish producing areas of Southeast Asia, fry and fertilizers make up the bulk of production costs. Combining these inputs with land and labor in the most cost-effective manner remains the goal of the more progressive producers in the private sector. Transmitting information on economically viable options to the private sector, in our view, is one of the greatest needs of the milkfish industry at the present time. The research community has fallen far short of meeting this need in the past. To do so in the future it is necessary, for economists at least, to take a broader view than that which is solely commodity-specific. This is not to suggest that milkfish economics research be abandoned; rather, this micro-level analysis must be supplemented, on the one hand, to include analysis of other potentially profitable options open to brackishwater producers (some would say a farming systems approach) and, on the other hand, as begun in this paper, to examine structural aspects of the market demand for milkfish and other species.

Given the market limitations to increased milkfish production and apparent declining profitability, pressure will be brought to bear upon less efficient farmers. Research advances, to the extent that they lower average costs for producing milkfish, are likely to assist farmers to become more efficient, but at the same time may concentrate the industry in fewer hands as less efficient farmers are weeded out. With increased competition for markets, smaller farmers are likely to be in a precarious position. Studies of economies of scale in milkfish production and marketing are particularly needed to see to what extent small farms will be able to remain competitive under these changing economic conditions.

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ARTIFICIAL PROPAGATION OF MILKFISH: PRESENT STATUS AND PROBLEMS

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Milkfish has been extensively cultured in Indonesia, Taiwan, and the Philippines. At present, the only source of fry for fish farmers is the coastal waters during the spawning season. The supply of fry is therefore often irregular and inadequate. Since the early 1970s attempts have been made to breed milkfish in captivity, particularly in Hawaii, Taiwan, and the Philippines. This paper reviews the progress problems and suggested future research direction for the following areas: induction of ovulation/spawning, sperm preservation, larval rearing, and induction of gonadal maturation.

INTRODUCTION

The extensive culture of milkfish *Chanos chanos* (Forsskal) in the Philippines, Indonesia, and Taiwan has made heavy demands on the supply of fry. At present, milkfish fry come mainly from the wild, and there are already signs of a shortage, particularly in Taiwan and in connection with pen culture in Laguna de Bay, Philippines. There is therefore a need for artificial propagation of milkfish to supplement the fry supply, and research toward this end has been carried out since the early 1970s, particularly in the Philippines, Hawaii, and Taiwan. This paper reviews the progress made and the problems encountered in the following areas: (1) induction of ovulation/spawning, (2) sperm cryopreservation, (3) larval rearing, and (4) induction of gonadal maturation. Other reviews covering one or more of these aspects include Juario et al (1984), Juario and Duray (1983), Kuo (1982), and Liao and Chen (1984).

INDUCTION OF OVULATION/SPAWNING

The available information on successful attempts to induce ovulation in milkfish is summarized in Table 1. The procedures used by the various investigators were variable and lacked standardization. The hormones used were salmon (SPH) or carp (CPH) pituitary homogenate in combination with human chorionic gonadotropin (HCG), or HCG alone. The dosages and other protocols used were also variable, as shown below:

Hormones:	
(a) SPH	6-10 mg/kg
(b) CPH	5-25 mg/kg
(c) HCG	180-2500 IU/kg
Number of injections	1-5 (mostly 2)
Injection interval	6-24 h (mostly 8-12 h)
Time to stripping	6-17 h (12 h appears best)

Part of this variability may have been due to differences in the initial gonadal condition of the fish. It appears that, as the initial egg diameter (eggs sampled by intraovarian cannulation) approaches 0.66 mm, higher dosages and more injections are required; conversely, as the initial egg diameter approaches 0.89 mm, lower dosages and fewer injections are required. However, the procedures have not been standardized and the dose-response relationship has not been studied. Hitherto it has not been possible to obtain enough spawners to conduct such studies, but with the availability of captive broodstock, the situation may change, and studies toward standardization should be carried out.

Partially purified salmon gonadotropin (SG-G100) has also been used (Nash and Kuo 1976, Liao and Chang 1976, Vanstone et al 1976), but the results obtained appear to have been less successful.

The use of HCG alone, shown to be successful in inducing ovulation/spawning in captive milkfish in Taiwan (Liao and Chen 1984), should be further studied. The application of HCG alone may be limited to fish with oocyte diameters of around 0.8 mm or higher (C. M. Kuo, pers. comm.). Fish with oocyte diameters from 0.66 mm to 0.8 mm may still require salmon or carp pituitary homogenate as priming injections. It is also possible that captive fish are more responsive to hormonal treatment than wild fish. HCG may not work as well in wild fish; higher doses and/or more injections may be required.

At the SEAFDEC Aquaculture Department (Philippines), the same dosages of hormones (SPH + HCG) were used to induce ovulation in both wild and captive fish (Table 1). It may be possible to use lower dosages for captive fish.

The ovulatory response of milkfish to hormones appears to be affected by environmental factors. For example, Kuo et al (1979) found that an abrupt change in salinity adversely affected the ovulatory response of milkfish to hormones, more so than gradual salinity adjustment; no salinity change was the best. The salinity level itself may also affect the dose-response relationship. In normal seawater, milkfish appear to require a lower dosage of hormones than at lower salinities (Table 1). Fish reared in brackish water may require an initial oocyte diameter of 0.72 mm (0.66 mm in seawater) before they can be successfully induced to spawn (C.M. Kuo, pers. comm.).

In determining the time of injection of hormones, the possibility of a circadian rhythm of responsiveness of oocytes to hormones should be considered. In the grey mullet *Mugil cephalus,* the oocytes are more sensitive to hormones at 0900 h and 1800 h than at other times (Kuo and Watanabe 1978). Whether such a circadian rhythm of oocyte responsiveness exists in milkfish should be investigated. Another factor to be considered in this connection is that natural spawning occurs at around midnight (C. Marte, pers. comm.). Injections may be timed such that stripping can be done at midnight; this might give better results.

There are certain behavioral markers which may help to determine both whether the injection given is effective and also the time of stripping. These include the following:

- Color change, due to melanophore stimulating hormone (MSH) in the pituitary homogenate;
- Increased drinking activity, probably to facilitate oocyte hydration;
- Release of calcium deposits, probably with increased drinking; calcium is retained in the gut and then released;
- Distension of abdomen, indicating oocyte hydration; and
- Dribbling of some eggs, indicating that ovulation may be close, consequently a good reference point to determine the time of stripping.

Natural spawning following hormone injections has so far been achieved only in Taiwan using pond-reared milkfish (Liao and Chen 1984). Natural spawning may give better hatchability and survival of the hatched larvae than stripping and artificial fertilization. However, nothing is known of the spawning requirements and behavior of milkfish, and these need to be studied. In the Taiwan experience, a sex ratio of two males to one female was used, but this may not be the ideal ratio.

Spontaneous spawning without hormone treatment has also been achieved with captive broodstock maintained in floating net-cages in the Philippines (Lacanilao and Marte 1980, Marte et al 1984). Again, the environmental triggers have not been identified. Temperature may be important (Wainwright 1982, Marte et al 1984, Lam 1983). It appears that 24°C is the minimum temperature required for milkfish spawning (Wainwright 1982).

PROBLEMS IN INDUCTION OF OVULATION/SPAWNING

When the initial oocyte diameter is less than 0.66 mm (0.72 mm in brackishwater milkfish), it has not been possible to induce ovulation in the fish (Table 2). Many hormone injections are required, and the fish usually dies before any significant advancement of oocyte development is achieved. Histologically, oocytes measuring 0.66 mm are already in the tertiary yolk globule stage (Juario et al 1984), but the maximum diameter of this stage is 0.89 mm. Perhaps at 0.66 mm vitellogenesis has really not been completed. Priming doses of hormones are therefore necessary before induction of spawning can be achieved. The priming hormones for vitellogenesis may include estradiol-17b, pituitary homogenate, and thyroxine (Lam 1982). This

Table 1. Induction of ovulation/spawning and artificial fertilization in milkfish *Chanos chanos* (Forsskal).

Fish	Holding conditions	Body weight (kg)	Initial oocyte diameter (mm)	Injection (IM[a]) Time	Injection (IM[a]) Total dose[b] (mg SPH/CPH* + IU HCG)	Injection (IM[a]) Specific dose[b] (mg SPH/CPH* + IU HCG per kg body weight)
Wild, injected within 4h of capture	6-m diameter canvas tank, seawater31 ppt, 28.3-29.0°C, 1 m deep	?	? (firm distended abdomen)	2100	60+4000	?
				0530	90+6000	?
	Salinity decreased to 27.6ppt 0630-0800h for 2nd female	?	? (firm distended abdomen)	1300	60+4000	?
				2215	90+6000	?
				0630	90+6000	?
Wild, injected imme- diately upon arrival in lab	?	6.5 (7.0[d])	0.75	0635	42+2800 +0.5 ml vit. B	6.5+430.8+ 0.08 ml vit. B
				1840	42+4200 +0.5 ml vit. B	6.5+646.2+ 0.08 ml vit. B
Captive or wild, injected within 26 h of first handling and sampling	35 ppt (no change)	4.1	0.73	0900 or 1800	100* + 10000	24.4* + 2439.0
				1800 or 0900 ?	as 1st dose	as 1st dose
	35 ppt (no change)	6.5	0.74	0900 or 1800 7	100* + 1000	15.4* + 1533.5
				1800 or 0900 7	100*+ 1500	15.4* + 2307.7
	38ppt (no change)	4.5	0.81	0900 or 1800 ?	25* + 2500	5.6* + 555.6
				1800 or 0900 7	as 1st dose	as 1st dose

Continued on pages 26-27

Time interval (h:min)	Diameter hydrated/ ovulated oocytes (mm)	Time to stripping/ spawning (h: min)	Fertilization	Males used	Reference
8:30	1.1-1.23 (fertilized)	15:30	dry and wet	2, similarly injected as female	Vanstone et al 1977
9:15 8:15	1.1-1.23 (fertilized)	8:30 (abdominal cavity exposed, loose eggs removed in both cases)	dry	3, spawned, untreated	
12:05	1.13-1.19	10:50-11:50	dry, 38%	1, ripe untreated	Liao et al 1979
9:00 ?	?	24:00[c]	?	?	Kuo et al 1979
9:00 ?	?	15:00[c]	?	?	
9:00 ?	?	23:00[c]		none available	

Table 1. continued

Fish	Holding conditions	Body weight (kg)	Initial oocyte diameter (mm)	Injection (IM[a])		
				Time	Total dose[b] (mg SPH/CPH* + IU HCG)	Specific dose[b] (mg SPH/CPH* + IU HCG per kg body weight)
	35 ppt (2 ppt increase per h from 7 ppt)	3.5	0.67	0900 or 1800 ?	25* + 2500	7.1* + 714.4
				1800 or 0900 ?	as 1st dose	as 1st dose
				0900 or 1800 ?	25* + 20000	7.1* + 45714.3
				1800 or 0900 ?	as 3rd dose	as 3rd dose
				0900 or 1800 ?	as 3rd dose	as 3rd dose
Wild, injected 2-4 h after release into holding tank	34 ppt, 26-30°C	7.0[d]	0.67 ±0.06 (n=68)	70+1250	0933	10+178.6
				70+10000	1745	10+1428.6
				as 2nd dose	0245	as 2nd dose
				as 2nd dose	0900	as 2nd dose
		7.0[d]	0.77 ±0.04 (n=113)	70+10000	0830	10+1428.6
				70+10000	1800	10+1428.6

Continued on page 28-29

Time interval (h:min)	Diameter hydrated/ ovulated oocytes (mm)	Time to stripping/ spawning (h: min)	Fertilization	Males used	Reference
9:00 ?					
9:00 ?	?	73:00[e]			
9:00 ?					
9:00 ?					
8:12 9:00 6:15	1.08±0.05	6:10	wet, 0%	2, injected with 5000 IU HCG and placed with female after her 2nd injection; insufficient milt	Juario et al 1979, 1984
9:30		10:30	dry, 59.4%	3, newly caught, ripe; placed with female after 1st injection; injected with 5000 IU HCG when female received 2nd injection	

Table 1. continued

Fish	Holding conditions	Body weight (kg)	Initial oocyte diameter (mm)	Time	Injection (IM[a]) Total dose[b] (mg SPH/CPH* + IU HCG)	Specific dose[b] (mg SPH/CPH* + IU HCG per kg body weight)
		10.0d	0.74	?	100+ 10000	10+1000
				?	100+ 20000	10+2000
Captive (net-cage)	34ppt, 26-30°C		0.76	7	40+ 5000	10+1250
				?	40+ 10000	10+2500
8-year old pond-reared	indoor tank, 30.5°C	(66 cm total length)	0.6 to 0.8 (n=10)	1800	100 mg phenobarbital	7
				soon after ?	0+3500	

[a] IM = intramuscular.
[b] SPH = acetone-dried salmon pituitary homogenate, CPH* = acetone-dried carp pituitary homogenate, HCG = human chorionic gonadotropin.
[c] Time from last injection.
[d] Estimated body weight.
[e] Time after cannulation (intraovarian oocyte sampling).

hormone combination was tried on mullet (*Crenimugil* sp.) with oocytes less than 0.6 mm in diameter. The results were encouraging, and when tried on milkfish the response was likewise good, but the milkfish could not tolerate more than three injections (Table 3).

Milkfish is highly sensitive to stress. Atresia of oocytes soon occurs in wild spawners (*sabalo*) if they are not given hormone injections within a few hours after capture. However, the fish usually die if given more than three injections. Handling the wild *sabalo* therefore poses a problem. The problem may be less for captive broodstock but is not absent. The use of valium (diazepam) as a tranquilizer was tried with success in wild milkfish (Kuo 1982); repeated injections of valium at 8- or 12-h intervals at 0.7 mg/kg did not interfere with oocyte maturation but did tranquilize the fish.

Another problem is egg dribbling after hormone injections. The eggs that are dribbled out are hydrated or hydrating but may not be ovulated and fertilizable. They therefore constitute a loss. One solution is the use of a plug (Juario and Duray 1983), but this problem should be studied. Egg dribbling may be a natural phenomenon; it may serve to release pheromone(s) for stimulation of males.

Time interval (h:min)	Diameter hydrated/ ovulated oocytes (mm)	Time to stripping/ spawning (h: min)	Fertilization	Males used	Reference
12:00	?	10 11:30	dry?, 25% 28%		
24:00	?	10 12 14	dry?, 9% 32% 10%		
	1.0-1.1	16:45	wet (several ml 20% glucose solution)	1, injected with 25 mg testosterone propionate + 1500 IU HCG at 1800 h	Tseng and Hsiao 1979

Other problems include: (1) limited availability of ripe males, (2) insufficiency of milt from one male, (3) milt resorption after 2-3 days in captivity, and (4) limited availability of gravid females. One solution to the first three of these problems is to use hormones such as HCG and androgens to induce spermiation; a long-lasting mixture of androgens, Durandron Forte "250" (Organon), has been used by Juario et al (1980) with success. Another solution is cryogenic sperm preservation, which is discussed in the following section. The problem of insufficiency of female broodstock is discussed in the section on induction of gonadal maturation.

SPERM CRYOPRESERVATION

Attempts have been made by Hara et al (1982) and Kuo (1982) to preserve milkfish sperm at near-zero temperatures (0-4°C) and in liquid nitrogen (— 196°C). Various extenders were used, but milkfish serum was found to give the best results in terms of motility and fertilizing capacity of the preserved sperm (Hara et al 1982). Cryopreservation was superior to near-zero liquid preservation. Nevertheless, the near-zero-preserved sperm still showed appreciable fertilizing capacity after 5 days.

Table 2. Unsuccessful attempts to induce ovulation in milkfish with oocytes of less than 0.66 mm in diameter.

Fish	Holding conditions	Body weight (kg)	Initial oocyte diameter (mm)	Injection (IM[a]) Time	Total dose[b] (mg SPH/CPH* + IU HCG)	Specific dose[b] (mg SPH/CPH* + IU HCG per kg body weight)	Time interval (h:min)	Remarks	Reference
Wild, injected immediately upon arrival in lab.	?	9.8 (7.5[c])	0.63	1600	45 + 1500 + 0.5 ml vit. B	4.6 + 153.1 + 0.05 ml vit. B		fish died; final oocyte diameter 0.71 mm	Liao et al 1979
				0445	45 + 3000 + 0.5 ml vit. B	4.6 + 306.1 + 0.05 ml vit. B	12:45		
				1600	45 + 3000 + 1.0 ml vit. B	4.6 + 306.1 + 0.1 ml vit. B	11:15		
				0400	180 + 6000 + 1.0 ml vit. B	18.4 + 612.2 + 0.1 ml vit. B	12:00		
Wild or captive, injected within 26 h of first handling and sampling	35 ppt (1 ppt increase per h from 7 ppt)	4.8	0.60	0900 or 1800?	50* + 5000	10.4* + 1041.7		no response in 3 days	Kuo et al 1979
							24:00?		
				0900 or 1800?	50* + 5000	10.4* + 1041.7			
							24:00?		
				0900 or 1800?	50* + 5000	10.4* + 1041.7			

Continued on opposite page

Table 2. continued

		5.0	0.62	0900 or 1800?	50* + 5000	10* + 1000	24:00!	no response in 3 days	
				0900 or 1800	50* + 5000	10* + 1000	24:00?		
				0900 or 1800?	50* + 5000	10* + 1000			
		4.5	0.62	0900	50* + 5000	11.1* + 1111.1		no response in 4 days	
				1800	100* + 10000	22.2* + 2222.2	9:00		
				0900	100* + 10000	22.2* + 2222.2	9:00		
				1800	100* + 10000	22.2* + 2222.2	9:00		
				0900	200* + 20000	44.4* + 4444.4	9:00		
				1800	200* + 20000	44.4* + 4444.4	9:00		
				0900	200* + 20000	44.4* + 4444.4	9:00		
Wild	?	6.5 (7.0[c])	0.63± 0.05 (n = 71)	0835	70 + 10000	10.8 + 1538.5		one oocyte group reached 0.76 ± 0.19 mm in diameter; fish died	Juario et al 1979
				1745	140 + 10000	21.5 + 1538.5	9:10		
				0430	140 + 15000	21.5 + 2307.7	10:45		
				1645	140 + 15000	21.5 + 2307.7	12:15		
Captive	35 ppt (4 ppt increase per h from 7 ppt)	2.25	0.625		(mg SG-G100) 5	2.2		no response	Kuo et al 1979
					5	2.2			
				0900 or 1800	10	4.4	?		
					10	4.4			
				?	10	4.4			

[a] IM = intramuscular.
[b] SPH = acetone-dried salmon pituitary homogenate,
CPH* = acetone-dried carp pituitary homogenate,
HCG = human chorionic gonadotropin.
[c] Estimated body weight.

Table 3. Use of estradiol-17β and thyroxine in addition to salmon pituitary homogenate and HCG to induce ovulation in fish with oocytes of less than 0.66 mm in diameter.

Fish	Body Weight (kg)	Day	Holding conditions	Oocyte diameter (mm)	Injection (IM[a]) Time	Total dose[b] (mg + IU HCG)	Specific dose[b] (mg + IU HCG per kg body weight)	Time interval (h:min)	Remarks
Wild mullet *Crenimugil* sp.	3	1	16 ppt, 30°C	0.64	1700 1800	3 mg E_2 + 30 mg SPH + 5000 IU HCG + 3 mg T_4	1 mg E_2 + 10 mg SPH + 1666.7 IU HCG + 1 mg T_4	1:00	
								12:45	
		2	25 ppt, 28°C	0.66	0645	30 mg SPH + 10000 IU HCG + 1 ml vit. B	10 mg SPH + 3333.3 IU HCG +0.3 ml vit. B		
								10:45	
		2	32 ppt, 30°C	0.71	1730	30 mg SPH + 20000 IU HCG + 1 ml vit. B	10 mg SPH + 6666.7 IU HCG + 0.3 ml vit. B		
		3	32 ppt, 27°C		0530				released a few ovulated eggs, stripped but no male
				0.97	0645				

Continued on opposite page

Table 3. continued

Wild milkfish *Chanos chanos* (Forsskal)	8	1	0.57	1022	8 mg E_2 + 80 mg SPH + 5000 IU HCG + 8 mg T_4	1 mg E_2 + 10 mg SPH + 625 IU HCG + 1 mg T_4	24:28	
		2	0.62	1050	as 1st dose	as 1st dose		
		3	0.66	1115	40 mg E_2 + 80 mg SPH + 10000 IU HCG + 8 mg T_4	5 mg E_2 + 10 mg SPH + 1250 IU HCG + 1 mg T_4		
		3		1710				fish died

[a] IM = intramuscular.
[b] SPH = acetone-dried salmon pituitary homogenate,
HCG = human chorionic gonadotropin,
E_2 = estradiol-17β,
T_4 = thyroxine.

Subsequent work (Hara and Tiro 1984) showed that dimethyl sulfoxide (DMSO) is a better cryoprotectant than glycerine in the cryopreservation of milkfish sperm. In fact, sperm preserved for 10 days in milkfish serum containing 12.5% DMSO even yielded apparently higher fertilization and hatching rates, as well as a higher survival rate of larvae at day 21, than fresh semen.

LARVAL REARING

Available information on successful rearing of milkfish larvae is summarized in Table 4. Feeding of larvae was consistently observed by the different workers to begin on the 4th day after hatching, and the critical period was between the 4th and 6th days.

Juario et al (1984) reviewed several years' experience in rearing milkfish larvae. Foods given were *Chlorella virginica, Isochrysis galbana, Tetraselmis chuii, Brachionus plicatilis, Tisbintra elongata* (copepod), *and Artemia salina.* A significant improvement in larval survival was found when *I. galbana* and *Tetraselmis chuii* were added to the rearing tanks in addition to *C. virginica,* perhaps related to the possibility that the latter is deficient in 20:5 w3 fatty acids, which are essential for marine fish (Watanabe et al 1983).

Larval survival rates as high as 71% were obtained (Juario et al 1984). Larvae from artificially fertilized eggs showed highly variable survival rates, whereas those from naturally spawned eggs showed consistently high survival rates. Concomitantly, there were more abnormal larvae from artificially fertilized eggs than from naturally spawned eggs.

Recent studies on the salinity tolerance of milkfish larvae (Dueñas and Young 1984) showed that, while larvae at day 0 and day 14 are fairly euryhaline and at day 21 highly euryhaline (0-70 ppt), those at day 7 are markedly stenohaline (27-28 ppt). This suggests that rearing milkfish larvae at a constant salinity of 27-28 ppt may improve their survival rate. Further studies are necessary.

INDUCTION OF GONADAL MATURATION

Milkfish are able to undergo sexual maturation in concrete tanks, ponds, enclosed lagoons, and floating net-cages. Some of the associated factors are summarized in Table 5. It appears that milkfish attain sexual maturity at around 5 years of age; males may reach maturity earlier, at around 4 years of age. It is difficult to pinpoint the important factor(s) for milkfish gonadal development. However, salinity does not seem important, since milkfish can mature in salinities ranging from 8 to over 100 ppt, although salinity affects ovulation and may exert some influence on gonadal development when it is extremely high (Crear 1980). Temperature and photoperiod may be important (Lee 1984, Marte et al 1984, Wainwright 1982, Lam 1983), but there is not enough information available. In the Philippines, the rapid gonadal development of milkfish prior to the spawning season seems to coincide with rising water temperatures from 25° to 32°C and with increasing photoperiod from 11 to 14 h of light (Marte et al 1984).

Table 4. Larval rearing in milkfish.

Incubation		Newly hatched		Food given					
Conditions	Period 00	Total length (mm)	Yolk sac (mm)	Day	Items[a]	Day feeding first observed	Critical period (days)	Survival rate	Reference
32 ppt, 28.4-29.2°C	30-35	3.5	large	?	?	?	?	one to day 7	Vanstone et al 1977
30-34 ppt, 26.4-29.2°C	25-28.5	3.2	2.15 long, 0.58 wide	2.5	Ch + TL	4th (3 days old)	4th-6th	two to day 6	Chaudhuri et al 1978
34 ppt, 27-32°C	25.75-32	3.4	2.20 long, 0.28 wide	1-21 2- 6 2-21 14-21	Ch E + TL R C + AN + F + PF	4th (72 h)	4th-6th	8.8-46.8% to day 21	Liao et al 1979
34 ppt, 26-29°C	24-35	?	?	1-21 2-10 2-21 2-21 7-21 10-21	Ch I T R C AN	4th	4th-7th	8-71% (artificially fertilized), 19-50% (naturally fertilized to day 21)	Juario et al 1984

[a]AN = *Artemia* nauplii
C = copepods
wild + *Tigriopus japonicus* (Liao et al 1979)
Tisbintra elongata (Juario et al 1984)
Ch = *Chlorella virginica*
5-35 x 10^5 cells/liter (Liao et al 1979)
2-5 x 10^5 cells/ml (Juario et al 1984)
E = fertilized eggs of oysters
F = flour
I = *Isochrysis galbana* (2-5 × 10^4 cells/ml)
PF = prepared feed
R = rotifers (*Brachionus plicatilis*)
10-200/ml (Liao et al 1979)
20-30/ml for days 2-10, 10-20/ml for days 10-21 (Juario et al 1984)
T = *Tetraselmis chuii* (2-5 × 10^4 cells/ml)
TL = trochophore larvae of oysters

Table 5. Factors associated with sexual maturation in milkfish.

Factors	Concrete tank		Pond (Hawaii)			Lagoon (Christmas Island)			Floating net cage (Philippines)
	Taiwan	Oceanic Institute (Hawaii)	Kauai	Kona	Oceanic Institute	Isles	Pelican	Azur	
Age(yr)	♂ 4+ ♀ 5+	6-7	?	?	?	4-5	4-5	6	5
Diameter or area	8.5-12 m	5.2 × 4.8 m	10 ha	1.4 ha	0.05 ha	~4 × 1 mile	~0.5 × 1.0 mile	~0.5 × 1.0 mile	9 or 10m
Depth (m)	1.2	1.3	?	1-2	1	~3	~3	~3	3
Temperature (°C)	21-31	26	24-30	24-30	24-30	27-32	27-32	27-32	25-32
Salinity (ppt)	14-30	32	38-42	8-12	32	102 - 130	60-76	80-100	25-38
Photoperiod (h light)	?	artificial[a]	10.5 - 13.5	10.5 - 13.5	10.5 - 13.5	?	?	?	11 - 14
Food (% protein)	37-46	Ralston Catfish Chow	?	?	Ralston Catfish Chow	benthic mat[b] + *Artemia salina*	benthic mat[b]	benthic mat[b]	42
Feeding rate	once to satiation	?	?	?	?	intense ?	intense ?	intense ?	2% body wt
Stocking density	20-30 per tank	9 - 12 per tank	?	700/ pond	12/pond (+100-200 mullet)	low	high	high?	80 - 100/cage (0.5kg/m^3)
Flushing rate	flow-through	4.9 gal/min	low	moderate (upwelling)	moderate		no flushing		good
Reference	Liao and Chen-1979, 1984, and pers. comm.	Lee 1984	Nash and Kuo 1976, Kuo et al 1979, Kuo 1982 and pers. comm.			Kuo 1982, Vanstone 1982, Crear 1980 and pers. comm.			Lacanilao and Marte 1980, Marte et al 1984 and pers. comm.

[a] Fish subjected to 6, 12, and 18 h of light at different times. [b] Composed of halophilic bacteria, blue-green algae, diatoms, and fungi.

Food seems to be an important factor. High protein diets were used in Taiwan, the Oceanic Institute (Hawaii), and the Philippines, and abundant food is available in the lagoons of Christmas Island. It is interesting that in the Isles Lagoon, where brine shrimp A. *salina* was introduced and has flourished, milkfish showed reproductive readiness throughout the year; the males were spermiating while the females showed maturing if not ripe gonads throughout the year (Crear 1980). Analysis of gut contents of the fish revealed that brine shrimp constituted about 25% (by volume) of their diet. Thus brine shrimp may be a good broodstock diet.

Obviously, experimental studies are needed to confirm the importance of temperature, photoperiod, and food in milkfish gonadal development. Other factors such as swimming space, stocking density, and feeding rate should also be investigated. Such studies are most worthwhile because manipulation of environmental and nutritional factors represents the most practical approach to induction of gonadal maturation in fish (Lam 1983).

Attempts have been made to use hormones to induce gonadal maturation in milkfish (Lam 1982, Lacanilao et al 1984, Lee et al 1984). The results obtained were not encouraging, except perhaps for the male (Lee et al 1984). The problems encountered were as follows:

- Stress due to frequent handling seemed to negate the stimulatory effect of hormones. Administration of hormones (salmon pituitary, estradiol-17b, and thyroxine) by pellet implantation was tried in order to reduce frequency of handling, but with little success (Lacanilao et al 1984, Marte and Crim 1983). The only handling-free method of hormone administration is through feeding. However, not all hormones can be orally administered; protein hormones such as gonadotropins cannot be given this way. Lee et al (1984) managed to obtain some stimulation of spermatogenesis in 4-year old milkfish through feeding of 17 a-methyl testosterone.
- Milkfish less than 4 or 5 years old may not have developed the receptors to respond to hormone treatments.
- Similarly, spent fish may lack hormone receptors. It is not known how long it takes spent fish to undergo recrudescence (rematuration) or whether they remature at all in captivity. It is also not certain whether milkfish are total or intermittent spawners.

CONCLUSION

It is clear from the above brief review that, although much has been done, much more needs to be done before artificial milkfish propagation can be carried out on a standardized routine basis.

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GONADAL DEVELOPMENT AND INDUCED BREEDING OF CAPTIVE MILKFISH IN TAIWAN

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The induced breeding of milkfish has been attempted by many institutes in the Philippines, Taiwan, Tahiti, Indonesia, and Hawaii. So far, a few successful trials have been achieved only in the Philippines and Taiwan, although different sources of spawners were used. In Taiwan the spawners used were reared from fry to sexual maturity in ponds and concrete tanks. This paper summarizes the gonadal development of captive milkfish at various stages of sexual maturation investigated from 1975 to 1980 and describes three successful trials of induced breeding in 1979, 1982, and 1983 in Taiwan. Finally, the problems that need further study are discussed.

INTRODUCTION

Being tough and highly resistant to diseases, milkfish is easy to culture and is therefore one of the most important cultured fishes in Southeast Asia. It is not only an excellent food fish but also an ideal bait fish for tuna. In the past 2 years it has been shown that milkfish production can be increased three to seven times by using improved culture techniques like deeper ponds and artificial feeds.

There is an increasing demand for milkfish fingerlings owing to the adoption of these improved culture techniques. In the past, 8 000-10 000 fingerlings were stocked in a 1 ha pond; however, 10 000-30 000 are now needed for stocking deeper ponds of the same size. It is now believed that the key point for further development of the milkfish industry is the adequate supply of fingerlings. Therefore, scientists in areas engaged in milkfish culture such as the Philippines, Taiwan, and Indonesia are trying to develop techniques for artificial propagation. So far, there are only a few cases of successfully induced breeding. Two different sources of spawners have been used, one from the wild (Vanstone et al 1977, Chaudhuri et al 1978, Liao et al 1979) and the other from tanks or ponds (Hsiao and Tseng 1979, Lin 1982) and cages (Juario and Duray 1980, Juario et al 1984).

In Taiwan, wild spawners have also been tried for artificial propagation; however, they are so few that more attention has been focused on tank- or pond-reared spawners since 1970 (Liao and Chang 1976).

This paper summarizes and discusses gonadal development and three successful trials of induced breeding of captive milkfish in Taiwan as well as related problems that need further study.

GONADAL DEVELOPMENT

Results of studies on milkfish reared to maturity in outdoor cement tanks at the Tungkang Marine Laboratory are used in this review. The gonads were examined macroscopically and microscopically for their maturity based on their weight, size, shape, color, and stage of gamete development. Since the external sex characteristics of captive milkfish are not obvious, it was difficult to determine the sex and maturity of first-time spawners. However, the fish were found to be heterosexual, and no incidence of hermaphroditism was present. The six stages of gonadal maturity are summarized in Tables 1 and 2. The gonadal development of milkfish was found to be synchronous. Histological study of the gonads showed that all of the 1 + year old fish contained undifferentiated germ cells, while 2+ year old fish contained spermatogonia in males and previtellogenic oocytes at the oogonium and chromatin-nucleolus stages in females. The sex of dissected fish older than 3 years could easily be distinguished by the presence of ovigerous lamellae in the ovaries of the females. Sperm cells at various stages were present in 4+ year old males. Mature spermatozoa were first observed in a 4 year old male (BW 2.55 kg, TL 70.1 cm, GSI 0.06), and milt oozed out upon pressing the abdomen. Males older than 5 years had running milt during the spawning season. Ovaries of 4+ year old females consisted mostly of oocytes at the chromatin-nucleolus and peri-nucleolus stages. Vitellogenesis first occurred in 5 + year old stock, and oocytes at the yolk vesicle stage were present in these fish. Yolky oocytes were present in most 6+ year old stock and coincided with the increase in gonad weight and gonadosomatic index (GSI). The results indicated that, among tank-reared milkfish, males first attain maturity in 4+ years, females in 5+ years. Seasonal fluctuation of monthly mean GSI values of captive adult milkfish (older than 5 years) over a 5-year period (1975-1980) is shown in Figure 1. The GSI value increased in May and attained a maximum in August, suggesting that the breeding season of captive broodstock is between late May and August. The monthly variation in the percentage of ovarian oocytes at different stages of development confirms the annual cyclic changes of the GSI value (Fig. 2).

The frequency distribution of oocyte diameter showed a distinct spawning pattern in mature captive milkfish (Fig. 3). Examination of ten ovaries revealed that only

Table 1. Macroscopic description of the maturity stages of the gonads of captive milkfish (Liao and Chen 1983).

Maturity stage	Testis	Ovary
Immature virgin	Two small, thread-like elongated bodies with a slightly pinkish-grey coloration suspended by a mesorchium from the ventral side under the ventral column.	As in males, not distinguishable macroscopically; but early oogonia can be recognized histologically.
Developing virgin	Pinkish-grey in color, thicker than thread-like structure.	Reddish-orange in color; increased in width and length; ovigerous lamellae easily discernible; ovarian oocytes not discernible by the naked eye.
Maturing	Pinkish-white in color, flattened and broader in shape, occupying more than one-half the length of the peritoneal cavity.	As in developing virgin stage, but considerably enlarged; ovarian oocytes visible to the naked eye.
Mature	Rosy-white, elongated, and broadest at the middle, occupying about two-thirds the length of the peritoneal cavity. Vas deferens enlarge and milt appears upon pressing the abdomen.	Yellowish-orange or bright yellow in color; occupying large portion of peritoneal cavity; yolk-laden oocytes visible to the naked eye, but not separable.
Gravid and spawning	Fully mature and whitish milt oozes out with pressure.	Abdomen distended, peritoneal cavity filled with the ovaries; eggs translucent golden, with a few opaque; ovulated eggs are released to coelomic cavity and extruded out through genital aperture on pressure.
Spent	Degenerated and reduced in size.	Flaccid and considerably reduced in size with lamellae shrunken and falling apart; reddish-brown in color; a few eggs left in ovaries and coelomic cavity.

Table 2. Histological changes in relation to maturity stages in the gonads of captive milkfish (Liao and Chen 1983).

Maturity stage	Testis	Ovary
Immature virgin	Lobules consisting of primary and secondary spermatogonia; a few primary spermatocytes present.	Ovarian oocytes at oogonium stage located in cysts in the ovigerous lamellae; some early chromatin-nucleolus oocytes present.
Developing virgin	Lobules consisting predominantly of secondary spermatogonia and primary spermatocytes; some lobules at primary spermatogonia.	Ovigerous lamellae containing oocytes at chromatin-nucleolus and peri-nucleolus stages.
Maturing	Testes consisting of various stages of sperm cells, mostly at secondary spermatocyte stage; considerable number of spermatids and spermatozoa present.	Ovarian oocytes mostly at late peri-nucleolus stage and yolk vesicle stage; some primary yolk globule oocytes present. The process of vitellogenesis starts.
Mature	Lobules gorged with spermatozoa, small cysts of developing sperm cells also present.	Oocytes mostly at yolk globule stage, some oocytes at early peri-nucleolus stage occur in the lamellae between the yolk oocytes.
Gravid and spawning	Lobules and spermatic duct are filled with spermatozoa.	Oocytes ripe with finely divided yolk globules, spherical in form, with no covering follicle layer.
Spent	Lobules empty, developing cysts of sperm cells recrudescent.	Empty follicles in each lamella; immature ovarian eggs at peri-nucleolus stage scatter throughout the lamellae; unreleased eggs become atretic and undergo resorption; formation of "corpora atretica."

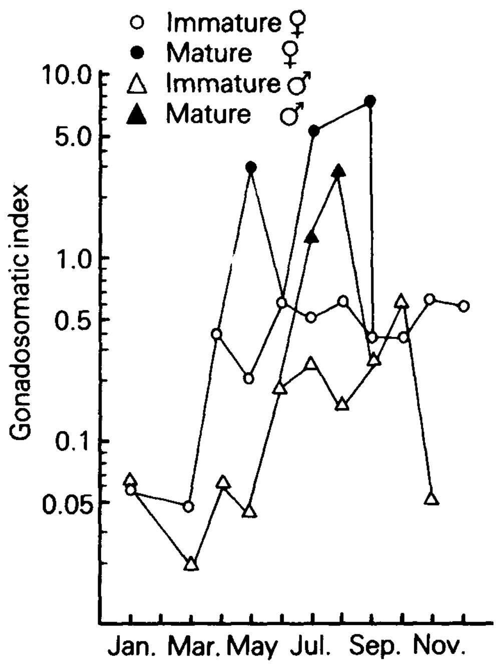

Fig. 1. Annual cyclic changes of gonadosomatic index of captive milkfish (Liao and Chen 1983).

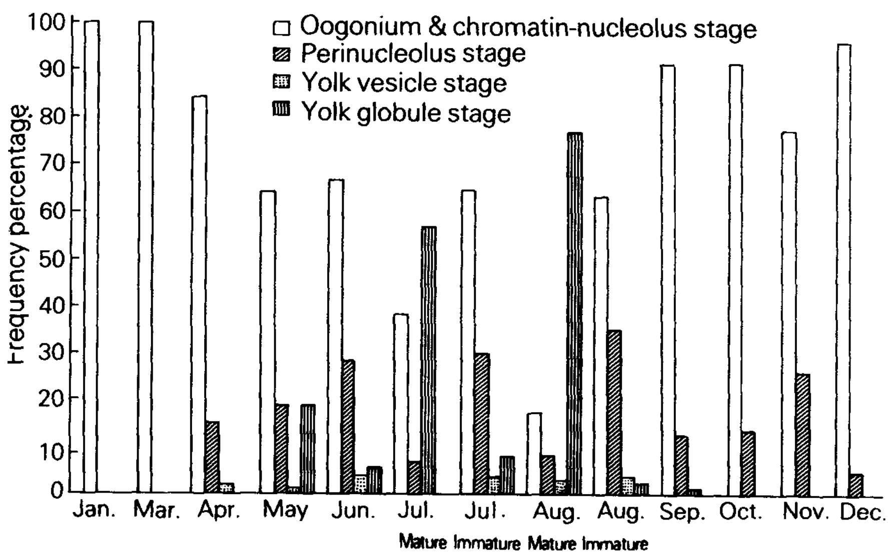

Fig. 2. Annual cyclic change in the frequency percentage of ovarian oocytes of captive milkfish during the period 1975-1980 (Liao and Chen 1983).

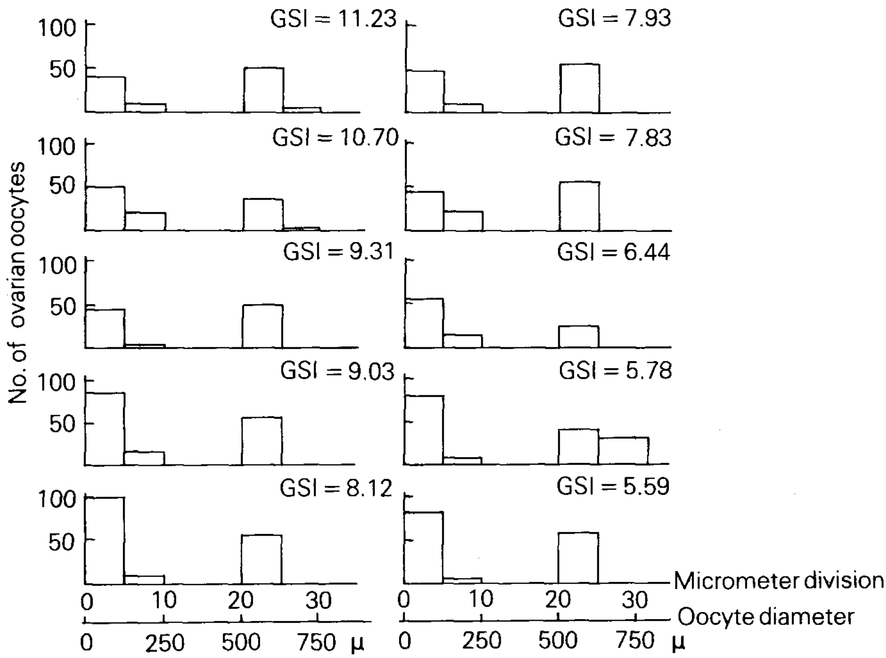

Fig. 3. Frequency distribution of oocyte diameter of ten mature captive milkfish (Liao and Chen 1983).

yolk-laden oocytes ranging from 500 to 750 mm and immature oocytes ranging from 10 to 250 mm in diameter were present. The intermediate group of maturing oocytes was not found. The frequency distribution of oocyte diameter and different stages of development suggest that captive milkfish have a synchronous spawning pattern. The fish spawns once a year during June-August.

INDUCED BREEDING

Work on the artificial propagation of captive milkfish in Taiwan has involved maintenance of broodstock, induction of maturation and spawning, artificial insemination, and larval rearing. Broodstock has been reared in cement tanks or earthen ponds which are in either low or highly productive condition. The pond area covers 150-750m^2. Salinity ranges from 14 to 34 ppt and temperature from 21 to 31°C. The stocking density ranges from 20 to 200 fish in each pond. The adult stock is fed daily with formulated diets, occasionally supplemented with natural food. For example, a high-protein diet (CP 45.7%) together with shrimp meal or adult *Artemia* is used at the Tungkang Marine Laboratory (Liao and Chen 1979); compound food for shrimp and/or freshwater fish plus seaweeds is used at the Shin-Li Fish and Shrimp Hatchery

(Hsiao and Tseng 1979); a diet containing rice bran, cereal soybean cake, eel feed, and some trash fish is fed to the broodstock at the Tung-Hsing Fish and Shrimp Hatchery (Lin 1982). During the breeding season, the adult stock shows an acceleration in gonadal development, with vitellogenic oocytes appearing and increasing in number. Some fish may become fully mature. At present, the percentage of broodstock which can reach full maturity and can be used for induced spawning trials is still quite low compared with that of other captive fish species. In general, about 8 out of 20 captive fish attain maturity, and of the 8 only 1 or 2 females are fully mature.

In Taiwan, captive milkfish were first successfully induced to spawn in 1979 (Hsiao and Tseng 1979). Much progress was made in 1982 (Lin 1982) and 1983 (Lin, pers. comm.). The results of successful trials to induce spawning are summarized in Table 3. Apparently, captive spawners can be used for induced spawning and mass production of fingerlings. So far, the best results of induced spawning among captive stock were obtained from females with egg diameters ranging from 0.6 to 0.8 mm which were injected with 1000-1300 IU human chorionic gonadotropin (HCG)/kg body weight. The suitable time to spawn/strip the fish was 15-20 h after injection. Males were injected with 750-1500 IU HCG/fish to improve milt quality. Eggs collected were artificially fertilized and incubated at a salinity of 31-34 ppt at 29-32°C.

The larvae started to hatch 20-25 h after fertilization. One day after hatching, *Chlorella* sp. was added to the rearing tanks and fertilized oyster eggs, rotifers, and *Artemia* nauplii were given subsequently as feed. Twenty-one days after hatching, the larvae attained a total length of 1.2-1.8 cm, which is the size of milkfish fry used for stocking ponds. At present, the survival rate of the larvae ranges between 11 and 43%. Compared with other marine fish, it seems relatively easy to rear milkfish larvae to fry. Further refinements of the technique will improve the survival rate.

DISCUSSION

Both wild and captive milkfish undergo regular, cyclic gonadal changes yearly. In Taiwan, captive milkfish do not spawn spontaneously without hormonal treatment. The annual breeding season occurs from late May through August, during which the GSI and the percentage of viable gametes increase. September is supposed to be the postspawning or regressive period, and the remaining months of the year are the resting or recovering period of gonadal development. Mature wild milkfish spawners were captured from April to June (Liao 1971), and the fry could be caught from April through October in the coastal waters of southern Taiwan (Liao et al. 1977). Thus, the breeding season of captive milkfish occurs later and is shorter than that of milkfish in their natural habitat. Although most of the captive stock first attain maturity at the age of 4 in males and 5 in females, females older than 6 years undergo rapid development from the time yolk is first deposited in the oocytes, i.e., in late May; some females reach full maturity in August. Males older than 5 years can attain full maturity and produce viable sperm. The captive 6+ year old adults can attain sexual maturity and be used for induced breeding regardless of their body length and weight, suggesting that age is a more crucial factor for sexual maturity than other parameters. In addition, as shown in Table 3, the probability of successful induced breeding increases if the spawners are more than 8 years old.

Table 3. Records of successfully induced breeding of captive milkfish in Taiwan.

	1st trial (Hsiao and Tseng 1979)	2nd trial (Lin 1982)			3rd trial (Lin, pers. comm.)		
No. of fish	1♀ 3♂	1♀ 2♂	1 ♀ 2♂	1♀ 1♂	1♀ 1♂	1♀ 1♂	1♀ 1♂
Age	8	8-9	9-10	9-10	9-10	9-10	9-10
♀ Body weight Body length	3.5 kg 66 cm	5.0 kg 76 cm	7.0 kg 80 cm	6.0 kg 72 cm	6.0 kg 73 cm	6.0 kg 71 cm	6.5 kg 75 cm
Egg diameter (before injection)	0.6-0.8 mm	—	—	—	—	—	—
Date and time of injection	14 July 1979 1800 h	4 Aug 1982 1120 h	20 July 1983 1600 h	1 Aug 1983 1600 h	2 Aug 1983 0800 h	16 Aug 1983 1630 h	18 Aug 1983 1800 h
Dosage of hormone injection	3500 IUHCG 100mg phenorbarbital	6000 IUHCG	10000 IUHCG	8000 IUHCG	8000 IUHCG	8000 IUHCG	8000 IUHCG
Date and time of spawning egg collection	15 July 1979 1033 h 1st 1045 h 2nd 1307 h	5 Aug 1982 — 1st 0220 h 2nd 0250 h	21 July 1983 0000 h — —	2 Aug 1983 1100 h 1100 h —	3 Aug 1983 — 0800 h —	17 Aug 1983 — 1130 h —	19 Aug 1983 0900h 1st 0900 h 2nd 0930 h

Continued on opposite page

Table 3. continued

Duration between injection & spawning	16 h 33 min	15 h 20 min	8 h	19 h	24 h	19 h	15 h
Estimated no. of eggs collected (total)	—	1st 300 000 2nd 500 000 (800 000)	(800 000)	(300 000)	(200 000)	– (250 000)	(600 000)
Incubation condition	29.0-31.0°C 33.2 ppt	29.5-30.0°C 29.5 ppt	31.0.32.0°C 31.2 ppt	30.0-31.5°C 31.2 ppt	30.5-31.5-°C 31.2 ppt	31°C 31.2 ppt	31°C 31.2 ppt
Date and time of hatching (time after fertilization)	16 July 1979 1645 h (24.0-32.0 h)	6 Aug 1982 0420 h (25.5-32.0 h)	21 July 1983 2030-2130 h (20.5-22.0 h)	3 Aug 1983 0900-1100 h (22.0-24.0 h)	4 Aug 1983 0700-0900 h (23.0-25.0 h)	18 Aug 1983 1000-1130 h (22.5-24.0 h)	20 Aug 1983 0700-0830 h (22.0-23.5 h)
Estimated no. of hatched larvae	120	120000	300 000	30 000	2 000	20 000	150 000
No. of fingerlings harvested (day after hatching)	32 (52nd)	13 266 (22nd)	1 500[b] (21st)	8 479[c] 21st-22nd		7600 (20th)	64 140 (21st)

[a] Spawned and fertilized spontaneously. At 0530 h, 21 July 1983 fertilized eggs in gastrula stage with germ ring formed were found.
[b] Due to overfeeding and poor condition of rearing water, mass mortality occurred 11 days after hatching.
[c] Larvae were cultured together, and fingerlings were counted on 25 Aug 1983.

Although captive milkfish can attain full maturity, the percentage of fully mature ones is still low, and individual variations in gonadal development are remarkable. This may be attributed to inadequate environmental and nutritional conditions. Environmental factors (such as size, shape, depth, and substratum of the pond, and circulation, turbidity, temperature, and salinity of the water), rearing conditions (such as stocking density and feeding rate), and type of feed seem to influence gonadal development and spawning, but the key factors have not been identified. However, it is recommended that for maintenance of spawners the holding pond should not be too small and the stocking density not too high, since insufficient exercise owing to limited space may cause obesity of the spawners and probably retard their gonadal development. Furthermore, the water quality should be kept as similar as possible to the natural habitat of wild spawners.

Development of an optimal diet for both female and male spawners to reduce the accumulation of visceral fat, stimulate gonadal development, and improve quality and quantity of gametes is essential for the establishment of captive broodstock. According to the experience of Tseng and Lin (pers. comm.), a high protein diet does not seem indispensable to induce gonadal development. However, gonadal development may require specific levels of some dietary components such as polyunsaturated fatty acids, which are generally found in some natural foods.

Domestication of captive broodstock can contribute greatly to success in the artificial propagation of milkfish. Captive fish are rather small, generally healthy, and easy to handle. It is possible to control gonadal development and induce breeding through environmental, nutritional, social/behavioral, and hormonal manipulation, and thus to minimize stress or physical injury.

With regard to induced spawning by hormone injection, pond-reared spawners apparently need a dosage lower than wild spawners. Only one injection of 1000-1300 IU HCG/kg was needed to induce spawning; however, Juario et al (1984) used 10 mg salmon pituitary homogenate (SPH)/kg + 1000 IU HCG/kg body weight for the first injection and 10 mg SPH/kg + 2000 IU HCG/kg body weight for the second injection to induce spawning in wild and captive stock reared to maturity in floating cages. The difference in response to hormone treatment can be attributed to the degree of domestication, stage of maturation, and physical condition of the fish. According to Liao and Chen (1979), fecundity of captive milkfish ranges from 620 000 to 1 300 000. However, Table 3 shows that the total number of eggs collected after hormone treatment is relatively low (ranging from 200 000 to 800 000). It seems, therefore, that the technique to induce ovulation or spawning is still unsatisfactory. Besides, the gamete quality of spawners should be taken into consideration. It is well known that poor egg quality causes low fertilization, hatching, and larval survival rates. Although the techniques of induced breeding for captive spawners have been preliminarily established, more reliable procedures to improve egg quality and fertilization, hatching, and larval survival rates remain to be developed and standardized.

Because of the difficulty in determining sex and maturity of virgin spawners from external characteristics, gametes have to be exteriorized through a cannula; however, handling of spawners during the breeding season easily causes atresia and resorption of the gonads. Prospective spawners should therefore be distributed to as many ponds as possible long before the breeding season. Techniques of determining sex and oocyte maturity which minimize stress, such as ultrasonography or immunological tests, should be developed. Furthermore, the milt of ripe males can be squeezed out on pressure, but the quantity produced from one male at one time is usually insufficient to fertilize the eggs of one female spawner, or the milt is not available when needed. Therefore, techniques to cryopreserve sperm effectively should also be developed.

To recapitulate, the ideal way to induce gonadal development and to breed milkfish is to allow them to mature and spawn spontaneously by a combination of hormonal, environmental, nutritional, and social/behavioral manipulations, and then to collect fertilized eggs or larvae for rearing. More research efforts must be devoted toward further improvement of techniques in these particular phases of milkfish culture.

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THE ECOLOGICAL ASPECTS OF MILKFISH FRY OCCURRENCE, PARTICULARLY IN THE PHILIPPINES

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This paper considers aspects of the time, place, and mechanism of occurrence of milkfish fry, defined as the postlarvae 10-17 mm in total length and 3 weeks of age. Fry occurrence shows seasonal patterns that differ by latitude. In the Philippines (15-21°N), fry appear earlier in the south (December-January) and later in the north (March-April); they disappear earlier in the north (July-August) than in the south (December-January). Various investigations indicate that the fry season is extended near the equator, with two peaks of which the eatlier (April-May) is higher, and is progressively shorter at higher latitudes, with only one peak (May-August). Greater numbers of fry occur in shore waters during the full moon and new moon periods, largely as a consequence of the greater spawning activity during the quarter moon periods. Fry catch by various active and passive filtering gear is greater at flood and high tide than at low and ebb tide. Milkfish fry occur in and are collected mostly from sandy beaches, particularly the surf zone and in and around river mouths. They appear to be distributed mostly near the surface, with greater numbers nearer shore. The bottom profile of the beach, the proximity of spawning grounds, the existence of favorable current systems, and access to coastal wetlands seem to be some of the factors that determine fry abundance. Milkfish eggs and larvae are planktonic. It appears that larvae smaller than 9-10 mm are distributed in midwaters, but once they reach this size they come up and are carried inshore by tidal and wind-driven currents. They accumulate in the surf zone to an extent regulated by the bottom profile. Once at the shore, the fry are affected by longshore currents and may be carried into coastal wetlands where they spend the juvenile phase.

INTRODUCTION

The milkfish fry shortage can be solved in two ways. One is to produce seed artificially in hatcheries; the other is to improve natural fry collection. Artificial seed production will take some time to reach the practical stage, and seed supply for ponds will remain dependent on the wild stock for a long time.

The supply of wild milkfish fry must be sufficient as well as predictable. These criteria can be assured through the application of appropriate fishing techniques and through understanding of the nature of fry occurrence in shore waters. Therezien (1979) lists 651 reference articles concerning milkfish; of these about 7% bear on the ecology of milkfish, mostly on fry occurrence. In these few reports, fry occurrence refers to the time the fry are caught, certainly an important aspect for fishing. In addition, however, we must know where, how, and why fry occur in shore waters to improve collection or develop new techniques. This paper is not a review of studies of milkfish fry occurrence, but rather a presentation of findings regarding the ecology of milkfish fry occurrence, particularly in the Philippines. Most of the work in support of this paper was carried out on Panay Island, particularly in Hamtik, Culasi, and Pandan on the western coast.

DEFINITION OF MILKFISH FRY

Any ecological study must deal with the right species. Morphological descriptions of milkfish fry in shore waters have appeared in the literature several times (Delsman 1929, Yoshida 1932, Blanco 1950, Liao et al 1977), but there have been mistakes. Delsman's (1926, 1929) description was long used in the identification of milkfish fry; Schuster (1960) cited Delsman's description; in turn Kuronuma and Yamashita (1962) cited Schuster in defining milkfish fry as "the pelagic larvae measuring 11-13 mm in total length." But Schuster (1960) had misinterpreted Delsman's work, and Delsman himself appears to have been partly mistaken in his identification. Among his five described and illustrated milkfish larvae measuring 6, 10, 11, 12, and 13 mm, only the two measuring 6 and 13 mm are milkfish. The other three larvae are described as having "a number of lengthened pigment spots along the upper side of the anterior part of the gut and along the ventral side of the posterior part." This description does not fit the pigmentation pattern in milkfish larvae, where the pigment spots found along the ventral sides of the gut first appear at the anterior part in larvae 10 days old and develop posteriorly (Liao et al 1979). There are some other papers in which the identification of milkfish fry is doubtful. The standard criteria for the identification of the fry must be agreed upon by researchers in this field. The fry fishermen, after all, find the identification no problem.

Milkfish fry have elongated transparent bodies like those of clupeioid larvae. In the fishermen's basin, only the eyes of the fry are conspicuous. They can be readily identified, however, by their energetic disposition and their tolerance of crowding. In containers, they exhibit very strong schooling behavior, circling continuously in the same direction. They go against water currents, and they react very quickly to shadow movements, sounds, etc. Under the microscope, they can be seen to be different from clupeioid larvae in having a parallel, instead of crossed, arrangement of muscle fibers in the myotomes. In front of the anus there are 32 myotomes, behind it 11-12. A series of black pigment spots can be found along the ventral side of the gut from the throat almost all the way back to the anus. The gut is straight and does not have transverse foldings. The liver is large, and under certain lighting looks like yolk material. The swimbladder is usually not inflated at the time of capture (which is usually daytime); when it is inflated, it is covered by a big pigment spot dorsal to it. Pelvic fins are absent, and remnants of the finfold can still be seen on the ventral edge.

One remarkable characteristic of milkfish fry is that they appear in shore waters year after year in such tremendous numbers, all within a very narrow size range. A total of 10 311 milkfish fry were collected from the western coast of Panay, Philippines from March to December in 1976 and from April to June in 1977. These fry measured 9.5-16.5 mm total length (TL) in 5% seawater formalin (Table 1). Most (93%) of the fry collected in 1977 were within the range of 12-15 mm TL (Table 2).

Table 1 shows the size range of milkfish fry in different localities. Milkfish larvae smaller than 10 mm could be collected with the larval net (Delsman 1926, 1929; Kumagai 1981) or from the bagnet of a 30-m deep *otoshi'-ami* (Kumagai et al 1976) set about 500 m from the usual fry collection beach. Those bigger than 15-16 mm are already in the transition stage and can be found in creeks, estuaries, lagoons, swamps, and similar places inside of the collection beaches (Kumagai and Bagarinao 1981).

From the work of Vanstone et al (1977) and Liao et al (1979) and from the daily size frequency distribution of milkfish fry over two years (Kumagai 1981), it is seen

Table 1. The size range of milkfish fry occurring in various localities.

Location	Date of collection	Sample size	Total length range (mm)
Philippines (Antique)	1976 fry season	4608	10.4 - 16.5
	1977 April-June	5703	9.5 - 15.9
Japan (Tanegashima) (Senta & Hirai 1981)	1978 summer	7326	10.3 - 16.2
Taiwan (Tungkang) (Liao et al 1977)	1976 fry season	166	12.5 - 16.2
Thailand (Kulong Wan)	1976 June 24	191	12.6 - 15.2
Indonesia (Lassem)	1976 May 15	134	10.4 - 14.6

Table 2. Size frequency distribution of the fry collected from April to June 1977, Antique, Philippines (Kumagai 1981).

Total length (mm)	Number of fry	Frequency (%)	Cumulative percentage
9.5 - 10.0	5	0.088	
10.0 - 10.5	13	0.228	
10.5 - 11.0	47	0.824	5.962
11.0 - 11.5	91	1.596	
11.5 - 12.0	184	3.226	
12.0 - 12.5	438	7.680	
12.5 - 13.0	911	15.974	
13.0 - 13.5	1171	20.533	
13.5 - 14.0	1435	25.162	92.793
14.0 - 14.5	986	17.289	
14.5 - 15.0	351	6.155	
15.0 - 15.5	67	1.175	
15.5 - 16.0	4	0.070	1.245

that the smallest fry (9.5 mm) in shore waters are about 2 weeks old and those of the mean size (13.5 mm) are about 3 weeks old (Table 2).

Kawamura and Washiyama (in press) counted 18-20 increments in the otoliths of eight milkfish fry of 12.5-14.2 mm TL from southern Japan.

In this paper, "fry" refers to the late postlarval milkfish, 10-16 mm TL, that appear in shore waters.

TIME OF FRY OCCURRENCE

The time of fry occurrence is of course related to the time of spawning. It is generally observed that milkfish fry are more abundant during the full moon and new moon periods (Fig. 1, Miyagami 1921, Schuster 1952, Thiemmedh 1955, Kuronuma and Yamashita 1962, Ramanathan 1969, Kumagai et al 1976). Apart from the influence of tides and wind-driven currents, this periodicity in fry abundance is a direct consequence of the periodicity of spawning activity. Egg collection data from 1976-80 show that, while milkfish spawns every night of the month during the season, spawning is most intensive during the quarter moon periods (Kumagai 1981). In larval net tows, yolk-sac milkfish larvae were collected during the quarter moon periods; the early postlarvae (5-10 mm, 4-14 days old) at all lunar phases; and fry only during the new moon period (total number of larvae = 42; Kumagai 1981). Since milkfish fry are 3 weeks old, they would appear inshore mostly during the new moon or full moon period following the previous first quarter or last quarter period, respectively, when they were spawned.

Fry occurrence shows seasonal patterns; different places have different seasons. Pandan and Hamtik, towns 130 km apart on the same western coast of Panay, have different fry occurrence patterns (Fig. 2). In Pandan (11.5°N), fry appearance starts at the end of March and lasts until early December, with a peak in May. In Hamtik

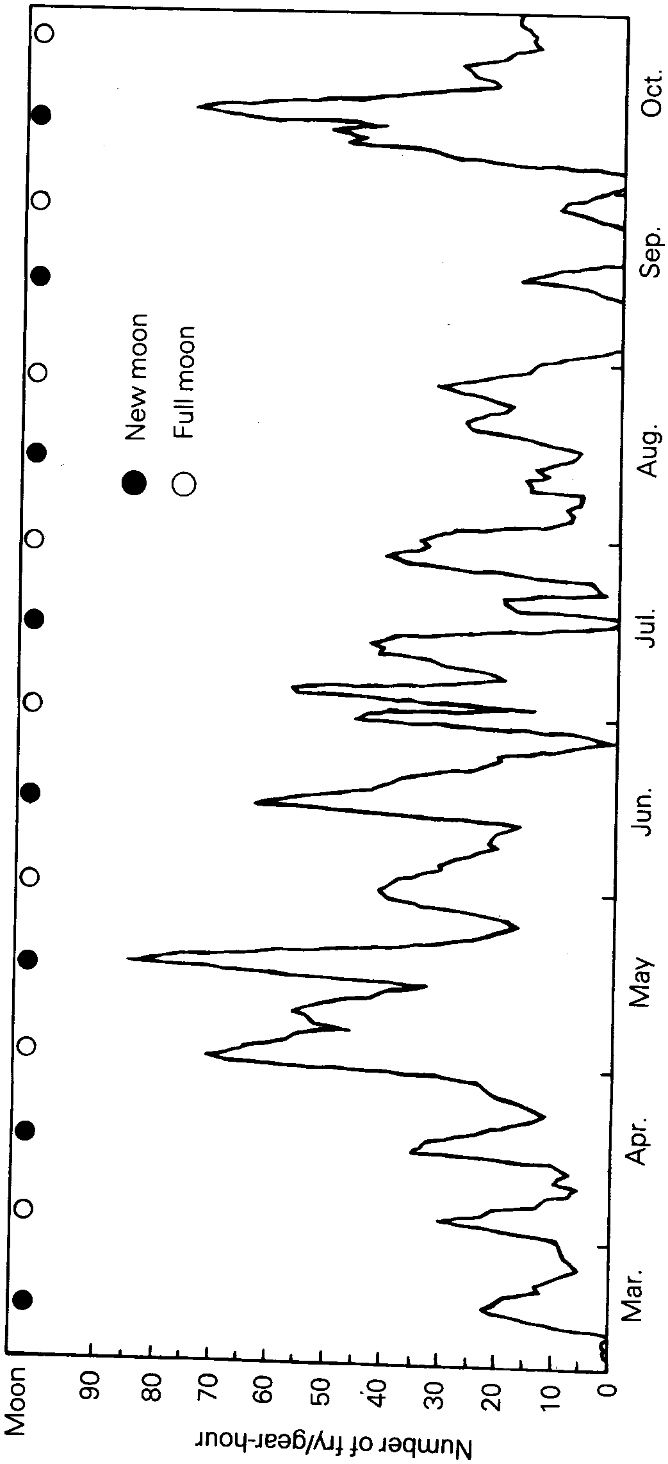

Fig. 1. The abundance of milkfish fry at Hamtik from March to October 1977, showing relation to lunar phase.

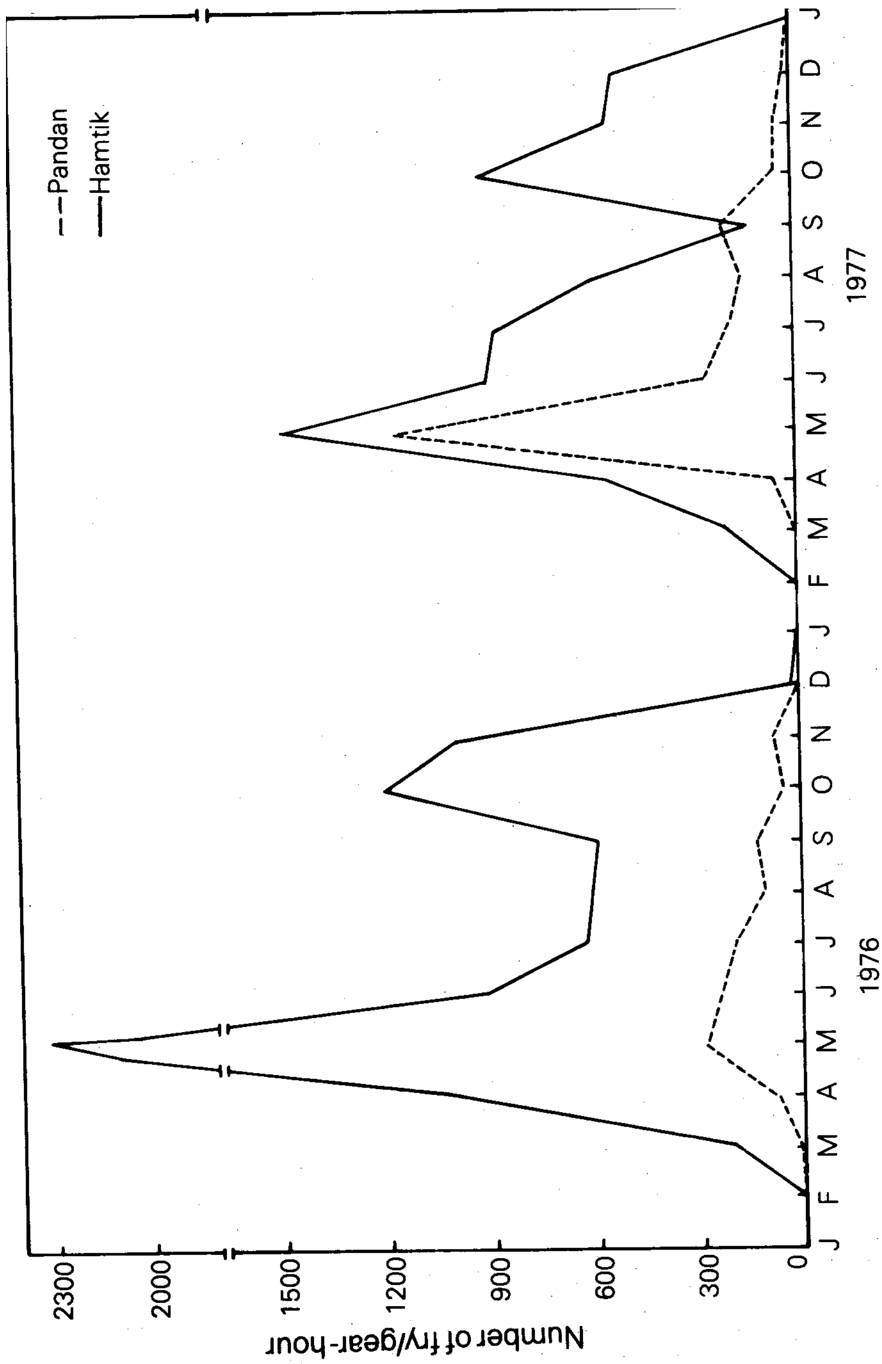

Fig. 2. The fry occurrence pattern in Pandan and Hamtik, Panay Island.

(10.5°N), fry appear in the middle of March and disappear by the middle of December, with peaks in May and October. The Philippines covers 5-21°N latitude. Fry appearance starts early (December-January) in the south and later (March-April) in the north; disappearance is earlier (July-August) in the north than in the south (December-January; Table 3). Moreover, in the south, about 5-11°N, there are two peaks, of which the earlier (April-May) is bigger; in the north, 12-21°N, there is only one peak (May-August). This latitudinal shift in the fry season can also be seen in other localities, such as in Vietnam (Kuronuma and Yamashita 1962). Figure 3 shows that the fry season is long near the equator and becomes progressively shorter at the higher latitudes in the northern hemisphere. In the southern hemisphere, few reliable data are available. In southern Thailand, southern India, and Sri Lanka, two peaks in fry occurrence are reported (Thiemmedh 1955, Tampi 1973, Ramanathan 1969); in northern India, there is only one peak (Basu and Pakrasi 1976).

The relation between spawner occurrence (in terms of range of gonadosomatic indices of adult fish) in Pandan, egg occurrence (in terms of frequency per larval net tow) in Cuyo East Pass, and fry occurrence (in terms of fry catch per gear-hour) in Hamtik and Pandan shows a lag of about 1 month between spawning and fry occurrence. Spawning activity starts in March, intensifies in April, and diminishes in July (Kumagai 1981). Fry occurrence starts in March or April, is highest in May, and tapers off in July.

Current fry collection methods and gear are based on active or passive filtration of fry from the water. Passive gear depends almost entirely on tidal currents, and even active gear is operated mostly during times of high water. Since the fishing area is usually limited to the surf zone, the phase of the tide and the consequent water volume and current affect the efficiency of gear operation and thus the fry catch. Within one tidal cycle, the current is strongest at flood tide; water movement is extensive, shorewards, and into straits. If and when there are fry offshore or in open

Table 3. Milkfish fry collecting season at various localities from north to south in the Philippines.

Latitude	Localities	Collecting Season	Peak
	Santa Ana	April to October	June
17.5°	Badoc	April to October	(July) August
	San Fernando	April to July	May
15.0°	Lingayen	(Mar) April to July	June
	Batangas	(Mar) April to July	May
	Naujan	April to August	May
12.5°	Tabaco	April to November	May
	Culasi	April to November	June
	Hamtik	March to December	May & October
10.0°	Cadiz	March to November	May & October
	Nana	March to December	May & October
	Sipalay	March to December	May & October
7.5°	Naawan	(Feb) March to December	May & November
	Malita	February to December	April & October
	Zamboanga	(Jan) February to December	(Mar) April & October (Nov)
-	Glan	January to January (end) (beginning)	(Mar) April & November

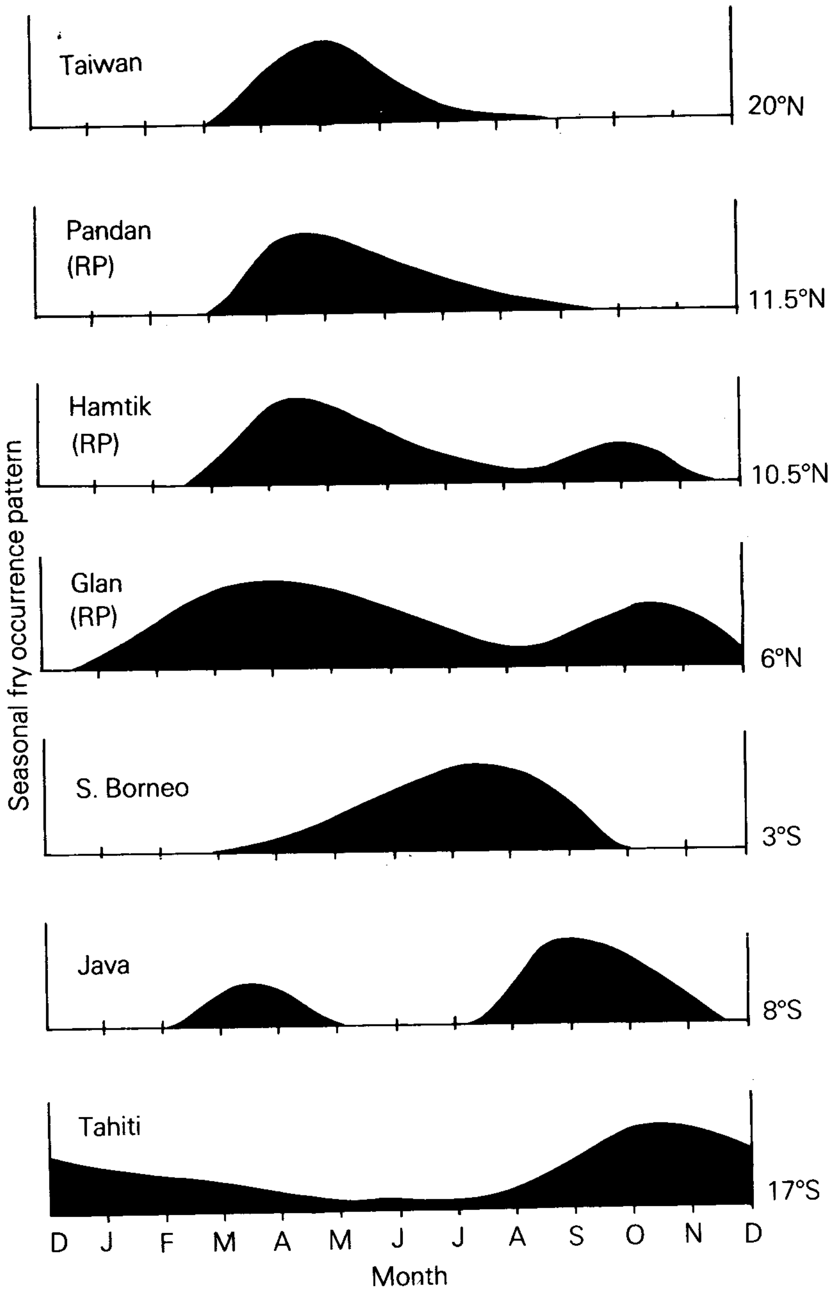

Fig. 3. Seasonal fry occurrence patterns at different latitudes (drawn from data of various authors).

waters adjacent to straits, the flood tide has the effect of concentrating them in the surf zone. During the fry season in April-May 1977 in Hamtik, the catch per unit effort (CPUE in fry/gear-hour) of regular fry collectors was monitored during one tidal cycle. Data were broken into four tidal phases (low tide LT, flood tide LT → HT, high tide HT, and ebb tide HT → LT; Fig. 4). At any phase of the tide, CPUE was usually less than 150. However, the CPUE frequency had its mode at 0-50 at low tide and ebb tide, and at 100-150 at high tide and flood tide. This confirms the contention of fry collectors that the catch is better at flood tide and high tide. Nevertheless, Figure 4 also shows that the fry do not necessarily disappear from shore waters during low tide and ebb tide, and in fact can be collected, albeit in lower numbers. In the Philippines, fry collectors make it a point to utilize flood tides and high tides, and they go to the extent of operating gear at night when necessary.

PLACE OF FRY OCCURRENCE

The fry collection gear currently in use is operated mostly in the surf zone and in and around river mouths; most are designed to filter the surface water (Kumagai et al 1980). Certain types of gear have recently been adapted for surface fishing some distance (up to 50 m) offshore, or for subsurface fishing. These trends have necessitated information on the horizontal and vertical distribution of milkfish larvae or fry, as well as on the effects of shore topography on distribution.

Sandy beaches are the most common fry collection grounds. The slopes of the bottom vary from gradual to steep. Water movements and volume in the surf zone are regulated by the bottom profile. Given that there are fry in shore waters, it may be expected that a certain type of bottom profile would maximize the accumulation of fry in the surf zone. To test this hypothesis, four observation sites were set at intervals of more or less 1 km along an almost straight shoreline. Site I had extended shallow water, i.e., a very gradual slope; Sites II and III had intermediate slopes; but Site III was located at the mouth of a small river and Site IV had a steep slope (Fig. 5). Fry catches at these four sites were compared. Sites II and III had the highest catches, Site IV an intermediate catch, and Site I the poorest. There is therefore some indication of a "suitable" shore profile for fry collection, an area that deserves further study.

In fry collection grounds that have nearly uniform slope, fry collectors do not necessarily distribute themselves homogeneously along the shore but prefer certain spots that apparently have higher concentrations of fry. These favored spots are usually the mouths of rivers and creeks where there is brackishwater runoff and extrusion of "smelly" organic sediments. Faith in the attractive qualities of river runoff leads fry concessionaires/collectors to take measures in time for the fry season to open up or excavate creek or river mouths closed off by sand deposits during the previous year's storms. To test this hypothesis, a length of beach 50 m from a creek mouth that was a concessioned spot was divided into five consecutive zones, each 50 m long. Fry collectors were asked to fish uniformly in these five zones, and their catch was recorded every 15 min. The data show no clear trend of increasing fry abundance the closer to the creek mouth, but rather a generally patchy kind of fry distribution in the surf zone. At periods when many fry can be caught 50-100 m from the creek profile of the shore. Once at the shore, the fry are affected by longshore currents. When they happen to be in the vicinity of rivers, creeks, and other inlets into coastal wetlands, they may be carried inside by flood tides and subsequently settle there.

Passive migration of milkfish fry from offshore waters to the surf zone and into coastal wetlands was suggested by the types of fry collection gear that are in effective use presently. Three types of gear illustrate passive migration, namely those that are:

- set against the incoming waves in the surf zone;
- set against the longshore current; and
- set across river and creek mouths.

These are exemplified by the sweeper fixed in the surf zone, the *tangab-balsa,* and the *tangab* (Kumagai et al 1980). In short, the fry arrive at the surf zone, accumulate there, drift along the shore, and may be carried inland — all largely by the action of water currents. Some investigators propose an alternate hypothesis, that of active migration (Buri and Kawamura 1983, Kawamura 1983), and indeed there is a lot of ground for discussion and further study. Behavioral developments in milkfish larvae are receiving due attention (Liao et al 1979, Kawamura and Hara 1980, Kawamura and Nishimura 1980, Kawamura and Shinoda 1980, Kawamura et al 1980, Kawamura 1983), and in time a full grasp of the mechanism of fry occurrence in coastal waters will be reached.

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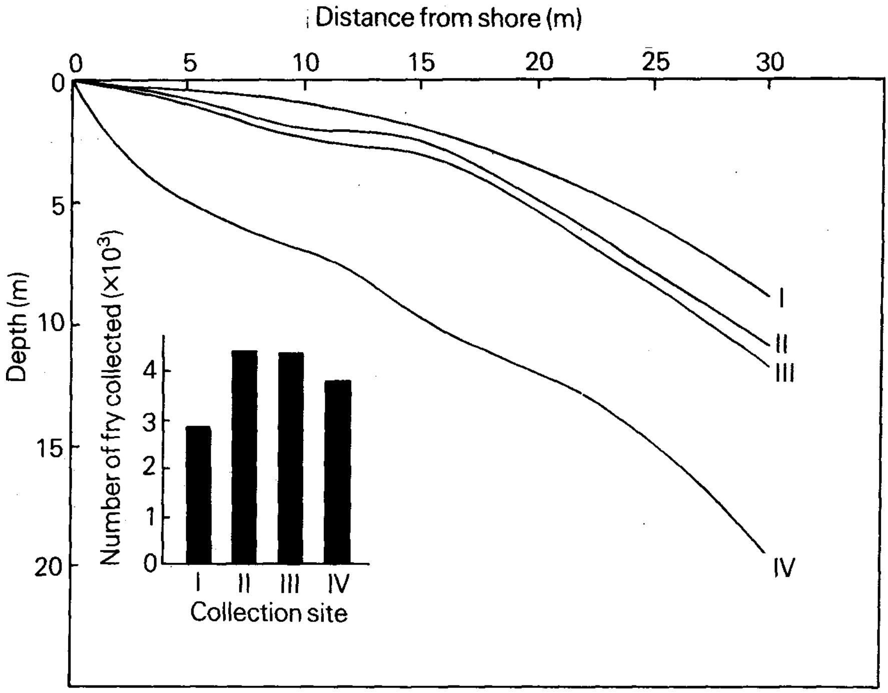

Fig. 5. Types of bottom profile from gradual (I) to steep (IV) and the corresponding milkfish fry catch.

mouth, many fry can likewise be caught 250-300 m away (Fig. 6). At periods when fry are scarce near the creek mouth they are also scarce farther away. Of course, the fry catch at the creek mouth itself is what matters most, but data on this were withheld by the concessionaire. It was also unfortunate that the test did not include the length of beach on the other side of the creek mouth. Nevertheless, it appears that milkfish fry arrive in the surf zone in small patches and may subsequently be transported by longshore currents.

In open waters, milkfish fry can hardly be collected, as the extensive larval net operations in Cuyo East Pass show. In all of about 600 surface and deeper layer net tows, 42 milkfish larvae were collected, and only two of these were fry (Kumagai 1981). On the other hand, fry can be collected from nearshore but at much lower densities than in the surf zone. In the fry collection ground in Hamtik, the bottom slopes very gently and is only about 5 m deep at points 100 m from the surf zone. To test for the horizontal distribution of fry nearshore, three "bulldozers" (a raft with wings and a bagnet, used mostly at night with a lamp; Kumagai et al 1980) were operated simultaneously for 3 h at distances of 40, 70, and 100 m from the beach; catches during 30 min periods were recorded. The results indicate that fry are more abundant nearer shore (Fig. 7); the catch at 100 m distance was about 2/3 that at 40 m. There also appeared to be a time element in the fry abundance at the three stations. When the catch was high at 100 m at 0100 h, the catch at 70 m was high 30 min later; when the catch at 70 m was high at 0100 h, the catch at 40 m was high(er)

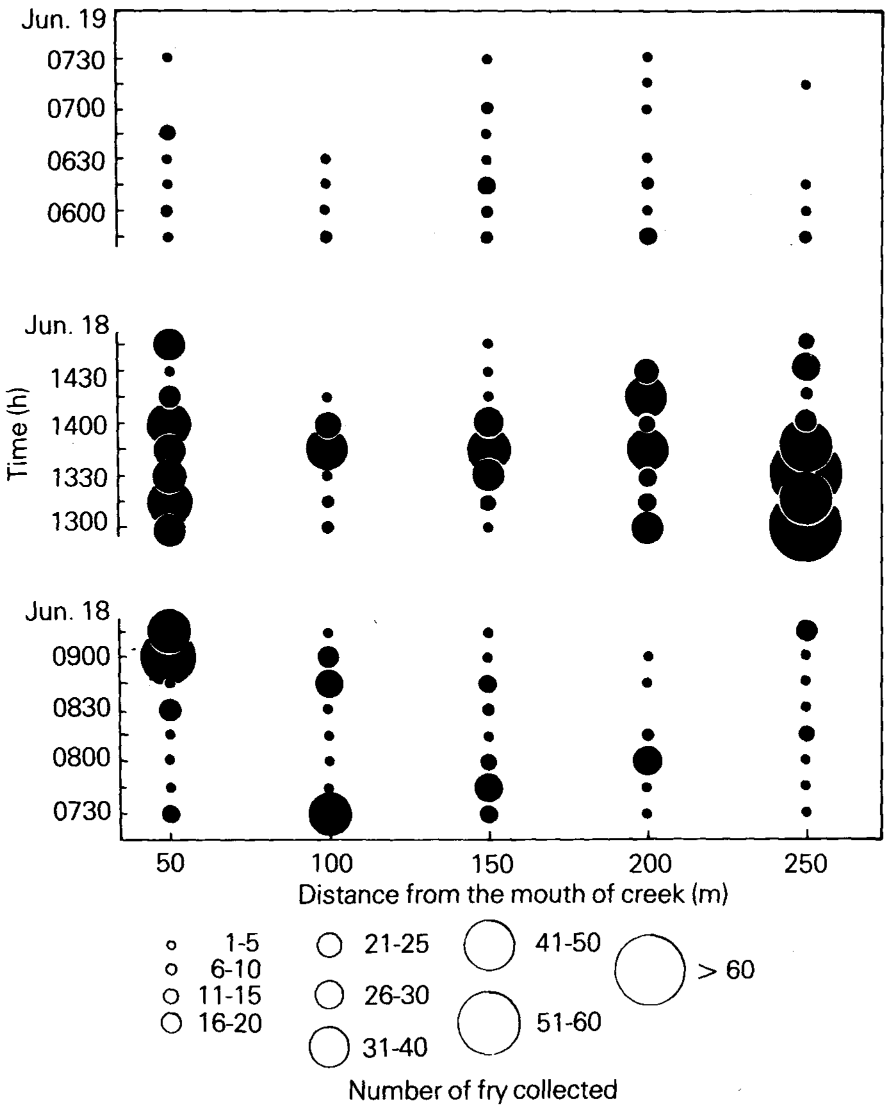

Fig. 6. The catch of milkfish fry at 5 consecutive zones adjacent to a creek mouth (which was a concessioned fry collection site). There is no clear trend of increase of fry abundance towards the creek mouth. The fry appear to arrive at the surf zone in patches.

30 min later (Fig. 7). These results indicate a gradual accumulation of milkfish fry in the surf zone.

The vertical distribution of fry in nearshore waters would be useful information but has not yet been determined. There are some data, however, regarding the vertical distribution of milkfish larvae in open waters (Kumagai 1981). Yolk-sac larvae were obtained by larval net from the surface down to about 40 m with no significant

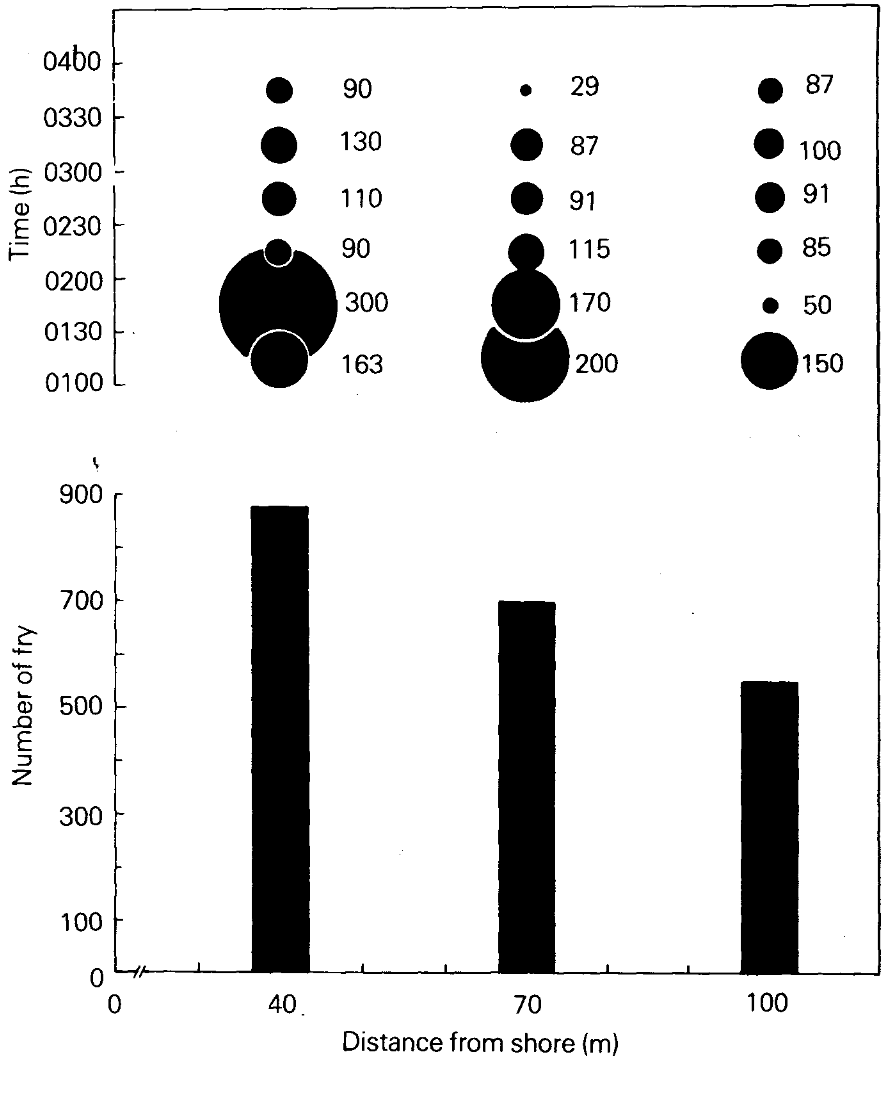

Fig. 7. The abundance of milkfish fry at distances of 40, 70, and 100 m from the surf zone in Hamtik as indicated by catch data from bulldozers. The catches at various times at these three sites suggest gradual accumulation of fry in the surf zone with time.

differences in density. Early postlarvae (5-10 mm, 4-14 days old) were caught as deep as 30 m, but mostly at the surface, whereas the late postlarvae (fry) were caught only at the surface. Moreover, early postlarvae as small as 5.8 mm were caught in the 30 m deep bagnet of the *otoshi-ami* set just 500 m from the fry collection ground in Pandan (Kumagai et al 1976).

Some fry collection grounds are better than others. The western coast of Panay

Island is one of the best in the Philippines; along this coast, Hamtik and Culasi stand out in fry catch. It is very difficult to say why this is so, and very difficult to project what a good fry collection ground should be like in terms of topography. Hamtik and Culasi are both sandy beaches; the former has fine white sand, the latter coarse black sand. Both have creeks and rivers that may be "attractive" as claimed. Hamtik has a very gentle shore profile and Culasi a rather steep profile. Culasi is located opposite confirmed milkfish spawning grounds, the waters around Maralison and Batbatan Islands (Senta et al 1980, Kumagai 1981). Only one milkfish egg has ever been collected off Hamtik. Schmittou (1977) suggested that the fry in Hamtik probably come from eggs spawned in the Cagayan Islands in the Sulu Sea, and milkfish eggs have indeed been collected from this area (Senta et al 1980). Many other factors must determine the fry productivity of coastal waters and collection grounds.

MECHANISM OF FRY OCCURRENCE

Why do milkfish fry come to shore? This question can best be answered by evolutionary biologists and is not the primary concern of this paper. Many species that live in the open waters as adults spend their early life stages in shallow inshore or inland environments. Settlement in shallow-water nurseries is evidently a requirement for life in milkfish; they come to shore and enter coastal wetlands where food is plentiful and predators are few (Buri 1980, Kumagai and Bagarinao 1980).

How do the fry come to shore? Milkfish spawns in the open waters around small islands, shoals, and coral or rocky promontories (Senta et al 1980), and the eggs and larvae form part of the plankton. The eggs were distributed at ratios of 20, 15,10, and 5 eggs per successful tow at depths of 10, 20, and 30 m (Kumagai 1981). Yolk-sac larvae tend to be uniformly distributed from the surface to about 40 m; this difference in egg distribution may be explained by the fact that yolk-sac larvae tend to sink. Early postlarvae still occur in deep water but apparently become more frequent at the surface as they grow older and develop further; at the late postlarvae stage they become confined to the surface. These facts indicate that milkfish larvae smaller than 9-10 mm are distributed in midwaters and that once they reach this size they come up and are carried inshore by tidal and wind-driven currents. The role of surface currents on larval transport was studied using drift cards (Kumagai and Bagarinao 1979). It was found that in Cuyo East Pass, which fronts the western coast of Panay, surface currents move away from the coast in December-April and along or toward the coast in June-October. Although these results do not include May, which is the peak of fry occurrence in the area, they do indicate that surface currents are not the main factor in fry transport. There is the possibility that the larvae use midwater currents to come to shore, but there are no data on this aspect.

Once the postlarvae are reasonably close to shore, the passive migration phase begins. They are carried by wind-driven or tidal nearshore currents into the surf zone, where they accumulate. Senta and Hirai (1981) noted that milkfish fry in Tanegashima were more abundant on days when moderately strong winds blew from the sea toward shore, and were more abundant at Kumano on the east coast facing the Kuroshio than at Shimama on the west coast. The degree of accumulation in the surf zone depends on the nature of water movement, which is regulated by the bottom profile of the shore. Once at the shore, the fry are affected by longshore currents. When they happen to be in the vicinity of rivers, creeks, and other inlets into coastal wetlands, they may be carried inside by flood tides and subsequently settle there.

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THE SENSE ORGANS AND BEHAVIOR OF MILKFISH FRY IN RELATION TO COLLECTION TECHNIQUES

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Only with some knowledge of the behavior of fish can fishing technologists objectively approach the problems of improving existing fishing techniques or of developing new ones. Behavior is the reaction of organisms to stimuli received through sense organs. This paper describes the sense organs and some of the behavioral characteristics of milkfish fry, based on studies conducted at the Aquaculture Department, SEAFDEC, Philippines and at Kagoshima University, Japan in 1979. Based on the experimental results obtained and the observations made in the Philippines, Indonesia, and Taiwan, existing fry collection techniques such as the employment of fish lamps and scare lines are considered effective and rational. Several recommendations are made for improvement of the collection gear and for research on fry behavior.

INTRODUCTION

The collection of milkfish fry from shore waters in the Philippines, Indonesia, and Taiwan is an important task crucial to the pond and pen culture industry. There is need to improve collection techniques to increase the catch, both to boost milkfish production and to provide remunerative employment to people in coastal villages. The development of fishing gear technology is not based on completely new concepts (von Brandt 1972). The highly modernized fishing gear of today is not fundamentally different from the so-called traditional or primitive fishing gear. Innovations in equipment and techniques have been due to the ingenuity of fishermen, engineers, and scientists who invent mechanisms and improve their quality and effectiveness to meet different fishing conditions and socioeconomic requirements. Although the traditional milkfish fry collection techniques are effective, these lack sound scientific bases and institutional arrangements for continuous improvement through innovation.

By knowing the behavior of fish in the vicinity or path of the gear, gear technologists can approach the problem of improving existing fishing techniques or developing new ones. Behavior is the reaction of organisms to some external stimuli received through sense organs. It is imperative, therefore, to know the sense organs and behavior of milkfish fry.

The objectives of this report are: (1) to describe the sense organs and some of the behavioral characteristics of milkfish fry from the studies made at the Aquaculture Department, SEAFDEC, Philippines and in Kagoshima University, Japan in 1979-83; and (2) to make recommendations for improving existing fry collection techniques in the Philippines, Indonesia, and Taiwan.

SENSE ORGANS OF MILKFISH FRY

Milkfish fry were caught in the shore waters of Kumano Bay, Tanega Island, Japan (Senta et al 1980). Some of them were fixed on the beach in Bouin's solution or in 2.0% osmic acid with 0.1 M sodium phosphate buffer; the others were reared in the laboratory for observation of the development of the sense organs using scanning electromicroscopy and histological techniques. All the sense organs of milkfish fry were considered functional at the time of their capture, and they could respond to optical, chemical, and mechanical stimuli.

Eye

Vision is the most important sense for the fry in feeding and in response to nets (Kawamura and Hara 1980a, Kawamura et al 1980). At the time of capture, the fry have the ability to move their eyes, and they exhibit a well developed regionally differentiated duplex retina (Fig. 1). The cell density and the thickness of the retina are highest in the temporal region (area temporalis), indicative of highest visual acuity towards the nose. Although rod density is low at this stage, retinomotor response is observed, and both photopic and scotopic vision must be possible. The adipose eyelid is not formed at the fry stage and appears only during metamorphosis. A tapetum lucidum is present in the pigment epithelium and may be functional under subdued light conditions. This is observed in nocturnal animals or fish in turbid environments (Walls 1942, Moore 1944). The S-potentials recorded from the retinae of young milkfish (12.5-14.0 cm in fork length) suggest the possession of color vision and show a spectral sensitivity with peaks at 492-522 nm and 582-621 nm (Kawamura and Nishimura 1980), although the fry have not been examined in this respect.

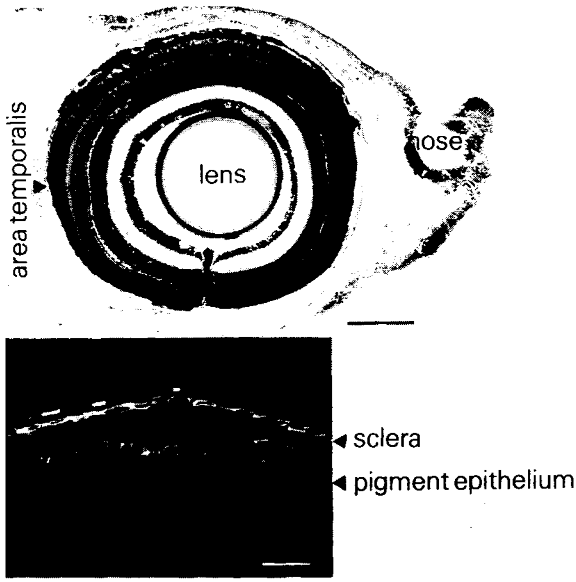


Fig. 1. Top, longitudinal section of the eye of milkfish fry showing the well developed retina with area temporalis. 4 mm thick, Azan stained; scale, 100 mm. Bottom, magnified photomicrograph of the retina of milkfish fry taken under differential interference contrast microscope. The retinal tapetum lucidum shines bright in the pigment epithelium. Scale, 25 mm.

Lateral Line

The receptor unit of the lateral line system is the neuromast, made up of ciliated pyriform receptor cells and covered with a gelatinous cupula. In larval teleosts, the system appears as free neuromasts found in the epidermis. With growth, some of these submerge into the dermis and form lateral line canals with pores; the others remain in the epidermis and are called pit organs. In adult teleosts, the canal organ functions as a mechano-receptor, and the neuromasts (pit organs) are sensitive to chemical, mechanical, and thermal stimuli (Katsuki 1978, Kawamura and Yamashita 1981). The function of the free neuromasts in larvae has not been well examined, but it is probably not different from that in adults. According to Iwai (1972), the free neuromasts become functional as mechanical receptors when the cupulae are well developed. At the time of capture, fry have numerous free neuromasts with well developed cupulae on the head and a few on the trunk (Fig. 2). During metamorphosis, the free neuromasts submerge and form canals in the dermis.

Inner Ear

The inner ear is the receptor of hearing and balance. The membranous labyrinth of fishes can be likened to a purse. Leading from the main pocket (utriculus) of this purse are loops (semicircular canals) and a side pocket (sacculus) that has yet another

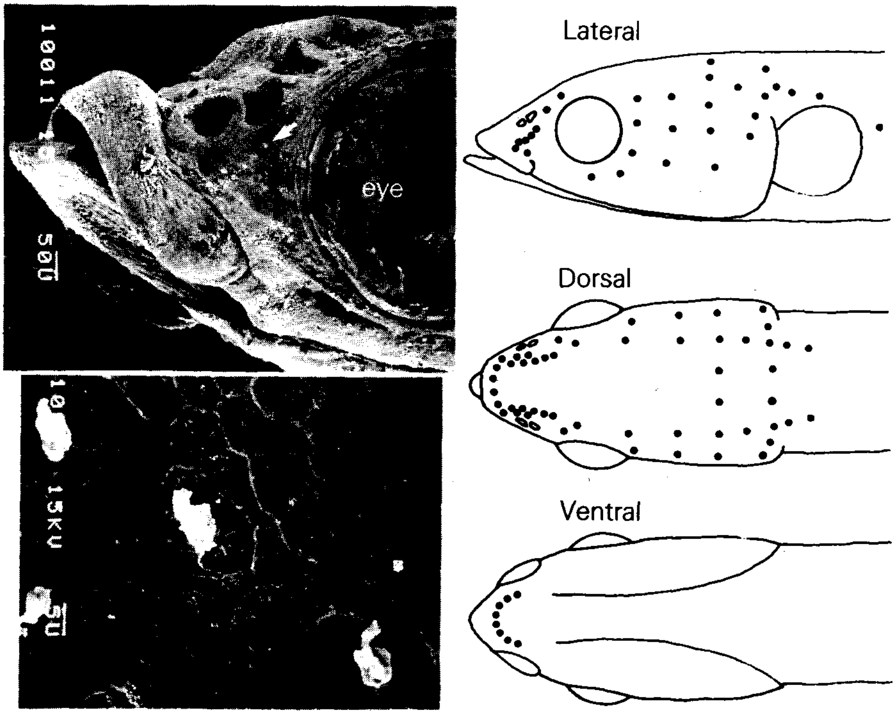
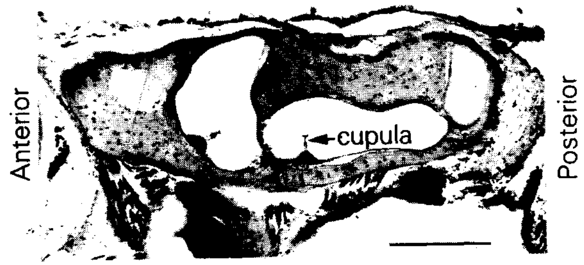


Fig 2. Left, scanning electronmicrographs showing the free neuromasts around the nares (shown by arrow) and the same when magnified. Right, the arrangement of the free neuromasts on the head and under the lower jaw.

pocket (lagena) opening from it. The main pocket and the three semicircular canals are responsible for equilibrium, and the sacculus and the lagena for hearing. At the time of capture, fry have well developed semicircular canals, but not well differentiated pockets (Fig. 3). Since there are neuromast cells with cupulae and otoliths in the main and anterior pockets, the inner ear can be considered functional enough for hearing and equilibrium maintenance.

Olfactory Organ

The olfactory organ of milkfish is a pouch that opens to the water through the anterior and posterior nares on each side of the snout. Division of the nares was incomplete in about half of the newly caught fry examined and becomes complete in all fry within 5 days after capture. The separation of incoming and outgoing water then becomes possible. The olfactory epithelium is not lamellated at the time of capture (Fig. 4). A deep fold appears 14 days after capture. Lamellation increases with growth, increasing the exposed surface area and hence the sensitivity.



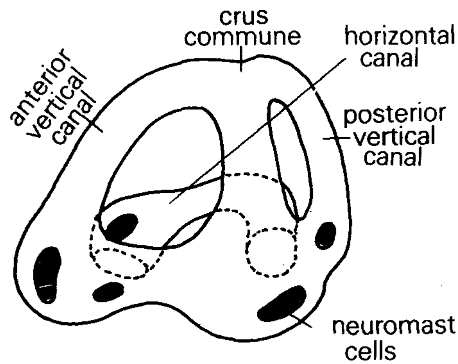
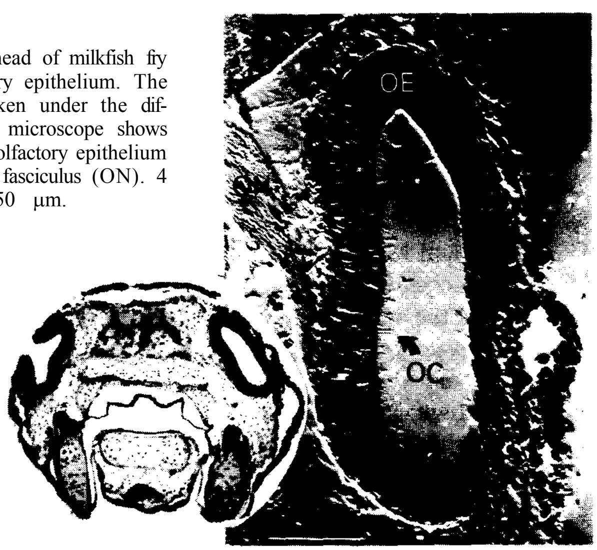


Fig. 3. Top, vertical longitudinal section of the inner ear of milkfish fry. Neuromast cells with cupulae can be seen in the main and the anterior pockets. 4 mm thick, Azan stained; scale, 200 mm. Bottom, the structure of the inner ear as reconstructed from successive sections.

Fig. 4. Cross-section of the head of milkfish fry showing the nares and olfactory epithelium. The magnified photomicrograph taken under the differential interference contrast microscope shows long olfactory cilia (OC), the olfactory epithelium (OE), and the olfactory nerve fasciculus (ON). 4 µm thick, Azan stained; scale, 50 µm.



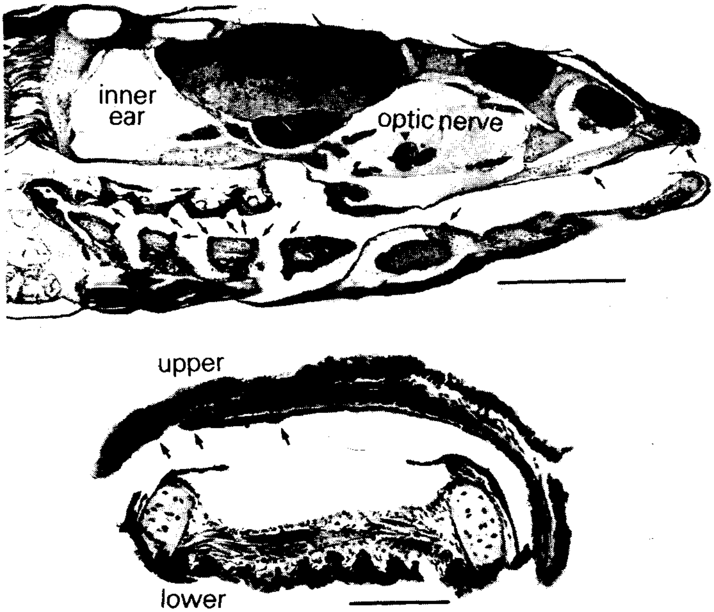


Fig. 5. Top, vertical longitudinal section of the head of milkfish fry showing the taste buds in the epithelium of the oral cavity and the gill arches (arrows). 4 mm thick, Azan stained; scale, 400 mm. Bottom, cross section at tip of mouth shows taste buds in the epidermis of the upper lip (arrows). 4 Um thick, Azan stained; scale, 100 mm.

Taste Buds

Fry at the time of capture have numerous taste buds in the epithelium of the oral cavity and the gill arches and in the epidermis of the upper and lower lips (Fig. 5). With growth, the taste buds in the mouth increase in number and size.

BEHAVIOR OF MILKFISH FRY

Distribution and Movement in Shore Waters

The depth of operation of any fishing gear is dictated largely by the vertical distribution of the desired species. Kumagai (1981) showed the vertical distribution of milkfish larvae by developmental stages from plankton net tows made in offshore waters. Buri and Kawamura (1983) compared catches between two fixed gear at different depths of operation in the mouth of the river at Hamtik, Panay, Philippines and found higher catches from the shallower gear.

The movement of the fry to the collection grounds appears to be an active process. This was first suggested by the results of the drift card experiment of Kumagai and Bagarinao (1979). Buri and Kawamura (1983) released 4060 marked fry 150-160 m offshore at Hamtik and observed active movement back to shore into collection gear and into backwaters (Fig. 6). Good fry collection grounds are usually located close to river mouths and swamp outlets. The entrance of fry into backwaters seems to take place only on suitable flood tides, 1-3 h before high tide.

There is a notable semilunar (circasyzygic) rhythm in the catch of milkfish fry; that is, more fry are caught during full moon and new moon periods (Kuronuma and Yamashita 1962, Kumagai 1981, Buri and Kawamura 1983). When the daily fry catch at Hamtik in 1980 was correlated with the lunar cycle, the catch fluctuation appeared to coincide well with a resultant rhythm composed of syzygic and semi-syzygic rhythms rather than the syzygic rhythm alone (Fig. 7). These studies on the rhythmic fluctuation of the catch of fry may later enable prediction of, and concentration of fishing effort during their peak appearance.

Schooling Behavior

Since a solitary fish behaves differently from a school, and fishing techniques have to be based on the distribution of solitary fish and on the size of a school, fishing technologists have been very interested in schooling behavior. Milkfish fry usually form a typical school in aquaria and similar captive conditions. However, it is not known whether or not the fry form a school or several schools in shore waters. Kawamura and Quinitio (unpubl.) analyzed the catch from two mobile fry sweepers operated independently within a fixed 100 m stretch of beach at Culasi, Panay, Philippines. The analysis was based on the assumption that, if the fry form a school, the catch of any gear would be governed by chance, and there would be low or no

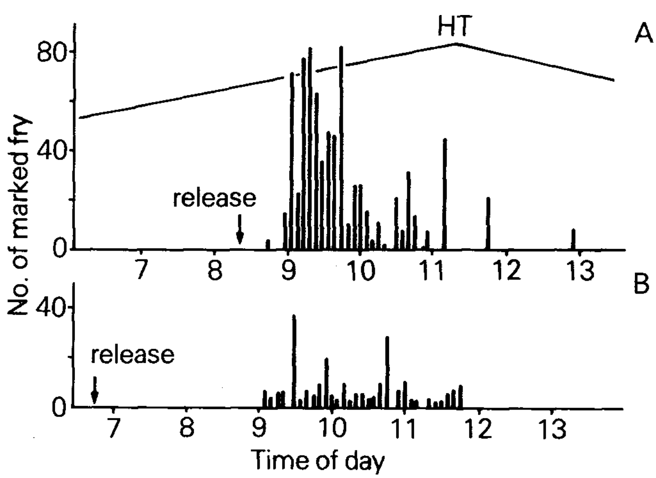


Fig. 6. Recapture of marked milkfish fry in all collection gear combined, from the first release (A, 30 April 1980) and the second release (B, 1 May 1980) at Hamtik. Time scale of B was shifted left to unite the time of high tide (HT) with that of A. The first batch (2060 fry) was released about 3 hours before high tide, the second batch (2000 fry) the following day about 5 hours before high tide. Recapture ratio was 37.2% for the first batch and 35.3% for the second batch (After Buri and Kawamura 1983).

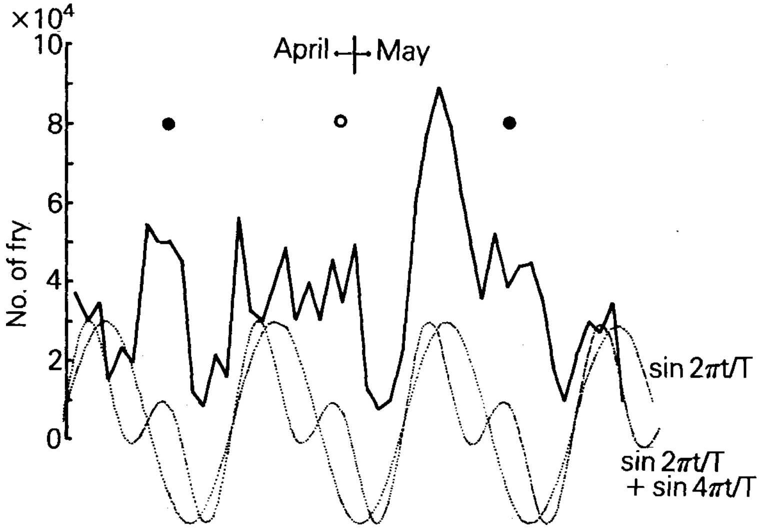


Fig. 7. Daily fluctuation of commercial milkfish fry catch at Hamtik from 7 April to 24 May, 1980 (bold line), shown with the syzygic rhythm and a resultant rhythm composed of syzygic and semi-syzygic rhythms (dotted lines). t = time in days, T = period = 14.77 days, open circle = full moon, closed circle = new moon.

correlation in catch between the two sweepers. However, although the catch was poor, relatively high correlation coefficients were obtained (Table 1), indicating that the fry disperse from an offshore school (if such exists) or form a loose aggregation in shore waters. This result is partly supported by the mark-recapture experiment of Buri and Kawamura (1983); recapture data indicated scattering of released fry over a large area, as far as 2 km from the release point.

Swimming Speed

The swimming speed of milkfish fry has been examined in the laboratory using a water tunnel. Komaki (1981) obtained a speed of 10.8 cm/s, whereas Kumagai et al (1980) observed 9 cm/s in sustained swimming and 24 cm/s in burst swimming. The swimming speed can also be estimated from the optomotor reaction (OMR). From the rotation velocity of the drum employed in the OMR experiment by Kawamura and Hara (1980b), the swimming speed was estimated to be about 9 cm/s. In the mark-recapture experiment, Buri and Kawamura (1983) found that one recaptured fry covered the distance of 150 m in 25 minutes at an average speed of 10 cm/s. Although the experimental methods employed were very different, the observed swimming speeds varied within a narrow range — 9-11 cm/s. On the other hand, the swimming ability of fish has been established to have a positive correlation with space in which to swim (Yonemori 1978). The speed of fry in shore waters may then be greater than that measured in captivity.

Table 1. Correlation coefficients of the catch of two fry sweepers operated simultaneously in independent directions (sometimes in the same direction, sometimes in counterdirection) off a fixed 100 m stretch of beach. The fry in the sweepers were counted every 30 minutes. (After Kawamura and Quinitio, unpubl.)

Date	Time	No. of operations	Total catch		Correlation coefficient	t	P
			Gear-A	Gear-B			
April 17	0700-1830	21	1063	542	0.720	4.300	<0.001
	1830-2400	10	153	174	0.106	0.301	>0.50
April 18	0800-1800	19	222	174	0.760	4.835	<0.001
	1830-0030	9	122	63	0.636	2.180	>0.05
April 21	0800-1700	18	77	46	0.766	4.763	<0.001
May 1	0900-1700	16	34	57	0.542	2.415	<0.05
May 2	0800-1700	18	192	124	0.888	7.710	<0.001

Phototactic Behavior

The use of lamps to attract milkfish fry is practised in the Philippines. The photopositive behavior of the fry was first confirmed in a tank experiment by Kumagai (unpubl.) at the Aquaculture Department of SEAFDEC. Thereafter, Kawamura and Shinoda (1980) in Japan examined the behavior of the fry in the field and in a tank and observed a change in phototactic behavior with growth. Fry exhibit strong positive phototaxis at the time of capture from shore waters. Three shifts in phototactic behavior were observed in fry grown in tanks. The photopositive behavior of the fry approaching metamorphosis became weak, and young juveniles showed photonegative behavior. About 7 weeks later, juveniles again showed photopositive behavior, whereas some 4.5 months after capture, no significant photopositive or photonegative behavior was observed. As the attracted fry can be guided by slowly moving light (Kawamura and Shinoda 1980), lamps can be used with both fixed and mobile gear. However, the light intensity has to be carefully decided upon because the fry have sensitive eyes and are repelled by light stronger than 200-300 W in experimental tanks (Kumagai, unpubl.).

Optomotor Reaction (OMR)

The OMR is an unconditioned reflex evoked by the sight or feel of movement and is of great importance in spacing and in school formation (Protasov 1970). Inside and outside a moving seine net, fish with OMR swim in the same direction at the same speed with the net and are caught when the net wings are closed (Parrish 1967).

The OMR of milkfish fry and juveniles was examined by Kawamura and Hara (1980b) at the SEAFDEC Aquaculture Department. The fish were placed in a beaker and their reactions to a moving striped paper drum were observed. When the drum was rotated in a certain direction, most of the fry turned slowly and moved in the same direction along the wall of the beaker. The OMR was somewhat weak during the first week following capture. It underwent a big change during metamorphosis, and juveniles showed perfect OMR. Although the amplitude of the OMR is somewhat low, newly captured fry in containers show very strong rheotaxis. This behavior may be evoked not only by vision but also with the aid of the already well developed free neuromasts. The role of the lateral line system in rheotactic behavior was elucidated by Inoue et al (1982).

Response to Nets

The fry collection gear presently used in various locations in the Philippines, Indonesia, and Taiwan are in principle operated by filtration, similar to plankton and larval nets. However, as Bridger (1956) reported, marine fish larvae visually avoid plankton and larval nets towed slowly in the daytime. The importance of vision in the response of fish to stationary and moving nets is well established (Ochiai and Asano 1955; Hiyama et al 1957; Kanda and Koike 1958a, b; Kanda et al 1958; Blaxter et al 1964). The fry have well developed eyes and feed on plankton mainly by vision (Kawamura and Hara 1980a). Therefore, although the amplitude of the OMR is somewhat low, the fry can respond to the collection gear by vision.

The responses of milkfish fry to moving and stationary nets were observed in a tank by Kawamura et al (1980) at the SEAFDEC Aquaculture Department. Since juvenile milkfish have color vision (Kawamura and Nishimura 1980), nets of different colors and mesh sizes were tested on the fry in an experimental procedure similar to that of Kusaka (1957). An experimental wooden tank (240 × 60 × 60 cm), painted blue on the inside, was filled with seawater to a depth of 20 cm. Black nylon twine of 0.53 mm diameter was stretched vertically on a blue-painted wooden frame at intervals of 5, 10, and 20 mm, and white nylon twine of the same diameter at 5 and 20 mm.

To observe fry response to a stationary net, 200 fry were driven to one end of the experimental tank and were blocked by a net set 60 cm from the wall. The number of fry which passed through the mesh was counted; this was taken as a measure of the visibility of the net to the fry and as a measure of the strength of the net avoidance response. Fry blocked by a stationary net turned around and formed one or two schools inside the net. Then a small or large part of the school passed through the mesh. It was evident that black and white twine had different effects on the fry; the fry easily and very quickly escaped through the white twine but were retained for a much longer time in the black.

For observation of fry response to moving nets, the fry were driven to one end of the tank where the net had been set beforehand next to the wall. The net was then moved at 3.5-4.0 cm/s toward the opposite wall. The number of fry that were passed by the net (i.e., not herded) was counted. The response of the fry to the moving net varied slightly with the mesh size and color of the twine. The fry swam forward in a relatively dense school, keeping a distance of about 10-45 cm from the moving black twine; they formed a loose school, keeping a distance of 3-45 cm from the moving white twine.

The response of fry to moving mosquito nets of white, black, and blue color was also observed in the tank. The fry reacted by turning away from and swimming in front of the nets, keeping a good distance ahead. However, the difference in the response of the fry to nets of different colors was not clear, probably because the underwater visibility of the nets varied with the space light, i.e., whether the fry were surface or contour-lighted.

The experimental results adequately show the importance of vision in net avoidance and indicate that fry can be driven by suitably visible nets. This implies that the wing parts of existing fry collection gear can be replaced with larger mesh netting such that the gear can be made larger in scale without undue increase in bulk.

FRY COLLECTION WITH INNOVATED GEAR

Based on the response of milkfish fry to stationary and moving nets, Kawamura and Quinitio (unpubl.) conducted fry collection experiments using fry gear with no wings or gear in which the wings were made of larger mesh netting. The experiments were done along the shore of Culasi, Panay Island, Philippines in April-May 1980. Fry sweepers and double stick nets were used in the experiments. The ordinary sweeper has wings and a cone made of fine mesh (0.8 mm) nylon netting. The two innovated sweepers used in the experiments had exactly the same parts and dimensions as the ordinary one, except that one innovated sweeper had wings made of dark green coarse mesh (2 cm) nylon netting, while the other had no wings. The ordinary double stick net uses fine mesh (*sinamay*). The innovated net had only the central part made of *sinamay* and the two ends of dark green coarse mesh (2 cm) nylon netting. The innovated and control fry gear were operated simultaneously along a fixed 100 m stretch of beach, sometimes in the same direction and sometimes in opposite directions. These were frequently exchanged among the operators to minimize bias in the catch data. The number of fry caught was counted every 30 minutes.

The results are summarized in Table 2 and show a lower catching efficiency for the innovated sweeper. Analysis of the catch data shows that in the innovated sweeper the bamboo frame itself and the large mesh netting of the wings have a considerable fry driving effect. At the same time, the filtration effect of the fine mesh wings of the ordinary sweeper is significant. It was seen that the innovated sweepers can be operated faster than the ordinary one due to reduced underwater resistance. This is reflected in the lower ratio of live fry to total fry for the innovated gear (Table 2). The innovated sweeper can be operated at a lower towing speed and will consequently be less tiresome for the fishermen.

The innovated double stick net had almost the same catch as the ordinary one. This suggests that the two sides of the net function not as a filter but as a driving device.

The catch obtained in the experimental collection does not warrant further catch analysis nor conclusive explanation. However, it seems reasonable that the wings of mobile fry gear should be made of coarse mesh netting, at least in certain collection grounds. Such improvement decreases the underwater resistance of the gear and enables fry collectors to operate bigger gear to cover more area for a longer time with less fatigue.

RECOMMENDATIONS FOR IMPROVEMENT OF FRY COLLECTION TECHNIQUES

Milkfish fry collection gear is variously designed to meet the requirements of particular collection grounds and to utilize locally available materials. Various items have been described by Kumagai et al (1980), Villaluz et al (1982), and Kawamura et al (1983). The following discussion will deal with the principles of fry capture and gear improvement.

Barriers

Fixed barriers or fences are set perpendicular to the beach across the current and fry movement. Assuming that the fry are distributed mostly at the surface and associate with floating materials in shore waters, fry barriers could be set floating at the water surface to move with the changing tide. Where longshore currents are pronounced, barriers could be set oblique to the shore to guide and concentrate the fry shoreward.

Scare Lines

The drive-in technique to catch milkfish fry using scare lines (*blabar*) is applied only in Indonesia. Since the milkfish fry are driven well by mobile gear (see above), the use of scare lines is an effective technique, especially in extremely shallow waters where larger mobile gear cannot be operated.

Table 2. Results of fry collection with innovated and existing gear (After Kawamura and Quinitio, unpubl.).

Gear[a]		Date, time	No. of operations	No. of fry: Alive	No. of fry: Total	Ratio: Alive/Total	x^2	P	Underwater (visibility) of gear (cm)
Control		17 April	21		1063		129.23	0.001	20-40
E1		0730-1830		—	542	—			
Control		17 April	10		153		1.10	0.250	unknown
E1		1830-2400		—	174	—			
Control		21 April	18	45	77	0.58	7.81	0.01	200
E1		0800-1700		22	46	0.48			
Control		2 May	18	179	192	0.93	14.63	0.001	200
E1		0800-1700		109	124	0.88			
Control		18 April	19		222	–	5.82	0.010	20-40
E2		0800-1800		—	174				
Control		18 April	9		122		13.72	0.001	unknown
E2		1830-0030			63				
Control		22 April	16	41	46	0.89	28.70	0.001	200
E2		0830-1630		5	7	0.71			
Control		1 May	16	34	34	1.00	5.81	0.010	200
E2		0900-1700		51	57	0.89			
Double stick net	Control	19 April	16		285		1.40	0.100	200
	Exp.			—	314	—			

[a]E1 - sweeper without wings,
E2 - sweeper with coarse mesh wings.

Fixed Filter Nets

This type of gear, found only in the Philippines, has V-shaped wings to guide the fry to a posterior bag of fine mesh netting. It is commonly set in the mouths of rivers, creeks, and similar places where fry come in with the high tide. Since a large portion of the fry population in shore waters enters rivers and creeks, it would be good practice to excavate the river mouth to attract and guide the fry to a place where the actual capture is made. This will make fry collection in backwaters possible, a definite advantage when the sea is rough and collection from the open shore is difficult. To minimize damage to fry due to strong currents, the posterior end of the filter net should form a deep bag to allow the trapped fry some room in which to swim around.

Skimming Nets

Skimming nets are handy enough to be operated even in places that are very rocky, or with obstructive mangrove roots. The larger skimming nets in Indonesia and Taiwan have a container at their posterior ends that retain the fry. In the Philippines, this container could be adopted and affixed to certain mobile gear to facilitate scooping of fry from the net and to minimize damage. In Taiwan, a specially modified skimming net without frame is operated at the water surface from a boat; it has a pocket at its posterior end where the fry are scooped.

Fry Sweepers

Fry sweepers or fry bulldozers are especially developed and very popular and effective on Panay Island, Philippines. While the sweepers exhibit large variations in construction and in scale, they all basically have a surface skimming net with rigid wings that drive the fry (see above) and prevent their escape. The posterior end should form a deep pocket to enable the fry to stay in the net without becoming injured.

Seine Nets

Double stick nets are operated in waist-deep water in the Philippines. A longer (15 m) fry seine net (1 m deep) without a bag is operated like a beach seine at Culasi, Panay Island. Its warps can be replaced with scare lines to drive the fry. The fine mesh netting, except for the central part where final scooping is done, can be replaced with coarser mesh netting to reduce towing resistance. A container can be attached at the central part of the seine net to facilitate scooping.

According to Villaluz et al (1982), recent modifications of the fry catching gear in the Philippines are directed to areas farther from shore. However, offshore exploitation may not be effective, as fry are concentrated in shore waters. Further fry exploitation should focus on shore waters; the following information is required:

- the behavior of fry in the vicinity of the gear to employ suitable catching and handling techniques,
- the vertical distribution of fry in shore waters at different times of day in different fry grounds to employ suitable depths of operation for more economic and effective fishing, and

the movements of fry in shore waters to enable effective operation of the collection gear.

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COLLECTION, STORAGE, TRANSPORT, AND ACCLIMATION OF MILKFISH FRY AND FINGERLINGS

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The present methods of collecting fry and fingerlings involve filtration by mobile or stationary devices. The bottom topography of the fry ground, wind direction, and tidal fluctuations are the most important considerations in the design and construction of fry and fingerling catching gear. The behavior of young milkfish in the different environments where they are exploited determines the catching methods to be employed. Collection, handling, storage, and transport activities expose the fish to undue stress, which contributes to poor survival. The simple method of lowering the salinity of the water medium considerably reduces mortality. Prior acclimation history has significant effects on subsequent survival and adaptation. Although it appears that milkfish fry are more hardy than the fingerlings, both have the same capability for resisting subsequent environmental stress provided sufficient time is given for the fish to recover from previous stress.

INTRODUCTION

The unavailability of seed stock is the main bottleneck in milkfish aquaculture. Even when hatchery-bred fry become commercially available in the future, the natural fry and fingerling fishery will remain an important and decisive factor in the culture of milkfish.

Methods and practices of collection, storage, transport, and acclimation of milkfish fry and fingerlings in the Philippines, Indonesia, Taiwan, and Sri Lanka are presented, and the probable factors affecting catch and survival are discussed in the light of recent findings about the ecology, behavior, and physiology of the fry and fingerlings.

COLLECTION METHODS AND GEAR

Bottom topography, wind and water current patterns, and tidal fluctuations in the fry grounds are the most important considerations in the design and construction of gear for catching milkfish fry and fingerlings. The behavior of the fish determines the collection methods to be employed in specific areas. The various methods and gear currently being used to catch milkfish fry and fingerlings in the Philippines (Kumagai et al 1980, Villaluz et al 1982b), Indonesia (Noor-Hamid and Mardjono 1976, Noor-Hamid et al 1977), Taiwan (Lin 1969), and Sri Lanka (Villaluz et al 1982a) are presented below. Illustrations of the gear used in the Philippines are found in Kumagai et al (1980) and Villaluz et al (1982b).

Fry Barriers or Fences

These are devices to which fry are attracted or on which they are concentrated by favorable wind and tidal currents. The gear is usually set perpendicular to the shore, extending 10-50 m into the water. Shallow intertidal areas along a narrow pass or tidal flats with a muddy or coralline substrate are suitable locations for this gear. Fry barriers are also set halfway across tidal creeks. Actual catching of fry is by skimming nets or double stick nets. This method and gear are employed in the Philippines and Indonesia.

In Indonesia, gear made of grass or dried banana leaves strung into a garland-like rope is used to drive milkfish fry in shallow water. The 20-m rope is laid in a wide circle and the diameter of the enclosed area is reduced gradually by pulling one end of the rope, the other being fastened to a stake. The fry are caught by a skimming net in the small central space of the closed ring.

Filter Bag Nets

Skimming net. This is usually used in mangrove areas, along fishpond dikes and canals, and in tidal flats with a muddy or coralline substrate. Women and children prefer it due to its light weight and ease of operation. It is used in the Philippines, Taiwan, and Indonesia.

Tidal set net. This consists of a catching chamber with fixed wings, usually constructed across the mouth of a river or tidal creek, and occasionally along the shore facing favorable wind and tidal currents. A series of two to four tidal set nets may be placed across the mouth of a relatively large river. The gear is generally operated by two to five men during flood tide. Although this gear has been introduced in Indonesia, its use for commercial collection of milkfish fry is limited to the Philippines.

Floating tidal set net. This is set against longshore currents and is particularly suited to coastal promontories with relatively shallow coralline platforms. In certain areas, several units may be set about 10-15 m apart, one in front of the other. The gear is usually operated during flood tide by one man. It is found only in the Philippines.

Push net. This is usually operated along the shore or river bank by two people, one pushing the gear and scooping the fry from the bagnet, the other taking charge of shuttling and sorting the fry. In some areas, the push net has bigger dimensions and is provided with a platform for basins and pails; in this case, one person pushes the gear while the other pulls it with a rope from the shore. The push net is also used in a stationary position along the shore or river mouth and is operated like a tidal set net. During stormy days, push nets are set against the surf. The push net has been motorized in some areas in Taiwan and the Philippines. In the latter, it is modified and attached to one side of a pumpboat with a 10-16 hp engine and operated in the deeper portions of the fry grounds. The push net has been demonstrated in Indonesia but there is no report whether it has been adopted by local fry collectors.

Push net with bamboo raft. This gear is usually operated in fry grounds with very extensive shallow intertidal waters up to 5 m deep. Two persons are required; one pushes the gear by means of a bamboo pole, while the other scoops and sorts the fry. Operation is usually undertaken at night until early morning (2100-0400 h), a lamp being used to facilitate catching and sorting of fry. At times, this gear is set along the river bank and is operated like a tidal set net. This method and gear have been reported only on Panay Island, Philippines. However, a motorized push net with a bamboo raft is common in Taiwan.

Tow net with bamboo floats. This is towed along the shore by two persons, one at the end of each wing. When one of the operators takes the fry to shore, the other continues towing by holding both ends of the wings. This gear is also used in rivers or creeks, either mobile or operated like a tidal set net. It has been reported only in southern Luzon, Philippines.

Tow net. The tow net is used in areas with steep shore profiles, high waves, and strong winds. Two persons operate it, each pulling on the bamboo pole at the end of one wing. The filtered fry are concentrated at the cod-end; the string at the cod-end is untied and the fry are poured into a plastic bag. The tow net can also be operated like a tidal set net in places where a sandbar has formed parallel to the shore. This gear and method have been reported only in the Philippines.

Seine Nets

Double stick net. This is towed by two persons along the shore or at the river mouth. It has undergone various modifications due to the cost of materials, prevailing local conditions, and mode of operation, including use of fine mesh nylon netting at the wings while retaining *sinamay* (abaca cloth) in the central portion where the fry are concentrated and scooped. In fry grounds with moderately steep shore profiles, the bamboo poles at one or both ends are replaced with rope loops, which allow the collectors to swim with the net. A smaller version of the double stick net is used by children mostly in shallow rivers or creeks. This type of gear is used in the Philippines, Sri Lanka, and Indonesia.

Fry seine. The fry seine is operated like a beach seine. Two persons operate it, one staying on the shore holding one end of the towline while the other casts the gear 50-100 m from the shore with the use of a small boat. The fry are concentrated and scooped at the shore. This gear has been modified to have a bag net at the center similar to the tow net with bamboo floats. The wings are longer and made entirely of fine mesh nylon netting. Four persons are required to operate this gear, which is used only in Antique Province, Philippines.

FACTORS INFLUENCING CATCH

The milkfish fry season occurs at different times of the year in different parts of its geographic range. In regions affected by monsoon or trade winds, peak fry seasons typically coincide with one or both of the twice-yearly wind shifts. These seasonal peaks are more or less predictable, but fry abundance may vary from year to year. The milkfish fry occurrence and peak seasons in the Philippines, Indonesia, Taiwan, and Sri Lanka are shown in Table 1.

More milkfish fry are caught 1-2 days before and up to 3 days after the new moon and full moon periods than at other times (Kuronuma and Yamashita 1962, Kumagai et al 1976, Noor-Hamid et al 1977). It is also observed that the catch increases when the direction of the wind is toward the shore. Schmittou (1977) suggested that this could be partially due to the increase in volume of surface water reaching the shore.

Milkfish fry generally utilize the tidal current as a passive means of transport, but they may actively enter coastal wetlands even during receding tides (Villaluz et al 1982, Buri and Kawamura 1983). However, most of the fry remain far from shore after high tides of spring tide periods. This makes the fry inaccessible to most of the gear currently being used. The fry seine used in Antique, Philippines, not only catches the fry in its path but probably also attracts other fry toward the shore, enabling them to be caught by other types of gear. Motorization of the push net also makes possible the exploitation of the deeper portions of the fry grounds.

Kawamura et al (1980) concluded from behavioral observations that the fry are not caught by filtering but by driving. They suggested that the fine mesh net of the wings of fry gear be replaced with a highly visible (black colored), larger mesh net. However, the fry collectors claim that, although this modification made the operation of the gear easier, it drastically reduced the catch. Hemings (1966), in his study of visibility of nettings in different sea conditions, found that illumination and turbidity of the water are significant factors in herding fish. The poor catch from modified gear with wings made of larger mesh net is probably due to the cancellation of the driving effect of nets on the fry in relatively turbid water near the shore during the fry season.

Current developments and modifications of milkfish fry gear are directed to areas farther from the shore. Encina and Gatus (1977) reported that milkfish fry congregate close to fish shelters located offshore and can be caught in sizable quantities in deeper coralline areas. In such a situation, where the water is clear, fry collection gear that effectively utilizes the driving effect and the optomotor response of the fish may be adopted.

The demand for milkfish fry also affects the catch. Smith (1981) attributed the steady increase in the nationwide catch of milkfish fry in the Philippines to higher prices elicited by increased demand. In Indonesia, fry are sometimes not gathered during the second season due to the absence of buyers (Noor-Hamid et al 1977).

Table 1. Milkfish fry occurrence and peak seasons in the Philippines, Indonesia, Taiwan, and Sri Lanka.

Location	Occurrence	Peak seasons		Source
		Major	Minor	
Philippines	Jan.-Dec.			
North	Mar.-Aug.	May-July	—	Villaluz et al 1982b
Central	Mar.-Jan.	Apr.-June	November	
South	Jan.-Dec.	Mar.-May	—	
Indonesia	Jan.-Dec.			
North	Apr. -Nov.	Apr.-May	—	Noor-Hamid et al 1977
Central	Mar.-Dec.	Aug.-Oct.	Apr.-June	
South	Dec.-Feb.	—	—	
Taiwan	Apr. - Aug.	May	—	Lin 1969
Sri Lanka	Apr.-Nov.	May	November	Ramanathan 1969

STORAGE OF FRY

The general practice of handling and storage of milkfish fry is similar in Indonesia (Noor-Hamid et al 1977, Noor-Hamid and Mardjono 1976), Taiwan (Lin 1969), and the Philippines (Villaluz et al 1982b), as described below.

Milkfish fry, together with fry of other fish and crustacean species, are brought to shore after capture. The whole catch is then transferred to an earthen jar, a plastic basin, or a water-tight bamboo basket. Counting and sorting are done with a small cup, bowl, or shell. The counted fry are placed in one container while dead fry and unwanted species are discarded. In the Philippines, a cylindrical device made of nylon netting is utilized for sorting fry if numerous undesirable organisms are present.

The fry are counted each time they are transferred from one container to another and also before and after being sold. An actual head count is done when the fry are few, but when the catch runs into several thousands, counting is done with the aid of pebbles, shells, or any suitable markers. One small pebble or shell represents 1 fry, while a bigger one would represent 100 fry. Another method of counting is by visual estimation; the density of fry in one container is compared to the density of fry in another container in which the exact number has been previously determined.

The day's catch is stored overnight in the fisherman's house or in a storage facility provided by the fry concessionaire or dealer. The fry are not fed at this time. The storage water is generally diluted with fresh water; in the Philippines, the ratio of dilution is 3 parts seawater to 1 part fresh water. The fry next pass through a fry dealer and are again counted and sorted before acceptance. They are then brought to the main warehouse of the dealer in oxygenated plastic bags, earthen jars, or bamboo baskets, and a longer-term storage follows. The water in the storage container is again diluted at ratios of 1 part seawater to 1 part fresh water in the Philippines and 1 part seawater to 4 parts fresh water in Indonesia. Another method of obtaining the desired water medium for storage of fry in Indonesia is by mixing salt with fresh water to obtain a salinity of 10 ppt.

The yolk of hard boiled eggs, pulverized rice, or wheat flour is given to the fry daily or every other day. The storage containers are inspected and cleaned of excess food, dead fry, and debris every morning and afternoon. Storage water is either completely or partially replaced with new water premixed at the desired salinity level every day or every other day.

Fry stored for more than 15 days are as a rule weak; very low survival is obtained when these are stocked in the nursery pond. The condition of the fry may be determined by the following procedures:

1. Observe the fry closely. Strong and healthy fry move continuously in the same direction along the wall of the container. If the fry display this behavior only occasionally, or when swimming is slackened, they are already weak.
2. Swirl the water. Healthy fry swim vigorously against the current.
3. Tap the container or move a hand over it. Fry which react with a quick diving avoidance movement are in good condition.

Some dealers keep fry alive and in reasonable condition for 1 month or longer by storing them in earthen jars and reducing the stocking density to a few hundred per container.

Milkfish fry storage practices in the Philippines, Indonesia, and Taiwan are summarized in Table 2.

FACTORS AFFECTING SURVIVAL DURING STORAGE

Milkfish fry are subjected to a number of stress factors during collection which, if not alleviated, cause immediate death or else have a deleterious effect on subsequent survival. Reduction of salinity to 20-25 ppt during storage enhances survival of fry by reducing osmotic stress. Tissue fluid osmolarity of milkfish fry collected from the shore has an osmotic pressure equivalent to a salinity of 13.67 ppt (Almendras 1982), and dilution with fresh water brings the salinity of the medium close to that of their body fluids. An increase in the activity of the fry often accompanies sudden changes of salinity; these may eventually be harmful if often repeated over short periods.

More fry can be stocked in plastic basins (300-500 fry/liter) than in earthen jars (100-200 fry/liter) because of the greater surface/volume ratio in the former. For long-term storage (>15 days), earthen jars are more appropriate. The cooler and darker environment of the jar decreases fry activity and energy expenditure. The lower temperature (<27°C), in combination with low stocking density (25 fry/liter) and high salinity (28-30 ppt), reduces stress and enables the fry to conserve energy while in storage.

TRANSPORT OF FRY AND FINGERLINGS

In Indonesia (Schuster 1952, Noor-Hamid et al 1977) and the Philippines (Villaluz et al 1982b) the fry are not fed before transport. Storage containers are cleaned and water is completely replaced. The fish are transferred to smaller containers and their number determined by actual count or visual estimation. Fresh water is sometimes added to reduce the salinity. In the Philippines, the ratio is 1-2 parts fresh water to 2 parts storage water, while in Indonesia, 9 parts fresh water to 1 part

Table 2. Milkfish fry storage in the Philippines, Indonesia, and Taiwan.

Conditions	Fry storage practices		
	Philippines	Indonesia	Taiwan
1. Container	1. a. plastic basin b. earthen jars	1. a. earthen jars b. bamboo basket	1. a. plastic basin b. bamboo basket
2. Water volume (liter)	2. a. 15-23 b. 10-20	2. a. 2 b. 30	2. no report
3. Salinity (ppt)	3. 10-25	3. 10-25	3. <20
4. Feeds and feeding	4. egg yolk or wheat flour every day or every other day	4. rice flour, dried wheat, or egg yolk	4. no report
5. Water management	5. complete change or 1/2 of total volume change every day or every other day.	5. complete change	5. no report
6. Stocking rate (fry/container)	6. a. 3000-8000 b. 2000-3000	6. a. 1000 b. 15 000	6. no report
7. Stocking density (fry/liter)	7. a. 150-500 b. 100-300	7. 500	7. np report
8, Days of storage	8. 1-7	8. 10-20	8. no report
9. Mortality (%)	9. 2-10	9. 5-10	9. <2
10. Source	10. Villaluz et al 1982b	10. Noor-Hamid et al 1977	10. Lin 1969

seawater is common. Water is removed with a shell, cup, or small bowl over a scoop net or nylon netting that excludes the fry. The fry are poured into double plastic bags. Oxygen is added at a volume equal to that of the water in the bag. The plastic bags are then placed inside palm bags or cardboard boxes if they are to be transported by land, or inside styrofoam boxes or jerricans in the case of air transport. Transport by boat using earthen jars or bamboo baskets as fry containers is practised in Indonesia. Since it usually takes 3 days to about 1 week for the fry to reach their destination, water in the container is changed daily.

In Sri Lanka, the fry are placed directly into double cylindrical plastic bags after capture. One part lagoon water is diluted with 1-3 parts fresh water before the bag is filled with oxygen. One bag contains about 4-6 liters of water and 8-12 liters of oxygen. The bags are not placed in cardboard boxes or similar containers as in other countries; they are simply arranged vertically inside a jeep or van (Villaluz et al 1982a).

Very little is known about the method utilized to transport fry in Taiwan. Lin (1969) reported that as a general rule the transport route is short and the fishermen take good care of the fry. Mortality during this phase of operation is negligible.

Methods of milkfish fry transport in the Philippines, Indonesia, and Sri Lanka are presented in Table 3.

Table 3. Methods of milkfish. fry transport in the Philippines, Indonesia, and Sri Lanka.

Conditions	Fry transport practices		
	Philippines	Indonesia	Sri Lanka
1. Container	1. plastic bag	1. a. plastic bag b. earthen jar/bamboo basket	1. plastic bag
2. Mode of transport	2. a. land b. air	2. a. air b. land or water	2. land
3. Transport time (h)	3. a. 2-14 b. 3-6	3. a. 12 b. 4-7 days	3. 5-10
4- Water volume (liter)	4. a. 8-10 b. 3-5	4. a. 10 b. 2 c. 30	4. 4-6
5. Salinity (ppt)	5. 12-22	5. 10-15	5. 10-30
6. Stocking rate (fry/container)	6. a. 4000-6000 b. 4000-8000	6. a. 10 000-20 000 b. 1000 c. 15 000-40 000	6. 1500-2000
7. Stocking density (fry/liter)	7. a. 400-750 b. 800-2000	7. a. 1000-2000 b. 500 c. 500-1300	7. 375-500
8. Mortality (%)	8. 2-6	8. a. 5 b. 20	8. 2-20
9. Sources	9. Villaluz et al 1982b	9. Schuster 1952, Noor-Hamid et al 1977, Noor-Hamid and Mardjono 1976	9. Villaluz et al 1982a

Transport of milkfish fingerlings has been reported only in the Philippines (Villaluz et al 1982b) and Sri Lanka (Villaluz et al 1982a). Both countries use plastic bags and oxygen. Similar procedures as in the transport of milkfish fry are followed. Dilution of transport water with fresh water, however, is not practised in the Philippines.

Another method of fingerling transport in the Philippines is by means of a "live boat." The boat has a flat bottom used as the fingerling compartment and provided with one to three holes for free entrance of water. A water pump is used to change the water in the compartment continuously. When passing muddy or polluted water, the holes are closed and the pump recirculates the water inside. Upon reaching the destination, the fingerlings are caught with a fine mesh seine and transferred by pails directly to fishponds or pens.

The methods of transporting milkfish fingerlings in the Philippines and Sri Lanka are summarized in Table 4.

FACTORS AFFECTING SURVIVAL DURING TRANSPORT

In the transport of fry and fingerlings, temperature is the most critical factor because of its effect on metabolic rate. Oxygen consumption of fry (5-8 mg body

Table 4. Methods of milkfish fingerling transport in the Philippines and Sri Lanka.

Conditions	Fingerling transport practices	
	Philippines	Sri Lanka
1. Container	1. a. plastic bag b. "live boat"	1. plastic bag
2. Mode of transport	2. a. land b. water	2. land
3. Transport time (h)	3. a. 3-6 b. 4-5	3. 5-10
4. Water volume (liter)	4. a. 10-15 b. 6-8 m^3	4. 4-6
5. Salinity (ppt)	5. a. 10-35 b. initial (20-30ppt), final depends on where fish are stocked (0-30ppt)	5. 10-50
6. Stocking rate	6. a. 500-600 (fish 3-4 cm TL) b. 200-300 (5-10 cm) c. 80 000-120 000 (3-5 cm) d. 50 000-60 000 (6-10 cm)	6. a. 600-800 (fish 2.5-3.5 cm FL) b. 200-400 (4.0-8.6 cm)
7. Stocking density (fish/liter)	7. a. 33-60 (fish 3-4 cm TL) b. 15-30 (5-10 cm) c. 20-30 (3-5 cm) d. 10-12 (6-10 cm)	7. a. 100-160 (fish 2.5-3.5 cm FL) b. 40-80 (4.0-8.6 cm)
8. Mortality (%)	8. a. no report b. 0.05-2	8. 2-100
9. Source	9. Villaluz et al 1982b	9. Villaluz et al 1982a

weight) increases from about 0.011 mg O_2/h per fry at 20°C to 0.056 mg O_2/h per fry when the temperature is elevated to 32°C. If the number and/or size of fish are small, the oxygen content of the water does not become a limiting factor. In a crowded situation, however, an increase in temperature can result in severe stress and high if not mass mortality. This indicates that the fry stocking density may be higher and the time of transport may be longer if the water temperature is lower.

Under the stressful situation of transport, water and ionic balance (Eddy 1981) and resistance to diseases (Wedemeyer and McLeay 1981) may be impaired, and fungal infestation and mass mortality may still occur a few hours or days after stocking of fry or fingerlings even in environments with optimal conditions. Physical injuries also cause mortality during transport because milkfish fry have the tendency to concentrate at the two bottom corners of the plastic bag, which become death traps during transport.

ACCLIMATION OF FRY AND FINGERLINGS

Milkfish fry are stocked in the nursery pond in the early hours of the morning or late in the afternoon after a period of acclimation to the quality of pond water. If the fry are to be stocked directly in the pond upon arrival, the fry containers are made to float in the pond for about 6-10 minutes. The water in the containers is then diluted with pond water, and the fish are released into the pond after 10-20 minutes. Survival after 1 day of stocking is from 20 to 100% (Schuster 1952, Villaluz et al 1982a, 1982b). If the fry are stocked in plastic basins prior to release into the pond, the water in the basin is either replaced or diluted about 25% with pond water 4-6 h after arrival. This is repeated every 2-4 h until the salinity more or less equals that of the pond. Most fish farmers transfer fry directly from basin to pond, while others let the basins float in the pond for about 10-15 minutes to further reduce temperature differences. Survival rate is 95-100% after 1 day of stocking (Villaluz et al 1982b).

Milkfish fingerlings transported inside plastic bags are acclimated directly in the pond upon arrival. If the "live boat" method of transport is used, acclimation to fresh water is done by gradual but continuous replacement of water in the fingerling compartment at 0.15-0.25% per minute. A mortality rate of 20-30% in the first week of stocking in Laguna de Bay, Philippines has been reported (Villaluz et al 1982b).

FACTORS INFLUENCING SURVIVAL DURING AND AFTER STOCKING

Improper acclimation has been blamed by most fish farmers as the cause for as much as 80% mortality of milkfish fry and fingerlings upon or shortly after stocking. Such mortality can be attributed to acute or chronic stress experienced by the fish from the time of capture up to stocking in grow-out ponds or pens. Stressed fish are also more vulnerable to predation.

Young milkfish can tolerate transient exposure to high temperatures up to 42°C (Pannikar et al 1953), but daily exposure to temperatures that increase from 25° to 34°C at 1°C/h might be lethal (Villaluz and Unggui, unpubl.). This means that the duration of exposure to thermal stress may be more critical to survival than the magnitude of the temperature change.

Milkfish fry initially exposed to low salinity (20-25 ppt) had higher survival rates (Quinitio and Juario 1980) when stored at different salinity levels (0, 8,16, 20, and 32 ppt) than those that were not previously acclimated. Mass mortality occurs if newly-caught fry are transferred to fresh water without proper acclimation. A gradual but continuous replacement of the original water with fresh water over a 12-h period was shown to be the best procedure in acclimating the fry to fresh water (Santiago et al 1982). Water and ionic balance of the fry generally stabilize 24 h after transfer to different salinity levels (Almendras 1982). On the other hand, newly-caught wild or pond-reared (pond salinity 28-50 ppt) fingerlings can be transferred directly to fresh water and vice versa without any ill effects (Villaluz et al 1982a). However, if these fingerlings undergo transport before direct transfer to fresh water, mass mortality may occur. Water and ionic balance of the fingerlings stabilize 60 h after transfer to different salinity levels (Almendras 1982). Since the fry recover from osmotic stress faster than the fingerlings, the former would seem more hardy than the latter. However, both fry and fingerlings have the same capability to resist subsequent environmental stress if given sufficient time to recover from previous stress.

CONCLUSION

Socio-economic and ecological conditions which would optimize milkfish fry catch vs. energy and labor while not depleting the natural supply should be examined and considered in the development of new collection methods and gear and/or the improvement of existing ones. The objectives should be not only to increase the supply of fry and fingerlings but also to give satisfying and remunerative employment to many. In order to increase the catch in a particular fry ground, appropriate fishing gear and methods should be utilized at different times of the day and at different locations. Offshore exploitation with the use of floating objects and chemical attractants to aggregate the fry should, be looked into so that search time is minimized and catch per unit of effort is maximized.

The different methods and practices from collection to stocking of milkfish fry and fingerlings have been established mostly by trial and error, which is sound enough as a basis in practical application. However, the various activities subject the fish to stress, which lowers their future performance and survival. Research is needed to minimize and/or alleviate such stress encountered by the fish in artificial environments and during handling.

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MILKFISH NURSERY POND AND PEN CULTURE IN THE INDO-PACIFIC REGION

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In culturing milkfish to marketable size, the fry (total length = 12-15 mm) are usually reared first in nursery ponds or pens (*hapa* nets) until they become fingerlings (total length = 2 cm or more). The fingerlings are then transferred to the grow-out ponds or pens where they are reared to marketable size. In some countries like the Philippines, fingerling production has become an industry by itself. This paper reviews the state of the art and constraints to and suggests future research directions for milkfish fingerling production in nursery ponds and pens.

INTRODUCTION

The culture of milkfish *Chanos chanos* (Forsskal) in brackishwater ponds is an age-old practice in tropical areas of the Indo-Pacific Region such as the Philippines, Taiwan, Indonesia, and Kiribati. Recently, developments in farming techniques have given rise to milkfish pen culture in the freshwater lakes of Laguna de Bay and Buluan in the northern and southern parts of the Philippines, respectively. Sri Lanka and India have tried to adopt the same techniques, but these are still at the experimental stage.

Milkfish is a well studied species, but much remains unknown about its growth, survival, and production as well as about its reproduction in localities which can be controlled or modified.

Indications are that milkfish production, whether by intensive culture or through expansion of area, is limited by the availability of fry. This depends in turn on how efficiently the milkfish fry industry exploits the wild fry resource, and on progress in research and development on milkfish broodstock and seed production. On the other hand, production of healthy and/or stunted milkfish fingerlings in nursery ponds or pens depends on the techniques practised by the farmer.

Milkfish production in nursery ponds or pens, be it for fingerlings or for marketable size fish, is still far from realizing its full potential. This review updates and consolidates the state of the art of milkfish nursery in ponds and pens, and highlights relevant information gathered from available reference materials.

BRACKISHWATER CULTURE

Pond Design and Construction

Brackishwater ponds for milkfish in the Indo-Pacific Region historically followed a general design and construction methods developed through long years of experience. For centuries ponds were manufactured by compacting mud and clay around the periphery of an enclosure. The site was drained, and the material excavated from the bottom was used to form the embankment, which was raised to a level above the high water level at spring tide. Thus, the pond could be emptied or filled at any time during the spring tide and neap tide cycles.

Fishpond engineering gradually emerged from the traditional level into the more advanced. Mechanization was introduced to shorten construction time and lessen labor, and, recently, riprap for pouring concrete dikes can be observed at some sites. Construction of coastal fish farms has further emphasized the importance of workable pond elevation in relation to various factors such as size, shore development, and shape of the site. Despite these known technologies, there are some areas that remain underconstructed. The stage of development of milkfish farms varies greatly from one country to another and even within a given country, depending on the availability of suitable sites, the interest of the people, and the far reaching effects of local politics.

Valuable information has been published on fishpond engineering establishing criteria for farm site selection, layout, construction plans, and specifications (Jamandre and Rabanal 1975, Denila 1977, Tang 1975, de la Cruz 1979, Lijauco et al 1979). Kato (1980) discussed basic techniques in coastal aquaculture engineering in detail, presenting attributes of soil quality and quantity. He also recommended construction and installation of water control structures to regulate the exchange of water between the pond system and the tidal stream or sea.

In the Philippines, Rabanal (1974) and Lijauco et al (1979) noted that milkfish farms have been classified according to type of operation into (1) purely nursery system, (2) purely rearing pond system, and (3) combination system having both the nursery and the rearing pond functions. The first type consists mainly of nursery ponds and transition or stunting ponds. Fry are grown to fingerlings, which are sold to other fish farmers. The second system does not provide nursery ponds at all. In the complete system, the farm is apportioned into nurseries (1-2% of total area), stunting ponds (3-5%), and rearing ponds (85-90%) where fry, fingerlings, and marketable size fish are reared independently.

Lin (1968) stated that the layout of milkfish farms in Taiwan (Fig. 1) that are located at the central part of the island follows a scheme which includes (1) nursery

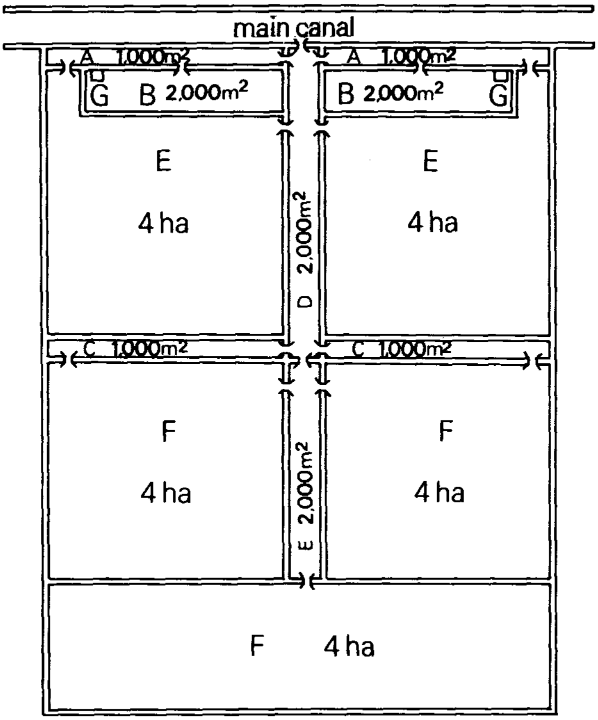

Fig. 1. Schematic sketch of a pond system of 21.2 ha. A, wintering ponds and passageways; B, nursery ponds; C, passageways; D, subcanal; E, subcanal and passageway; F, production ponds; G, acclimation pools.

ponds with small, built-in acclimation ponds; (2) overwintering ponds one-half the size of the nursery ponds, lying beside them and provided with a windbreak to protect the fingerlings from the chilly north wind; and (3) production or rearing ponds.

In the South Pacific, Gopalakhrisnan (1976) reported that nursery ponds are constructed to rear milkfish fry to fingerling size for bait.

Site selection, layout, and construction of brackishwater fishponds in Indonesia follow criteria similar to those in the Philippines (Jamandre and Rabanal 1975, Padlan 1979).

Natural Food Base

Rearing milkfish fry to fingerlings in brackishwater ponds is almost wholly dependent on natural food. The major concern of the fish farmer is establishing, propagating, and maintaining the natural food in the pond until the desired fish size and survival are attained. Concerted efforts are required for (1) the removal or eradication of residual pests and predators, (2) the application of organic and/or inorganic fertilizer to bolster the natural food, and (3) maintenance of good water quality favorable to both the stock and its natural food.

The types of natural food base commonly grown in brackishwater nursery ponds are *lumot, lablab,* and plankton.

Lumot. *Lumot* consists primarily of filamentous green algae such as *Enteromorpha* sp. and *Chaetomorpha* sp. The *lumot* method was common in the Philippines before the 1960s, but at present it is practised in only a few regions. Propagation is either by planting or by the broadcast method, and the algae are dressed with commercial fertilizer. Tang and Hwang (1976) stated that the reported species contain relatively high percentages of protein but have extremely low palatability and digestibility to milkfish, especially during the fry to fingerling stage. *Lumot* also interferes with the process of manipulating the milkfish fingerling population and competes with the stock for living space.

Lablab. This type of natural food complex consists of minute plants and animals which form a yellowish or greenish mat on the pond bottom. *Lablab* is currently used by most fish farmers because it is more nutritious and digestible than *lumot* (Rabanal 1974, Tang and Hwang 1976, Lijauco et al 1979). *Lablab* is grown by using a combination of organic and inorganic fertilizers. In Indonesia, *lablab,* locally called *klekap,* has also been used to rear milkfish fry to fingerlings to ensure rapid growth and a high survival rate (Padlan 1979).

To increase the carrying capacity of the *lablab* pond, Dureza (1977) used nylon screen strips arranged like tennis nets across the pond bottom to increase the surface area for the attachment of the mat. Verification of this method in two 1500 m^2 nursery ponds revealed that 0.005 g milkfish fry stocked at 50/m^2 had an average weight of 3.3 g and a 78% survival rate after 60 culture days (Baliao, unpubl.).

Plankton. This consists of minute plants and animals suspended in the water. Plankton are grown by the application of inorganic fertilizer to deep water (65-100 cm) ponds. The plankton method was developed because of strong indications that milkfish is a plankton feeder (Kafuku and Kuwatani 1976, Poernomo 1976, Tampi 1976, Vicencio 1977). However, Lijauco et al (1979) reported that, for some reason, the plankton method of culturing milkfish has not yielded consistently good results. The common practice is to grow *lablab* and switch to plankton towards the end of the culture period, when *lablab* deteriorates or fails to recover.

Advances have been made recently in supplemental feeding for milkfish fingerling production, but the practice still remains largely an art. The results of a recent study indicated that, at a stocking density of 75 fry/m^2, rice bran given as a supplementary feed to fry at 5% body weight yielded a mean survival rate of 71.5% (Villegas and Bombeo 1981). Lijauco et al (1979) recommended the same feed to fingerlings in transition ponds, where the culture period is prolonged from 6 months to 1 year.

Nursery Pond Management

Fry mortality has been observed to occur mostly between the time of collection and the time of stocking. This is attributed to poor handling techniques, the presence of predators, dirty facilities, and salinity or temperature shock. To minimize loss of fry, the fish farmer should sort out predators and acclimate the fry to temperature and salinity conditions (IFP 1973, PCARR 1976, Lijauco et al 1979). Camacho (1976) also recommended the use of an aeration system during acclimation, sorting, and counting to increase fry survival before stocking.

Milkfish fry are stocked in the nursery pond at the rate of 30-50 fry/m^2, usually in the early morning or late afternoon when the temperature is cool. It is recommended that, before releasing the fry into the nursery pond proper, they should pass through an acclimation pool (Fig. 1) built within the nursery pond. Schuster (1969) and Huet (1969) mentioned that milkfish fry are first kept for a few days in a small pool or "baby box" built in the middle of the fry pond. This technique ensures that the fry are not subjected abruptly to the harsh conditions of the pond, which would make them more vulnerable to predation. Within 5-7 days they develop some scales and may be able to escape predation upon release into the nursery pond proper.

In the nursery pond, fry are nurtured until they reach fingerling size (2-5 g) after 1-2 months of culture. During this period the water inside the pond is replaced regularly, especially at spring tide cycles.

When the fry reach the fingerling stage (at a normal rate of 0.05 g/day), they are transferred to stunting or transition ponds, then stocked in rearing ponds. Overwintering ponds in Taiwan, which are similar to stunting ponds in the Philippines and Indonesia, are built to protect the fingerlings from the low temperatures between November and March; water temperature is maintained at 16°C. Stocking density in stunting ponds is 15 fingerlings/m^2 (Lin 1968, Lijauco et al 1979). Supplemental feed (rice bran and/or peanut cake) is given daily.

In the South Pacific, milkfish fry stocked at 10/m^2 in nursery ponds reached bait size in about 8-10 weeks (Gopalakrishnan 1976). Further intensive trials in the region are being planned.

Camacho (1976) reported that, through the use of net enclosures *(hapas)* suspended in fertilized ponds, milkfish fry could attain an average weight of 1.5 g after 60 days of rearing at a density of 500-1000/m^3. Recovery ranged from 30 to 35%. The net enclosure provides a predator-free environment for the still vulnerable fry.

In Sri Lanka, newly arrived fry/fingerlings caught in lagoons in the northern part of the island are emptied into concrete holding compartments (3 × 25 m) where they are acclimated to brackishwater conditions. While in these compartments, they subsist mainly on natural food (plankton). Occasionally, poultry feed is given as a supplement. The fingerlings stay in the pond for a week or two, after which they are distributed for stocking in tanks, dams, and reservoirs (Baliao 1982, Villaluz et al 1982).

FRESHWATER CULTURE

Pond Culture

Not much has been done on the commercial production of milkfish in freshwater ponds in the Indo-Pacific Region, particularly on the production of fingerlings. In India and Sri Lanka, extensive culture of milkfish along with other finfish species like tilapia and carp has been undertaken in freshwater ponds, seasonal or village tanks, dams, and reservoirs with fingerlings coming from lagoons, tidal pools, or streams. Mane (1979) reported milkfish fingerling production in freshwater ponds by one fish farmer in the Philippines where 33-37% recovery was obtained, following the system used in brackishwater nurseries. At the Aquaculture Department of the Southeast Asian Fisheries Development Center, exploratory studies on the development of a seed bank for milkfish in fresh water showed 42% survival of fingerlings stocked in a plastic-lined pool (PCARRD 1982).

Pen Culture

Pen culture has been practised for many years in several countries, but to varying degrees of development (Table 1). Freshwater species being cultured include milkfish, carp, tilapia, and snakehead in the Philippines, and catfish and goby in Thailand. Marine species cultured are snapper, mullet, sea bass, sea bream, grouper, and milkfish (Anonymous 1979).

Fishpen design and construction. Fishpens are constructed in various sizes and shapes: square, circular, and rectangular. A variety of materials ranging from locally available to imported items has been used, including netting material (kuralon and nylon), bamboo, and wooden or palm poles. Depending on the substratum, the poles are staked in the mud at depths of 15-30 cm or more. For more details regarding design and construction of fishpens, refer to Alferez (1977), Marichamy (1979), and Felix (1980).

The milkfish fishpen industry. While culture of milkfish in fishpens has been done on an experimental basis in India (Marichamy 1979) and is at the initial stage in Sri Lanka (Jayamaha 1979), additional research in this industry appears imperative.

In the Philippines, commercial pen culture of milkfish was started in Laguna de Bay in 1971, covering an initial area of 9000 ha. Lately, the technique has been adopted in Buluan Lake in the southern part of the country. In Laguna de Bay alone about 5000 ha of fishpens produce an average of 5000 kg/ha per yr (Baguilat 1979). It is known that culture of milkfish in pens has some advantages, namely: (1) there is an

Table 1. Status of pen (p) and cage (c) culture in various countries, 1979 (Anonymous 1979).

Country	Operational		Initial		Planning	
	Freshwater	Marine	Freshwater	Marine	Freshwater	Marine
Bangladesh					c	
Canada	c	c				
Egypt			c/p			
Hungary and Eastern Europe	c/p					
India	c	c/p				
Indonesia	c		c/p			
Malaysia		c	c			
Nepal			c			
Nigeria					c/p	
Philippines	c/p			c/p		
Siena Leone					c	c
Singapore	c	c				
Sri Lanka					c	c
Sudan					c	c
Thailand	c/p	c/p				c/p
Turkey					c	

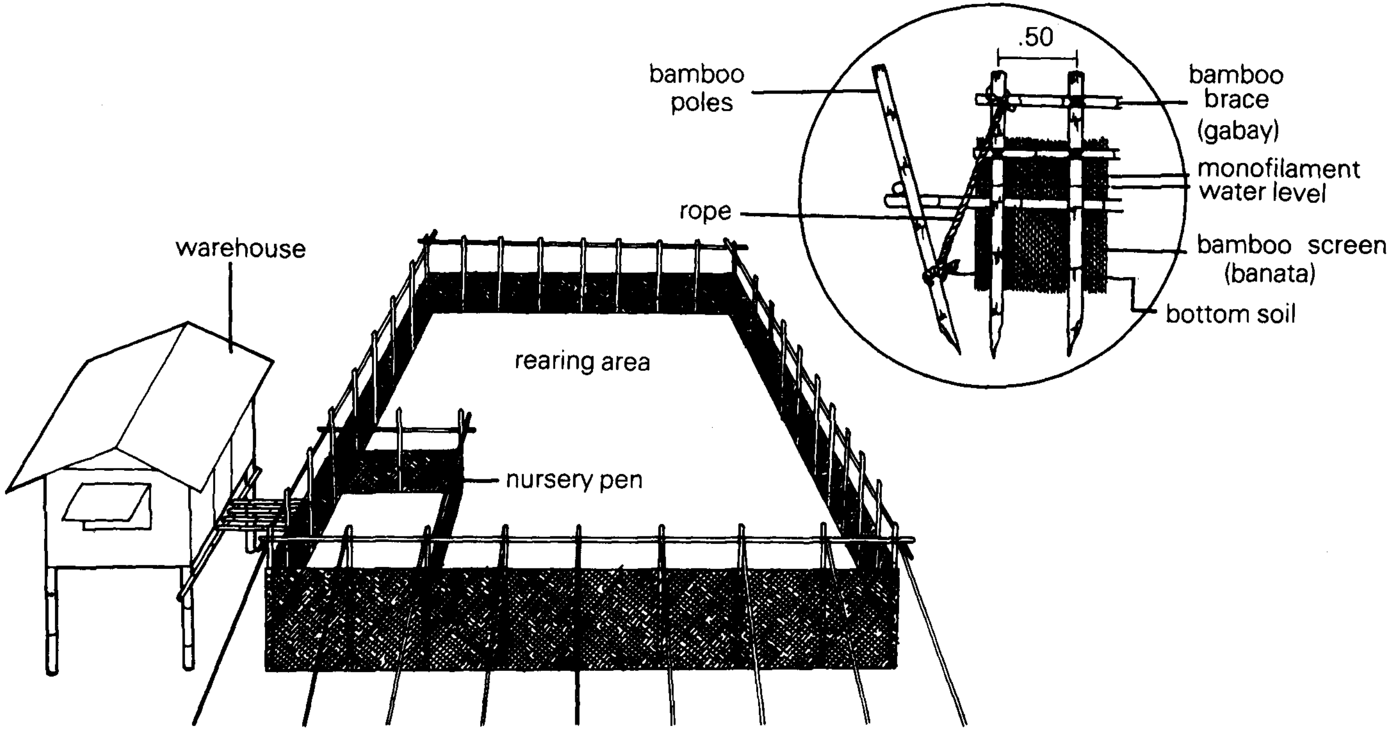

Fig. 2. A typical fishpen with a built-in nursery pen.

annual potential yield of about 5 t/ha, (2) an abundance of natural food in the lake makes supplemental feeding minimal, and (3) vacant areas adjacent to the pens serve as refuge and breeding grounds for other finfish species and thus provide a source of livelihood for lakeshore inhabitants. However, in selecting sites, one should consider a number of factors such as protection from the elements, water circulation, water quality, soil type, access, security, and other legal and social aspects.

Milkfish nursery pen operation. When milkfish production in fishpens was not yet developed in the Philippines, the only buyers of fingerlings were fishpond operators. The establishment of the fishpen industry has also carried along with it a great demand for milkfish fry, thus making the supply inadequate and the price of fry more unstable.

Milkfish fingerlings (1-2 g) stocked in fishpens are usually purchased or produced in nearby brackishwater pond nurseries. In India and Sri Lanka, milkfish fingerlings are caught from lagoons, creeks, and tidal pools. The fingerlings are transported from source to fishpen in oxygenated plastic bags; in the Philippines, "live-boats" (*petuya*) are used (Mane 1979). Mane (1979) also pointed out that fingerlings are first acclimated in nursery pens (Fig. 2) for about 5-6 h to counteract stress after transport.

In the Philippines, nursery pens equivalent to about 1/20 of the rearing pen are prepared of fine mesh nets supported by a bamboo fence *banata* prior to stocking. Unwanted species are removed through seining. The fingerlings are reared for about 1 month. During this period, they subsist on natural food. Supplemental feeds such as rice bran, ground shrimps, and bread crumbs are also given regularly. Mortality rates during this period range from 20 to 40%.

From the nursery pens, the fingerlings are released at 30 000/ha into the rearing pen, where they are grown to marketable size (200 g or more) in 5-6 months (Mane 1979).

SUMMARY AND RECOMMENDATION

The potential of the Indo-Pacific Region for milkfish nursery pond and pen culture in both fresh and brackish water is great. Area expansion and/or culture intensification along with proper pond design and engineering and pond management can surely augment present production. The development and expansion of the milkfish industry, however, is hampered by the scarcity of fry and fingerlings — a very weak link since the industry depends entirely on collection from the wild. Milkfish fry are also not available all year round. Stunting techniques should, therefore, be developed.

Techniques have been developed to rear milkfish fry to fingerlings, particularly those dealing with stocking densities, feeds, and feeding, in order to increase production per unit area of ponds and pens, but survival rates are still erratic. Efforts to stunt milkfish fingerlings for 3-6 months have not been very successful. The development of an economically viable and nutritionally effective diet for fingerlings should be considered a priority in institutions involved in milkfish research.

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MILKFISH CULTURE TECHNIQUES GENERATED AND DEVELOPED BY THE BRACKISHWATER AQUACULTURE CENTER

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This paper reviews the work on milkfish *Chanos chanos* (Forsskal) culture techniques conducted from 1973 to 1983 by the Brackishwater Aquaculture Center, the aquaculture research arm of the College of Fisheries, University of the Philippines in the Visayas at Leganes, Iloilo, Philippines. Significant findings and innovative techniques dealing with milkfish fry collection and fingerling production such as those obtained from survival studies of fry during collection, sorting, handling, acclimation, storage, transport, and rearing in nursery ponds or land-based nurseries are reviewed. Fingerling production utilizing improved methods and techniques is discussed. Results of work on pond culture techniques; the use and application of organic manure and of the different nitrogen-phosphorus ratios in inorganic fertilizers to increase pond productivity; adaptation of milkfish production techniques such as monoculture, polyculture, and integration of milkfish culture with other agricultural activities are presented and discussed. Recommendations for future work and tips on proper utilization of various culture techniques are given.

INTRODUCTION

The Brackishwater Aquaculture Center (BAC, formerly the Inland Fisheries Project — IFP, Brackishwater Fish Culture Research Station) initiated its milkfish research program at its establishment in 1971. The initial funding support of IFP came from the Government of the Philippines through the National Science Development Board (NSDB, now the National Science and Technology Authority — NSTA) and the Government of the United States through the U.S. Agency for International Development. The University of the Philippines, through its College of Fisheries, Institute of Fisheries Development and Research, implemented the project in collaboration with Central Luzon State University and other government agencies which carried out the provisions of the Memorandum of Agreement by and between the Philippines and the U.S. Government to help the country in its food production campaign by increasing fish production through the generation of improved aquaculture technologies. Under this agreement, BAC developed its research programs with emphasis on milkfish culture because this fish was and is still considered the primary species for brackishwater fish culture in the country. The key areas of concern in milkfish culture that were identified and pursued from the beginning by BAC are the following:

- Evaluation, improvement, and development of pond culture systems and techniques
- Fry and fingerling survival
- Acid sulphate soils
- Use of agricultural by-products and waste for fish culture

The researchers of BAC pursued research in these areas both individually and collectively. Although other areas of concern were identified later, new technologies and information derived from the pursuit of the identified problems, particularly on milkfish, were generated and verified, and a number of them have been used by local fish fanners and/or introduced to other countries.

This paper reviews the selected technologies for milkfish culture generated by BAC. The main objective is to present in capsule form those techniques that are considered innovations in milkfish culture. Although many of the selected technologies have been utilized by the industry, a number of them still need to be verified before transfer and utilization.

HISTORICAL CONSIDERATIONS

Until the 1970s, milkfish culture was based on trial and error methods. Most, if not all, of the technologies and practices were expressed in terms of yield. The culture method was nothing more than just growing the *lumut* (filamentous algae, primarily *Spirogyra* sp.), stocking milkfish fingerlings, and then waiting for 4-6 months to harvest and restock again for the next cropping. This practice was done until the *lablab* method or the shallow water method of milkfish culture was introduced into the Philippines from Taiwan in the 1960s by Mr. Yun-an Tang, an FAO consultant, and widely accepted by fish farmers.

In the early 1970s, another method was introduced—the plankton method or the deep water method of milkfish culture. This method was based on the hypothesis that milkfish is primarily a plankton feeder as evidenced by its fine gill structures, particularly the gill rakers. It was also recognized that this method has several advantages concerning the biological requirements of milkfish, e.g., higher dissolved oxygen content of water and no significant fluctuation of temperature as in the shallow water method. Therefore, stocking density could be increased and decomposition of fishpond organisms, particularly *lablab,* causing oxygen depletion is not likely to occur.

Up to the present, milkfish aquaculture techniques have not been standardized, as there are inconsistencies in their application. Techniques that work successfully in one area do not necessarily work in another. For this reason, BAC continues to work on them in an attempt to answer various questions posed by the industry.

GROWTH AND SURVIVAL STUDIES IN NURSERY PONDS

Rate of Growth and Survival in Nursery Ponds

A series of studies conducted by the Center on the rate of growth and survival of milkfish fry in brackishwater nursery ponds was done in the facilities of the Bureau of Fisheries (now Bureau of Fisheries and Aquatic Resources) in 1974 at Molo, Iloilo City. The first study used a stocking density of 16 000 milkfish fry/ha and reared them for 33 days under the *lablab* method. This resulted in a survival of 89.6%, attaining a mean individual weight of 7100 mg from an initial weight of 1.7 mg (IFP 1974a).

In a related study, the rate of growth of milkfish fry in nursery ponds was studied using a higher stocking density of 28.75 fry/m^2 (287 500 fry/ha), cultured under *lablab,* plankton, and a combination of *lablab*-plankton culture methods. The fry were reared for 46 days; mean daily weight increments of 48, 36, and 41 mg for the *lablab,* plankton, and *lablab*-plankton methods, respectively, were attained; and survivals were recorded to be 65%, 80%, and 76%, in the same order. This trial indicated the advantage of the plankton method of culture in rearing milkfish fry to fingerlings (Fortes 1975).

Rearing of Fry to Fingerlings in Production Ponds

Based on the hypothesis that milkfish fry require considerably less food than and do not compete harmfully with fingerlings, fry and fingerlings were stocked at the same time in the same ponds. This way, at least two croppings of milkfish per year can be expected without interruption.

Fry (mean weight 4-1 mg) were stocked at 4000/ha in some ponds (Treatment A). In another set of ponds the same size of fry were stocked at the rate of 3000/ha (Treatment B). In both treatments, fingerlings with sizes of41.3-89.5 g were stocked 20 days later. After 153 and 133 days of culture, the stocks were harvested. The production data are shown in Table 1 (IFP 1976a).

It appears from Table 1 that production data were low. It should be noted, however, that during that time the productive capacity of the ponds used was only 300 kg/ha; therefore the method was still promising. One problem that needs to be settled, however, is the type of gear to be used in selectively harvesting the bigger fish because the gill net, although effective, removes some scales of the milkfish. Filipino housewives normally prefer to buy milkfish with intact scales; otherwise the fish commands a lower price.

Another attempt to maximize the utilization of ponds while improving milkfish fingerling, roduction was done by installing *hapas* (fine mesh nets) within the rearing

Table 1. Production data of mixed culture of milkfish fry and fingerlings (or a culture period of 153 days.

Treatment	Production (kg/ha)			Survival (%)	
	Marketable size	Fingerlings	Total	Marketable size	Fingerlings
A. 3 000 fingerlings/ha plus 4 000 fry/ha	314	42	356	97	73
B. 3 000 fingerlings/ha plus 8 000 fry/ha	348	77	425	96	65

pond stocked with milkfish fingerlings being grown to marketable size. Three 4000 m^2 ponds were used and seven *hapas* (each 1 m × 1 m × 1 m) were installed in each pond. All treatments (stocking densities) were represented in each pond, viz., 500, 1000, 2000, 4000, and 6000 fry/*hapa.*

After a 1-month culture period, survival was observed to range from 9% (6000/ hapa) to 71% (500/hapa), which indicated that density-dependent factors had started to show effects. It was suspected that the two most important factors that caused high mortality were oxygen deficiency and predation. Based on these results, another run was made using the following stocking rates: 367, 500, 1000, and 2000/*hapa.* After 2 months of rearing, the fry grew from an initial weight of 0.2 g to a final weight of 3.3, 3.1, 4.1, and 2.4 g, respectively, with survival rates of 93.2%, 83%, 86%, and 52.5%, in the same order. These growth and survival rates were attained without any supplemental feeding. In addition, the production of milkfish stocked in the ponds averaged 558 kg/ha in a 4-month period (IFP 1976b).

POND CULTURE TECHNIQUES

Evaluation of Fertilizing Materials

The most commonly used inorganic fertilizing materials for milkfish production in the Philippines are solophos (0-20-0), monoammonium phosphate (16-20-0), di-ammonium phosphate (18-46-0), and urea (46-0-0); all are intended for agricultural crops, not for fishfood organisms. The organic materials are chicken manure and rice bran. The Center evaluated these fertilizing materials to develop a fertilizer analysis suitable for fishponds.

In an exploratory trial, the effects of solophos and diammonium phosphate plus chicken manure on the production of fishfood organisms in ponds were determined. The production of fishfood organisms after 32 days was 335 mg/liter and 264 mg/liter, respectively, indicating better response of fishfood organisms to solophos (IFP 1973a). In another study, the effects of various fertilizing materials on the production of fishfood organisms in ponds were studied. The different treatments tested are shown in Table 2.

Table 2. Effect of various fertilizing materials on the production of fishfood organisms.

	Treatment	Rate of application	Remarks
I	16-20-0	10 g/m^2	Better *lablab* formation than IV
II	Rice bran plus chicken manure	60 g/m^2 200 g/m^2	With reddish brown and oily film on water surface
III	Rice bran	60 g/m^2	With reddish brown and oily film on water surface
IV	Chicken manure	200 g/m^2	Good *lablab* formation
V	16-20-0	10 g/m^2	Slightly improved *lablab* growth
VI	16-20-0 plus rice bran	60 g/m^2	No *lablab* production

In a related trial, the effects of chicken manure, 18-46-0, 20-0-0, and fertilizers with various N:P ratios (1:1, 1:2, and 1:4) on *lablab* in 26 days were studied in tanks (IFP 1973b). See Table 3.

Another study was made in pursuit of solutions to the problems encountered in the first two studies mentioned above. This was conducted in newly constructed ponds of the Center which were stocked with milkfish. The various fertilizing materials and their combinations were tested in both the *lablab* and plankton methods of milkfish culture (IFP 1975b). The following were the various treatments:

A. *Lablab*
1. Chicken manure only
2. Chicken manure plus 0-20-0
3. Chicken manure plus 46-0-0
4. Chicken manure plus 16-20-0
5. 16-20-0 only
6. 0-20-0 only
7. 46-0-0 only
8. Unfertilized

B. Plankton (same treatments in A).

Table 3. Effect of various fertilizing materials on *lablab* production.

Treatment	Rate of application (g/m^2)	*Lablab* (ml/m^2)
Chicken manure	200	560
18-46-0	2	450
21-0-0	2	150
1:1 (N:P)	1 + 1	250
1:2 (N:P)	1 + 2	500
1:4 (N:P)	1 + 4	340

The effects of the various fertilizing materials on production of fishfood organisms and on fish production appeared not to be correlated. However, the importance of phosphorus, other nutrients, and chicken manure was demonstrated in all the studies. Rice bran had an unfavorable effect on the fishfood organisms, contrary to the claim of fish farmers. It was also surmised that the inconsistent effects of the various fertilizing materials on the growth and production of fishfood organisms and on fish production could be due to inherent differences in the pond soil. Thus it is important to have the soil analyzed first before any fertilizer is applied. Analysis should be made to determine the nutrients that are deficient and to avoid application of unnecessary nutrients.

In a related study, an attempt was made to determine the influence of the various fertilizing materials on the production of fishfood organisms. This was done in miniature habitats that simulated pond conditions and where the effect of single nutrient enrichment on the growth and development of fishfood organisms could be determined. The nutrients tested were N, P, and K. Results of the study showed that, in general, production of plankton was greatest in P-treated units (mean = 306 906 cells/ml), followed by N-treated units (mean = 132 153 cells/ml) and K-treated units (mean = 83 923 cells/ml). The control units yielded 63 923 cells/ml of fishfood organisms (IFP 1976c).

The need to evaluate organic manure application in milkfish ponds was identified. The present practice is to apply 1-2 t/ha of chicken manure every cropping period. Some practitioners apply dried chicken manure during the culture period to serve as feed for milkfish and as fertilizer for the fishfood organisms. An organic matter content of the pond soil higher than 5% produces good growth of *lablab* and therefore of milkfish. Based on these observations, a study was made to compare the production of *lablab* and fish in ponds with two levels of soil organic matter content — 6% and 8%, which were arbitrarily chosen because the initial organic matter content of the pond soil was approximately 5%, which was considered the minimum level. The first set of ponds had an average organic matter content of 5.52%, which was raised to 6% by an additional input equivalent to 6.6 t/ha of chicken manure. The other set of ponds had a mean of 5.54% organic matter content and required 36.6 t/ha of chicken manure to raise it to 8%.

The ponds with higher organic matter content (8%) produced significant growth of *lablab* and other fishfood organisms and yielded an average of 609 kg/ha of milkfish in 90 days at a stocking rate of 3000/ha. The ponds with lower level of organic matter (6%) had significantly lower *lablab* production and yielded a mean of 279 kg/ha of milkfish (IFP 1976d).

A follow-up study was made right after the termination of the first trial, but without addition of chicken manure to both treatments. Thus the residual effect of heavy doses of chicken manure could be determined. Milkfish with an average individual weight of 0.9 g were stocked in both treatments at 2880/ha and cultured for 93 days. It was observed that the ponds with 8% level of soil organic matter (OM) produced much more *lablab* than those with the 6% OM content. Furthermore, the ponds with higher soil OM content produced 504 kg/ha of milkfish while those with lower OM content yielded 473 kg/ha of milkfish (Leary and Laureta 1977). It was surprising to note, however, that fish production in the 6% OM ponds was higher than in the first trial of the same level, indicating that, while the heavier doses of organic matter had an advantage over the lower doses in terms of the short-term effect on the production of fishfood organisms, in terms of residual effect the lower dose of organic matter would benefit the fish farmers more in the long run.

Early Attempts to Improve Milkfish Production with Feeding

The effect of feeding on the production of milkfish under brackishwater conditions was determined by comparing the performance of milkfish on *lablab,* plankton, and fish pellets (IFP-1) as the main food sources. The feed composition of IFP-1 was 37.4% crude protein, 14% crude ash, 11% fat, and 9.4% crude fiber with 26% NFE. The *lablab* and plankton ponds required fertilizer doses equivalent to 10 kg P_2O_5/ha per application. The ponds that received feeds were not fertilized. Milkfish production after 181 days from ponds that received feeds only was 814 kg/ha. *Lablab* and plankton ponds had 504 kg/ha and 352 kg/ha, respectively (IFP 1972a). The effect on fish production of fertilized *lablab* ponds (16-20-0) was further compared with that of the ponds supplied with feed. After 82 days of culture, the ponds that received feed only gave the highest milkfish production of 320 kg/ha compared to 217 kg/ha (fertilizer only), 67 kg/ha (fertilizer plus lime), and 262 kg/ha in ponds with feed and lime (IFP 1972b). A follow-up study that tested *lablab, lablab* plus feed, and feed only showed highest milkfish production in the feed only treatment (IFP 1972c).

The above observation indicated that milkfish could perform well with pelleted feed. However, a more practical and economical feed needed to be developed. This prompted the researchers of the Center to screen commonly available material such as ipil-ipil (*Leucaena* sp.) leaf meal, which contains a high level of good quality protein (up to 25% dry weight) and has been used successfully as a feed ingredient, at limited levels, for livestock and poultry. Ipil-ipil was used successfully to make up 40% of a feed for *Macrobrachium.* Although ipil-ipil leaf meal contains mimosine, a toxic alkaloid that limits the level of this ingredient that can be added to feeds, its undesirable effect on fish has not yet been established. For this reason, it was tested on milkfish as a supplemental feed given daily at approximately 1600 h at 1% of total fish biomass. This was placed inside a floating enclosure (four hollow bamboo trunks joined at the corners to form a square 2.25 m on a side) to prevent it from being blown to the downwind shore. The daily ration was increased after every fifth feeding day by an increment based on the estimated daily growth increment of the fish. Milkfish fingerlings were stocked at the rate of 3000/ha.

An increase in net production of 23-30% over the control ponds (ponds receiving only 16-20-0 fertilizer at 50 kg/ha every 2 weeks) was attained after 179 days of culture. From an economic standpoint, ipil-ipil leaf meal as a supplemental feed for milkfish looks promising (IFP 1976b). Further studies, however, are needed to determine the optimum level of ipil-ipil leaf meal that will not cause undesirable effects. Studies could also be made on ipil-ipil leaf meal as a source of protein in pelleted or prepared feeds to minimize the use of animal protein for fish feeds, particularly for milkfish, which is considered a primary herbivore.

Innovations in Milkfish Culture Techniques

The foregoing studies were rather confirmatory and evaluative of existing practices and techniques for milkfish culture. Although some ideas may have been new, the use of fertilizers (organic and inorganic) and feeds and the rearing of milkfish utilizing natural food by encouraging the growth of certain food types (plankton, *lablab,* or *lumut)* by nutrient enrichment had been practised for many years. However, refinements of these practices were needed to make the methods more effective and efficient in producing milkfish, and the Center embarked on the following innovations:

Use of substrates to increase area of attachment for fishfood organisms. The introduction of substrates to bluegill (*Lepomis macrochirus* Refinesque) ponds resulted in higher production of bluegill due to greater production of fishfood organisms that attached to the added substrates (Pardue 1973). This encouraged the Center to evaluate this method for milkfish production based on the fact that *lablab* production or the abundance of natural food is dependent upon the area of the pond bottom. Using nylon screens that were cut into strips (30 × 10 m) and installed vertically like a series of pingpong nets across the ponds along the east-west direction (to avoid obstruction of sunlight) and set about 20 cm above the pond bottom, the following percent increases of surface area were tested: 0% (control), 15%, 30%, and 60%. The ponds were stocked with milkfish fingerlings (average weight 3.9 g) at a stocking density of 3000/ha.

The results indicated that a 30-60% increase in surface area is needed to effect a significant increase in fish production (IFP 19760f).

To lower the cost of increasing the area of attachment for fishfood organisms, locally available materials, particularly agricultural waste products, may be used. The abundance of rice straw in the locality prompted the Center to test its use as the additional substrate. Three methods of placing straw in ponds were tried: broadcasting, staking, and hanging. Initially, a single dose of 800 kg/ha of rice straw was used in all treatments. The hanging method was found to produce 6-8% more milkfish than the other treatments (IFP 1976g). In order to determine the appropriate amount of rice straw, another trial was conducted using the broadcast method based on the ease and practicality of application. The varying amounts of rice straw tested were 1 000,6 000, and 10 000 kg/ha. It was obvious that the higher amounts (6 000 and 10 000 kg/ha) had ill effects on milkfish production, although the 1 000 kg/ha approximated milkfish production in the control ponds. This indicated that the amount of rice straw used as a substrate for fishfood organisms should be within 1000 and 5000 kg/ha. Moreover, care should be taken for there are indications that residues of pesticides applied to rice are accumulated by rice stalks, which could affect the fish (Fortes et al 1977).

Stock manipulation. An attempt was made to modify the stock manipulation technique as practised in Taiwan to suit Philippine conditions. Three 1500 m^2 ponds were each stocked with three size groups of milkfish, viz., half grown, 1500/ha; post-fingerling, 1500/ha; and fry, 3000/ha. One month after stocking, another batch of fingerlings was added to the ponds at the rate of 1500/ha. This was followed by another batch of fingerlings at a stocking rate of 1500/ha. Two months after the initial stocking, 50% of the marketable size fish (stocked as half grown) were harvested. The other 50% was harvested one month later. On the fourth month after the initial stocking, 50% of the marketable size fish (stocked as the first batch of post-fingerlings) was harvested. One month later, the remaining 50% was harvested. A monthly harvest was thereafter programmed until the last batch of fingerlings was harvested. A gill net with specified mesh size for selective harvesting was used in all harvests.

The results showed a significant difference in milkfish production between stock manipulation ponds and nonstock manipulation ponds. Production in the former ranged from 734 to 961 kg/ha, while in the latter, it was from 613 to 702 kg/ha (IFP 1976h), indicating that stock manipulation can be done in the Philippines with certain modifications to suit prevailing conditions.

Polyculture.

• The first attempt of the Center to culture milkfish in combination with other species was made in 1973 using *Penaeus indicus.* At a stocking rate of 3 330/ha for milkfish and 28 756/ha for *P. indicus,* production after 85 days was 510 kg/ha and 109 kg/ha, respectively (IFP 1974c).

In another trial, milkfish was stocked at 3 000/ha and *P. indicus* at 30 000/ha. Heavy shrimp mortality occurred in this trial, but the following important information was noted: (IFP 1975c).

1. Use of aeration during handling increased survival and lowered stress of milkfish and shrimp fry;
2. Shortening of the acclimation process for shrimps to 1.5 h significantly increased stress;
3. Adding *lablab* to the holding container of the shrimps reduced cannibalism; and
4. The use of an acclimation pond was found very useful for both the shrimps and the milkfish fry.

• Some years after the introduction of tilapia (*Oreochromis mossambicus*) into the Philippines in 1950, fish farmers started regarding it as a nuisance or pest in milkfish ponds, and the trend was to eradicate it. Tilapia, because of its high reproduction rate, caused overcrowding, resulting in greater competition and undesirable fish size. It was thought that, if a young tilapia population could be controlled, an additional crop in terms of bigger tilapia could be obtained. The Center conducted an experiment wherein milkfish and all-male tilapia were cultured in combination. Tilapia was stocked at 2000 and 4000/ha and milkfish at 3000/ha, and they were raised for 80 and 85 days.

The results of the experiment showed that the daily weight increment of milkfish in monoculture (1.8 g/fish per day) was the same as that attained in polyculture with tilapia. Milkfish in monoculture attained an average yield of 554 kg/ha. In polyculture with tilapia, average milkfish production was 521 kg/ha (with 2000 tilapia/ha) and 467 kg/ha (with 4000 tilapia/ha). In terms of total production, the two milkfish-tilapia ratios produced 680 kg/ha and 800 kg/ha in 85 days, respectively (IFP 1975b). These results show that there is a good promise for polyculture of milkfish and all-male tilapia.

The labor-intensive method of manual sexing of tilapia and the technical constraints in producing all-male tilapia by sex inversion and hybridization posed a problem in the use of milkfish-all-male tilapia polyculture. Because of this, the use of a predator to control the population of young tilapia was tried. Fortes (1980) established a tarpon (*Megalops cyprinoides*): tilapia ratio of 1:10 as adequate to control the young tilapia population and to allow the original stocks to grow. Using this technique, a milkfish-tilapia'tarpon combination was tested.

The different treatments used were: (1) milkfish (3000/ha); (2) milkiish (3000/ha) + mixed-sex tilapia (2000/ha); (3) milkfish (3000/ha) + mixed-sex tilapia (2000/ha) + tarpon (200/ha). They were cultured for 120, 107, and 90 days, respectively.

To compare the results with those of milkfish and all-male tilapia, another experiment was conducted with the following treatments: (1) milkfish only (3000/ha); (2) mixed-sex tilapia only (1000/ha); (3) mixed-sex tilapia (1000/ha) + tarpon (100/ha); (4) all-male tilapia (1000/ha); (5) all-male tilapia (1000/ha) + milkfish (3000/ha); and (6) mixed-sex tilapia (1000/ha) + milkfish (3000/ha) + tarpon (100/ha).

The results of the first study indicated that tarpon was an effective predator on young tilapia in the presence of milkfish and did not harm the milkfish. Fish production from the various treatments in the first study was as follows:

Treatments	Production (kg/ha)
1. Milkfish only (3000/ha)	533
2. Milkfish (3000/ha) + mixed-sex tilapia (2000/ha)	612
3. Milkfish (3000/ha) + mixed-sex tilapia (2000/ha) + tarpon (200/ha)	574

Production in Treatment 2 consisted of 41% young tilapia, 22% adult tilapia, and 37% milkfish. Treatment 3 consisted of 7% young tilapia, 25% adult tilapia, 66% milkfish, and 2% tarpon.

In the second study, the contribution of young tilapia to total production in treatments with tarpon was minimal (6% in Treatment 3, less than 1% in Treatment 4). Marketable size fish comprised 94% (Treatment 3) and 90% (Treatment 6) of the total production. In the treatment without tarpon (2) young tilapia comprised 64% while large tilapia made up 36%. Milkfish comprised 83% of total production in Treatment 6. This suggested that production of milkfish was favored in the milkfish-mixed-sex tilapia-tarpon combination over the milkfish-all-male tilapia polyculture (Fortes 1983).

• The tri-species culture of milkfish, mullet, and tiger shrimp (*P. monodon*) was tried to determine their effect on each other. In terms of competition index (CI) tiger shrimp had a negative effect on milkfish, but milkfish favored the production of tiger shrimp. Milkfish and mullet had a fairly high competition, but mullet and tiger shrimp favored each other, thus, improving total production (Fortes 1982).

Integrated system. The success of fish-pig culture under freshwater conditions has been demonstrated, but reports of its practice in brackish water appear to be lacking. On this basis, milkfish was cultured in combination with all-male tilapia in brackishwater ponds where pigs at 40 head/ha were raised in pens built above each pond. The pens were washed daily using pond water to rinse the manure and uneaten feed. The pigs were bathed with rainwater, and all washings went directly into the ponds.

The results indicated that in polyculture of milkfish and all-male tilapia (4000/ha and 2000/ha, respectively), piggery wastes could affect the growth and production of milkfish negatively (Fortes et al 1980). However, milkfish production could be improved using fresh pig manure at appropriate dosage, using the following equation (Tamse 1983):

$$OSR = 24.65 + (176 \pm 158)\, m + (0.2 \pm 0.1)\, t$$

Where OSR = oxygen saturation reduction
m = manuring
t = time (number of days)

Regular daily manure application following the above equation prevented oxygen depletion and resulted in higher milkfish production.

RECOMMENDATIONS

The work at BAC has centered on milkfish seeds collected from the wild. Hence, the following are recommended for consideration for future work, not only for the Center but also for other institutions:

- Although work should continue on fry from the wild, particularly collection, transport, holding, and rearing, more concerted efforts should now be focused on milkfish seeds from hatcheries in the following areas:
  - — environmental requirements of hatchery-produced milkfish fry;
  - — feed and nutrient requirements of milkfish larvae for maximum survival during larval rearing; and
  - — more studies on natural food sources and the nutrients required for their production.
- More systematic and scientific methods of milkfish broodstock development are needed.
- Refinement of existing culture techniques (ponds, pens, etc.) to standardize methods must be done.
- More studies should be directed toward hybridization and genetic work, possibly determining a species that could be used to strengthen the lone species of *Chanos.*
- Evaluation and confirmatory work should continue in support of the needs of the milkfish industry.

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ACID SULFATE SOILS AND THEIR MANAGEMENT FOR BRACKISHWATER FISHPONDS

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The major problems of fishponds built on acid sulfate soils are low pH; ionic imbalance and toxic levels of aluminum, iron, and sulfate; deficiency of phosphorus and poor response to fertilizer application; slow and poor growth of fish food organisms and fish; erosion of dikes; and in some cases fish kills. For economic operations and to remedy the problems of poor algal growth, fish kills, and low yields, the acid in the pond bottom and dikes has to be neutralized or removed. Although the acids can be neutralized by adding enormous amounts of lime at prohibitive cost, it is not necessary to neutralize them all because a large part can be removed. A repeated sequence of drying, tilling, and flushing with seawater is a cheap, fast, and effective reclamation method that can be done in one dry season. Following this method, the dry soil pH improved; exchangeable aluminum, pyritic iron, active iron, active manganese, and sulfate decreased; and available phosphorus improved. The values for alkalinity, phosphate, aluminum, iron, and sulfate in the pond water improved greatly. *Lablab* production every 2 weeks in control ponds was 32.9 g/m^2 against 112 g/m^2 in reclaimed ones. Fish production was about three-fold more in reclaimed ponds (375-510 kg/ha) compared with the control ponds (50-173 kg/ha).

INTRODUCTION

Soil is important to pond productivity because of its ability to adsorb and release the nutrients needed for the growth of algae and other microorganisms, the natural foods of milkfish. Soil is also the main and, perhaps, the only economical source of dike building materials. The quality of water in the pond is strongly affected by the nature of the soil in the pond bottom and in the dikes surrounding it. This influence of soil on pond conditions becomes clear in the case of adverse soil conditions such as acid sulfate.

In fishponds built on acid sulfate soils, a highly acidic condition develops which is detrimental to both food organisms and fish. Elements and ions like iron, aluminum, sulfate, and in some cases manganese are released to the water in toxic quantities (Singh 1982a). Likewise, acid sulfate soil renders essential nutrient phosphorus unavailable to the algae and thus, without reclamation, there is generally no response to phosphorus fertilization.

In the first 5-10 years after construction of fishponds in acid sulfate soils there are major problems precluding economic operation or even production. Growth of algae is inhibited or restricted by the low pH and the very low phosphate level of the pond water. The growth rate and condition of fish are impaired by the unfavorable ionic composition of the pond water, the periodic presence of finely dispersed ferric hydroxide, and the poor growth of fish food. Moreover, there are sudden fish kills during rains after extended dry periods owing to extremely acidic water seeping into the ponds from surrounding dikes.

After about a decade, these problems gradually recede, but fish production remains low, only on the order of 300-600 kg/ha per year. This should be compared with an average of 1.5 or, with recommended management and fertilizer levels, up to 2.5 t/ha per year in areas with non-acid coastal clays (Brinkman and Singh 1982). Although occasional fish kills are caused by acid sulfate soils in acute situations, chronic, sublethal effects that inhibit pond biota in general are probably more detrimental in the long run.

Traditional, small fish fanners dig very shallow ponds to minimize problems and limit capital costs. They survive and learn to live with the problems but do not rise above poverty within a decade, and do so slowly even after that period. Large fanners whose holdings are mainly externally financed, as well as companies developing extensive areas for fishponds, tend to abandon their efforts on this land and sell it after a few years of failure; then another victim repeats the process.

Until about a decade ago, much of this area was mangrove forest, and smaller areas were used for one poor crop of rice per year and for fishponds. In recent years, due to poor returns from rice cultivation and to other land uses, the area of fishponds has increased rapidly at the expense of mangroves and rice fields. Fishponds now appear to be the most important kind of land use in the coastal acid sulfate areas in the Philippines. Although the conversion to fishponds appears to be economically sound, this requires considerable financial resources because it is a major engineering operation; but it can result in an economically viable production system if the area is properly reclaimed and managed. However, even after reclamation, some hazards and problems remain, requiring special management methods. For successful operations, available phosphate needs to be raised above the deficiency level; potential acidity in the subsoil should be kept immobilized; and soluble iron and aluminum concentrations need to be kept low.

In this paper the formation, properties, extent, and identification of acid sulfate soils and the problems of fishponds built on them are reviewed, and a rapid and low-cost reclamation and management method developed at the College of Fisheries, University of the Philippines in the Visayas, Iloilo — tested and verified at several privately owned fishponds — is presented.

ACID SULFATE SOILS

An acid sulfate soil has been defined as a drained soil with free as well as adsorbed sulfates having yellow mottles of jarosite and a pH less than 4 in water. A potential acid sulfate soil is a reduced and waterlogged soil that contains pyrites with pH values near neutral and that will eventually become acidic upon drainage and oxidation (Brinkman and Pons 1973, Bloomfield and Coulter 1973). Soils that develop extreme acidity upon drainage and drying occur in freshwater and brackishwater mangrove tidal swamp environments.

Acid sulfate soils are derived from marine and estuarine sediments which, upon drying and aeration, show a definite and severe acidification due to the oxidation of sulfides (mainly pyrite, FeS_2), leading to the formation of sulfuric acid. Such soils in a marine environment are generally found in estuaries, deltas, and tidal flats where sulfides have accumulated in marine sediments as a result of the bacterial reduction of seawater sulfates. In the acidic state they contain concentrations of aluminum, iron, and manganese that are toxic to both fish and other fishpond organisms. Some elements, particularly iron and aluminum, are released into the pond water in toxic quantities that render phosphorus unavailable, thus causing phosphorus deficiency in algae. Under such conditions, there is generally no response to phosphorus fertilization (Singh 1982a).

Formation of Acid Sulfate Soils

In mangrove swamps, the formation of acid sulfate soil is favored because of the abundant supply of sulfates and organic matter. The mangrove vegetation (especially dense fibrous roots) in the swamps facilitates the accumulation of inorganic and organic materials and helps in the buildup of sediments by trapping mud and therefore in controlling erosion (Van der Kevie 1973). Decomposition of organic matter in the soil depletes the oxygen, giving rise to anaerobic conditions and thus activating the sulfur-reducing bacteria. These obligate anaerobes decompose the organic materials and at the same time utilize the sulfates present in seawater for their respiratory processes, producing sulfides (Campbell and Postgate 1965).

The resulting sulfides may accumulate in the sediments as hydrogen sulfide gas or may combine with available iron to form insoluble black iron sulfide. Further transformation of the iron sulfide will produce pyrite, the mineral chiefly responsible for the formation of acid sulfate soil. Pons (1969) and Richard (1973) proposed that pyrite may be formed through the following reactions:

$$2\ CH_2O + SO_4^{=} \rightarrow HCO3 + HS + CO_2 + H_2O$$
$$H_2S + Fe \rightarrow FeS + 2\ H^{+}$$
$$FeS + S \rightarrow FeS_2\ \text{(pyrite)}$$

The final pH of the soil depends, however, on the amount of pyrite oxidized and on the buffering capacity of the soil. The acidity can be neutralized by bases coming from minerals, mainly calcium carbonate, and by metal cations coming from the exchange complex. Thus, soils with a low amount of bases will develop into strongly acid soils.

Processes During Drying and After Filling

Pond soil, initially reduced when flooded, contains the usual marine salts and considerable amounts of exchangeable ferrous iron. Upon oxidation, ferric hydroxide is formed and the soil may become partly aluminum-saturated. The pH drops from near neutral to a lower value. In acid sulfate soils, pyrite oxidation produces jarosites and iron hydroxide as well as sulfuric acid, which attacks the clay minerals. The pH drops to a very low value. The soil becomes largely aluminum-saturated, some free acid remains, and aluminum salts are formed (Brinkman and Singh 1982).

After inundation, the pond soil becomes reduced again. Acid is consumed by the reduction of ferric hydroxide to ferrous ions. Part of the free acid and the aluminum salts and, somewhat later, large amounts of ferrous salts diffuse from the soil into the pond water. This process appears to be speeded up by the salts in the saline or brackish water. Rain falling on previously dry dikes leaches further quantities of acid and aluminum as well as ferrous salts into the pond water, both from the surface and from the interior of the dikes. In the course of a few days, the ferrous iron is oxidized, producing more acid and finely distributed ferric hydroxide, which remains suspended in the pond water for several days. If powdered lime is used to reduce the acidity of the water, ferric hydroxide is formed more rapidly. Any phosphate that might have been present in the water is quickly trapped by the large amounts of aluminum salts or by free aluminum in the surface soil.

IDENTIFICATION AND EXTENT

Acid sulfate in pond soil can be recognized (Brinkman and Singh 1982) by the very low pH values measured in the pond water when it is flooded for the first time after drying, by the reddish iron oxide that may form on the pond bottom after flooding, by the poor growth or absence of algae, and by very low pH values (generally less than 4) measured in dry soil.

Acid sulfate in dikes can be recognized by a very low pH (generally less than 4), by the poor or spotty growth or absence of vegetation on them even several years after construction, by pieces of organic matter encrusted with whitish and pale-yellow salts, and by very acidic water seeping out of the dikes into the pond during heavy rains.

The acid sulfate soil areas in Southeast Asia (Table 1) are found extensively in coastal brackishwater as well as freshwater environments in Indonesia, Thailand, Vietnam, Malaysia, and the Philippines (Singh 1980). The extent of these areas in the Philippines seems to be less than 0.5 million ha (Brinkman and Singh 1982), and they are of the saline type. They are concentrated mostly in coastal brackishwater areas on the islands of Panay, Negros, and Bohol in the Visayas; in the provinces of Misamis Oriental and Agusan in Mindanao; and in Bicol, the Cagayan Valley, Pangasinan, Quezon, and Mindoro. Except on Panay, where they are reported to be about 20 000 ha (Singh 1982b) these areas have not been adequately surveyed.

PROBLEMS

The main problems of fishponds in acid sulfate soils are the insufficient growth of algae, the poor condition and consequent slow growth of fish, and the hazard of sudden fish kills during heavy rains after a long dry period. These are because of low pH, ionic imbalance, and toxically high levels of iron, aluminum, and sulfate; dike erosion; and deficiency of phosphorus (Singh 1980, 1982a). Even if these problems are solved, the very low efficiency of phosphate fertilizers remains (Potter 1976, Brinkman and Singh 1982).

The growth of algae is inhibited or retarded by low pH, high aluminum concentration, and low phosphate level. The low pH and high aluminum concentration may kill the fish or, in less severe cases, weaken them so that they become easy prey for diseases and parasites. The sudden influx of acid water and aluminum salts from dikes during rains causes an ionic imbalance in the fish that is commonly lethal to a large proportion of the population. Finely divided ferric hydroxide subsequently appears in the pond water and clogs the gills of the survivors, killing another contingent and weakening the remainder (Brinkman and Singh 1982). A lesser problem is the erosion of the dikes because of little or no vegetation on them, and thus those dikes remain acid-producing, at least during the first few years after construction. This further adds to the maintenance cost.

Table 1. Distribution of acid sulfate soils in South, Southeast, and East Asia.[a]

Country	Area (1000 ha)	Type
Bangladesh	700	Sulfaquents and Sulfaquepts
Burma	180	Sulfaquents
China	67	Sulfaquepts and Sulfic Haplaquepts
India	390	Highly organic Sulfaquepts and Sulfaquents
Indonesia	2000	Highly organic Sulfaquents, Sulfaquepts, and Sulfimists
Japan	21	Sulfaquepts and Sulfic Haplaquepts
Kampuchea	200	Mainly Sulfaquepts
Korea, Republic of	3	Sulfic Haplaquepts and Sulfaquepts
Malaysia	160	Mangrove acidified marshes
Philippines	7	Sulfic Tropaquepts, Sulfaquepts, and highly organic Sulfaquepts
	20	
	500	Sulfic Tropaquepts, Sulfaquents,
Thailand	670	and Sulfaquepts
		Sulfaquepts, Sulfic Tropaquepts,
Vietnam	1000	and organic Sulfaquents

[a] After Van Breemn and Pons (1977) and Singh (1980).

RECLAMATION

Acids in the pond bottom can be neutralized in two ways. They can be permanently neutralized by adding enormous quantities of lime over a period of several years, but only few farmers can afford such amounts. The acids can be made temporarily harmless by flooding the pond bottom about 3-4 weeks before stocking. During this period, the reddish iron oxides and organic matter in the soil combine to reduce the acid. However, the acid will appear again as soon as the pond bottom is dried. Acids in the dikes can also be neutralized by very large amounts of lime. It is not ordinarily possible to make them harmless by flooding because flooding of dikes to the reduced stage is usually not feasible.

It is not necessary, however, to neutralize all the acids in the pond bottom and the dikes, because a large part can be washed out and removed to the sea. Without such treatment, the pond will improve, but very slowly over a period of about 10-20 years, from almost no production to moderate levels; but most pond owners cannot afford to wait for such long periods for the natural rate of improvement. A system for rapid improvement of acid sulfate soils has been worked out at the Brackishwater Aquaculture Center of the University of the Philippines in the Visayas that can be carried out in one dry season (about 3 months) at a relatively low total cost in the range of ₱900—₱1000/ha. It has been tried in several locations in private ponds on Panay Island quite successfully. The studies conducted in developing this method include those of Poernomo (1983), Poernomo and Singh (1982), Brinkman and Singh (1982), Singh (1980; 1982a, 1982b), and Camacho (1977).

The basic concept for permanent reclamation is to remove the source of acidity by oxidizing the pyrite from the pond bottom (10-15 cm deep layer) and flushing this out of the pond to prevent further diffusion of acids, aluminum salts, and large amounts of ferrous salts from the subsoil to the upper layer and the pond water during the fish rearing period. At the same time the acid materials and other toxic elements from the relatively big dikes are also leached and removed.

The procedure involves a precisely planned sequence of drying the pond, tilling or cultivating the pond bottom by tooth harrow, filling and draining the pond, and finally broadcasting a small amount of lime (about 1 t/ha or less) on the pond soil and dikes. During the same period, the tops of the surrounding dikes are made into a series of long, narrow ponds by making small levees along their edges with soil dug out of the center of the dikes (Fig. 1); seawater or brackish water is pumped or carried into these to leach the acids from the dike soil. If the dikes are small, however, there may be no need of leaching them, or the leaching of the dikes may be restricted to those relatively big primary dikes or in some cases to secondary dikes surrounding nursery and fingerling ponds where compartment sizes are usually small. The details of this method can be seen in articles by Brinkman and Singh (1982) and Poernomo (1983). After completing the reclamation, the ponds are applied with organic and inorganic fertilizers; growing of fish food organisms and rearing of fish follow as usual.

RESULTS

The results obtained after applying this procedure at different locations in northeast Panay have been very encouraging and successful. The properties of pond and

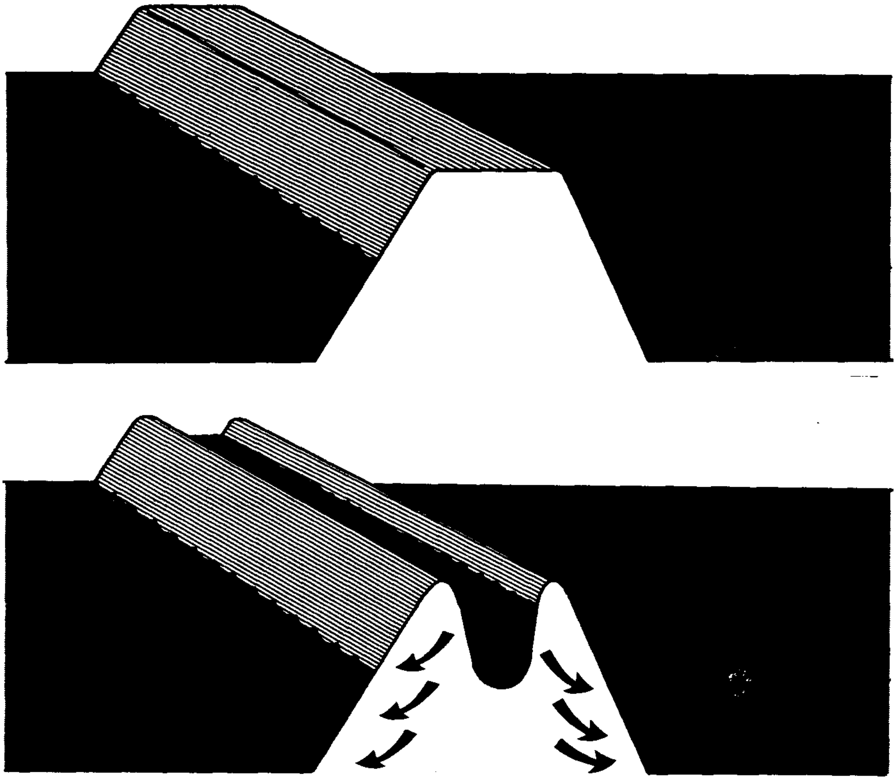

Fig. 1. Leaching of levees.

dike soil and pond water before and after reclamation and after the harvest of the first crop are shown in Tables 2,3,4, and 5. The results of *lablab* and fish production are shown in Table 6.

Soil Properties

In the beginning, the low pH combined with high concentrations of exchangeable aluminum, active iron, and acetate soluble sulfate (Table 2) indicated extremely acidic conditions. The dike soil was even more acidic than the pond bottom because of the intense oxidation of pyrites (Table 2). The concentrations of aluminum and iron in the pond soil were very high due to low pH and were far beyond the tolerable limit of most fish, which is generally about 0.5 ppm and 0.2 ppm for aluminum and iron, respectively (Nikolsky 1963). The extremely low concentration of available phosphorus in the pond bottom soil was attributed to the binding capacity of excess amounts of aluminum and iron (Table 2).

After 3 months of reclamation, the decrease in concentration of acetate soluble sulfate (5612-633 ppm) — potential acidity — coupled with decreased concentrations of aluminum (132 to 12 ppm) and iron (7607 to 3633 ppm) resulted in an

Table 2. Some physical and cbemical properties of surface soil of pond bottom and dikes in acid sulfate areas.

Properties	Pond bottom	Dikes
pH (wet)	5.8	3.6
PH (dry)	5.7	3.1
Potential acidity (meqH/100g)	23.6	24.1
Organic matter (%)	4.1	3.4
Exchangeable Al (ppm)	150.0	333.0
Active Fe (ppm)	7 845.0	9 650.0
Active Mn (ppm)	15.0	15.0
Pyritic Fe (ppm)	3 346.0	3 120.0
Acetate solution-SO_4 (ppm)	6 145.0	8 717.0
Available PO_4 (ppm)	0.25	0.39

increase (1.1 to 1.4 units) in dry soil pH in the treated ponds. The available phosphate in treated ponds increased from 0.25 to 1.03 ppm. In contrast, there was only a little change in the pH and in other properties of the control ponds (Table 3), due to washing from the rains.

The dry soil pH (4.8) attained after reclamation (Table3) was enough to maintain an ideal pH (6.8) in the wet reduced pond bottom soil and a pH of 7.0-8.5 in the pond water during *lablab* and fish growing because of continuous submergence. This situation in turn was optimal for the solubility and availability of phosphorus for *lablab* growth, since fixation of phosphorus is minimal at these pH levels (Table 3). A similar trend was also observed for dike soil (Table 4).

After fish harvest from both the ponds that were applied with 2 t of chicken manure, 48 kg N, and 60 kg P_2O_5/ha as standard operating procedure, the treated pond soils attained a higher dry pH (5.7) and had lower concentrations of aluminum (10 ppm), active and pyritic iron (2963 ppm and 1920 ppm, respectively), and sulfates (704 ppm) than the controls (Table 3). The treated ponds also had a higher level of available phosphorus (1.43 ppm). The values of aluminum, active and pyritic iron, and sulfates in control ponds were generally more than two-fold higher, registering 63 ppm, 7676 ppm, 3206 ppm, and 200 ppm, respectively.

Table 3. Some properties of pond bottom soil before and after reclamation and the harvest of first crop.

Properties	Before reclamation		After reclamation		After harvest	
	Control	Treated	Control	Treated	Control	Treated
pH (wet)	6.0	5.4	5.6	6.0	5.8	6.8
pH (dry)	3.9	3,6	3.7	4.8	3.8	5.7
Eh (mv)	2.3	220	72	10	-120	-150
Exchangeable Al (ppm)	162	135	85	12	63	10
Active Fe (ppm)	9 278	7 607	7 913	3 633	7 676	2 963
Pyritic Fe (ppm)	3 378	3 321	3 140	1 867	3 206	1 620
Active Mn (ppm)	17	16	12	18	7	0
Acetate Solution SO_4 (ppm)	6 723	5 612	2 075	633	2 000	704
Available PO_4 (ppm)	0.33	0.25	0.66	1.03	1.13	1.43

Table 4. Some properties of dike soil before and after reclamation.

Properties	Before reclamation		After reclamation	
	Control	Treated	Control	Treated
pH (wet)	3.6	3.7	3.8	4.1
pH (dry)	3.0	3.1	3.8	4.1
Eh (mv)	374	360	340	293
Exchangeable Al (ppm)	367	309	253	118
Active Fe (ppm)	9 854	8 996	9 167	5 285
Pyritic Fe (ppm)	2 330	3 215	1 767	1 362
Acetate Solution SO_4 (ppm)	9 442	8 358	2 374	1 083
Active Mn (ppm)	17	13	11	6
Available PO_4 (ppm)	0.39	0.39	0.55	0.79

Water Properties

The chemical properties of pond water before and after reclamation and after harvest of the first crop are presented in Table 5. The chemical properties of both the control and treated ponds before reclamation had similar magnitudes. The pH of the water was 3.9, alkalinity was 22 ppm, aluminum 3.5 ppm, iron9.3ppm, and sulfate 1800 ppm. Due to the low pH and the high aluminum, iron, and sulfate levels, the dissolved phosphorus in the water was essentially zero. These conditions indicate a very highly acidic and unfavorable condition for milkfish and prawns.

After the 3-month reclamation period, the pond conditions improved significantly; the pH of the water increased to 6.5, alkalinity to 47 ppm, and the levels of aluminum, iron, and sulfate decreased to 0.18 ppm, 1.35 ppm, and 773 ppm, respectively. Dissolved phosphorus improved from 0.0 to 0.02 ppm. Some improvements were also seen even in the control ponds, but these were due mainly to occasional draining of the pond water because of heavy rains during the reclamation period, and the magnitude of improvement was smaller in these ponds (Table 5). After harvest of the fish grown in control as well as treated ponds (both had received the same fertilizers and other management inputs), the water quality of the treated ponds was remarkably better than that of the controls. The levels of aluminum and iron in treated ponds decreased to negligible, sulfate decreased considerably, and pH, alkalinity, and phosphorus levels increased significantly (Table 5).

Table 5. Some properties of pond water before and after reclamation and after harvest of first crop.

	Before reclamation		After reclamation		After harvest	
Properties	Control	Treated	Control	Treated	Control	Treated
pH	3.9	3.9	4.2	6.5	6.9	8.0
Alkalinity (ppm)	20.3	23.1	23.1	47.3	48.9	98.5
Aluminum (ppm)	2.9	4.1	1.7	0.18	0.04	0.02
Iron (ppm)	9.3	9.3	3.9	1.3	0.37	0.16
Sulfates (ppm)	1 723	1 930	1 063	773	1 070	680
Phospate (ppm)	0.0	0.0	0.1	0.02	0.02	0.20

Lablab and Fish Production

The significantly lower production of *lablab* in the control ponds (Table 5) compared with that in reclaimed ones is attributed to the constantly low concentrations of available phosphorus due to the rapid fixation of phosphorus released from the fertilizer. In the reclaimed ponds, on the other hand, fixation of phosphorus by the soils seemed to be minimal. The *lablab* mat that grew evenly on the pond bottom seems to have acted as a barrier and to have prevented phosphorus fixation into the soil. Also, the soil in these ponds was no longer very acidic and therefore had lower phosphorus fixation. *Lablab* growth in all the reclaimed ponds was so thick that thinning was done to avoid the danger of sudden decomposition.

Fish production in the treated ponds (375-510 kg/ha) was significantly higher than in the control ponds (50-173 kg/ha), although both had received same management inputs (Table 6). Twice in the control ponds there were mortalities, which resulted in only 43% survival. Survival in the treated ponds was 93%. Ideally, the weight gain

Table 6. *Lablab* and milkfish yield in a culture period of 90 days.

	Lablab		Milkfish		
	Ash free dry weight (g/m^2)				
Treatment	Total	Per two weeks	Survival (%)	Weight (gain/fish)	Yield[a] (kg/ha)
Control	230.1	32.9	43	107.6	50-173
Treated	783.4	112.0	93	124.1	374-510

[a] The range in yield indicates the difference among sites used.

in the control ponds should have been higher than in the treated ones because of the smaller number of fish, but the results were otherwise; the fish in the treated ponds had a higher weight gain (124.1 g) than those in the control (107.6 g). This indicates that the food supply in the control ponds was not sufficient and the water quality not optimal. This was further confirmed by length-weight analysis. Fish production in both treatments was significantly correlated with *lablab* growth.

Although there may be no significant difference between ponds with and without dike leaching in terms of *lablab* and fish production, there were more acids and other toxic elements in the dikes without leaching. The results of leaching indicate that more acids were washed and removed from the leached dikes compared to the unleached ones. The leached dikes pose a smaller hazard of acid water seeping out than the unleached and thus have more potential for fish kills. In other words, the effect of dike leaching on *lablab* and fish production may be undetectable in the first season of rearing fish, but it could be more pronounced in subsequent growing seasons, especially during rainy months.

Other methods of improving acid sulfate soils include liming; covering the acidic soil with a more suitable material like neutral clay, river bottom mud, or filter mud press; covering pond dikes with vegetation to check erosion; and lining the dikes with limestone.

CONCLUSIONS AND RECOMMENDATIONS

Based on the studies cited in this paper, the following conclusions and recommendations are drawn:

1. The development of fishponds in mangrove areas should be undertaken with caution, and prior to any development a detailed soil survey must be conducted.
2. Though acid sulfate soils are undoubtedly detrimental if they are developed into fishponds, they can be rapidly improved into productive soils following a proper method of reclamation (Singh and Poernomo 1983).
3. A repeated sequence of drying, tilling, and flushing the pond with seawater and leaching of relatively big dikes, preferably during the dry season, is a cheap and fast method of reclamation (Singh 1980, Brinkman and Singh 1982, Poernomo and Singh 1982, and Poernomo 1983).
4. A moderate amount and low rate of application of powdered lime (500 kg/ha) broadcast on the pond bottom immediately after reclamation or during pond preparation for fish rearing helps speed up soil reduction; suppresses the concentrations of aluminum, iron, and acids that may be released into the pond water; and reduces the phosphorus fixation into the soil. The application of waste materials like mud press from sugar mills and burnt rice hulls on the wet pond bottom is also effective in reducing the phosphorus fixation in the soil (Singh 1982b).
5. To further avoid excessive phosphorus fixation by pond bottom soil, small weekly dressings of preferably slow release fertilizers are recommended (Singh 1982a).
6. Instead of prefingerlings, the postfingerling size of milkfish or of other hardy fish should be used for stocking in the first or second year after reclamation. Prawns should be tried afterwards in polyculture with milkfish on an experimental basis before embarking on intensive commercial prawn monoculture after several years (Singh 1982b).

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MILKFISH NUTRITION

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This paper reviews major contributions in the field of milkfish nutrition since the First International Milkfish Aquaculture Conference in 1976. Substantial progress has been made toward understanding the digestion, foods, and feeding behavior of milkfish, which in its natural habitat apparently feeds on planktonic microorganisms and is most frequently designated as a microphagous planktovore. It has fine, almost membranous gill rakers and a specialized epibranchial organ that may help to concentrate microplankton. Vision seems to be the most important sensory mechanism for feeding in fry as well as in juveniles and larger milkfish. Active carbohydrases, proteases, and lipases have been detected in the pyloric caeca, pancreas, and intestines of milkfish. The most active carbohydrases were those involved in the hydrolysis of α-glucosidic bonds. Milkfish trypsin was inhibited by a tryptic inhibitor from *Chaetomorpha brachygona,* one of the most commonly occurring filamentous algae in milkfish ponds. This may account for the slow growth rate of milkfish on this natural food base. There is very scant information on nutrient requirements and other important aspects of milkfish nutrition. A preliminary study on protein requirement showed that a dietary level of 40% protein was required by fry. Other studies showed that fry responded positively and were easily trained to accept artificial diets. The "deep water method" of growing milkfish practised in Taiwan demonstrated that, with the use of formulated diets, productivity in milkfish aquaculture could be increased threefold over traditional culture methods, which rely on natural food bases. Undoubtedly, productivity can still be enhanced through further improvement in the nutritional quality of diets.

INTRODUCTION

The intensification of milkfish aquaculture is a direction the milkfish industry may soon have to take. With the increase in the pressure from alternative uses of coastal land, suitable areas for aquaculture may steadily decrease. Productivity will have to be increased through a shift from extensive aquaculture, dependent on predominantly natural food bases, to intensive aquaculture, which utilizes formulated diets. Fundamental research on milkfish nutrition, including studies on digestibility, digestive enzymes, nutrient requirements, and metabolism, is necessary to be able to formulate economically feasible and nutritionally adequate milkfish diets.

Interest in research on milkfish nutrition was markedly enhanced after the First International Milkfish Aquaculture Conference in 1976, and this paper reviews the major contributions in the field since then. Substantial progress has been made toward understanding the digestion, food, and feeding behavior of milkfish.

FOOD AND FEEDING

Milkfish, in its natural habitat, apparently feeds on planktonic microorganisms and is most frequently designated as a microphagous planktovore (Smith 1980). All fish that share the unique characteristics of attaining very large body size on a diet of phytoplankton or zooplankton have very elaborate modified branchial structures — gill rakers or epibranchial organs. These special structures appear to function as food processing devices and serve to filter, collect, and concentrate the food (Nelson 1967, Hyatt 1979). Milkfish has fine, almost membranous gill rakers that suggest filter feeding. It also has a specialized epibranchial organ above and behind the gills that may help to concentrate microplankton (Kuwatani and Kafuku 1978, Smith 1980). A study of the food and feeding periodicity of milkfish fry collected from coastal waters suggested, however, that planktonic organisms constitute a minor component of the food intake of the fry (Banno 1980). Only about 3-11% of fry collected in marine waters and 5-9% of those collected from estuaries had planktonic organisms in their gut. The most common organisms were a centric diatom (*Coscinodiscus* sp.), a cyclopoid copepod (*Oithona* sp.), and calanoid copepods (*Paracalanus* sp. and *Calanus* sp.). Detrital materials suspended in the water column or settled at the bottom were suggested as a major source of food for the fry (Banno 1980).

Vision seems to be the most important sensory mechanism for feeding in milkfish fry and appears to develop before the other senses (Kawamura and Hara 1980). Gut content analysis of fry collected from both marine and estuarine waters suggested that milkfish fry are daytime visual feeders, with peak feeding at 0700 and 1300 h (Banno

1980). In the laboratory, the captive fry did not feed in the dark. However, the ability to feed in the dark increased as the fish grew to young juveniles, probably due to the development of chemosensory and auditory mechanisms (Kawamura and Hara 1980). An electrical device for recording feeding activity in larger milkfish that weigh about 2-3 kg showed that the fish also feed preferentially during the day. Feeding activity was significantly less at night (Kawamura and Castillo 1981).

The eyes of milkfish larvae are pigmented on the second day after hatching, and feeding on exogenous food starts on the third day when the yolk is completely absorbed (Liao et al 1979). At about 3 weeks of age, wild fry were observed to have well-developed, regionally differentiated retinae with all retinal elements already present (Kawamura and Hara 1980). A retinal tapetum was also observed in the pigment epithelium, and its presence suggested that the fry may be adapted for vision in optically turbid shore water or in dim or subdued light (Kawamura and Hara 1980). The sensory mechanisms associated with feeding activity are described by Kawamura (1984) in greater detail elsewhere in this volume.

Biochemical studies showed a high correlation between the intestinal feeding index and amylase activity in milkfish grown in fishponds (Chiu and Benitez 1981). The intestinal amylase activity consistently peaked daily at about noon, when the milkfish gut was full. In contrast, enzyme activity was significantly lower at 0030 h, when the gut was empty. These data confirm that milkfish is a daytime feeder and suggest an efficient digestive capacity in which the periodicity of secretion of digestive enzymes is in phase with the daytime feeding activity of the fish (Chiu and Benitez 1981).

Milkfish aquaculture in the Philippines depends on the utilization of either of two natural food bases, one consisting predominantly of unicellular algae, diatoms, and other organisms associated with the algal community and locally known as *lablab*, the other consisting mainly of fibrous filamentous green algae, mostly *Chaetomorpha brachygona* (Rabanal 1966, Vicencio 1978, Guerrero 1979). Most fish farmers concede that, on the basis of faster growth rate and therefore better productivity, *lablab* appears to be a better food base for milkfish. Consequently, a number of scientific research studies were made on the nature of *lablab* as food for milkfish. Both floating *lablab* and the benthic algal mat designated here as adhering *lablab* were studied.

Sampling of *lablab* posed technical difficulties until a standard sampling procedure was designed. With this procedure, it was shown that floating and adhering *lablab* differ markedly in quality and quantity. The quantity of *lablab* could be assessed with reasonable precision by analysis of ash-free dry weight. Analysis of protein content appeared to be the most appropriate indicator of *lablab* quality. Floating *lablab* had higher mean protein content (14.98%) than adhering *lablab* (5.99%). There was no detectable difference in lipid content among samples, but at about 1.0% lipid was considered a minor component (Jumalon 1978). More detailed chemical analyses, however, showed differences in sterol and fatty acid composition of floating and adhering *lablab* (Teshima et al 1981). Adhering *lablab* had a relatively higher concentration of 24-E-ethylidenecholesterol (13.3%), while floating *lablab* contained only 1.0%. Cholesterol, at about 40% of total sterols, was the predominant sterol in both floating and adhering *lablab*. The high cholesterol content was attributed to zooplankton since blue-green algae, the major algal constituent of *lablab,* generally contains cholesterol as a minor sterol. On the other hand, the 24-methyl, 24-ethyl-sterols and their Δ^{22} derivatives detected in *lablab* were suspected to be derived mainly from blue-green algae and phytoplankton.

The major fatty acids in both floating and adhering *lablab* were palmitic acid (16:0) and palmitolic acid (16:1); while *lablab* contained 3.6% 18:2 ω6 and 4 5% 18:3 ω3 long-chain polyunsaturated fatty acids, 20:5 ω3 and 22:6 ω3 were present at extremely low levels of about 0.5% and 0.6%, respectively (Teshima et al 1981). These quantities were essentially confirmed by subsequent studies which showed that *lablab* contains about 2.0% 18:2 ω6 and 4.0% 18:3 ω3 but no detectable amounts of 20:5 ω3 (Gorriceta 1982, Benetez and Gorriceta 1983).

Most fish show a greater requirement for ω3 fatty acids such as 18:3 ω3, 20:5 ω3, and 22:6 ω3 than for ω6 fatty acids such as 18:2 ω6 and 20:4 ω6 (Cowey and Sargent 1977, Watanabe 1982) except *Tilapia ziliii,* a tropical euryhaline herbivore that appears to require ω6 rather than ω3 fatty acids (Kanazawa et al 1980). Since *lablab,* the primary food of captive milkfish, contains very small amounts of 20:5 ω3 and 22:6 ω3, the question was posed whether milkfish, like other marine fish, has a strict requirement for 20:5 ω3 as an essential fatty acid or instead possesses the ability to convert the dietary fatty acid 18:3 ω3 to 20:5 ω3 and 22:6 ω3 (Teshima et al 1981). Subsequent studies detected significant quantities of long-chain polyunsaturated ω3 fatty acids such as 20:5 ω3 and 22:5 ω3 in the livers of milkfish grown in *lablab* ponds (Benitez and Gorriceta 1983). The presence of these long-chain fatty acids in the liver, despite their absence in *lablab,* suggests that milkfish have the capacity to convert dietary ω3 and ω6 fatty acids, through chain elongation and desaturation, into long-chain ω3 and ω6 polyunsaturated fatty acids and implies further that the major site of such metabolic transformation is the liver (Benitez and Gorriceta 1983).

Milkfish is cultured mainly in coastal ponds, where salinity can fluctuate from 10 ppt during the rainy season to 60 ppt during the dry months. As a euryhaline species, it is known to thrive successfully in natural waters of 0-100 ppt. The highly productive freshwater pen culture of milkfish in Laguna de Bay in the Philippines is widely recognized (Felix 1975, Dalagan 1980, Pullin 1981). On the other extreme, milkfish are known to thrive in landlocked hypersaline ponds on Christmas Island (Crear 1980). The highest salinity at which an individual milkfish was found was 158 ppt, a value which exceeds salinity tolerances previously reported for other vertebrate species. In the hypersaline ponds, milkfish fed extensively on benthic mats composed of halophilic bacteria, blue-green algae, diatoms, and fungi. *Artemia salina,* which was introduced in 1971, has subsequently colonized many hypersaline ponds on Christmas Island. Several inspections of the alimentary tract of milkfish from these ponds indicated that brine shrimp accounted for 25% (by volume) of their diet (Crear 1980).

An unusual feature of the milkfish population in some hypersaline ponds of Christmas Island is the stunted size of the adults, possibly the first report of salinity stunting in a natural vertebrate population (Crear 1980). High salinity appears to inhibit growth significantly but does not impede fat deposition and the maintenance of a generally sound physiologic balance within the organism. Aside from their reduced size, the milkfish in these hypersaline ponds exhibit no externally evident detrimental effects from osmotic stress. A review of the salinity data for the isolated hypersaline ponds and the gonadosomatic indices of their milkfish populations suggested that reproductive readiness is controlled by the interaction of salinity and diet (Crear 1980). A diet of benthic mat and brine shrimp produced a positive response in reproductive readiness even in the hypersaline environment, while a diet without brine shrimp stimulated reproductive readiness only at lower salinities when the osmoregulatory stresses on the fish were reduced. Undoubtedly, the study of the nature and composition of food ingested by milkfish in its natural habitat can provide important clues about its nutrient requirements.

DIGESTION

Carbohydrases

Crude extracts from various regions of the digestive tract of pond-grown milkfish were tested for their ability to catalyze the hydrolysis of various carbohydrates (Chiu and Benitez 1981). Nine distinct regions of the digestive tract that were tested were the epibranchial organ, esophagus, cardiac stomach, pyloric stomach, pyloric caeca, anterior intestine, posterior intestine, pancreas, and liver with gall bladder. The most active carbohydrases were those involved in the hydrolysis of α-glucosidic bonds. Maltose, trehalose, dextrin, starch, and glycogen were rapidly hydrolyzed by crude extracts from the intestines and pyloric caeca. Amylase was found to be a major digestive enzyme in milkfish and was detected in almost all regions of the digestive tract. High activity was observed in extracts from the intestines, pancreas, pyloric caeca, and liver. The intestinal amylase of milkfish had an activity optimum of about pH 6.2 and a temperature optimum of about 50°C. This temperature is above the usual range observed in fishponds. The digestion of starch can apparently proceed even at high temperature. This is advantageous since fish in general have very limited ability to thermoregulate. The amylase activity of a number of warmwater fishes has a temperature optimum of 50°C or above (Morishita et al 1964).

Although the milkfish studied by Chiu and Benitez (1981) fed mainly on naturally occurring algae and other plant materials in the ponds, no cellulase activity was detected in any region of the digestive tract. Complex polymeric substrates with β-glucosidic linkages such as microcrystalline cellulose and sodium carboxymethyl cellulose were not hydrolyzed. Similarly, no hydrolysis was detected with cellobiose as the substrate. Significant amounts of salicin and p-nitrophenyl-β-D-glucose were, however, hydrolyzed by crude extracts from the pyloric caeca and the intestines, confirming the presence of a specific β-glucosidase of limited substrate specificity. In general, milkfish can digest with ease most naturally occurring carbohydrates such as dextrin, starch, and glycogen. Evidently, substrates with β-glucosidic linkages are not as easily digested (Chiu and Benitez 1981).

Proteases

The protease activity of crude extracts from various organs of the digestive tract of two groups of milkfish was determined (Benitez and Tiro 1982). One group derived its food from ponds that had predominantly unicellular algae (*lablab*), while the other group was reared on ponds dominated by filamentous green algae, C. *brachygona.*

Milkfish have proteases of varying specificities and activities. Proteases were most active in the pyloric caeca, intestines, and pancreas. At pH 7.6, no protease activity was observed in extracts from the cardiac and pyloric stomachs for both groups of fish. At about pH 2.0, however, slight peptic activity could be observed in the stomach extracts.

The intestinal proteases showed activity peaks at pH 7.2 and 9.3 for fish reared on *lablab,* indicating a predominance of alkaline proteases. The fish reared on filamentous green algae showed an activity peak at pH 10. The optimum temperature for milkfish intestinal protease activity was between 50 and 60°C for fish reared on *lablab. A* broader peak of 45-60°C was observed for fish reared on filamentous green algae. The two most common alkaline proteases are trypsin and chymotrypsin. Using specific chromogenic substrates, it was possible to detect the presence of these two proteases in crude extracts of pancreas, pyloric caeca, and intestines of milkfish. Milkfish chymotrypsin was detected in fish reared on *lablab* as well as in those grown on filamentous green algae (Benitez and Tiro 1982). Chymotryptic activity from the digestive tract of milkfish was inhibited by L-l-tosylamide-2-phenylethylchloromethyl ketone (TPCK). TPCK specifically and completely inhibits mammalian chymotrypsin by alkylation of a histidine residue at the active site of the enzyme (Schoellman and Shaw 1963, Neurath 1964). The inhibition of milkfish chymotrypsin by TPCK indicates that its active site may be structurally similar to the mammalian enzyme and that a histidine residue is likely involved in the proteolytic process (Benitez and Tiro 1982).

High tryptic activity was observed in extracts from the pancreas, pyloric caeca, and intestines of milkfish reared on *lablab,* but no tryptic activity could be detected in any of the extracts from the digestive tract of milkfish reared on C. *brachygona.* It is quite evident, however, that milkfish can synthesize trypsin. In an in vitro test, extracts from C. *brachygona* completely inhibited milkfish trypsin when preincubated with an equal volume of crude extract from milkfish pyloric caeca and pancreas, strongly indicating that the absence of tryptic activity is caused by the presence of a powerful tryptic inhibitor in the algal diet. A number of trypsin inhibitors have been isolated and purified from tissues of various plants (Kanamori et al 1976, Schwartz et al 1977, Tashino and Maki 1979). Seeds of leguminous plants are particularly rich in trypsin inhibitors (Wagner and Riehm 1967, Willson and Laskowski 1973, Odani and Ikanaka 1977). The *Choetomorpha* inhibitor may, however, be the first report of a trypsin inhibitor in an aquatic alga (Benitez and Tiro 1982, Tiro and Benitez 1982). Most fish farmers have observed that milkfish grown on filamentous algae have slow growth, which may be accounted for by the presence of a trypsin inhibitor in these algae.

Lipases

Lipase is widely distributed in the digestive tract of milkfish. For fish reared on *lablab,* as well as for those reared on C. *brachygona,* the highest enzyme activity was observed in intestinal extracts and, in both cases, the anterior portion had a stronger activity than the posterior (Gorriceta 1982). It has been suggested that lipase activity in the intestines of fish is due to the presence of pancreatic lipase. However, more recent histochemical studies showed that the intestinal mucosa of several teleost fishes are truly capable of lipase secretion (Sastry 1974 a, b). Lipase activity was also observed in milkfish pancreatic extracts (Gorriceta 1982). As in most teleost fish, the pancreas of milkfish is diffused. The absence of a well-developed compact pancreas in teleost fish is partly compensated by the secretion of lipase by the intestinal mucosa, in addition to the secretory activity of the diffused pancreas (Sastry 1974b).

The lipase activity of extracts from the anterior intestines of milkfish shows two pH optima, one at about pH 6.8 and another at pH 8.0. This indicates the presence of both acidic and alkaline lipases and suggests a physiological versatility for digestion of lipids. Similarly, the pancreatic extract has two pH optima at pH 6.4 and 8.6 (Gorriceta 1982). The pH optima of intestinal lipase differ from those of pancreatic lipase, perhaps indicating that the pancreatic lipase is a different molecular entity from the intestinal lipase. Further characterization of milkfish lipases should be done to confirm this.

The optimum temperatures for milkfish intestinal and pancreatic lipase activity were found to be 45°C and 50°C, respectively. As was also true of milkfish amylase and proteases, milkfish lipases are quite active even at relatively high temperatures. From the temperature activity profile, it is clear that the digestive enzyme activity of milkfish is minimal at 0-25°C. This may in turn affect digestion and metabolism and may be manifested in terms of poor or reduced feeding activity of the fish at lower pond temperatures. These findings may account for the common observation of many fish farmers that growth rate and feeding activity during the cold months are lower than in warm months.

NUTRIENT REQUIREMENTS

There is very scant information on nutrient requirements and other important aspects of milkfish nutrition. A preliminary study on the protein requirement of fry under controlled laboratory conditions showed that a dietary level of 40% protein was required for maximum growth, efficient feed conversion, and high survival rate (Lim et al 1979). Forty fish with an average weight of 40 mg were stocked in a 60-liter aquarium filled with 30 liters of filtered seawater with a salinity of 32-34 ppt and a temperature of 25-28°C. They were fed diets containing 20, 30, 40, 50, and 60% protein and 2740 kcal of digestible energy per kg at a daily rate of 10% of biomass for a period of 30 days. The five semipurified diets contained casein as the protein source, dextrin as the carbohydrate source, equal parts of cod liver oil and corn oil as the lipid source, and a vitamin and mineral supplement. The fry were fed twice daily (half of the ration at 0900 h and half at 1700 h), 7 days per week, at the rate of 10% (dry matter) of their body weight per day. Fish that were fed the diet containing 40% protein had the highest weight gain (134.7 mg), which was significantly higher than those receiving the lower dietary levels of protein. Slightly lower weight gains were obtained when fish were fed diets containing 50 and 60% protein. Although feed conversion values were not statistically different among all treatments, the value for the 40% protein diet (1.96) was the best. There was no significant difference in the survival rates of fish receiving different diets; however, mean survival rates were low for all treatments, with the highest at 30% for the fish fed the 40% protein diet. The relatively high mortality in the study may have been due to environmental Stresses such as high salinity (32-34 ppt) and low water temperature (25-28°C), which might have caused the gradual death of the fry. However, the fact that 40% protein supported the highest survival rate suggests that this level of protein is adequate to maintain satisfactory resistance of milkfish fry against environmental stresses (Lim et al 1979).

Using a recirculating system, experiments were performed to determine the requirements of milkfish fry for protein, carbohydrates, fats, and vitamins (Camacho and Bien 1983). The test diets consisted of vitamin-free casein, gelatin, white dextrin, corn and cod liver oil, and vitamin and mineral mixtures. These diets were fed to milkfish fry (10-35 mg body weight) for 28-30 days at stocking densities ranging from 2000-4000/m^3 of water, the salinity of which was maintained at 16-18 ppt. The results showed that a purified diet with the following formulation was required by milkfish fry for normal growth: 40-45% vitamin-free casein, 12-15% gelatin, 8-10% fat, and 3-4% vitamin mixture. Unexplained but consistent mortalities occurred during the third week after stocking; syndromes associated with vitamin and amino acid deficiencies were also observed (Camacho and Bien 1983).

RESPONSE TO ARTIFICIAL DIETS

The response of milkfish fry to artificial diets has been investigated both in diluted seawater and fresh water. In a feeding trial, milkfish fry with a mean weight of 7.00 mg were stocked at 4 fry/liter in 300-liter fiberglass tanks with filtered diluted seawater (14-18 ppt) in a flow-through system (Jamandre 1980). The fry were fed three artificial diets containing a minimum protein level of 42%. Training milkfish fry to receive artificial feed was accomplished with no difficulty; they were found to respond to conditioning and were observed to feed at a designated place.

Growth and survival were satisfactory up to the third week of feeding. At the end of the 28th day, the highest survival rate was about 63%. In a second experiment, using an airlift system for aeration, the highest survival rate after 42 days was about 18%. In both trials, after the first 3 weeks the fry lost weight and developed crooked backs and enlarged reddish heads—characteristic signs of vitamin C deficiency. The diets appeared satisfactory for the first 3 weeks but were not fit for the older and larger postlarvae (Jamandre 1980).

In another study, milkfish fry with a mean weight of about 15 mg were reared in fresh water for 5 weeks using four artificial diets, *Moina,* or blended water hyacinth leaves as feed (Santiago et al 1983). The artificial diets had an estimated crude protein content of 40%. The fry were stocked at 4 fry/liter in glass aquaria filled with 30 liters of filtered fresh water provided with aeration. After 5 weeks of feeding, the fry fed with the four artificial diets had significantly higher mean weight gains (0.16-0.18 g) than those fed with *Moina* (0.09 g) or blended water hyacinth leaves (0.06 g). Survival rates on the artificial diets were high (83-95%), while only about 16% survived with *Moina* and 22% with water hyacinth (Santiago et al 1983). The formulated diet containing 40% crude protein with fish meal as the major protein source appeared adequate for the fry. Substitution of up to 5% crude protein from plant sources did not appreciably affect growth (Santiago et al 1983).

The response of the hepatocytes of milkfish fry and fingerlings to starvation and subsequent feeding was evaluated by electron microscopy (Storch and Juario 1983). Large variations in the ultrastructure of the hepatocytes were observed and were attributed to differences in nutritional condition. Starvation promoted ultrastructural changes hitherto unknown for other teleost species; nevertheless, the hepatocytes could rapidly attain their prestarvation condition when fed live *Anemia* nauplii and *Brachionus plicatilis.*

In a subsequent study, it was observed that the hepatocytes of milkfish fry can alter their ultrastructure in response to artificial diets (Storch et al 1983). The hepatocytes showed patterns of alteration in cell size, nucleus, endoplasmic reticulum, mitochondria, glycogen, and lipids. A lipid-oriented diet resulted in an increased deposition of small lipid droplets in the cytoplasm and even in some nuclei of the hepatocytes. A carbohydrate-oriented diet did not, however, result in deposition of glycogen. A protein-rich diet resulted in the best recovery of hepatocytes. The hepatocyte ultrastructure may serve to determine acceptability and quality of food or may be used as an indicator of the general nutritional situation of the fish (Storch et al 1983).

The positive response of milkfish to artificial diets has been responsible for high productivity following a revolutionary change in the way milkfish is farmed in Taiwan (Chen 1981). In the so-called "deep water method," the depth of the grow-out pond is increased from the conventional 10-30 cm to as much as 2-3 m depending on the nature of the soil. The stocking rate is increased from the conventional annual total of 1 200 to a total of 20 000-40 000. The pond water is mechanically aerated. The fish are fed commercial pellet feed containing about 23.5-29.0% crude protein in daily amounts equal to 3-4% of their total weight. The feed conversion ratio is claimed to be 1:2-1:6 without taking into consideration the natural food produced in the ponds. The productivity of the deep water farming technique is three times that of the traditional culture technique, which relies mainly on natural food bases (Chen 1981). Undoubtedly, the productivity of milkfish aquaculture can still be enhanced through improvements in the nutritional quality of diets.

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DISEASES OF MILKFISH

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Although the history of *Chanos chanos* (Forsskal) culture has been quite long, reports of major epizootics have been few. Trained manpower and disease diagnostic services in most milkfish growing areas have not been readily available. Hence, earlier reports of etiologic agents of these epizootics were limited mostly to direct microscopic examination of specimens. Significant disease cases reported were attributed to bacterial, mycotic, parasitic, and toxic causes. Bacterial infections, primarily due to *Vibrio* sp., have been frequently associated with mortality. To a lesser extent, fungal infections have also been reported. Intoxication of stock in freshwater systems by *Microcystis* toxins has caused massive fish kills in Laguna de Bay, Philippines. In most instances, affected fish were predisposed by environmental stress incurred in handling, storage, and transport. The fry and fingerling stages seemed severely affected compared with the older stages. Control of these infections must include assessment of fish husbandry practices first, before the use of chemotherapeutic agents like antibiotics is considered. Moreover, research thrusts should be geared toward the improvement of vaccination methods as well as defining the disease mechanisms of major milkfish pathogens and stress agents.

INTRODUCTION

The culture of milkfish, *Chanos chanos* (Forsskal), is now a major commercial concern in the Philippines, Taiwan, and Indonesia. As such there is growing interest in maladies that could reduce survival. Cases of epizootics occur among milkfish, but in most instances they remain undocumented due to lack of trained manpower and of available diagnostic services. In the Philippines, a few of these outbreaks attributed to parasites were summarized by Velasquez (1975, 1979). Subsequent reports included other pathogenic organisms (Delmendo 1978, Mercene 1978). Major diseases causing significant mortality among milkfish and other fish in the Philippines were described in a recent report (Lio-Po et al 1982). The present paper is an updated record of cases of milkfish diseases so far reported in the Philippines as well as in other countries. It categorizes milkfish diseases into bacterial, fungal, and miscellaneous etiologies.

BACTERIAL INFECTIONS

A number of significant mortalities among milkfish have been attributed to pathogenic bacteria. The earliest report indicating bacteria as a potential cause of milkfish mortality was that of Ronquillo, Villamater, and Angeles in 1957, which noted reduced mortality of fry and fingerlings with the addition of an antibacterial agent, Terramycin, and Vigofac in the milkfish diet for 2-3 weeks.

In the Philippines, fingerlings stocked in concrete tanks and maintained in crowded conditions in brackishwater ponds manifested signs of eroded fins and discolored patches on the skin. Long, slender bacterial rods were seen on smears made from the kidney, the liver, and external lesions. Associated infestations with *Trichodina* and *Scyphidia* were observed (IFP 1973). Experimental tests showed that the bacterial pathogen was part of the natural flora of either the fish or the rearing water and attacked fish predisposed to handling stress (Table 1).

In another case, mass mortality affecting more than 10 000 milkfish fingerlings occurred a week after stocking in fishpens; the cause was reportedly of bacterial etiology (Duncan 1974). Secondary bacterial infection was also diagnosed among dead milkfish with bruised bodies and injured snouts and eyes resulting from seining injuries and crowding (IFP 1975b).

In Taiwan, the bacterium *Vibrio anguillarum* was identified as causing "red spot disease," which resulted in significant milkfish mortality (Huang 1977). The red spots were hemorrhagic lesions on the body surface of affected fish. Experiments revealed the virulence of the bacteria at increasing concentrations as well as at a lower temperature of 15°C (Song et al 1980). Vaccination experiments using the HIVAX V. *anguillarum* bacterin manufactured by Tavolek, Inc. (Redmond, Washington, USA) indicated that in 30 days milkfish of 1-1.5 g developed some degree of immunity (Song et al 1980). Further experiments, however, showed that the mortality difference between immunized and control fish after challenge was not statistically significant (Lin et al 1982).

In 1980, deaths among hatchery-reared fry at the SEAFDEC Aquaculture Department were associated with the appearance of red spots on rearing tank surfaces which yielded *Vibrio* sp. isolates (Lio-Po et al, unpubl.). The red spots disappeared when fresh water was introduced directly into the tanks (Duray; pers. comm.). Among milkfish juveniles, post-transport deaths have been associated with a preponderance of bacterial elements in the liver and kidney. A daily bath using oxytetracycline for 5

Table 1. Results of a preliminary experiment on bacterial disease development among milkfish fingerlings 24 h after stocking in plastic bags.[a]

Bag no.	No. of fish	%dead	% with frayed fins	% with skin discoloration	Bacteria in kidney smears
1	30	27	80	27	yes
2	20	10	100	10	yes
3	10	0	100	—	yes

[a] Summarized from IFP 1973.

consecutive days arrested the infection (Lio-Po, unpubl.). For fingerlings subjected to transport stress, the use of Furanace at 1 ppm for 5 consecutive days also proved effective (Muroga, unpubl.). This concentration can be tolerated by milkfish fingerlings (Torres 1979). *Vibrio* sp. has also been isolated from pus-forming wounds of the hormone-implanted musculature of milkfish spawners reared in floating cages at Guimaras, Philippines (Lio-Po et al, unpubl.). Affected fish, however, did not exhibit mortality. In India, the bacterium *V. parahemolyticus* (Biotype 2) has been implicated in "scale disease," which causes scale protrusion with pus among cultured milkfish (Mahadevan et al 1978).

Another incidence of fish mortality was associated with gram positive, long, slender bacterial rods in liver and kidney smears (IFP 1973). In addition, the rearing water became yellowish-brown. This occurrence of the yellow water phenomenon had been earlier reported in Taiwan (Chao 1969). Its occurrence was reportedly harmful to milkfish growth, but it did not seem to develop when the blue-green alga *Enteromorpha* bloomed. Gram positive and gram negative rods and cocci were isolated from the yellow waters of milkfish ponds during June-November.

Incidences of fin rot among milkfish have been frequently reported in the Philippines. In one case, the bacterium *Chondrococcus columnaris* was identified as causing erosion of fins among milkfish juveniles in brackishwater ponds. Two percent of stocked fish were affected (IFP 1973-74). Erosion and inflammation of fins were also associated with the presence of a large number of unidentified bacteria and with mortality in freshwater ponds in the Philippines (IFP 1975a). Rabanal et al (1951) likewise mentioned an epidemic of fin rot. A similar condition affecting the caudal fins of milkfish fingerlings was also observed in Hawaii (Timbol 1974). In the Inland Fisheries Project report of 1973-74, two outbreaks of fin abnormality, affecting 30% of juveniles in one case, were reported. In the second case a history of "low silty water" was noted. It is not known whether these last four incidences of fin rot/ inflammation were of bacterial etiology, although earlier reports indicated the association of bacteria with this pathological condition.

In a recent report, bacteria closely related to *V. parahemolyticus* were isolated from the outer corneal layer of opaque-eyed milkfish juveniles. The findings were substantiated by in vivo experiments confirming bacterial pathogenicity by reproducing signs of the eye disease (Muroga et al 1983). The report further revealed the public health implications of the strain isolated.

MYCOTIC INFECTIONS

Very few incidences of fungal infection among milkfish have been reported, and records of identification have not been clearly discussed. Diagnosis has seemed to be based primarily on visual or microscopic examination of affected organs. The earliest report of fungus infection among milkfish fry gave 3% of the sampled fish as being affected (IFP 1973). A similar diagnosis was made on a batch of milkfish juveniles in which 8% of the total stock was killed (IFP 1973-74). The fungal pathogen grew on the eye covering and caused clouding of the area. Upon harvest, 7% of the stock had fungal infections identical to the one reported earlier. In Hawaii, milkfish with missing scales were observed to be susceptible to fungus infection. Treatments with potassium permanganate (1:100 000), pyridyl mercuric acetate (1:500 000), or malachite green (1:100 000) were reportedly effective (Timbol 1974). Delmendo (1978) reported that fungal infections among fry and fingerlings usually occur during the colder months of the year.

The occurrence of "milky eye disease" among milkfish (*sabalo*) affecting one or both eyes was reported in 1976 (IFP). Affected fish manifested a milky white opaqueness in the cornea that partially or completely covered the remainder of the eye. The diagnosis of fungal etiology was based primarily on the resemblance to frayed white cotton fibers at the margin of the opaque area. The disease occurred within 24 h after the fish were handled and released into pens. Recovery without treatment was observed in 3-6 days.

DISEASES OF MISCELLANEOUS ETIOLOGY

Other diseases of an organic nature have been reported. A case of stomach lesions defined as "gastritis" affecting 56% of wild milkfish weighing 2-8 kg was first reported in Hawaii (Smith 1978). Superficial erosion and punctuate ulcerations of the mucosa were observed to affect the female of the species predominantly. In 1980, Smith reported the finding of a thrombus occluding the lumen between the bulbus arteriosus and the ventricle of an adult milkfish, maintained in a circulating seawater pond, that unexpectedly began to thrash and died within a few minutes. Only one of the stocked fish was affected.

DISCUSSION

The history of milkfish mortality attributed to microbial disease dates back to early milkfish aquaculture practices. Mortality, though, was considered more as the result of culture practices than of disease as a primary cause. Hence, records of these abnormal phenomena took the form of minor observations in reports on culture techniques (Rabanal 1951).

Eventually, in the early 1970s, the association of mortality or clinical signs with bacterial or fungal infections was considered. Possibly for lack of adequate diagnostic facilities or trained manpower, reports were not very specific. For instance, bacterial or mycological causes were indicated, but specific identification or confirmation of pathogenicity was not established. It was probably only in the latter half of the 1970s that scientific attention was given to diseases of milkfish.

Tables 2, 3, and 4 summarize the records of milkfish diseases attributed to bacteria, fungi, and unknown etiologies so far reported. No virus pathogen has ever been linked to milkfish death, and no attempts to isolate viral organisms have been made because there are no existing facilities. It seems that mass mortality of microbial cause has been quite rare. Foremost in this category are the more than 100 000 dead fingerlings stocked in fish pens (Duncan 1974), red spot disease reported in Taiwan

Table 2. Summary of reports of bacterial diseases among *Chanos chanos* (Forsskal).

Cause	Stage affected	Signs of disease	Remarks	Reference
Bacterial rods	fingerling	eroded fins, skin discoloration	concrete tanks, crowded conditions, brackish water, bacteria in kidney and liver, gills with heavy infestation of *Trichodina* and light infection with *Scyphidia*	IFP 1973
Gram positive rods	juvenile	mild congestion of fins and belly	yellowish-brown pond water, brackish water, preliminary experiment conducted, bacterial isolation unsuccessful	IFP 1973
Chondrococcus columnaris	juvenile	erosion of fins	2% affected, brackish water	IFP 1973-1974
Bacteria	fingerling	fin erosion/ inflammation	freshwater ponds	IFP1975a
Bacteria	fingerling	bruised bodies, injured snouts and eyes, mortality	secondary infection, grown with tilapia	IFP 1975b
Bacteria	fingerling	mortality	more than 100 000 died within a week of stocking in fishpens, handling stress	Duncan 1974
Vibrio anguillarum	fingerling	hemorrhagic spots on body surface (red spot disease)	breaks out in winter, sensitive to chloramphenicol and tetracycline	Huang 1977
V. parahemolyticus		scale protrusion with pus (scale disease)	marine	Mahadevan et al 1978
Vibrio sp.	fry	red spots on tank surface, fry mortality	pathogenicity tests conducted	Lio-Po et al, unpubl.
Vibrio sp.	adult	pus-forming wound at hormone implanted sites	pathogenicity tests conducted	Lio-Po et al, unpubl.
Vibrio sp.	fingerling	heavy mortality, hemorrhagic spots on body surface	brackish water, transport-stressed	Lio-Po et al, unpubl.

Table 3. Summary of reports of fungal diseases among *Chanos chanos* (Forsskal).

Cause	Stage affected	Signs of disease	Remarks	Reference
Fungus	fry	apparent fungus infection	samples from fry dealers, 3% affected	IFP 1973
Fungus	juvenile	eye covering had dense, white, rhizoid growth, clouding the membrane	8% affected, brackish water	IFP 1973-74
Fungus	prefingerling, fingerling, juvenile	none reported	affected fish had missing scales	Timbol 1974
Fungus	spawner	milky, white opaqueness of the cornea (milky white disease)	affected 3 of 4 fish stocked in pens recovery in 3-6 days	IFP 1976
Fungus	fry, fingerling	none reported	occurs usually during the colder months of the year	Delmendo 1978

Table 4. Summary of reports of diseases of unknown etiology among *Chanos chanos* (Forsskal).

Stage affected	Signs of disease	Remarks	Reference
Fingerling	fin rot	brackishwater ponds	Rabanal et al 1951
Fingerling	eye abnormalities, constricted pupils	5% affected	IFP 1973
Juvenile	eroded fins	30% affected	IFP 1973-74
Juvenile	eye abnormalities	3% affected	IFP 1973-74
Juvenile	fin inflammation	history of silty water	IFP 1973-74
Juvenile	constricted pupils, no lenses, very small eyeballs without pupils or lenses	3% affected, bilaterally affected fish were slightly smaller than average	IFP 1973-74
Juvenile	whitening of one or both eyes	impaired feeding	Timbol 1974
Prefingerling, fingerling, juvenile	tail rot	seawater aquaria, flow-through system	Timbol 1974
Adult	thickened, hyperemic gastric rugae and focal hemorrhage (gastritis)	occurs predominantly among female adults weighing 2 000 g or more	Smith 1978
Adult	lethal clot formation occluding the lumen between the bulbus arteriosus and the ventricle	seawater pond, sudden death	Smith 1980

(Huang 1977), the *Vibrio* infected fry associated with red spots on the rearing tank surfaces (Lio-Po et al, unpubl.), and the deaths associated with the algal bloom of *Microcystis* (Delmendo 1978). Fungus infections have not figured in major catastrophies in the milkfish industry.

In most of these occurrences, environmental factors have been strong indicators of predisposing conditions. Deaths, whether affecting a few or a large number of milkfish, have almost always been associated with stress due to transport, handling, or crowding (IFP 1973, 1975b; Duncan 1974). In addition to these are toxic levels of un-ionized ammonia (Jumalon 1979, Cruz 1981, Cruz and Enriquez 1982), temperature stress (Tsai et al 1970, Huang 1977, Delmendo 1978, Lin 1982), starvation (Rabanal 1951), and gas supersaturation (Lio-Po et al 1983). In addition, it is not generally known whether the presence of pesticides in the rearing water has some stressful effect on milkfish; studies have established pesticide accumulation in milkfish tissues (Palma-Gil et al, unpubl.). A common observation of stressed milkfish is the development of a dark blue to blackish color on the back of the fish. Smith and Ramos (1976, 1980) recommended methods of detecting stress conditions among milkfish through tests for the presence of occult hemoglobin on the mucus of the skin with chemical analysis of certain skin mucus such as lactic acid, glutamic oxaloacetic transaminase, sodium, calcium, and chloride. Where intensive culture methods are used, the probable outbreak of disease must be considered. Moreover, it is claimed that freshwater milkfish are more sensitive to stress than those under brackishwater conditions (IFP 1975a).

Frequently reported observations of diseased milkfish are eye abnormalities including constricted pupils, absence of lenses, very small eyeballs without pupils or lenses, and whitening of one or both eyes (IFP 1973, 1973-74, 1976; Timbol 1974; Tamse et al 1983; Muroga et al 1983). Fungal, bacterial, and nutritional etiologies have been cited. Richards and Roberts (1978) mentioned the disease vibriosis in other fish species resulting in corneal opacity, which may develop into ulceration and evulsion of the orbital contents. It does seem that stress from physical injury or handling superimposed by bacteria in the water is the most plausible explanation. The most significant implication, though, is the apparent effect on fish weight which, from the aquaculturist's point of view, will affect production.

When posed with the problem of fish kills, the usual question of the appropriate chemotherapeutic agent is asked. Although this is probably the easiest solution, it may not be a panacea. Tolerance levels of the host fish, effectivity of the drug, condition of the fish, economics, and, most important, the eventual development of drug resistant strains must be evaluated in the light of the urgency and seriousness of the disease condition. Tolerance limits of milkfish to potassium permanganate (Cruz et al 1983), furanace (Torres 1979), formalin, and oxytetracyline (Cruz, unpubl.) have so far been worked out. Disease prevention through physical or biological methods should be given priority. In Taiwan, studies on vaccination against vibriosis due to *V. anguillarum* have been initiated (Song et al 1980, Lin et al 1981). Research on further improvement of the methods used as well as the involvement of indigenous *Vibrio* species will be very useful.

Aware of the hazards awaiting cultured milkfish in rearing systems, aquaculturists will be best benefited if outbreaks of disease are immediately made known to fish disease workers in the area. Then accurate diagnosis and scientific documentation can be done and possible recommendations can be made for existing or future stocks. Research on the mechanisms of disease development of major milkfish pathogens, including their physiological and ecological requirements, should likewise be pursued.

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PESTS/PARASITES AND DISEASES OF MILKFISH IN THE PHILIPPINES

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This paper presents all known parasites of milkfish in the Philippines. The major parasitic groups include acanthocephalans, copepods, isopods, and heterophyid flukes. The number of parasitic species found in ponds is small compared with those harbored by the fish in its natural environment. Parasites with a direct life cycle usually survive in ponds as flagellates, ciliates, myxosporidians, coccidia, and parasitic arthropods under improper management. The methods of treatment, prevention, and control of these parasites are discussed.

INTRODUCTION

In the Philippines, milkfish culture has been a traditional enterprise without a scientific basis for many years. Lately, the industry has expanded into fishpens in large bodies of water such as Laguna de Bay. Barring other calamities such as typhoons and floods, entrepreneurs have profited as long as no epizootics have occurred. Attempts to increase the productivity of fish farms, to improve stocks, and most of all to acclimate fish to new environments require detailed knowledge of the parasites inhabiting the different localities involved. For fish in a fishpond, migration from an unsuitable environment is not possible, and infestation may result in death and economic loss.

Every parasite living in or on a fish exerts some degree of harmful influence on its host. Parasites can influence the body of the fish in many different ways — either mechanically or physiologically. In some cases, the influence may be so slight as to cause no external signs, but extensive changes in individual organs or tissues or a general effect on the host may occur. Knowledge of the development and biology of the parasites of fish is necessary if successful prophylactic measures are to be devised. For example, many endoparasites enter the host through the alimentary canal by being swallowed with food. If not regulated, invertebrate food fauna in areas new to the fish may cause outbreaks of epizootics. On the other hand, ectoparasites develop externally and are more influenced by the conditions of the macroenvironment (i.e., environment of the fish host).

Upon arrival of the fry at the fishpond from the spawning ground, profound changes in their physiology are bound to have an effect on their resistance to parasitic diseases. Differences in water quality between seawater and pond water such as reduced salinity, plus methods involved in the management of ponds such as polyculture, may enhance mass infestation or infection, resulting in enormous losses. The density of the fish population is one of the most important factors in the outbreak of disease in ponds; crowding, along with lack of food supply, lessens fish resistance.

However, conditions in pond fisheries allow for preventive and control measures. Methods of treatment which are not possible in large bodies of water are feasible in confined areas. These methods include baths, drying of the pond, treatment of the bottom with lime, quarantine of single ponds or entire farms, extermination of wild fish and birds that may be not only predators but carriers of parasites, proper waste disposal, and cleaning of the surrounding area.

The parasitic fauna in fishponds differs greatly from that of natural environments and may include flagellates, ciliates, myxosporidians, coccidia, and parasitic arthropods, all with direct life cycles. This paper presents all known parasites of *Chanos chanos* (Forsskal) in the Philippines, organized by major groups.

MAJOR PARASITIC GROUPS

Acanthocephala

The Acanthocephala form a clearly defined group of worms. They are cylindrical and are provided with spines in the proboscis; hence they are called "spiny headed worms." Sexes are separate, the females being usually somewhat larger than the males. Intermediate hosts are arthropods (Yamaguti 1963).

The Acanthocephalan life history may be divided into four distinct phases (Yamaguti 1963): (1) within the egg, the hooked *acanthor* is formed; (2) upon ingestion by a suitable intermediate host, the parasite emerges within the gut, loses its larval hooks, and becomes an *acanthella;* (3) this progressively develops into a *juvenile* (infective stage); and (4) when the infected intermediate host is eaten by an appropriate final host, the juvenile is liberated, immediately attaches itself by its proboscis to the intestinal mucosa of the host, and becomes an *adult.* A final host may also become a potential intermediate host.

Numerous worms were found in the intestinal walls of *sabalo* (adult milkfish) from Nasugbu, Batangas and from the Bureau of Fisheries and Aquatic Resources (BFAR) station in Mindoro (Velasquez 1979). Ulceration of the intestinal wall was evident, with the proboscis of the worm securely attached to the wall. The *sabalo* had acquired the *Acanthocephalus* sp. infection in the open sea by eating infected arthropod intermediate hosts.

Milkfish from fishponds have been found negative to acanthocephalosis.

Copepoda

Fingerlings infected with *Lernaea cyprinicea* L. 1958 reared in Himalayan fishponds and those of the fishpens of Laguna de Bay were diagnosed (Velasquez 1979). The copepods protrude wormlike from the nostrils or from the skin of the infected fish, usually at the base of the fin. The visible portion is cylindrical and whitish, often with two eggs extending from its posterior end. When carefully dissected out of the fish, the modified head appears anchor-like, giving the organism the name "anchor worm." This parasite goes through developmental stages from fish to fish, resulting in considerable damage to the host, and mass infestation results in great economic loss.

A salt solution bath of about 3-5% concentration has been found effective in treatment of copepod infestation (Velasquez 1979). However, because the adults are difficult to kill, dessication of infected ponds and liming are recommended before restocking with healthy fish.

Caligus patulus Wilson 1937 frequently infects *sabalo* reared in experimental tanks whose water is supplied directly from the sea without adequate filters (Velasquez 1979). Concentration of the planktonic caligids results in the infestation and death of some of the *sabalo*.

All members of the family Caligidae are parasites (Kabata 1979). They cling to their host's surface with their flat bodies, somewhat like large adhesive discs, aided by prehensile appendages. They are capable of movement over the host surface. The first larval stages and the final adult stage are free-swimming. The adults occur free in plankton. The second pair of antennae are provided with claws and have two suckerlike organs located close to the anterior end of the cephalothorax. The nauplii are positively phototropic and swim up close to the surface of the water. The final stage of metamorphosis, however, becomes negatively phototropic and finds its host near the bottom of the water. The copepodid stage in caligids is extremely characteristic and is generally known as the chalimus stage. It is found attached to the host, usually to a fin or scale, by a long filament that is formed by the hardening of the secretion derived from a gland located in front of the eyes. The larva undergoes several molts while remaining attached this way, each molt bringing it to a stage nearer to the adult. When the adult male emerges from its final molt, it breaks off the thread and immediately searches for a female. The latter remains attached until fertilized, and only then breaks away to lead a planktonic existence. However, during confinement — as in the case of adult milkfish in rearing tanks — the planktonic caligids from the ocean find their way to the fish, wander over their hosts' bodies, and suck their food with the aid of a tubular mouth part. Caligid adults never stay very far from their hosts.

For treatment, the use of a 1-3% formalin bath is recommended since it is less harmful to other organisms in the tank. Laviña (pers. comm.) used neguvon (Dylox), an acaricide, with positive results. However, neguvon dissipates quickly in seawater.

Isopoda

Rocinella typicus and *Ichthoxyenous* are vicious killers. They kill not only the fry and fingerlings but also fish of marketable size. Under laboratory conditions, they attack, traumatize the fish, and eventually kill them. Mass killing of fish in fishponds has occurred (Velasquez 1979).

A direct life cycle and fast multiplication enhance the intensity and incidence of infection. It is recommended that (1) all infected fish be removed from the ponds, (2) survivors and non-infected fish be placed in clean ponds, and (3) all ponds with infected fish be dried and limed for several weeks before subsequent use.

Heterophydae

Various species of heterophyid flukes (Digenea: Trematoda: Heterophyidae) are etiologic agents of heterophyidiasis, a disease in man caused by these very small flatworms. The larvae (metacercariae) of *Haplorchis varium, H. yokogawai,* and *Procerovum calderoni* have been found encysted in the muscles of milkfish obtained from fishponds at the BFAR Dagatdagatan Experimental Station, Malabon, Rizal (Velasquez 1973a, b; 1975). They are of zoonotic significance.

Human infection or infection of piscivorous birds and mammals occurs following ingestion of the flesh of raw or inadequately cooked fish harboring metacercariae of heterophyid flukes. Excystment of young flukes takes place in the small intestine, and they develop into adults in 5-10 days or more. In humans, the infection may cause mild diarrhea. However, the continuous practice of eating insufficiently cooked infected bangus may result in cardiac and visceral complications. To date, the only heterophyid life cycle known in the Philippines is that of *P. calderoni* (Velasquez 1973a). The snail intermediate host is *Thiara requetti.* The eggs are eaten by the snail and develop into the early developmental stages in the hepato-pancreas. Emerged cercariae penetrate and encyst in a suitable fish such as milkfish.

Infection of fish can be avoided by proper waste disposal and by strict observance of preventive measures.

CONCLUSION

The composition of the parasitic fauna of *Chanos chanos* (Forsskal) is affected not only by the physiological and biological features of the host but also by management in the case of pond fisheries.

Prophylactic measures, treatment, prevention, and control should be in accordance with the ecological conditions existing in the locality. Chemotherapy of fish for human and farm animal consumption should be employed in accordance with Food and Drug Administration rules and regulations.

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MILKFISH AQUACULTURE IN SRI LANKA

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Milkfish fry and fingerlings are abundant in coastal and brackishwater areas in Sri Lanka, yet the industry remains in a stage of underdevelopment. The main seed collection centers are Mannar and Kalpitiya in the northwest and the season is from March to June. The annual fry production potential of the Mannar tidal flats is estimated to be about 4 million. The brackishwater aquaculture potential of Sri Lanka is estimated to be about 120 000 ha. In the past, returns from fry collected from tidal pools and stocked into perennial tanks have been very poor. The recently initiated seed resources survey and investigations into scientific collection, transport, and culture including pen culture should help develop farming of milkfish in Sri Lanka. Polyculture of the species with other fish and shrimp and its culture in salterns are being attempted.

INTRODUCTION

The milkfish, *Chanos chanos* (Forsskal), known in Sinhala as *wekkaya* and as *palmeen* in Tamil, is one of the principal species used in brackishwater aquaculture in the Indo-Pacific Region. Schuster (1960) reported that the coastal area encircling the southern part of the east and west coasts of India and the whole of Sri Lanka constitute a zone where milkfish fry are available. The abundance of fry and fingerlings of the species in tidal pools has been revealed through surveys conducted in Sri Lanka. Plans by the Ministry of Fisheries are underway for the proper utilization of this valuable seed resource for raising of food fish.

AREAS OF AVAILABILITY OF SEED AND JUVENILES

Location and Extent

Milkfish fry and fingerlings are abundant along the coastal and inland waters of Sri Lanka. They occur from March to June in shallow tidal pools such as in Mannar, South Bar, and Vankalai (Ling 1962); in brackishwater areas such as Puttalam, Negombo, and the Mannar district (Ramanathan 1969); and in tidal creeks such as in Erukulampiddy and Vankalai.

Villaluz et al (1982), who conducted a survey of known and possible fry and fingerling grounds in Mannar and Puttalam, confirmed earlier observations. Figure 1 shows the main fry and fingerling collection grounds. About 1500 ha of shallow tidal pools could definitely serve as collection grounds for milkfish fry if the estimates of Pillai (1965) and Ramanathan (1969) for Mannar are put together. The fry season at the Kalpitiya lagoons begins almost simultaneously with that in the coastal areas. The Gulf of Mannar serves as a breeding ground (Pillai 1965) and natural nursery for milkfish fry (Ramanathan 1969), and it needs to be properly preserved and developed. Table 1 indicates the numbers of fry collected in the years 1961-68 and 1979-83 by the Ministry of Fisheries. The major part of the collection was done at Vankalai and Erukulampiddy in Mannar, and the rest in Kalpitiya.

Season of Availability of Fry

Milkfish fry first make their appearance in mid-March in the Mannar tidal flats. The collection season is usually from March to June, with the peak in April-May. Milkfish fry also occur from March to June in estuaries and bays and off sandy beaches throughout the Indo-Pacific Region (Pitcher and Hart 1982). A second season of much lesser magnitude is October-November (Ramanathan 1969). Pillai observed that large-scale collection of fry in Mannar occurs in April, May, June, and November. In recent years, however, collections in November have been very poor. Milkfish fry can also be collected in April and May in the Kalpitiya area and in some areas around Negombo. The reduction in fry occurrence in the month of June may be due to the increased salinity of the shallow tidal pools of the Puttalam area, which may result in large-scale fry mortality. Fry collection in Sri Lanka and the Ramnad District in South India extends over the same period, from April to July (Schuster 1951).

Fry are most abundant in April-May, when salinity varies from 36 to 38 ppt. Availability is lowest in June, when salinity is high; tidal pools dry up and the salinity rises to lethal levels, thus destroying the biota. However, there appears to be a positive correlation between fry availability and lunar phases; the peak collections were recorded during full moon and new moon periods (Ramanathan 1969).

METHOD OF COLLECTING AND TRANSPORTING SEED

Gear Used and Method of Operation

The method of capturing fish fry presently employed in Sri Lanka is by the use of a piece of organdy cloth or nylon netting (1.6 mm mesh) about 80 cm wide and 1.3 m long attached to the ends of two wooden sticks. This fry seine, known as *kaddipuwa* in

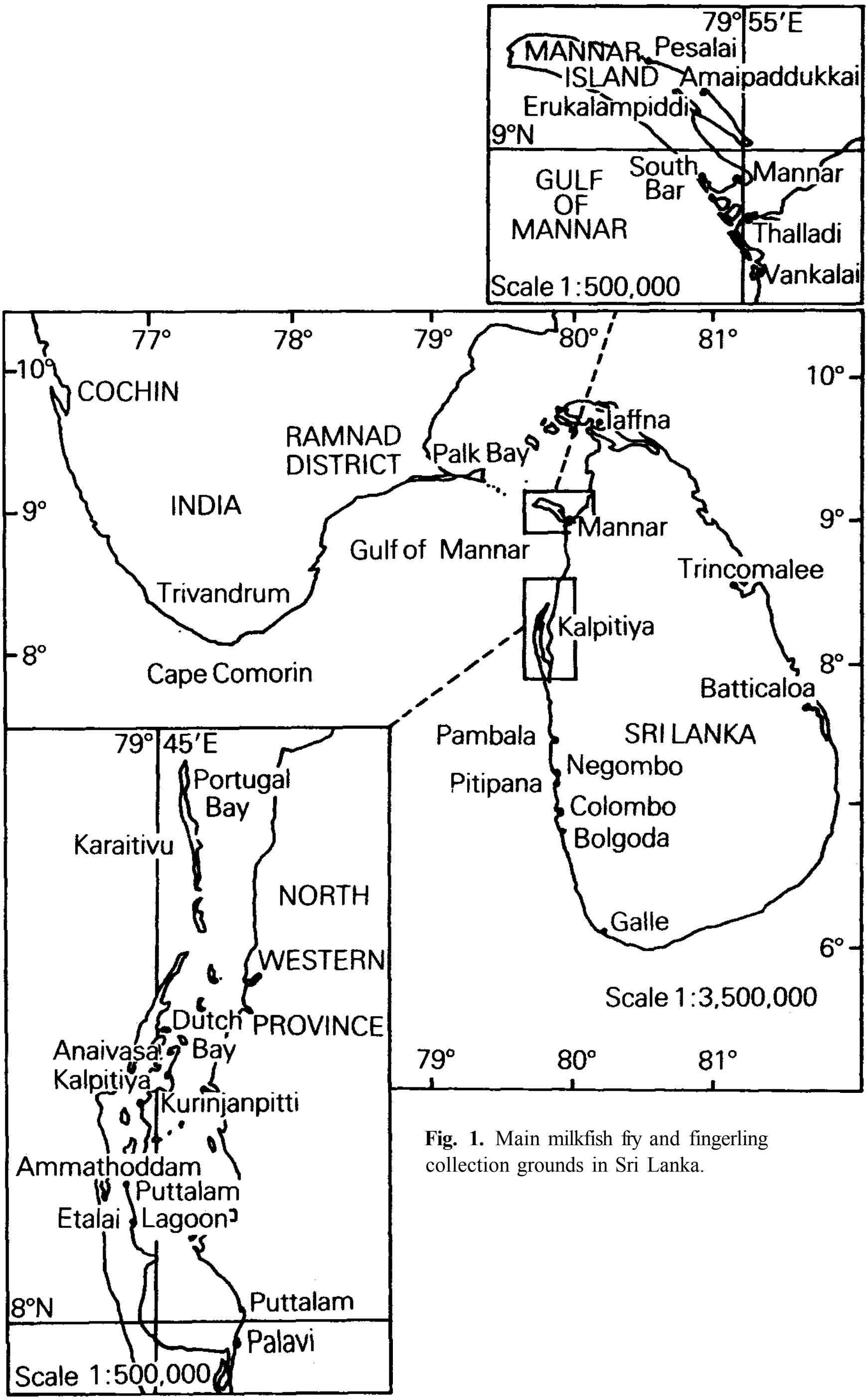

Fig. 1. Main milkfish fry and fingerling collection grounds in Sri Lanka.

Table 1. Milkfish fry collection during 1961-68 and 1979-83[a].

Year	Fry captured	Season
1961	9 000	April - May
	3 000	October - November
1962	18 000	April - May
	Nil	October - November
1963	68 000	April - June
	2 000	October - November
1964	56 000	April - June
	Nil	October - November
1965	31 000	April - June
	Nil	October - November
1966[b]	2 000	April - May
	Nil	October - November
1967[b]	45 000	April - June
	Nil	October - November
1968	46 000	April - May
	1000	October - November
1979	213 500	March - May
	Nil	November - December
1980	1 356 200	March - June
	Nil	November - December
1981	702 500	April - June
	Nil	November - December
1982	626 850	April - July
	Nil	November - December
1983	786 155	April - May

[a]Fry collection figures for the years 1969-78 are not available.
[b]Regular surveys were not carried out.

Sri Lanka and *sagap* in the Philippines, is operated by two persons dragging the cloth in the shallow tidal pools where the fry take shelter and grow. Ramanathan and Jayamaha (1972) mentioned that fry are encountered 5-15 cm below the water surface. Sheltered tidal pools 40-50 cm deep provide the maximum number of fry. The schooling behavior of young milkfish is observed during the collecting season when the translucent, needlelike young ones swim in the same direction. Fish larvae and juveniles form small schools in the early morning hours, then combine to form bigger schools later in the day. The fright stimulus is used to drive the fry to form a compact "ball," and the seine net is moved toward such fry concentrations that have been guided to shallow portions of the tidal pools, where the fry are scooped up. This is accomplished before midday to avoid re-scattering of the fry. Villaluz et al (1982) mentioned that about 500-3000 fry and fingerlings (sizes varying from 11.5 to 50 mm fork length) can be captured in 15-20 minutes of seine net operation by two persons, usually between 0800 and 1130 h.

Fry Potential

In a four-year survey, Pillai (1965) estimated the milkfish fry potential of a hectare in Mannar to be 500 fry/man per hour. He calculated that Mannar could produce about 400 million fry annually. Ramanathan (1969) estimated the milkfish fry potential of the Puttalam lagoon area to be about 200 million/year.

Transport of Fry

The collected fry are transferred at the site to plastic bags by scooping. The double polyethylene bags are filled with oxygen at the ratio of 1 part water to 2 parts oxygen. The bags are then arranged vertically in vehicles and transported to brackishwater fishery stations. The number of fry placed in each bag, filled with 4-6 liters of seawater, may vary from 200 to 2000. Fry mortality is almost negligible, as salinity is reduced from 20 to 0 ppt. Transfer to lower levels of salinity will.not cause mortality in young milkfish; fish seed can therefore be released and transported easily in either fresh or brackish water.

REARING OF FRY

Acclimation and Sorting of Fry

The dilution with fresh water of the saline water in the plastic bags carrying the fish seed is the only acclimation done during transport. It is only at the brackishwater station that the fry are gradually acclimated to temperature and salinity conditions, in cement cisterns, prior to their release in ponds to be raised to fingerlings.

The fry collected in the nets are usually needle-like and translucent. Also trapped in the collection are fry of *Megalops cyprinoides, Elops machnata, Oreochromis mossambicus,* and mullet. Ramanathan and Jayamaha (1972) mentioned the practice of removing the unwanted species from the collection before transport. This could be impractical when large collections are to be handled and transported quickly. The removal of unwanted associated fry is generally done during the process of acclimation in cisterns at the fishery station.

Fertilization

The acclimated fry, devoid of unwanted species, are now stocked in rearing ponds fertilized earlier with cow dung. The fry are fed a supplemental diet using poultry feeds. About 2 weeks after rearing at the fishery station, fingerlings are distributed for freshwater and brackishwater fish culture. Baliao (1982) mentioned the improved nursery rearing techniques using the *lablab* method that he conducted in concrete ponds with earthen bottoms at the Pitipana Brackishwater Experimental Station in Negombo. Before stocking, the pond bottom was dried and treated with a mixture of lime and urea to eradicate unwanted species. Nylon screen substrates, pretreated with *lablab*-mud mixtures, were installed like tennis nets across the pond bottom to increase the area for attachment of fish food. The ponds were fertilized with chicken manure and then gradually filled with water over 10 days until they reached 45 cm deep. Milkfish fry (average weight 0.067 g) were stocked at the rate of 500 000/ha.

Inorganic manure was applied every 2 weeks. At the end of 30-45 days, 98-100% survival of fingerlings of 2.25-2.45 g was attained. Mean salinity and pH values ranged from 12 to 30 ppt and 6.9 to 9.1, respectively. Baliao (1982) considered these findings comparable to those obtained in the Philippines.

SEED DISTRIBUTION AND CULTURE OF MILKFISH

Stocking Waters, Kind and Extent

The brackishwater aquaculture potential of Sri Lanka is estimated to be about 120 000 ha (Ministry of Fisheries 1980). Pillai (1965) indicated that of 100 000 acres of shallow lagoons, tidal flats, mangrove swamps, and saline marshes, about 27 000 acres are suitable for milkfish farming. The salterns can also be used fot milkfish culture and pilot studies.

Milkfish fingerlings may be stocked in either fresh or brackish water. Milkfish can be used as the principal species in brackishwater fish culture along with mullet and shrimp. In fresh water, milkfish can be cultured with carp.

Culture Trials

In 1965, an experimental yield of 781 kg/acre of milkfish and grey mullet was reported (Pillai 1965). Samarakoon (1970) recorded yields of 99.9 kg and 144.9 kg of milkfish in a 6-month culture period in two ponds of 0.12 ha stocked with about 17 000/ha and 30 000/ha, respectively.

In 1982, a pond area of 0.7 ha was stocked at the rate of 2400 milkfish fingerlings/ha with an average weight of 5 g. After 5 months of rearing, a production of 547 kg/ha was obtained with an average weight of 177 g. The survival rate was 99%.

Despite these attempts, no systematic effort at farming milkfish has ever been made in Sri Lanka. The fingerlings collected by the Ministry of Fisheries are stocked in existing freshwater bodies that have not necessarily undergone pond preparation, therefore resulting in poor production.

An important factor that hinders the culture of milkfish in seasonal tanks is the very low water level in July-August, the period when milkfish seeds reared in ponds are available for stocking. In addition, restricted periods of water availability and the presence of predators and competitors (mostly tilapia) greatly hamper the growth and survival of the stocked milkfish. Farming of the fish under desirable conditions would be an effective way of utilizing this commodity.

Pen Culture

A trial pen culture of milkfish sponsored by the International Development Research Centre (IDRC) of Canada revealed the possibility of farming milkfish using this method in Sri Lanka. A 0.25 ha fishpen (50 m × 50 m) was constructed in the Puttalam Lagoon in October 1982 using bamboo poles spaced about 6 mm apart. About 8000 milkfish with average length of 2 cm and weight of 0.79 g were stocked in November 1982. The average water depth in the pen was 1.5 m and the maximum 2 m at high tide. The fish were fed daily with a mixture of rice bran and fish meal in the proportion of 9:1. To date, three harvests in all yielding 83 kg of milkfish have been made. Some shrimp (*Penaeus indicus*), mullet, and a few other fish species were harvested with the milkfish.

Another pen culture trial is about to begin in Bolgoda Lake, near Colombo.

PROBLEMS IN MILKFISH FARMING

Technology Transfer

One of the principal reasons for the underdevelopment of milkfish farming in Sri Lanka is lack of technology. Brackishwater farming techniques have appeared to be less developed than freshwater fish culture. To fill up the technology gap it is necessary to get experts to train technical personnel at the Ministry in fry handling and transport, pond culture and management, and production of fish food organisms to enable them to extend new techniques to fanners effectively.

Nonavailability of Suitable Waters

Well laid out brackishwater farms or ponds are lacking. The freshwater ponds available are utilized mainly for the farming of carp, along with which milkfish could be cultured, but only in small numbers. The large perennial ponds have established fisheries, particularly for tilapia, and the chances of adequate survival and good growth of milkfish in these ponds appear small. The seasonal ponds that abound in Sri Lanka and have an estimated area of 100 000 ha (Thayaparan 1982) are located in the Dry Zone. These ponds have limited periods of water retention, which fluctuate from year to year. They also abound in fish brought by the incoming water. Until methods of keeping milkfish fingerlings in stunted condition are developed that might ensure their availability for stocking when the seasonal ponds are properly filled with water, effective use of these bodies of water for growing milkfish does not appear possible.

Untested Market Preference and Demand

Milkfish is liked by the fish-eating population in Sri Lanka as evidenced by its ready sale and good market price of about US $0.61-0.74/kg (Rs 24 = US $ 1). (The market price of the most commonly available freshwater fish, tilapia, varies from US $0.33 to 0.41/kg. Seer, *Scomberomorus* sp., the preferred marine food fish, fetches a price of US $1.85-2.05/kg in the market.) Ling (1962) mentioned that large milkfish are caught throughout the year all over the island, particularly in and near the large lagoons. He referred to not less than 999 kg of the fish being caught per year in the Negombo area. Milkfish has been observed in markets in the Jaffna area and also in Mannar Town, Vankalai, and Arippu. In the absence of catch statistics on the species, it is difficult to estimate the quantity captured and marketed each year, but the species constitutes only a small percentage of the known marketable supply of fish in Sri Lanka, as observed in fish markets. The market preference and demand for the species is essentially not known. It is difficult to say if this lack of knowledge of the market could be a factor retarding development of milkfish farming, considering that brackishwater farming itself is not well developed.

CULTURE POTENTIAL FOR MILKFISH

A very rough estimate of the production potential of milkfish based on fry availability and land resources for pond construction reveals the immense possibilities of milkfish farming. The fry available, allowing for reasonable mortalities, may be adequate for stocking over 10 000 ha of brackishwater ponds. The attractive selling price of milkfish should serve as an incentive for taking up its culture.

Programs for the development of milkfish farming in Sri Lanka are being assisted by international agencies such as IDRC, SEAFDEC, and the Asian Development Bank (ADB). This assistance is in the area of expertise as well as financing for the development of brackishwater milkfish monoculture and polyculture with shrimp. With financial support from IDRC, the SEAFDEC Aquaculture Department has provided experts who have surveyed seed resources and demonstrated fry rearing techniques. IDRC is also supporting a research project to determine the feasibility of pen culture of milkfish in selected areas. In 1984, ADB will begin its Aquaculture Development Project for Sri Lanka, which aims to provide assistance in the development of brackishwater resources in which polyculture of milkfish would be tried in experimental as well as commercial ponds and pens.

CONCLUSIONS

The available resources of Sri Lanka are not being utilized in milkfish monoculture. The future of milkfish farming in the country seems to be tied up with the growth of brackishwater fish farming, an area where, despite available resources, little investment and attention have been given. Gradually, however, the Ministry of Fisheries is taking up this program in earnest.

In recent years requests have been received from Iraq, Singapore, Taiwan, the Philippines, and the US for export of milkfish seed from Sri Lanka, but there are no private operators engaged in milkfish seed capture or transport. The Ministry has limited manpower engaged in seasonal seed collection and transport that is geared to support local aquaculture programs. With the expansion of brackishwater fish farming, particularly among private fish farmers, skilled manpower may emerge capable of handling seed collection and transport on a large scale.

With better seed collection, transport methods, and improved culture techniques, it is hoped that the milkfish aquaculture potential of Sri Lanka will be developed. This should contribute to the country's improved nutrition and economy.

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MILKFISH RESEARCH IN THE PHILIPPINES

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Development and directions in milkfish research in the Philippines from 1976 to the present are reviewed and analyzed. The problems of milkfish culture are dichotomous: low productivity vis-a-vis seasons of glut and price fluctuations. To intensify fish production, extensive research has been conducted on fertilizer management, reclamation of acid sulfate soils, and pond construction and engineering. Research efforts have also been heavily directed toward increasing fry production through artificial propagation, improvement of fry collecting gear, and increasing fry survival through nutrition, control of parasites, and proper handling. Research on improved icing, packaging, and processing techniques along with market analysis are necessary for maximizing economic returns.

INTRODUCTION

Milkfish, *Chanos chanos* (Forsskal), is the predominant fish cultured in the Philippines. In 1981, 170 431 t of milkfish were harvested from about 195 000 ha of brackishwater ponds, accounting for 90% of the total fishpond production in the country. Milkfish is popular even with Filipino communities abroad, to which most of the 5261 of exported frozen milkfish went in 1981. Philippine exports of canned milkfish have increased steadily in recent years, and there is a growing demand for milkfish juveniles for tuna bait.

Much remains to be done, though, to increase the present annual average milkfish fishpond production of 870 kg/ha. This low yield is related, among other reasons, to an insufficient use of inputs, large tracts of underdeveloped fishpond areas, and irregular supplies of fry. In marketing, seasons of glut, variable price levels, and abnormal market flows are common problems.

The government, the research community, and the private sector are exerting concerted efforts toward increasing milkfish production and stabilizing the industry. Yields of more than 2 t/ha per year from the more progressive fish farms of Bulacan and Iloilo indicate the potential for increased production.

MILKFISH AS A RESEARCH PRIORITY

Aquaculture research in the Philippines accelerated during the 1970s due in part to the establishment and strengthening of better-equipped aquaculture research and training centers. Later, a national research system was developed through the Philippine Council for Agriculture and Resources Research and Development (PCARRD). There has been increased government and international support for fisheries research along with active participation by the private sector in research and extension.

Milkfish culture and related studies are top priority research areas in aquaculture. The lead agencies in milkfish research are the Aquaculture Department of the Southeast Asian Fisheries Development Center (SEAFDEC-AQD) and the Brackishwater Aquaculture Center at the University of the Philippines in the Visayas. Adaptive trials are carried out by the Bureau of Fisheries and Aquatic Resources and by fishery schools throughout the country.

Within the PCARRD registry, about 80 research studies in milkfish were completed from 1973 to 1982, most of which dealt with pond management techniques. Extensive research was conducted to optimize fertilizer efficiency in the production of *lablab* and plankton as a food base. Field trials were conducted on the reclamation of acid sulfate soils, and a number of experiments on the polyculture of milkfish with tilapia, shrimp, mudcrab, and other nontraditional cultured species were carried out. Breakthroughs were achieved in broodstock development, induced spawning, and sex differentiation of milkfish breeders. Various aspects of the biology and physiology of fry and broodstock were also explored. For postharvest handling and processing, methods and fish formulations were standardized. Ample data were gathered on the economics of the milkfish industry. This paper reviews the research conducted over the past 8 years.

RESEARCH STATUS (1976-1983)

Culture Techniques

Pond engineering. The design and construction of brackishwater milkfish ponds have evolved through years of commercial practice by the private sector. Engineering principles and technologies have recently been applied to these practices. Current pond engineering technology has established the following: (1) criteria concerning site selection; (2) relationship between the size of gate, pond water level, and design tide curve; (3) design elevation for foundation; (4) relationship among the sizes of pond compartments according to their functions; (5) different types of layout schemes; (6) size and proportioning of dikes; (7) control of internal erosion and seepage; (8) methodology of pond construction and repair, including related facilities; and (9) construction tools and machinery (de la Cruz 1979).

Through the progression system of pond culture, it has become possible to raise at least six crops per year. In this system, three adjacent ponds with a 1:2:4 area ratio form a module. Stock is transferred from a smaller to a bigger pond after a 30-day culture period in each compartment. Once a pond is vacated, it is immediately prepared for another stock. The progression system is a continuous program of pond preparation, stocking, transfer, and harvest. Potential production is about 3 t/ha per year.

Fertilization and growing of natural food. Research on optimizing fertilizer use has taken into consideration the types and amounts of elements needed, the nutrient ratios, sources of nutrients, and the frequency, time, and methods of fertilizer application. A series of studies indicated that about 1 ppm of nitrogen and 1.5 ppm of phosphate should be maintained in the pond water for sustained growth of benthic algae. Among traditionally used fertilizers, mono- and diammonium phosphate proved to be superior. Split applications at an interval of 2 weeks in 3 months resulted in higher milkfish production than bulk doses of the same amount (Singh, unpubl.). Applications made on a semisubmerged platform or in solution improved the fertilizer use efficiency and reduced phosphorus losses (Ladja 1983).

The use of artificial substrates is promising in increasing production in brackishwater ponds. Nylon nets are set in the pond bottom to which *lablab* can attach and grow. At 60% of pond area added artificial substrates, it is estimated that a 15-20% increase in fish production is possible compared to the conventional *lablab* method.

Acid sulfate soil. A technology has been generated to reclaim acid sulfate soils common in new brackishwater ponds. This type of soil was found to respond poorly to phosphorus fertilization and to release nearly lethal concentrations of aluminum and iron, leading to low productivity. The reclamation technology involves a repeated sequence of intensive draining, drying, and flooding before the residual acid is neutralized by liming (Singh 1982, Singh and Poernomo 1984).

Nutrition and feed development. Nutrition studies have indicated that 40-50% protein is required in the diet by milkfish fry for maximum growth, efficient feed conversion, and high survival rate. High density rearing of fry to fingerlings in an indoor system seemed feasible using a purified diet with prophylactic treatment (Camacho 1975).

No clear-cut technology on milkfish feed formulation seems to be available. Present practices utilize single-ingredient materials like rice bran, bread crumbs, and corn bran. Addition of Terramycin and Vigofac in these feed materials favored the growth rate of milkfish. Other forms of feed ingredients used are copra meal, hog mash, dried rice straw, broken bones, fish meal, egg yolk in small quantities, *ipil-ipil* (*Leucaena leucocephala*) leaves, and *kangkong* (*Ipomoea reptans*) leaves. For natural food, dried grass, filamentous green algae, particularly phytoflagellates, and *gulaman* (*Gracilaria* sp.) are being used. Feeding techniques, however, need to be standardized.

Parasites and diseases. At present, the extent and kinds of diseases and parasitism in milkfish have not been established. Various parasites and diseases affecting milkfish in different parts of the country have been described (Velasquez 1979). Lio-Po et al (1982) reported the known diseases of economically important fish species in the Philippines including those of milkfish. Bacterial (*Vibrio* sp.) and fungal diseases and parasites (isopods and copepods) of milkfish were described. Prophylactic treatments are known but are only effective and adaptable in small confined areas.

Environmental factors that may cause widespread infestation of fish in the pond are not known. Knowledge of the life cycle of fish parasites is needed to devise successful prophylactic measures.

Polyculture. Polyculture of milkfish with prawn or mudcrab is traditionally practised, as these species enter milkfish ponds with the incoming tide. To systematize the practice, five different stocking combinations of milkfish and prawn (*Penaeus monodon*) were evaluated in brackishwater ponds. The polyculture of 2000 milkfish and 6000 prawns/ha was reported to be economically feasible, with average milkfish and prawn production per 100 days of 388.06 and 75.58 kg/ha, respectively (Pudadera 1980), although the monoculture of prawn (production of 144.30 kg/ha per 100 days) was more profitable. Trials have also been conducted on the polyculture of milkfish with *P. semisulcatus* and with all-male *Oreochromis mossambicus* (IFP 1976a). Milkfish-tilapia trials consistently gave high yields (IFP 1976b).

Freshwater production. Milkfish pen culture has been a profitable enterprise in Laguna de Bay since the technology was successfully demonstrated by the Laguna Lake Development Authority in the early 1970s, with an average production of 5 t/ha per year. The industry is beset by serious problems such as the occurrence of destructive typhoons and high fingerling mortality rates, seasonal off-flavor taste, and occasional fish kills. In studies conducted to improve fishpen design and construction, criteria for site selection and several fishpen models were recommended.

Acclimation methods were also developed to reduce fingerling mortality. It was shown that, with nursery pond-reared fingerlings at 12-15 ppt salinity, mortality can be reduced by 10% if dilution progresses over a 6-hour period (Baguilat 1980). Cages were tested for rearing fry to fingerlings to minimize handling, salinity, and transport stress. One trial showed that the effective cost of rearing fry to fingerlings in freshwater ponds is equal or almost equal to purchasing fingerlings from brackishwater nurseries (Mane 1979). More studies on freshwater nursery techniques are needed, however.

Fry Collection, Storage, and Transport

Fry grounds and seasonal occurrence. Milkfish fry appear throughout the year in one location or another, but have marked peak periods, and the fry supply fluctuates to some degree from year to year. Fry catch for a given level of effort varies from day to day within the month, with peak gathering periods occurring during the monthly high tides associated with the full and the new moon (Librero et al 1976, Smith 1981, Villaluz et al 1982).

Traditional and new fry grounds were reported along with corresponding catching gear being used in these areas and the degree of resource exploitation. Larval net tows showed that Antique Province has one of the most productive fry grounds in the country.

Collecting gear. The design, construction, and area of operation of fry collecting gear are dictated primarily by the topography of the fry ground, the wind direction, the local current system, and tidal fluctuations. Traditional gear and methods of collection are modified for convenience and as the result of availability and cost of materials (Villaluz et al 1982).

The common types of milkfish fry collecting gear used on Panay Island were classified by Kumagai et al (1980) according to mobility as passive filtering or active (dragged or pushed). Experiments were conducted to test the efficiency of modifications of traditional collecting gear using netting materials of various meshes and colors (Kawamura et al 1980, Quinitio and Kawamura 1980, Paler 1981). Efficiency was based on the number and survival of fry gathered compared to those caught by the original gear. Driving effect, ease in handling, and visibility of fry were also considered for every gear tested.

Storage and transport. Fry dealers have developed their own techniques for storing and feeding fry prior to sale or transfer to a nursery. Consequently, different stocking densities during storage are used, no standard feed is given, and the suitable water salinity for storing fry is not known. The fry are commonly stored in water with low salinity and fed with boiled egg yolk. Mortalities range from 3% to 10% in at most 2 weeks of storage.

It is commonly believed that mortality can be reduced when fry are stored in fresh water. A study of the effect of various salinity levels and stocking density manipulation methods on the survival of milkfish fry during storage revealed, however, that it is not necessary to reduce the salinity of the water used. It is more important to provide sufficient food and to maintain good water quality by changing about three-fourths of the water every morning to obtain better survival (Quinitio and Juario 1979). The recommended stocking density for storing milkfish is 150-400 fry/liter in plastic basins and 100-122 fry/liter in earthen jars.

Fry are transported in oxygenated plastic bags. Fingerlings are transported in the same manner but are considered more fragile than the fry, more susceptible to disease, and therefore in need of more careful handling. For the Laguna de Bay fishpens, most of the fingerlings are transported by *petuya,* an open boat with a pump aerator which allows for changes of water.

Artificial Propagation

An analysis of the milkfish fry industry in the Philippines by Smith (1981) indicated that fry resources are sufficient and can meet present demands if they are fully exploited. Nevertheless, a steady supply of artificially produced milkfish fry for culture to marketable size would help stabilize the milkfish culture industry by reducing dependence on the natural fry supply. Several studies were therefore conducted in the past decade to learn more about wild milkfish and to learn how to induce them to spawn in captivity and to rear the resultant larvae to fry. These have been followed by studies on captive broodstock reared in pens and cages at the SEAFDEC-AQD Igang Substation.

Biology. Sex differentiation of milkfish spawners based on discernible anatomical differences in the anal regions of mature fish has been observed (Chaudhuri et al 1976). Milkfish egg collections around Panay Island indicated spawning migration patterns (Senta et al 1976). The eggs occurred in waters of 10-900 m depth. A considerable number were obtained from 200 m-deep waters, although the majority of the eggs were found close to the coast.

The probable transport and movement of milkfish eggs and larvae from the spawning ground to the fry collection ground were discussed by Kumagai and Bagarinao (1979) based on drift card experiments. The results of the experiments suggested that the vertical and horizontal distribution of milkfish eggs and larvae at various developmental stages-, current, and the active movement of the postlarvae are to be considered in determining drift patterns or mechanisms of transport of milkfish eggs and larvae at sea.

Induced spawning. Induced spawning and larval rearing of milkfish were pioneered by SEAFDEC-AQD. Attempts to induce ovulation in *sabalo* (milkfish spawners) using different hormones succeeded as early as 1977. In the following years further studies led to the formulation of an effective spawning dose for the wild and captive stock. After a series of experiments, SEAFDEC-AQD published a guide to induced spawning and larval rearing techniques that recommended the use of a mixture of acetone-dried pituitary gland homogenate of coho salmon (SPH) and human chorionic gonadotropin (HCG) for the female and Durandron Forte "250" (DF), a long-acting androgen, for the male. Careful capture, handling, and transport were also recommended to ensure successful induced spawning (Juario and Duray 1982).

From the experiments on rearing newly-hatched milkfish larvae, the highest survival rate was achieved by giving various feeds from day 1 to day 21, changing one-third of the water whenever necessary, and maintaining the light green color of the water throughout the rearing period. Figure 1 shows the feeding schedule for milkfish larvae during the 21-day period.

Maturation in cages. Following the land-based studies, significant findings were achieved when milkfish matured sexually and spawned spontaneously in floating cages at Igang in August 1980 (SEAFDEC 1980). The fertilization rate of the eggs was 55-65%, the hatching rate 30-50%, and the larval survival rate 50%. Spontaneous spawnings recurred in 1981, 1982, and 1983 (Marte, pers. comm.). More studies are being conducted to determine optimum requirements for gonad maturation.

Economics

The average yield of milkfish ponds is 870 kg/ha per year. Recent studies concluded that this low production is a result of extensive farming techniques in the Philippines. Generally, inputs are not used in sufficient quantities to increase yield substantially. The average stocking rate of fry is too low, while the average stocking rate of fingerlings is too high. Levels of organic and inorganic fertilization need to be increased. Other significant factors that may explain current milkfish yields include age of pond, status of tenure, miscellaneous operating costs, farm size, and climate (Librero et al 1977, Chong et al 1981).

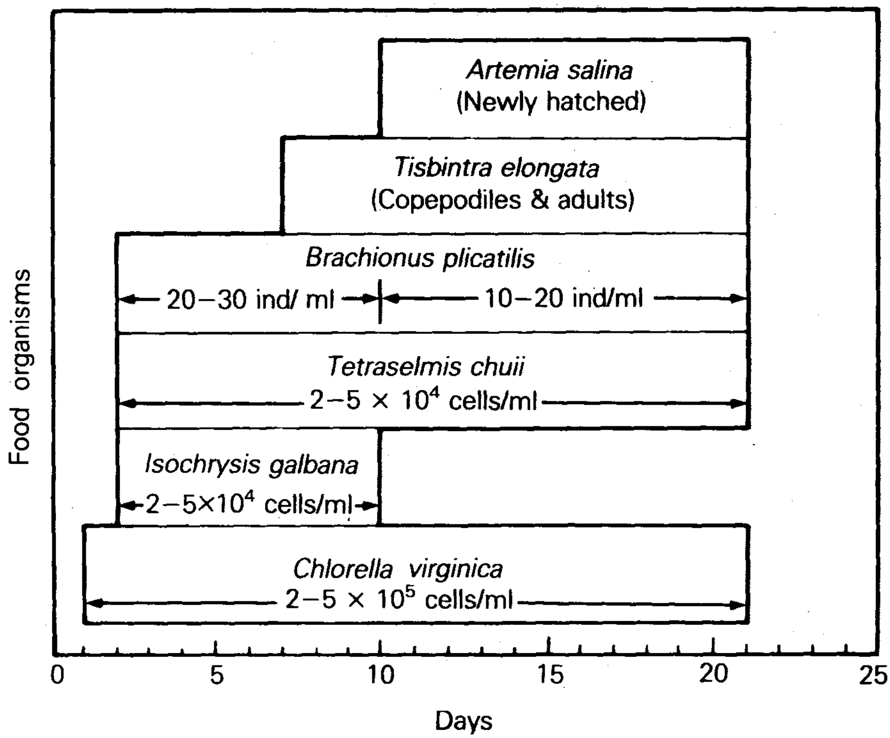

Fig. 1. Feeding schedule for milkfish larvae during the 21-day rearing period (from Juario and Duray 1982).

Larger farms are more efficient than medium and small farms (Chong et al 1981). Milkfish farmers should be encouraged to reorganize and restructure small units of production into large units to make production more efficient and profitable. With group farming, farmers should also be encouraged to apply more yield-increasing and yield-protecting inputs such as fertilizers and, whenever appropriate, to encourage the use of cheaper indigenous materials for fertilization and pesticide application.

Postharvest Handling and Processing

As with other aquatic products, the price of milkfish is dictated by its quality upon reaching the consumer. A portion of the harvested fish can be processed to make them last longer. Postharvest operations and product utilization technologies have been developed for dissemination and commercial application to milkfish (Orejana 1979). A National Science Development Board assisted project dealing with post-harvest fish handling preservation and processing has come up with a publication entitled "Milkfish (*Bangos*) as Food" (NSDB 1978), which includes handling, freezing, canning, other processing methods, and use of the by-products of milkfish processing.

Handling, chilling, and freezing. Dolendo et al (1978) determined the proper handling and icing of milkfish to preserve its quality during transport and storage. Pre-chilling to 4°C immediately after harvest with appropriate ice to fish ratios was found to maintain the quality of the fish. Suitable containers for every mode of transport, blast freezing, proper packaging, and storage methods were recommended after considering economy, length of the trip, and ease of handling.

Processing. Product formulation studies were conducted for canned milkfish prepared in various styles and recipes (Palomares et al 1978). Drying, smoking, fermentation, and pickling were also studied, and procedures for sun-dried milkfish, soft-boned and deboned smoked milkfish, and fermented and pickled milkfish were recommended (Guevara et al 1978).

By-product utilization. Hand in hand with the processing of milkfish, particularly in the canning operation, the utilization of waste has to be considered. Fish meal, fish silage, hydrolysate (*bagoong* and *patis*) and oils, and guanine extracts are some of the more important by-products prepared from milkfish waste. Publications on the canning of milkfish and the preparation of its by-products are now available. Further improvements in keeping the quality of frozen and processed fish, e.g., improved packaging, will be needed. Likewise, quality standards for processed fishery products should be established.

RESEARCH THRUST

The national research system coordinated by PCARRD guides the research activities pursued by various agencies. Research areas have been identified and organized into a framework of activities under general research thrusts. In the aquaculture commodity, the five general research thrusts involve priority research areas on milkfish culture as follows:

- Increased pond production through intensive culture by
  - — Improved aquaculture engineering systems
  - — Improved pond management
  - — Sociological and production economics studies
- Postharvest handling, processing, and marketing
- Production of seedlings
  - — Seed production of cultivable species
  - — Broodstock development
  - — Nutrition and feed development
- Development of integrated agro-fishery systems
- Development of pen/cage culture

CONCLUSIONS/RECOMMENDATIONS

The need for intensification and adoption of appropriate technology in milkfish production has to be pursued more vigorously. The more progressive pond operators have shown that the national average production of 870 kg/ha per year may possibly be raised to 2 t/ha per year.

It is necessary to emphasize the advantages of investing in necessary inputs to increase production. Levels of inputs — including fry, fingerlings, miscellaneous operating costs, and organic and inorganic fertilizers — that were found to be significant determinants of output per hectare can indicate the areas where further research can help improve cultural practices (Chong et al 1981).

Extension and technology dissemination should receive additional support, both from the government and from the private sector. Identification of and solutions to site-specific problems will require a linkage between researchers and extension specialists.

Active government support is equally needed in financing and marketing. With more incentive and liberal credit programs developed, loans for buying supplemental inputs can be made available to operators. Provision can be made for adequate infrastructure support and marketing channels.

Though prawn culture may give higher returns, milkfish will nevertheless still be the primary cultured fish in brackishwater fishponds. This fish has great potential in the processed food industry. The canned milkfish industry is picking up with increased local demand, serviced by both small private entrepreneurs and large canning factories.

It is hoped that the potential demand will encourage milkfish pond operators and other sectors involved in the industry to make Philippine milkfish farms more productive and profitable.

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THE MILKFISH INDUSTRY IN TAIWAN

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This paper attempts to explain empirically the entire milkfish industry in Taiwan, covering (1) the gathering and marketing of milkfish fry — the procurement subsystem; (2) the production of milkfish fingerlings for the baitfish industry; (3) the production of market-size milkfish — the transformation subsystem; and (4) the marketing of market-size milkfish — the delivery subsystem. A constant elasticity of substitution production function is used to estimate the input-output relationship for baitfish and market-size production systems, with all inputs classified into labor and capital. An important finding is that the elasticity of substitution between labor and capital exceeds unity, indicating rather easy substitution between the two inputs in the milkfish industry in Taiwan. The area for aquaculture has expanded rapidly during the past two decades, but the milkfish production area has remained at about 15 000 ha and yields have increased slowly compared with those of other cultured species. The revenue per hectare is also lower for milkfish production than for other freshwater fish. The improvement of fishpond management and the adoption of new rearing technologies are essential to avoid such inefficiencies in production and to increase the income of producers.

INTRODUCTION

The fisheries sector, including aquaculture, has played a significant role in the agricultural development of Taiwan. The relative importance of this sector can be seen in the fact that its share of total agricultural production increased from 11% in 1950 to 22% in 1982, while the share of crop production declined from 64% to 49%.

Intensive land use is a tradition in Taiwan. Farmers grow crops and raise animals year-round wherever possible and have changed from crops to fish culture to maximize the profit from their farmland and to sustain their relatively high standard of living. The area devoted to fish culture increased from 38 148 ha in 1965 to 64 663 ha in 1982. Milkfish is the most important species cultured in Taiwan; in 1982 15 218 ha — about 23% of the total area — were used for milkfish.

Basic biological research on milkfish in Taiwan has been intensive, but there have been few economic studies of production. Moreover, there has been no economic analysis of the fry input sector, nor of the marketing of milkfish. Thus, a systematic economic analysis of production and marketing of milkfish is needed to assist production programs and to sustain the incomes of producers and other support groups within the sector.

This paper examines the entire milkfish system in Taiwan, including fry gathering and marketing, baitfish production, market-size rearing, and marketing, the last consisting of three subsystems, namely, procurement, transformation, and delivery. The paper provides an overview of the milkfish industry to: (1) examine the gathering and marketing of milkfish fry, (2) measure the production efficiency of the baitfish industry, (3) explain the input-output relationship of production of market-size milkfish, and (4) describe the marketing of market-size milkfish.

GATHERING AND MARKETING OF FRY

Fry Gathering

The main sources of fry are located on the southern and eastern coasts of the island. However, there are significant regional variations in procurement. During 1980-82 the eastern coast accounted for about 53% of the total fry catch. The total procurement of fry varies yearly due to meteorological and oceanographic changes that affect milkfish spawning and, consequently, the distribution of eggs and fry. Fry procurement is also influenced by the technique of fry gathering and by the degree of water pollution in the coastal areas.

There is an important relationship between technique of fry gathering and fry procurement (Chen 1952, Lin 1968). Fry gathering can be increased by gear improvement. There are different methods used in Taiwan to catch fry, ranging from simple hand-operated scoop nets and sweepers that can easily be handled by one person to motorized rafts and boats.

Fluctuations in fry supply occur from year to year. From 1965 to 1982, the catch varied from a low of 33.96 million (1967) to a high of 234.87 million (1970). Since 1970, fry procurement has decreased year by year, nearing 101.42 million in 1982 (Taiwan Fisheries Yearbook 1982).

The trend in fry procurement can be presented by regression equations for the periods 1965-82 and 1970-82. On the average, the trends over the two periods were:

$$Q = 144\,872.08 - 3224.27\ t\ (1965\text{-}1982),\quad r^2 = 0.1260$$

$$Q = 180\,001.31 - 9327.37\ t\ (1970\text{-}1982),\quad r^2 = 0.5425$$

where Q stands for the quantity of fry caught and t shows the number of years. The equations indicate that the number of fry caught decreased annually at an average of 3224 and 9327 thousand pieces during these periods.

Taiwanese fry procurement is characterized by extreme seasonality, reflected in marked peaks and slack periods. The index of seasonal variation reached 578.03% and the standard deviation of seasonal variation was 120.90.

Marketing and Distribution of Fry

Fry marketing and distribution are the core of the procurement subsystem and involve methods of transportation, marketing channels, marketing margins, regional distribution, and price variation.

Methods of transport. As a general rule, the transport route for fry is short and usually involves only three transactions: (1) from gatherers to middlemen, (2) from middlemen to dealers, and (3) from dealers to milkfish and baitfish rearing ponds.

The main methods used to transport fry from the gatherers to the middlemen are bicycle (75%), walking (16%), and motorcycle (9%), and the distance of the fry middlemen from the seashore averages 4.8 km. The most common type of transaction is for the middlemen to go to the seashore where the fry are stored temporarily by the gatherers (75%), but 14% of the middlemen go to the gatherers' houses, and 11% of the gatherers deliver their fry to the middlemen.

Short distances are also involved between the middlemen and the dealers, and the fry are transported by taxi (55%), motorcycle (27%), truck (9%), and train (9%) with a 98% survival rate. Transportation costs depend on the distance and transportation facility used, but the average transportation cost per 10 000 pieces is US$5.22.

The last phase involves moving the fry from the dealers to the baitfish rearing ponds and market-size milkfish rearing ponds. Traditionally, the fishpond operators go to the dealers to buy the fry, and they handle transport themselves. Fry are most commonly transported by motorcycle or truck, depending on the distance and the quantity purchased.

Marketing channels and marketing margins. The marketing channels for fry can be divided into two phases: (1) before the middlemen phase — where 100% of the fry pass from gatherers to middlemen and (2) after the middlemen. After the middlemen, the method of distribution varies: 3% are transported from middlemen to market-size rearing ponds, 92% go to dealers, and 5% move directly to baitfish rearing ponds. Finally, the dealers distribute their fry to market-size milkfish rearing ponds (58%), overwinter fry nursery ponds (23%), and baitfish rearing ponds (19%).

Because the marketing channels for fry are short, the marketing margins are also small. The prices per fry received by fry gatherers and dealers were US$0.06 and US$0.07, respectively, in 1979.

Distribution of fry. Tainan City is considered the fry trading center of Taiwan; 66% of the fry come from the eastern coast and 31% from the southern coast. The primary demand for fry comes from the Tainan area: 44% of the fry go to Tainan Hsien, 24% to Tainan City, 14% to Chai-I Hsien, and 11% to Kaohsiung Hsien.

Price analysis of fry. As the quantity of fry increases, the price decreases. This relationship between the price of fry and the supply can be represented by regression equations for the periods 1965-82 and 1970-82:

$$\log P_f = 8.5211 - 0.7108 \log Q_f \qquad (1965\text{-}82)$$
$$(t \text{ value} = -3.7060) \qquad r^2 = 0.4780$$

$$\log P_f = 8.0853 - 0.6758 \log Q_f \quad (1970\text{-}82)$$
$$(t \text{ value} = -4.4002) \quad r^2 = 0.6377$$

where P_f stands for the price of fry (in real terms) and Q_f shows the quantity caught. These equations indicate that the supply of fry is the main factor affecting their price.

To determine the long-term trend of fry prices, the least squares method was used to calculate the regression equations. The trends of fry prices are as follows:

$$P = 0.5644 + 0.0853\ t \quad (1965\text{-}82)$$
$$r^2 = 0.4820 \quad \text{(at current prices)}$$
$$P = 1.8246 - 0.0272\ t \quad (1965\text{-}82)$$
$$r^2 = 0.0457 \quad \text{(at constant prices)}$$

and

$$P = 0.2785 + 0.1693\ t \quad (1970\text{-}82)$$
$$r^2 = 0.9244 \quad \text{(at current prices)}$$
$$P = 0.9381 + 0.0604\ t \quad (1970\text{-}82)$$
$$r^2 = 0.4569 \quad \text{(at constant prices)}$$

where P stands for the price of fry and t is the number of years. The equations show that the price of fry increased annually in terms of current price and decreased annually in terms of constant price during 1965-82, but during the period 1970-82, the fry price increased annually in terms of both current and constant prices. The seasonal variation in price is high because fry gathering is characterized by extreme seasonality. The total range of seasonal variation in the price reached 200% and the standard deviation of the seasonal index was 52.02.

The price stability of fry can be computed by using the Michaely Index. On the average, the indices of instability of fry price at current prices measured by the Michaely Index during 1965-82 and 1970-82 were 65.78% and 24-86%, respectively, which indicate extreme instability. At constant prices, the indices of instability were 62.46% and 20.43%, respectively, for the same periods, which also indicate extreme instability.

PRODUCTION OF FINGERLINGS FOR BAITFISH

Due to the development of the deep-sea tuna long-line industry in recent years, the production of milkfish fingerlings for baitfish has become an important business. Many factors such as the demand for such fingerlings, the production environment of milkfish, and the relative profitability of market-size milkfish and baitfish affect the rearing of milkfish fingerlings.

The rearing of fingerlings depends on a favorable rearing environment and on the supply of fry caught from early April to September. There are three periods for fingerling rearing: (1) in early April for harvest before the end of May, (2) in early June for harvest within 60 days, and (3) in early August for harvest at the end of October (about 90 days are required because the weather is cooler and the fry grow more slowly).

Resource Use of Baitfish Farms

Baitfish rearing is a capital-intensive and labor-saving industry. Based on a field survey in 1980 the land input per farm averages 1.8 ha, the capital input per hectare is US$3186, and the labor input per hectare is 86 days. The capital input per hectare increases and the labor input per hectare decreases as farm size increases. For farms less than 1 ha, the average direct cost is US$3110 and the labor input is 96 days; the figures for farms larger than 1 ha are US$3237 and 80 days. Direct costs include fry, feeds, labor, fuel, and materials, while the indirect costs include rent, water, electricity, interest, maintenance, taxes, and depreciation of gear.

The relationship between farm size and stocking rate per hectare for baitfish rearing is very significant. For farms under 1 ha, the stocking rate of fingerlings per hectare is 37 091; for farms over 1 ha, the rate reaches 41 621. The survival rates are 96% for farms under 1 ha and 92% for those larger than 1 ha.

Baitfish rearing in Taiwan has significantly affected both the benefit-cost ratio and rate of farm income as well as the factor productivity and elasticity of substitution. Milkfish fingerling rearing increases overall agricultural output and family farm income. Table 1 shows the benefit-cost ratio and the rate of farm income of different size baitfish farms in Taiwan. From the point of view of farm income, the benefit-cost ratio is highly related to the size of the baitfish farm. Farms under 1 ha have lower farm income than larger farms. The rate of farm income increases with an increase in the size of the fingerling-rearing farm. The rate of farm income was higher for farms over 1 ha than for farms under 1 ha.

The factor productivity of baitfish farms has advanced remarkably due to the increase of production per hectare and to the price of baitfish compared with market-size milkfish. Factor productivities are usually considered as important indicators of the level of economic efficiency of production of small farms. One important implication is that milkfish fingerlings have made a remarkable contribution to the growth of land, capital, and labor productivities. Hence, policy makers should place more emphasis on how this type of farming enterprise can be more effectively promoted within the milkfish sector if the market price and resource allocation are available.

A CES (constant elasticity of substitution) production function was used to measure elasticity of substitution in this study. The CES production function is:

$$Q = \gamma \left(KC^{-\rho} + (1 - K)N^{-\rho}\right)^{-\upsilon/\rho}$$

Where Q, C, and N represent output, capital input, and labor input, respectively, γ is a scale parameter denoting the efficiency of a production technology, K is the distribution parameter indicating the degree to which technology is capital intensive, υ represents the degree of homogeneity of the function or the degree of return to

Table 1. The benefit-cost ratio and rate of farm income per hectare for baitfish farms.

Farm size (ha)	Farm receipts (US$) (1)	Production costs (US$) (2)	Farm income (US$) (3)=(1)-(2)	Farm income/ production costs (4)=(3)/(2)	Rate of farm income (5)=(3)/(1)×100
< 1	4521.39	3287.25	1234.14	0.38	27.30
> 1	4836.03	3392.86	1443.17	0.43	29.84
Average	4782.03	3351.22	1430.78	0.42	29.92

scale, and ρ is the substitution parameter equal to $(1 - \sigma) / \sigma$, where σ is the elasticity of substitution. Then we can estimate σ where $\sigma = 1/(1 + \rho)$. The results of estimation of the CES production function and estimated parameters for a baitfish farm are shown in Table 2.

Based on the farm survey data in 1979, baitfish rearing showed a significant relationship with factor productivity, which varied with farm size. Data from southern Taiwan indicate that the productivity of different size baitfish farms is closely related to the productivity of land, capital, and labor (Table 3). Factor productivity per hectare increases considerably with the adoption of intensive agricultural operations such as capital intensive inputs and new rearing technologies.

Based on the estimated parameters of the CES production function of baitfish farms, it is clear that the effect of technology ( ) on the production of baitfish farms is significant. With relative increases in capital inputs and relative decreases in labor inputs, capital is a significant substitute for labor, and labor-saving technology has been utilized in the baitfish farms.

The elasticity of substitution between capital and labor in baitfish farms was high. On the average, the value of elasticity of substitution was greater than 1 because capital input is growing more rapidly than labor input in this type of farming.

Marketing Channels and Marketing Costs of Baitfish

The marketing channels are very short for milkfish used as baitfish. Baitfish producers buy fry from fry dealers, and the farmers raise and sell some of the fingerlings to market-size milkfish producers (about 35% of the total) because of the decline in demand for milkfish as bait for deep-sea fishing in recent years. The fry, after being stocked in the nursery ponds for 60-90 days, become fingerlings that are suitable as baitfish for tuna long-liners.

In 1979, the marketing cost for 100 pieces of milkfish-bait was US$5.50. Of this total, the profit of the middlemen accounted for about 51%, salaries 12%, transportation 15%, oxygen 5%, losses 8%, and other expenses 9%.

PRODUCTION OF MARKET-SIZE MILKFISH: TRANSFORMATION SUBSYSTEM

Overview of Milkfish Production

Milkfish production is centered in the southern coastal areas of Taiwan and is entirely in the private sector, largely individual milkfish farmers whose ponds range from under 1 ha to 20 ha. A small number of companies are involved in milkfish production, and their farms are larger than 50 ha.

The total production area showed a slight decrease from 15 616 ha in 1965 to 15 218 ha in 1982. Total milkfish production was stable between 27 000 and 32 000 t/year from 1965 to 1982, although the annual fry catch varied from 34 million to 235 million during the same years. Annual milkfish production per hectare increased from 1765 kg in 1965 to 2087 kg in 1979 and declined to 1940 kg in 1982.

Milkfish production is influenced not only by the relative profitability of baitfish rearing but also by the relative yield per hectare of other freshwater fish. The area

Table 2. Results of estimation of CES production function and estimated parameters for baitfish farm.

	Farm size (ha)		
	>1	<1	Average
	2.8358	3.5711	2.7845
B2	0.1095 (6.0180)*	0.6961 (0.1358)*	0.2635 (0.3044)
B_3	0.6998 (0.3710)	0.2912 (5.7405)*	0.6223 (0.6932)
B_4	9.2204 (7.5015)*	3.6017 (0.1172)	1.4067 (0.2431)
F_2	54.2665	396.5886	295.7764
R	0.9585	0.9876	0.9715
n	11	25	36
γ	17.0442	35.5555	16.1914
K	0.1353	0.7051	0.2975
υ	0.8092	0.9873	0.8858
ρ	0.1948	0.3509	0.1520
σ	1.2419	1.5405	1.1793
R^2	0.9585	0.9876	0.9715
S	0.1293	3.5863	7.6406

Note: Numbers within parentheses are t-values; an asterisk denotes significance at the 95% confidence level. Number of farm households equals n.

devoted to milkfish production compared with the total aquaculture area decreased from 41% in 1965 to 23% in 1982, while the production of other species increased from 59% to 77% in the same period.

Resource Use of Milkfish Farms

For small farms with large capital, the relative importance of land in milkfish production has gradually decreased. Working capital is the major factor substituting for land in the expansion of milkfish production.

In 1979, land input for milkfish farms ranged from an average of 1.82 ha for farms below 3 ha, to 5.75 ha for farms between 3 and 10 ha, to 25.64 ha for farms above 10 ha. The capital inputs of milkfish production consisted of 91% in direct costs and 9% in indirect costs. The average total capital input per hectare was US$2571. Labor inputs per hectare decreased relative to farm size from 117 days for farms of below 3 ha to 84 days for farms between 3 and 10 ha to 71 days for farms above 10 ha.

Table 3. Productivity and factor-factor ratio of baitfish farms.

	Farm size (ha)		
	<1	>1	Average
Per labor capital input C/N (US$/man-day)	31.11	41.92	38.83
Per capital labor input N/C (man-day/US$)	0.0000227	0.0000184	0.0000198
Per capital land input D/C (ha/US$)	0.0000002	0.0000002	0.0000002
Per land capital input C/D(US$/ha)	3264.75	3365.08	3345.55
Per labor land input D/N (ha/man-day)	0.010378	0.012460	0.011605
Per land labor input N/D (man-day/ha)	96.36	80.26	86.17
Land productivity Q/D (US$/ha)	4521.38	4844.47	4782
Labor productivity Q/N (US$/ha)	46.92	60.25	55.50
Capital productivity Q/C (US$/NT$)	0.0383332	0.04	0.0397221

Economic Analysis of Milkfish Production

The benefit-cost ratio and rate of farm income for market-size milkfish farms are closely related to farm size (Table 4), with large farms practising more efficient farming, resulting in higher farm income per hectare. The benefit-cost ratio and rate of farm income increased as farm size grew, mainly because of smaller labor inputs per hectare and increased efficiency of capital and labor in the larger milkfish farms. In larger farms, farmers can take advantage of technological change in combination with reduced labor inputs.

In comparing Tables 1 and 4, which show the benefit-cost ratios and rates of farm income in baitfish and market-size milkfish farms, it is clear that production of milkfish fingerlings for the baitfish industry is more profitable and efficient.

The productivity of a factor also depends on the quantities of other resources used. Table 5 shows that factor productivities are closely related to farm size.

By comparing with Table 3 it can be seen that the factor productivities are much higher in baitfish farms than in farms that produce market-size milkfish. If the purpose of using the milkfish resource is to maintain adequate resource returns and farm income in the face of growing competition from other freshwater fish rearings, a change from milkfish production to baitfish rearing if the market price and produc-

Table 4. Benefit-cost ratio and rate of farm income of milkfish farms.

Farm size (ha)	Farm receipts (US$) (1)	Production costs (US$) (2)	Farm income (US$) (3)=(1)-(2)	Rate farm income production costs (4)=(3)/(2)	Rate of farm income (5)=(3)/(1)×100
< 3	2684.03	2539.75	144.28	0.0568	5.38
3 - 1 0	2774.61	2569.08	205.53	0.0800	7.41
> 10	2866.53	2574-30	292.22	0.1135	10.19
Average	2834.81	2570.72	263.20	0.1024	9.28

Table 5. Productivity and factor-factor ratio of milkfish farms.

	Farm size (ha)			
	<3	3 - 1 0	>10	Average
Per labor capital input C/N (US$/man-day)	21.64	30.72	36.25	33.83
Per capital labor input N/C (man-day/US$)	0.0000335	0.0000249	0.0000213	0.0000227
Per capital land input D/C (ha/US$)	0.000003	0.0000003	0.0000003	0.0000003
Per land capital input C/D (US$/ha)	2539.75	2569.08	2574.30	2570.72
Per labor land input D/N (ha/man-day)	0.00852	0.01196	0.01409	0.01316
Per land labor input N/D (man-day/ha)	117.41	83.62	71.00	75.98
Land productivity Q/D (US$/ha)	2684.03	2774-61	2866.53	2834.81
Labor productivity Q/N (US$/ha)	22.86	33.20	40.39	37.31
Capital productivity Q/C (US$/NT$)	0.0293555	0.029999	0.0309749	0.0306305

tion environment are suitable is necessary for increasing productivity and efficiency of production.

Capital inputs play a very important role in milkfish production; thus, analysis of the capital inputs and elasticity of substitution between capital and labor in milkfish farming is useful for examining resource use and technological change in milkfish production. The elasticities of substitution are shown in Table 6, which is based on the CES production function. The high elasticity of substitution between capital and

Table 6. Results of estimation of CES production function and estimated parameters for milkfish farms.

	Farm size (ha)			
	<3	3-10	>10	Average
B_1	2.6376	3.1691	2.5641	2.9078
B_2	0.5288 (1.2202)	0.6793 (1.1070)	0.7742 (1.0507)	0.7660 (1.1968)
B_3	0.4051 (0.2829)	0.1659 (0.0261)	0.2116 (1.0079)	0.0170 (1.0044)
B_4	0.0234 (0.1752)	0.0019 (-1.0042)	- 0.0070 (- 0.9065)	0.0033 (-0.9120)
F	143.7766	56.6120	64.6766	171.6590
R^2	0.9664	0.8457	0.9023	0.8788
n	19	45	31	95
g	13.9797	23.7871	12.9883	18.3165
K	0.4337	0.8037	0.1358	0.6783
υ	0.9339	0.8452	0.8958	0.7830
ρ	0.2037	0.0286	0.1340	0.3998
	1.2556	0.9722	0.8818	0.7144
R^2	0.9664	0.8457	0.9023	0.8788
S	0.08030	0.0586	0.0643	0.0573

Note: Numbers within parentheses are t-values; number of farm households equals n.

labor in milkfish farming is primarily for farms under 3 ha, for which the value of elasticity of substitution (σ) is greater than one. The values of elasticity of substitution are less than 1 for the other two farm sizes.

MARKETING OF MARKET-SIZE MILKFISH: DELIVERY SUBSYSTEM

Marketing Channels and Marketing Margins

Three major marketing channels provide the link between producers and consumers:

- Producers — wholesalers — city fish markets — dealer-retailers — retailers — consumers
- Producers — cooperatives — city fish markets — dealer-retailers — retailers — consumers
- Producers — dealers — dealer-retailers — retailers — consumers

Milkfish farmers sell 71% of their products to wholesalers, 15% to cooperatives, and 14% to dealers.

The farm-retail marketing margins show the share of the consumer's money going to each intermediary. Producers received 74% of the retail price, with the remaining 26% being absorbed in the marketing process. The wholesalers and retailers received 79% and 89% of the city retail prices, respectively, in 1979.

Table 7 compares the wholesale farm prices and retail city prices, used to calculate the producer's share of the retail price during the period 1970-82. The producer's share generally decreased annually; on the contrary, the marketing group's share rose from 19% in 1970 to 31% in 1982, and the difference between the wholesale price of production and the retail price rose sixfold over the same time span.

Marketing Costs

Table 8 shows the marketing costs of milkfish in Taiwan. The total marketing cost per 100 kg was US$73.64, and the proportion of marketing cost to retail price was

Table 7. Farm price and retail price (US$/kg) of milkfish.

	Wholesale price of production (1)	Retail price in cities (2)	Difference in prices (3)=(2)-(1)	Producer's share (1)/(2) X 100
1970	0.63	0.78	0.15	2.25
1971	0.71	0.87	0.16	2.26
1972	0.84	0.94	0.10	2.53
1973	0.09	1.04	0.15	2.39
1974	1.35	1.45	0.10	2.58
1975	1.05	1.76	0.71	1.67
1976	1.21	1.91	0.70	1.75
1977	1.37	2.30	0.93	1.65
1978	1.55	2.61	1.07	1.64
1979	2.14	2.91	0.77	2.05
1980	2.245	3.16	0.91	1.97
1981	2.21	3.07	0.86	2.00
1982	1.97	2.84	0.88	1.92

Source: Taiwan Fisheries Yearbook.

Table 8. Marketing costs per 100 kg of milkfish by expenses.

	Marketing costs (US$)	Percentage of marketing costs
Market management	7.20	9.78
Taxes	5.33	7.24
Fisherman insurance	2.97	4.04
Freezing	3.03	4.10
Packaging	3.83	5.20
Transportation	5.72	7.78
Miscellaneous	9.94	13.50
Profit	35.61	48.36
Total	73.64	100.00

Source: Based on Lin and Chen (1980).

26%. Among the cost items, profits, market management and taxes combined, and freezing, packaging, and transportation combined were 48%, 17%, and 17% of total cost, respectively. Profits therefore accounted for the highest percentage of the costs incurred in marketing.

The marketing costs of milkfish in Taiwan can also be illustrated by the marketing costs of the different marketing agencies: the dealers, wholesalers, and cooperatives (Table 9). Dealers are considered as the lowest cost incurred in marketing. Because the dealers transport fish directly to dealer-retailers or retailers, there are no taxes, market management, and fisherman insurance fees during the marketing process.

Price Analysis of Milkfish

It is possible to explain the price variation of milkfish by long-run trend, seasonal variation, and price instability. The least squares method can be used to compute the regression equation for the period 1970-82. Trends in milkfish prices were:

At current prices

Wholesale farm price: $P_1 = 15.5050 + 5.0023\,t$ $\quad r^2 = 0.8820$

Retail city price: $P_2 = 43.3238 + 0.7196\,t$ $\quad r^2 = 0.4638$

At constant prices

Wholesale farm price: $P_1 = 14.7535 + 8.0605\,t$ $\quad r^2 = 0.9436$

Retail city price: $P_2 = 54.3923 + 1.6363\,t$ $\quad r^2 = 0.3257$

where P is the price of milkfish and t is the number of years. From these equations, the prices of milkfish, whether wholesale farm price or retail price, increased annually at

Table 9. Marketing costs per 100 kg of milkfish by different agencies.

	Dealer		Wholesaler		Cooperative	
	US$	%	US$	%	US$	%
Salary	2.11	12.65	2.22	8.82	1.86	9.27
Transportation	3.47	20.80	3.44	13.67	4.81	23.93
Freezing	2.08	12.48	2.08	8.27	2.89	14.38
Packaging	1.06	6.32	1.06	4.19	1.58	7.88
Profit	7.22	43.26	6.06	24.04	—	—
Taxes	—	—	1.94	7.72	.92	4.56
Market management	—	—	4.86	19.29	4.64	23.10
Fisherman insurance	—	—	2.53	10.03	2.42	12.03
Other expenses	.75	4.49	1.00	3.97	.97	4.85
Interest	.56	3.33	.53	2.10	.19	0.97
Equipment depreciation	—	—	—	—	.08	0.42
Water	—	—	—	—	.03	0.14
Electricity	—	—		—	.17	0.83
Fishery development funds	—	—	.31	1.21	.28	1.38
Mail and telegrams	.19	1.16	.17	0.66	.22	1.11
Total	16.69	100.00	25.19	100.00	20.08	100.00

both current and constant prices. The total ranges of the indices of seasonal variation of milkfish price were 89% and 115% of the wholesale farm price and retail city price, respectively. This shows that seasonal variation is higher in the retail city price than in the wholesale farm price.

To measure the price instability of milkfish, the Michaely Index was adopted to compute price data from the wholesale farm price and retail city price at both current and constant prices. At current prices, the wholesale farm and retail city prices showed substantial instability (17.95 and 13.70, respectively), while they showed substantial and slight instability (14.04 and 8.27, respectively) at constant prices.

Finally, comparisons between the price of other fish/shellfish and that of milkfish are required because milkfish is considered as a substitute for other fish. The trend in the freshwater fish/shellfish-milkfish price ratio from 1965 to 1982 decreased annually, except for oysters, the price of which increased annually faster than that of milkfish (Table 10).

The price ratio of milkfish to other freshwater fish increased annually during the 18 years under study because milkfish is considered a good fish in Taiwan. Nevertheless, the relative importance of milkfish in terms of production area relative to the total aquaculture area decreased from 41% in 1965 to 23% in 1982. This was because freshwater fish farms adopted new fishpond management and rearing technology, and the yield in these farms was higher than in milkfish production (Table 11).

CONCLUSION

In Taiwan, the demand for aquatic products increases proportionately with economic growth and per capita income increase. As a result, the aquaculture area has expanded rapidly. However, the milkfish production area has remained at about 15 000 ha and yields have increased slowly compared with other freshwater fish species. The revenue per hectare is also lower for milkfish production than for other freshwater fish. Under such conditions, growth in milkfish production has slowed. Improvement of fishpond management and the use of new rearing technologies are essential to avoid such inefficiencies in production and to increase the income of producers.

The main problems of the procurement subsystem are the supply and price of fry. To increase and maintain fry sources and stabilize prices, the control of water pollution in coastal areas, the improvement of fry gathering techniques, and the development of artificial spawning of milkfish fry must be emphasized. A good resource system should provide flexibility for the adjustment of farm management in response to changes in economic and technological conditions. For economies of scale and production efficiency, farmers should be encouraged to participate in group farming and contract farming to broaden their base of operations and to increase yields by adopting new rearing technologies such as deep water systems. This will allow them to meet the needs of dynamic economic and technological situations.

In 1979, the milkfish shipped to city markets through cooperative marketing by the Fisherman's Association accounted for only 15% of total milkfish production. Farmers should be encouraged to participate in cooperative marketing so that marketing costs can be decreased and producers' income can be increased.

Table 10. Average price ratios between other fish/shellfish culture and milkfish.

Year	Milkfish	Tilapia / Milkfish	Common carp / Milkfish	Grass carp / Milkfish	Silver carp / Milkfish	Eel / Milkfish	Oyster / Milkfish
1965	16.77	45.29	69.96	109.84	82.46	398.79	33.60
1966	17.29	45.51	20.63	108.67	82.13	379.95	35.99
1967	18.07	39.44	75.30	102.74	72.06	305.83	35.30
1968	20.12	38.40	71.16	95.15	65.62	382.90	43.49
1969	20.87	40.96	69.63	89.39	63.04	358.28	49.50
1970	21.29	38.94	70.42	91.27	58.72	372.19	91.94
1971	20.66	45.59	79.08	95.19	67.29	588.05	95.96
1972	23.13	40.25	65.23	88.78	54.39	745.41	95.75
1973	28.09	42.07	60.65	82.65	49.43	562.95	130.41
1974	36.93	40.58	51.35	71.99	45.45	471.52	113.36
1975	38.02	34.05	53.52	79.37	53.20	611.78	149.22
1976	42.24	37.41	57.32	77.06	40.00	423.46	138.43
1977	65.86	32.49	40.88	51.07	35.57	317.07	83.89
1978	59.40	37.76	49.90	57.54	42.12	499.03	127.68
1979	64.52	41.75	48.22	55.45	37.24	363.53	134.23
1980	90.34	33.59	43.33	45.63	32.82	219.60	109.68
1981	94.57	28.63	42.28	53.30	35.23	200.65	73.75
1982	67.80	43.50	62.46	81.05	52.96	359.82	162.47

Source: Calculated from Fisheries Yearbook, Taiwan Area.

Table 11. Yield ratios between other fish/shellfish culture and milkfish.

Year	Milkfish (kg)	Tilapia / Milkfish	Common carp / Milkfish	Grass carp / Milkfish	Silver carp / Milkfish	Eel / Milkfish	Oyster / Milkfish
1965	1 765	180.06	77.76	75.64	18.97	173.87	60.18
1966	1 863	169.19	58.87	72.46	19.88	204.21	64.74
1967	1 468	233.04	77.91	100.71	24.79	278.06	86.66
1968	1 216	303.59	95.75	137.32	35.40	458.96	110.90
1969	1 166	314.23	103.61	314.35	33.37	834.74	107.75
1970	1 703	305.96	49.82	52.77	34.86	420.50	79.20
1971	1 918	233.39	40.22	47.19	35.21	304.95	68.29
1972	1 590	195.47	71.69	66.43	40.56	385.52	89.04
1973	2 020	140.40	61.33	99.51	41.08	554.69	74.10
1974	1 847	164.09	80.06	109.47	44.95	570.20	81.04
1975	1 982	170.13	87.82	97.59	41.99	486.79	71.40
1976	1 621	237.08	93.89	138.98	63.72	702.31	86.40
1977	1 632	224.29	96.76	136.49	67.50	784.63	93.38
1978	1 935	172.79	81.04	146.40	80.16	512.10	87.38
1979	2 087	320.56	141.27	249.87	151.09	963.79	146.04
1980	1 249	299.92	175.31	203.39	145.42	1 114.54	133.55
1981	1 603	328.99	169.67	207.75	143.45	806.68	97.05
1982	1 940	251.15	137.87	154.15	103.50	709.67	87.62

Source: Calculated from Fisheries Yearbook, Taiwan Area.

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ECONOMIC AND TECHNOLOGICAL ASPECTS OF THE INDONESIAN MILKFISH INDUSTRY

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In this paper, the authors provide a broad overview of the economic and technological aspects of Indonesian milkfish aquaculture based on existing information. In doing so, the authors have brought together in a single report information on the economic importance of milkfish, fry capture and distribution, milkfish grow-out system, economics of production, and milkfish marketing and distribution.

In Indonesia, milkfish is regarded as a high value food item. Because of various constraints to high milkfish yield, Indonesian milkfish ponds are still grossly underutilized. As a consequence, these constraints and the resulting present low per hectare yield level would not be able to support the government's drive toward self-sufficiency in fish in the near future. This is in spite of government assistance which has been mainly production-oriented. By this is meant that in seeking solutions to low per hectare output of milkfish, the emphasis has been or is on technological solutions.

Of equal importance is the necessity to understand the socioeconomics of milkfish production such as the attitudes of producers toward present low yield and the reasons why they are not using more inputs. Government assistance should not be narrowly focused on production alone but should also encompass organized marketing and distribution involving as much as possible the private sector in moving the fish, and continuous follow-up to monitor progress of government projects.

Economic analyses can help to single out research areas which require further attention. For example, out of all the possible factors affecting milkfish yield, which ones are more important? Because government funds are not unlimited, it is important that only the more significant or immediate problems be looked at first.

INTRODUCTION

Like the Philippines and Taiwan, Indonesia has a long history of milkfish aquaculture. In 1980, the Indonesian milkfish industry was worth US$31.7 million (US$1.00 = Rp. 980)[1] and total output was 52 922t. Indonesian milkfish farming covers an area of 182 000 ha, which is roughly 65% of the total area under aquaculture. There are reportedly another 6 million ha of tidal land suitable for brackishwater fish production, some of which is at present under cultivation using salt-tolerant crops or agricultural practices to overcome saline soil conditions.

In a country where the population is growing rapidly, it is but natural for the Government to be preoccupied with food production and employment. The Government's push for increased milkfish production stems from the widely-observed shortage of protein in the diet of the population. The per capita consumption of protein (16 kg), especially that of animal origin, is still far below the nationally determined minimum requirement, and the Government views milkfish production as a very appropriate means to increase animal protein consumption. The Government's goals for milkfish aquaculture are both extensification (expansion of area) and intensification (use of greater quantities and variety of inputs) to increase the supply, generate employment, and improve the incomes and living standards of rural Indonesians.

As in the Philippines, Indonesian milkfish farmers' lack of accessibility to modern technology and pond management methods has been cited as one of the major constraints to achieving high yields. While experiments in Java, Sumatra, and Sulawesi have demonstrated that more than 2 t of milkfish can be harvested annually from a 1-ha pond (DGF 1978), the national average yield is about 450 kg/ha per year, showing at least a fourfold yield gap between actual and potential production levels.

The Indonesian Government, however, has a more modest and realistic target: to increase average yields to 800-1000 kg/ha per year (Jamashita, n.d.; Duncan 1982; Padlan 1979; Anon 1979). Among the numerous recent projects to raise milkfish production and productivity, the Indonesia Brackishwater Aquaculture Production Project (IBAPP) with US$ 900 000 in USAID support and an equivalent amount of Government counterpart funding deserves special mention. The main objective of the IBAPP is to increase brackishwater pond (*tambak*) production and to create

[1] Throughout this paper the current foreign exchange rate of US$1.00 = Rp. 980 has been adopted. The Indonesian rupiah underwent two other changes prior to the latest devaluation (US$1.00 = Rp. 415, US$1.00 = Rp. 625). Historical price and value data used to convert to US dollars thus reflect the latest exchange rate.

an organizational base upon which *tambak* area expansion can take place (Duncan 1982). The purpose of the International Development Association credit line for intensification and diversification of brackishwater pond production is to assist milkfish farmers to adopt modern technology and management methods for greater productivity. The 8-year (1971-1978) UNDP/FAO Project on Brackishwater Shrimp and Milkfish Culture Applied Research and Training also had increased milkfish production as one of its objectives.

ECONOMIC IMPORTANCE OF MILKFISH

Milkfish culture has historically been the largest aquaculture industry in Indonesia. Table 1 summarizes the production and the value of production of milkfish from 1967 to 1981. Brackishwater pond production provides employment to at least 60 000 farmers and to approximately the same number of pond caretakers/laborers, excluding secondary, tertiary, and other ancillary employment such as fry collecting, net-making, ice-making, fish marketing, and milkfish processing (e.g., smoked milkfish). Off-farm employment resulting from milkfish farming is significant.

In Indonesia, milkfish, locally called *bandeng,* is a high value food item. Unlike in Taiwan and the Philippines, where the milkfish price has recently declined, the price in Indonesia has increased. The decrease in price in Taiwan and the Philippines has been due in part to the increasing availability of tilapia *Oreochromis* sp., especially in the Philippines, where tilapia competes with milkfish. Moreover, there is lower consumer preference for tilapia in most parts of Indonesia. It will be some time before tilapia can begin to supplant the role of milkfish in Indonesia. Sullivan (1981) estimated that with the present level of technology and limited expansion into new *tambaks,* a shortfall of 2525 t of milkfish is projected for 1985 given current production and consumption patterns. But matching production regions with consumption centers is important.

A socioeconomic profile of milkfish farming in Indonesia showed that the majority of the farms were family-owned and operated. Many farms were small, making hired labor less necessary, out of 1.7 workers per farm, 1.4 were supplied by family labor (Sugito 1978). The average farm size was about 2.5 ha.

In Java, the range in farm size was from less than 1 ha to more than 15 ha. The size of farm operations was defined as small (<2 ha), medium (2-5 ha), or large (>5 ha) (Sugito 1978). According to the most recent data based on the 1973 Milkfish Census for Java, 56.9% of small farms accounted for 20.2% of the total area and 26.3% of the total milkfish production. At the other extreme, large farms accounted for 44.8% of all areas under milkfish and 36.4% of the total milkfish output. According to Poernomo (1974), the average farm sizes in East, West, and Central Java were 3.62, 2.41, and 1.42 ha, respectively. In Central Java, the local government has decreed that no farmer can own more than 2 ha, but farmers who have more than 2 ha overcome the ruling by registering land under the names of the wife or children (Wirutallingga and Basmi 1974).

The island of Java, by far the most densely populated, has 60% of the country's people as well as more than 50% of the total area of brackishwater ponds, which are generally older than those in the other islands. South Sulawesi's average annual yield

Table 1. Production and value of production of milkfish, Indonesia, 1967-1981 (Fisheries Statistics of Indonesia 1982).

Year	Total area (ha)	Total production (t)	Total value (US$ million)	Average price (US$/kg)	Milkfish production as percent of total (%)		
					Fish supply	Brackishwater aquaculture	All aquaculture
1967	165 007	36 320[a]	n.a.[b]	n.a.	3.1	64.0[a]	26.4
1968	172 054	27 860	n.a.	n.a.	2.4	64.0	24.0
1969	177 061	33 200	n.a.	n.a.	2.7	64.0	28.9
1970	179 911	35 800	n.a.	n.a.	2.9	64.0	26.6
1971	182 073	38 900	n.a.	n.a.	3.1	64.0	28.1
1972	178 297	32 800	n.a.	n.a.	2.6	64.0	25.0
1973	184 090	38 439	8.34	0.22	3.0	63.6	27.6
1974	186 167	41 650	8.60	0.21	3.1	62.4	28.4
1975	182 701	44 692	11.71	0.26	3.2	56.7	27.1
1976	164 594	44 027	15.00	0.34	3.0	54.9	28.5
1977	174 605	48 641	20.35	0.42	3.1	55.5	30.4
1978	171 544	48 287	19.99	0.41	2.9	54.9	28.2
1979	181 792	46 187	24.23	0.52	2.6	49.3	25.3
1980	188 601	52 922	31.73	0.60	2.9	54.1	26.4
1981	192 490	—	—	—	—	—	—

[a]Figures for 1967-1972 are estimates based on the species composition of brackishwater culture of milkfish, shrimp, and other species (e.g., tilapia). Sugito (1978) reported that milkfish, on the average, comprised 64% of the total output from brackishwater ponds.
[b]n.a. = not available.

is the highest in the country (Pownall 1975), and the lowest is recorded for Kalimantan. There is wide variability in average yield from area to area depending on the stage of development of the ponds and on local conditions.

Tambak real estate is more valuable than rice land; for example, in Central Java a hectare of *tambak* was worth Rp. 300 000 in 1973 while the price was only Rp. 200 000/ha for rice land (Wirutallingga and Basmi 1974). At present a hectare of milkfish pond is worth Rp. 5 million, or 17 times more than the value in 1973.

For 1980, the Directorate General of Fisheries (DGF) reported that brackishwater pond operators applied a total of 2600 t of organic fertilizer (or 15 kg/ha per year), 2431 t of inorganic fertilizer (or 13 kg/ha per year), and 44 t of pesticides (or 0.2 kg/ha per year). Thus, it is clear that, on the average, Indonesian milkfish producers are still not applying adequate levels of inputs to increase the output. It is only recently that the Government has made available subsidized fertilizers to milkfish producers; prior to 1975, the fertilizer subsidy scheme was available only to agricultural farmers. Even so, out of a total of 63 247 milkfish farming households, 45% have not used any type of fertilizer.

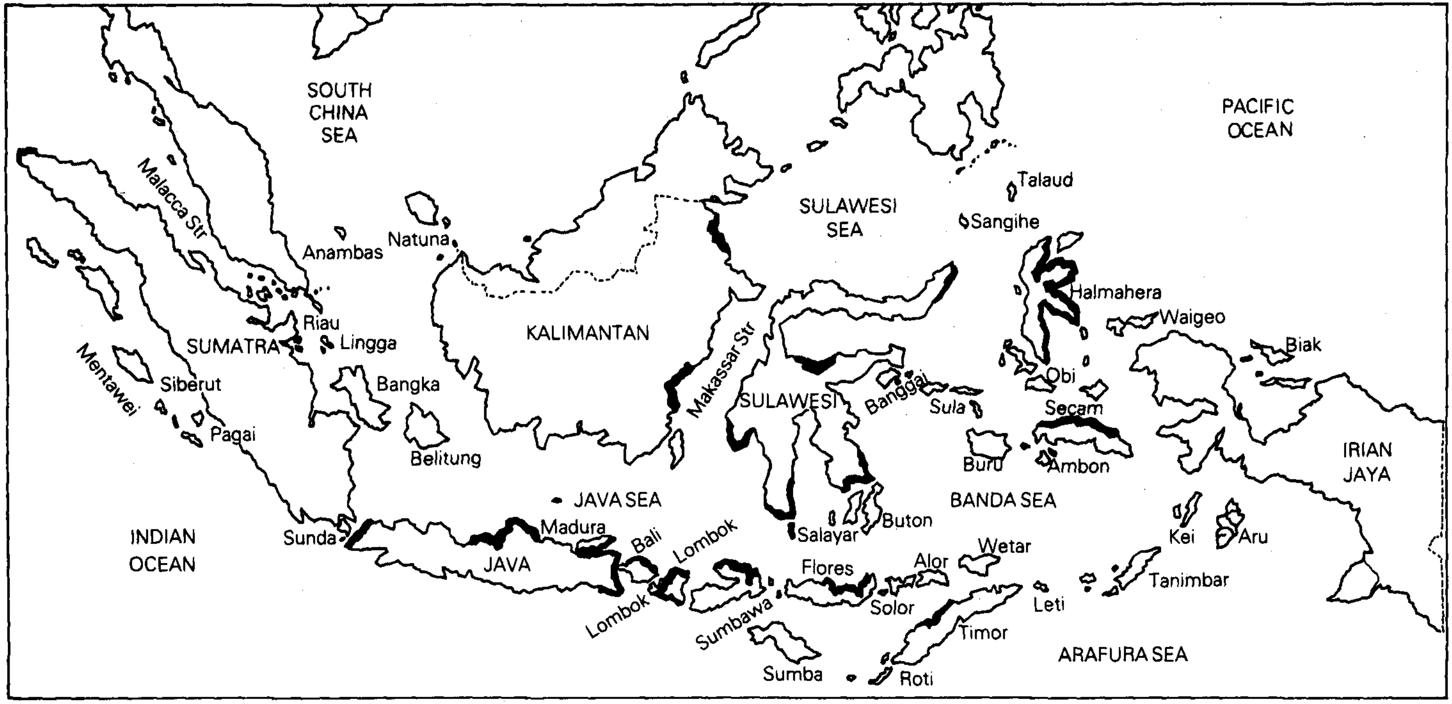
FRY CAPTURE AND DISTRIBUTION SYSTEM

Although a milkfish hatchery is now under construction in Gondol, Bali, it will be several more years before artificially spawned fry become available for stocking ponds. The basis of production continues to be wild fry, the catch being estimated at 700-800 million fry/year. Milkfish fry appear and are collected in coastal and estuarine waters from April to June and from September to December. According to popular belief, fry caught early in the latter season and also those caught off the island of Madura fetch higher prices because of higher survival rates. The farmers claim that the quality and vigor of these fry are higher. They attribute the difference in quality to skillful handling of the fry.

Historically, West and Central Java have been fry deficit areas, and Bali, South Sulawesi, Halmahera and Aceh Madura have been surplus fry areas, the latter traditionally supplying the former. Figure 1 shows the locations where milkfish fry are present and where milkfish culture is concentrated. For the most part, these areas are along the northern coast of Java and Sumatra and along the coasts of South Sulawesi.

The most common method of collection depends on concentration of the fry by a device called a *belabor,* which consists of cut, dried leaves of banana or certain kinds of grass woven into a long rope. The *belabor* can either be used as an encircling device or staked in the water. The fry are collected by a triangular fine mesh push net or a dipper. Satisfactory quantities of fry are caught during high tides in the mornings and evenings, especially during the full and new moon, which coincide with spring tides.

In Indonesia, milkfish fry are transported in plastic bags and either clay pots (*periuk* or *kepeng*) or containers called *waluh* woven out of split bamboo bark or the leaves of the fan palm (*siwalan*) and plastic bags. To be able to hold water, these woven containers are coated inside with tar or cement. A *kepeng* with a diameter of 40 cm can hold 1 000 fry, while a 70-80 cm diameter *waluh* can hold 10 000 fry for a long haul and 30 000 fry for a short distance.



Total Area = 188 600 ha (100%)

Java = 99 156 ha (52%) | South Sulawesi 58 743 ha (31%) | Aceh = 25 227 ha (13%) (Sumatra)

Fry ground

Fig. 1. Major milkfish production and fry collection centers in Indonesia, 1980.

Interisland transportation of fry is mostly by water, sometimes by air, but, in a country with 13 677 islands, land transportation is understandably restricted.

At the beach, the fry landed are sold to *welijos,* the first link between the fry collectors and middlemen in the fry marketing chain. In turn, the *welijos* sell fry to *juragan jalans* (literally "walking middlemen"), who in turn sell them to *juragan duduks* (literally "stationary or sitting middlemen"). The milkfish farmers obtain their fry supply from the *juragan duduk.* This, however, does not mean that the milkfish farmers are restricted to buying from the *juragan duduk;* they have the option to buy from any of the above market intermediaries, and in fact some have been reported to deal directly with fry collectors or *welijos.* The common marketing practice within a province, however, is the system described above; among provinces the system is slightly different (Fig. 2). Under the present milkfish pond management system (underdeveloped, developing, and advanced), about 1.2 billion fry are required to stock the 182 000 ha of milkfish ponds. The main sources are Aceh in Sumatra, Maluku, Bali, Nusa Tenggara, and South Sulawesi. These fry are largely shipped to Java. At present only about 740 million fry are landed (Fig. 3). There is thus a shortage of about 460 million fry.

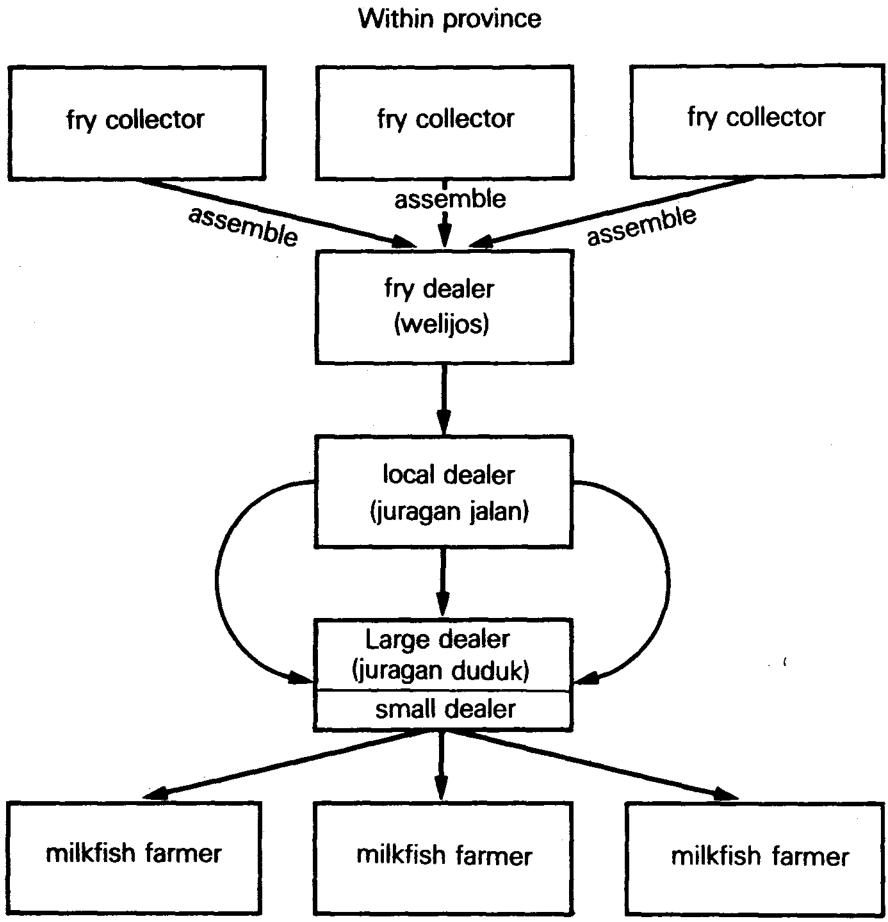
GROW-OUT SYSTEM

Distinguishing the meanings of two Indonesian terms will help in understanding part of the problem of perennially low milkfish yields in the country. The first is the *tambak,* in which milkfish are traditionally grown. Milkfish culture started about 600 years ago in mangrove swamps using traps (Cremer 1983). The next step was to enclose the water in a tidal flat or mangrove area to trap the milkfish and allow them to grow. This was the *tambak.* Because it is an enclosure constructed with loose mud, and no digging is done, the water within is only as deep as it was before the embankment was built. Furthermore, it is affected by changes in the tide levels. Other Indonesian words used to describe the *tambak* are *petak, pematang,* and *batas,* meaning bunds or boundaries. The bunds retain the water and fish within the enclosed *tambak.* Two other words for *tambak* are *benteng* and *empang,* which connote "walling-off" a water area to retain water and fish. No digging below the ground level is implied, and the depth of the water is necessarily shallow.

On the other hand, the word *kolam* connotes digging, and the bottom of the *kolam* is well below the surface of the ground. A *kolam* is thus a dug-out pond while a *tambak* is a levee-type pond. The dikes of the *kolam* are usually stronger and higher, while the bunds of the *tambak* are low and not as well constructed.

Tambaks are found in coastal areas while *kolams* are situated inland. Slamet (1983) stated that the word *tambak* is normally reserved for a brackishwater pond system and *kolam* is specific to freshwater systems.

In East Java, milkfish is also grown in padi field and is referred to as *sawah tambak,* because the farmers there liken *tambaks* to padi fields (*sawah* is the Indonesian word for rice field), implying shallowness. In describing the conditions of Indonesian milkfish ponds, Padlan (1979) pointed out that it is not unusual to see water only in the peripheral ditches and in the longitudinal canals purposely excavated to hold the milkfish during neap tide. Furthermore, he added that



maintenance of adequate water depth especially during the dry season is almost impossible. It appeared to him that shallow water is not yet recognized as a major problem and that the situation is actually desired. Nevertheless, experiments to increase milkfish yield in shallow, undrainable ponds have shown that yields can be substantially increased over existing levels.

Fish yields from *kolams* are generally higher than those from *tambaks,* due in part to the difference in the water depths of the two systems[2] and, accordingly, to differences in stocking rates. Unlike in Taiwan, supplementary feeding is not widely practised in Indonesia. The economic basis of production in Indonesia is the primary productivity of the shallow water column, usually without organic or inorganic fertilization (Djajadiredja and Poernomo 1971). Also, predatory fish and other unwanted species

[2]According to Schuster (1952), 21% of the *tambaks* in Java are simply too shallow to be productive. Although Schuster made his observations in the 1950s, the same conditions prevail in many areas to this day.

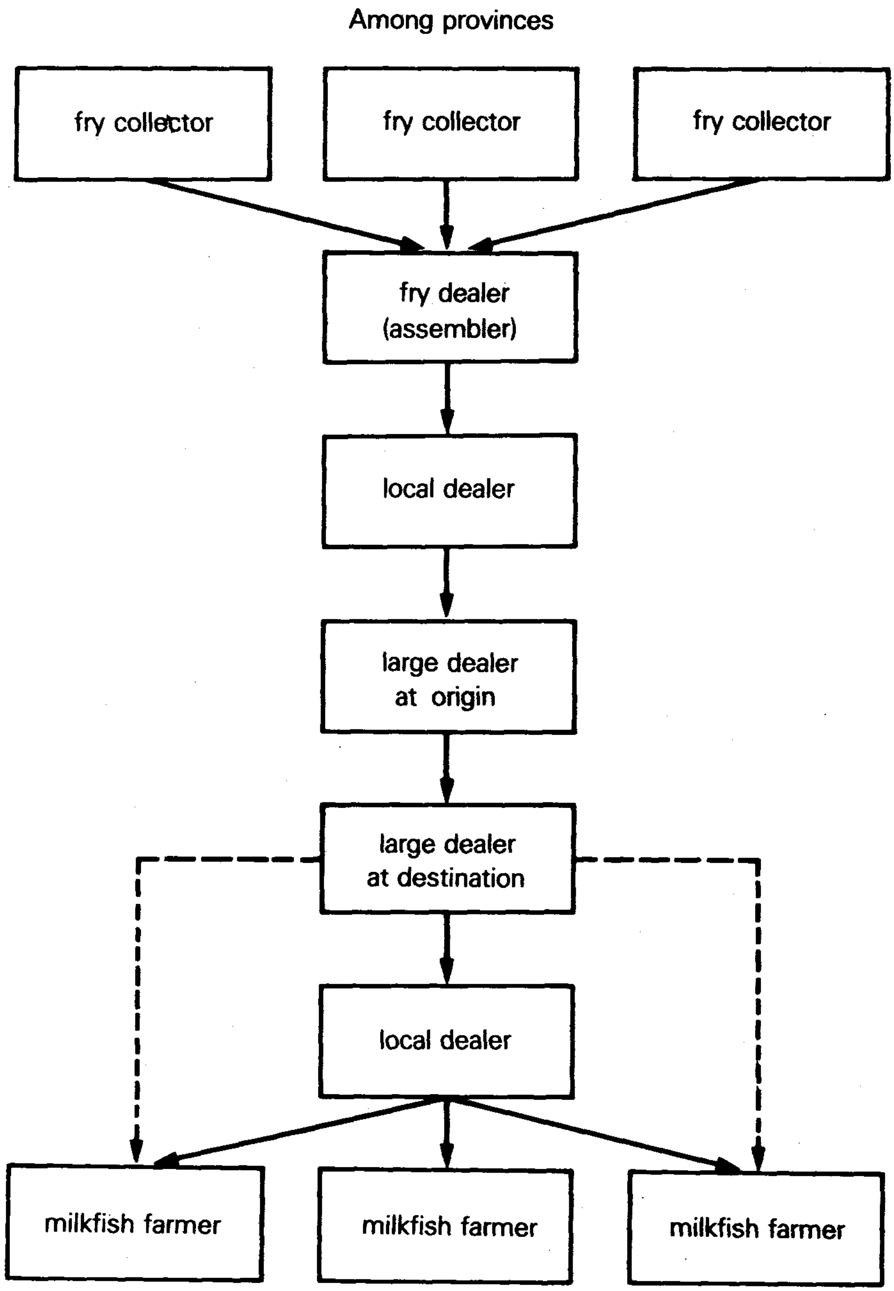
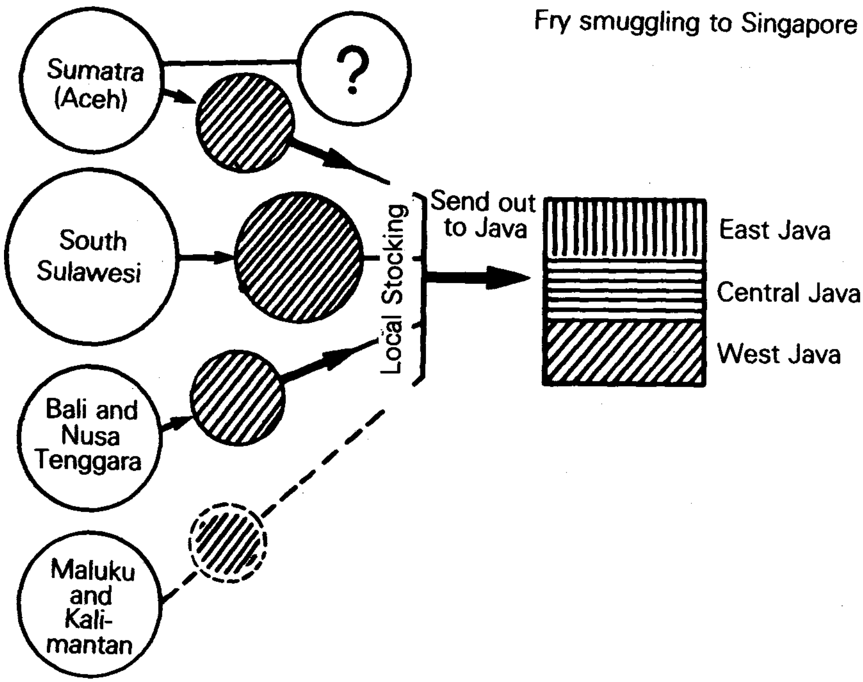


Fig. 2. Indonesia milkfish fry marketing system.



Fry ground	Number of fry (million)	Fry ground	Number of fry (million)
Sumatra (Aceh)	143.6	Central Java	104.4
South Sulawesi	182.7	Bali and Nusa Tenggara	11.3
East Java	160.0	Kalimantan	n.a
West Java	138.0	Maluku	n.a

Total 740.0 million

Fig.3. Source and distribution of milkfish fry, 1979.

(pests) are not properly eradicated; they not only compete for the available food in the water column but also prey on the milkfish. Milkfish fry are especially vulnerable; the shallow water does not help them to escape, either.

Tambaks are shallow for another important biological reason. *Kelekap* or microbenthic algae — milkfish pastures — require shallow water to grow and flourish; water depths greater than 20 cm inhibit the growth of *kelekap*. *Kelekap* is by far the most important traditional, preferred source of food for milkfish. Because of the water depth requirement of this type of fish food, such ponds thus become structurally shallow. If microbenthic algae are the basis of production, milkfish ponds cannot be very deep. Perhaps, kitchen ponds can be considered as a way out.

On the other hand, if plankton (phyto- and zoo-) is the type of food to be relied upon for milkfish growth, ponds can be made deeper, because plankton grows well in deep water, Milkfish farmers in Taiwan and to a small extent in the Philippines have already taken advantage of this water depth requirement for different food types to raise milkfish productivity.

TYPES OF POND SYSTEM

Although brackishwater aquaculture in Indonesia has been in existence since the 15th century, pond layout as well as pond management still vary greatly in different localities. Layout started from a very simple method wherein each pond compartment was connected to each other because no separate water gates were made (serial water supply); in the present, improved system each compartment has a separate gate, nursery ponds, transition ponds, rearing ponds, catching ponds, and a water supply system.

In East Java, milkfish farmers have designed two unique pond systems which are now widely used. These are called the *taman* and *porong* type of ponds (Fig. 4). The principal difference between these two types of pond is that the location of the catching pond is at the middle in the *taman* type and adjacent to the main water supply canal in the *porong* type. Temporary nursery ponds or *ipukan* are provided in both cases, where the fry are stocked and nursed for one week. Transfer or release of the fry into the rearing ponds is done simply by breaking the dikes. Usually the *ipukan* is located in the center or at the extreme end of the rearing pond.

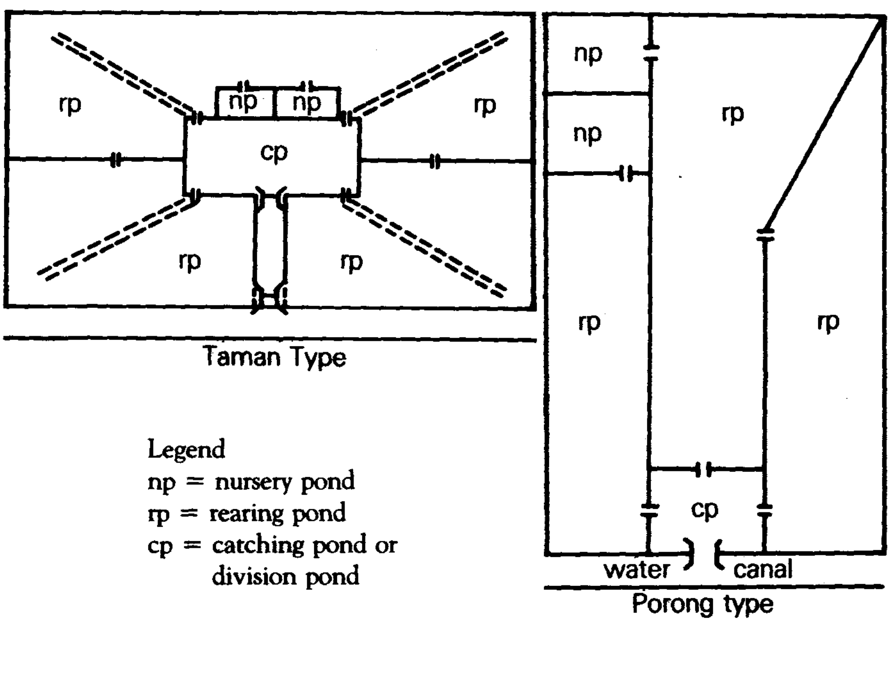


Fig. 4. Layout of *porong* and *taman* types of milkfish ponds.

Many milkfish farms are small, ranging from 0.25 to 6.0 ha. Recently, several modifications in pond design have been made such as well-built peripheral and partition dikes laid out in straight patterns, regularly shaped compartments of manageable size, and better situated supply and/or drainage canals and gates to facilitate independent water management for each compartment (parallel system). The bottoms are cleared of tree stumps and provided with deeper periphery canals.

The nursery ponds in the improved system, however, are still very simple and are located at the middle of each rearing pond. They are constructed by making temporary dikes. The fry are nursed there for about 3 weeks, then released into the rearing ponds by cutting the dikes. Natural food is grown through preparation of the pond bottom, fertilization, and pest control, while shelter is also provided to protect the fry against the heat and heavy rains. Two to three crops per year can be grown.

ECONOMICS OF PRODUCTION

Milkfish production rates vary from area to area, largely determined by the levels of management: rates of stocking, rates of fertilization, control of predatory fish and other pests, number of croppings per year, etc. (Chong et al 1982). Before a cost and returns analysis of milkfish culture is presented it is worthwhile to examine the price differential between the producer and consumer (Table 2). While milkfish farmers receive an average of 75% of the final consumer price per kg in Aceh, producers in Java receive only 46% (Sullivan 1981), the implication being that milkfish farmers in Java must make sure that their production costs are less than 46% of final retail price for their operations to be profitable.

Cost and Returns Analysis

The lack of more recent data on costs and returns of milkfish production in Indonesia prompted the reconstruction of the cost and returns analysis in Table 3

Table 2. Average monthly milkfish prices in 20 provinces, 1982 (Directorate General of Fisheries, unpubl. data).

Month	Producer price (US$/kg)	Consumer price (US$/kg)
January	1.05	1.38
February	0.84	1.18
March	0.93	1.11
April	0.96	1.13
May	1.07	1.22
June	1.27	1.47
July	0.96	1.16
August	1.07	1.28
September	0.77	1.12
October	1.11	1.41
November	0.44	0.63
December	1.01	1.21
Average	—	1.26
Lowest	—	0.80
Highest	—	2.05

Table 3. Cost and returns profile for milkfish.

Partial operating costs		Rp
9000 pcs. milkfish fry @ Rp. 15 each		135 000
390 kg urea @ Rp. 100/kg		39 000
1000 kg cow dung @ Rp. 10/kg		10 000
200 kg rice bran @ Rp. 20/kg		4 000
195 kg triple superphosphate @ Rp. 100/kg		19 500
150 kg tobacco dust @ Rp. 25/kg		3 750
1000 kg rice chaff @ Rp. 3/kg		3 000
	Subtotal	214 250
Returns		
2168 kg of milkfish @ Rp. 650/kg		1 409 200
Gross returns		1 194 950

based on government experiments on the intensification of milkfish production. The costs and returns are synthesized based on the set of recommended husbandry practices presented by Djajadiredja and Poernomo (1971). The per crop application of 130 kg/ha of urea, 65 kg/ha of triple superphosphate, and 1000 kg/ha of rice chaff, among others, gave the highest yield in a series of experiments—2168 kg/ha per year or 542 kg/ha per crop. The stocking rate was 3000 fry/ha per crop. The more progressive farmers were adopting an improved technique in which fingerlings were used. The milkfish were harvested after 90 days. 1982 prices for inputs and output have been used to reconstruct the cost and returns profile. (Note that this is not based on any actual farm data but has been synthesized using suggested recommendations.)

Profit

The gross returns represent returns to management, land, labor, and capital. No costs for repair and maintenance, depreciation, marketing, taxes, or other miscellaneous inputs such as fuel have been included. Thus, if we deduct the cost of labor (wages), cost of capital (interest), cost of land (rent), and cost of management (owner-operator's salary) as well as repair and maintenance, depreciation, etc. from Rp. 1 194 950, we will arrive at the net profit of milkfish production.

As a measure of profitability, Sullivan (1981) reported that the returns to management and capital for milkfish farming were about Rp. 190 000/ha per year and for rice-cum-fish farming Rp. 210 000/ha per year.

MARKETING SYSTEM

Post-harvest handling of milkfish is as important as fry handling and grow-out in ponds because, if post-harvest handling and marketing are not given proper attention, gains made at the earlier stages of production will be lost. In Indonesia, pond-reared fish are normally sold fresh in local markets (Cremer 1983). Milkfish farmers generally sell their produce on the farm site (pond site market). According to Slamet (1983), milkfish are first iced when they change hands from the producer to the middleman. In fact, Slamet points out that the milkfish are already dead when they are packed into baskets to be brought to the market. Thus, post-harvest losses can become large because the milkfish are not iced immediately after they are harvested.

Indonesian milkfish fanners report that they do not view icing as part of their production costs or responsibilities. Instead, it is the middlemen who have to assume such costs, in contrast to the marketing practice in Taiwan or the Philippines. Also, in Indonesia no sorting is carried out on the farm; sorting into different size categories is done only at the market. This grading into different size categories overlooks the keeping quality aspects of fish.

Milkfish are usually sold within 3-4 days after harvest. Sales are often seasonal, declining from October to March when increased marine fish landings depress market prices (Cremer 1983). Also, Indonesian milkfish farmers do not have access to market price information or similar market intelligence. Wherever transportation linkages are developed and milkfish can be shipped economically from island to island or from one area to another, they are sent out from the local markets. Because of the distances separating the different islands, milkfish markers in Indonesia are largely localized.

With localized markets, any effort to encourage farmers to increase their output runs into serious marketing problems, because the increased output cannot be disposed off easily without depressing the price. Sullivan (1981) reported that the milkfish intensification project in Aceh had lost momentum and milkfish farmers had cut back on production because of low prices.

The importance of marketing and market development should thus not be overlooked in any effort to increase production. Aquaculturists should learn from the marketing problems of the Green Revolution.

CONCLUSION

In Indonesia, milkfish is regarded as a high value food item. Because of various constraints to high yields, the *tambaks* are grossly underutilized. These various constraints include but are not limited to the following: (1) limited application of improved technology, (2) less than optimum stocking rate of fry, (3) inadequate application of fertilizers, (4) high mortality rate, (5) high interisland transportation costs, (6) relatively shallow and silted ponds, (7) lack of incentives and adequate economic returns because of low productivity and direct competition from marine fish.

support the Government's drive toward self-sufficiency in fish in the foreseeable future, in spite of Government assistance, which has been mainly production-oriented. Because of marketing difficulties, many milkfish farmers who had participated in the Government intensification program have discontinued intensifying their production operations. Government assistance should not be narrowly focussed on production alone but should also encompass organized marketing, distribution, and continuous follow-up to monitor the progress of Government-initiated and -assisted projects.

More rigorous economic analyses (micro- and macroeconomic studies) of the industry are clearly needed to pinpoint areas in which the Government can contribute to fostering greater growth of the industry. Economic analyses can also help to single out research areas which require further attention. For example, out of all the possible factors affecting milkfish yield, which ones are more important? Because Government funds are not unlimited, it is important that only the more significant or immediate problems be looked at first.

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THE MILKFISH INDUSTRY IN THE PHILIPPINES

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Milkfish is the most commercially important fish species in the Philippines. Out of the present 208 120 ha of fishponds, 195 830 ha are brackishwater ponds, of which 91% are milkfish farms. Fishpens, concentrated mainly in Laguna Lake, constituted 30 000 ha in 1983, but are now being curtailed; 62 000 ha of mangrove are available for fishpond development. Milkfish production from the marine fisheries and aquaculture sectors has increased at an average rate of 22%. In 1981, production was valued at ₱1.9 billion (212 000t), representing 14% of total fish production value. About 73% of milkfish production came from brackishwater ponds, while the rest was contributed by fishpens (26.3%) and marine fisheries (0.5%). The national yield average was 870 kg/ha per year. Local marketing is handled by brokers, who distribute the fish to wholesalers, cooperatives, retailers, and consumers. Exports experienced a more than 600% increase from 1977 to 1980 and a slight decrease in 1981. Traditional export markets include the US, Canada, Japan, and Singapore. The frozen/chilled form constitutes the bulk of exports. Inherent problems of the industry include shortage of input supply, frequent typhoons and flooding, presence of acid sulphate soils, and extreme tidal fluctuations. Inadequate credit, deficient ice and cold storage facilities, an inadequate transport system, and limited processing plants are additional bottlenecks. Nevertheless, the potential for further growth of the industry is strong in view of recent research on intensive farming, induced spawning, Tearing in controlled conditions, and polyculture techniques. The government is providing support through the establishment of infrastructure facilities, strengthening of extension and training, provision of credit, and development of efficient marketing.

INTRODUCTION

The aquaculture industry in the Philippines is one of the most important segments of the fishing industry in the country. It is continuously gaining attention as a potential source for increasing production. Over the years, aquaculture has expanded as a result of technological developments and widening knowledge of the biology and life cycle of various cultivable species. Production intensification in existing fishpond areas is being carried out to increase yields. Seafarming has grown to include not only the traditional mussel and oyster culture operations, but the propagation of seaweeds as well as various finfishes in cages. Fish farming in cages has also been adopted in inland waters such as rivers, lakes, and reservoirs. The expansion of fishpen culture in Laguna de Bay has been contributing a significant percentage to aquaculture production. Recently, rice-fish culture techniques, after passing several trials, have reached actual implementation and are expected to expand extensively in Central Luzon and in landlocked areas where the fish supply is scarce.

The series of fuel price increases in the last decade has negatively affected both marine municipal and commercial fisheries, and a leveling off of production from these sectors is foreseen. Aquaculture is thus the sector most capable of meeting the future fish requirement of the country. In 1981, the aquaculture sector contributed 19% to a total fish production of 1.8 million tons. Of the total aquaculture production, brackishwater fishponds contributed 50%, freshwater fishponds 3%, fishpens 17%, fish cages 2%, and seafarms 28%. Milkfish dominates aquaculture production; its popularity among local consumers has continually expanded the milkfish industry over the years. Aside from its culture in brackishwater ponds, milkfish has recently been extensively cultured in fishpens and, to a small extent, in freshwater ponds.

CURRENT RESOURCES

Of the total of 195 830 ha of brackishwater fishponds in the Philippines, 91% are assumed to be milkfish farms (GOPA Consultants 1983). Existing milkfish ponds are in various stages of development, years in operation ranging from less than 5 years to over 20 years. The size of the farms ranges from a few hundred square m to 250 ha or more (Chong et al 1982).

The culture of milkfish in fishpens is concentrated mainly in Laguna Lake, the largest lake in the Philippines, with a total area of 90 000 ha. In 1980, it was estimated that fishpens in operation around the lake covered 7000 ha (Mane 1981). However, reports reveal that this figure increased to about 30 000 ha in the early part of 1983, exceeding the total carrying capacity of the lake, which is estimated at about 20% of the total lake area (LLDA 1983). For better management, conservation, and protection of the lake, the Laguna Lake Development Authority (LLDA) is currently implementing a comprehensive zoning plan of the lake to gradually reduce the existing fishpens by 30%.

From survey data, the country still has many mangrove areas that can be utilized for fishpond development or other industrial and commercial purposes such as logging or land reclamation for human settlement. The Bureau of Forest Development (BFD) estimated the existing mangrove areas at 242 000 ha (1981), while the Natural Resources Management Center (NRMC) figured 140 000 ha (1978). The discrepancy in the figures is due to the definition and methods of inventory used. BFD defines a mangrove swampland as a forest that stands in a swamp tidal area consisting primarily of *Rhizophora* and associated species. The methods of inventory used by BFD are ground survey, air photo analysis, and statistical projections based on 1977 data of 249 083 ha of mangrove. NRMC defines mangrove as an area with characteristic *Rhizophora* and associated species wavelength emissions, shown by digital analysis of LANDSAT imagery with Image 100. Cognizant of the immense value of mangrove resources to the country, the government proclaimed 78 000 ha out of the NRMC total of 140 000 ha as preservation and conservation areas under Presidential Proclamations 2151 and 2152, leaving only 62 000 ha open for fishpond development. In support of this, the Ministry of Natural Resources, through the Integrated Fisheries Development Plan (IFDP), gave emphasis to the intensification of production in existing fishponds rather than to the opening of new areas.

PRODUCTION PERFORMANCE

Milkfish production steadily increased from 1977 to 1981, with an average growth rate of 22%. In 1981, it reached a total of 211 586 t valued at ₱1.9 billion, including production from marine fisheries and aquaculture from brackishwater fishponds and fishpens and representing 12% of total fish production and 14% of total fish production value for the year. Production from brackishwater fishponds was 155 092 t or 73.3% of total milkfish production, while fishpens and marine fisheries contributed 56 299 t or 26.6% and 195 t or 0.1%, respectively (Table 1).

Table 1. Milkfish production (tons).

		Marine		Aquaculture			
Year	Commercial	Municipal	Total	Brackishwater[a] fishpond	Fishpen	Total	Grand total[b]
1977	1	358	359	105 338		105 338	105 697
1978	—	411	411	108 001	—	108 001	108 412
1979	—	982	982	121 574	—	121 574	122 556
1980	—	163	163	155 092	56 299	211 391	211 586
1981	—	195	195				

[a]91% of total brackishwater fishpond production.
Ave. Growth Rate 9%.
[b]Annual average growth rate of 22%.
Source: BFAR Fishery Statistics of the Philippines, 1977-81.

Average production figures per hectare per year for different provinces and for different sizes of milkfish farms vary considerably. According to 1981 Bureau of Fisheries and Aquatic Resources (BFAR) statistics, Bulacan and Iloilo are the two highest producing provinces with an average production of 1500 and 1250 kg/ha per year, respectively. These figures are far above the present national average of 870 kg/ha per year (Table 2). In a study conducted by the International Center for Living Aquatic Resources Management (ICLARM), the Fishery Industry Development Council (FIDC), and the Bureau of Agricultural Economics (BAEcon) (Chong et al 1982), these two provinces were also identified as the highest producing areas in the country (Tables 2, 3, and 4).

The study revealed that generally there is a direct relationship between yield and size of milkfish farm (Table 3). However, a wide variation in production can be observed, as shown in Table 4. In terms of the variables influencing milkfish pond yield, the study revealed that out of the 11 variables examined, 5 have significant relations to production output. Three of these 5 variables relate to production inputs, namely, stocking rate, use of organic and inorganic fertilizers, and miscellaneous operating costs. Thus, it can be assumed that production output can be increased with the optimum use of fertilizers and improved stocking rates.

SUPPLY AND DEMAND PROJECTIONS

The Integrated Fisheries Development Plan (IFDP) for the 1980s expects that the increase in brackishwater fishpond production will continue over the next 10 years. Thus, the IFDP targetted brackishwater fishpond production at 256 700 t by 1985 and at 395 000 t by 1990. To achieve these production targets, the IFDP programmed for the intensification of culture in the existing 176 000 ha of fishponds and the conversion of 20 000 ha of mangrove into new ponds. Out of the total area available for fishpond development, the IFDP projects that these 196 000 hectares will still be used for milkfish culture until 1990. Based on this assumption of cultivable area and an average production target of 1 t/ha per year in 1985 and 1.5 t/ha per year in 1990, milkfish ponds are expected to produce 216 730 t by 1985 and 335 095 t by 1990 (Table 5). On the other hand, the LLDA's Comprehensive Laguna Lake Zoning Plan, which takes into consideration the lake's carrying capacity, the concept of fish sanctuary, and the provision of access navigational channels and fish enclosures, projected that the 30 000 ha of fish enclosures existing in the lake will be reduced by 30% in 1985. Assuming that 70% or 21 000 ha of these fish enclosures are retained and produce an average production of 4 t/ha per year, a total production of 84 000 t will be attained in 1985. Assuming further that out of the 21 000 ha, 99% will be allocated for fishpens culturing milkfish, a total annual milkfish production of 83 000 t will be expected from 1985 to 1990.

The demand for milkfish is likewise projected to increase from 1985 to 1990. Demand for fresh milkfish alone was targetted at 132 771 t in 1985 and 145 6901 in 1990 based on a per capita consumption of 2.5 kg. However, demand for locally consumed processed milkfish cannot be projected since per capita consumption for processed milkfish is not presently available. Meanwhile, milkfish exports are also

Table 2. Fish production by province (1981).

Region	Province	Hectarage	Average production (kg/ha)		Total production (kg)
			BFAR statistics[a]	Based on studies[b]	
I		13 409	1 169		15 679 000
	Ilocos Norte	41	488		20 000
	I locos Sur	284	598		170 000
	La Union	704	899		633 000
	Pangasinan	12 380	1 200	589	14 856 000
II		819.03	649		532 000
	Cagayan	819.03	649	253	532 000
III		42 992.88	1 192		51 267 000
	Bataan	2 105.48	1 200		3 727 000
	Bulacan	18 876.60	1 500	1066	28 315 000
	Pampanga	19 509.58	920		17 949 000
	Zambales	1 501.22	850		1 276 000
NCR		752	900		677 000
	Metro Manila	752	900		677 000
IV		29 982.79	619		18 553 000
	Batangas	590.40	450		266 000
	Cavite	883.35	480		424 000
	Marinduque	1 915.26	480		919 000
	Mindoro Occ.	5 603.25	840		4 707 000
	Mindoro Or.	1 656.00	760		1 259 000
	Palawan	2 181.66	350		764 000
	Quezon	16 719.33	600	969	10 032 000
	Romblon	335.54	447		150 000
	Aurora	100.00	320		32 000

Continued on pages 220-221

Table 2. continued

Region	Province	Hectarage	Average production (kg/ha)		Total production (kg)
			BFAR statistics[a]	Based on studies[b]	
V		12 090.52	424		5 130 000
	Albay	497.43	322		160 000
	Camarines Norte	1 685.15	320		539 000
	Camarines Sur	3 415.33	320		1 093 000
	Catanduanes	485.11	348	95	169 000
	Masbate	3 778.66	650		2 456 000
	Sorsogon	2 228.84	320		713 000
VI		44 500.70	1 149		51 123 000
	Aklan	4 173.26	970		4 048 000
	Antique	307.50	849		261 000
	Capiz	11 323.35	1 210		13 701 000
	Iloilo	17 666.74	1 250	1 1.10	22 083 000
	Negros Occ.	11 029.85	1 000		11 030 000
VII		6 783.71	608		4 126 000
	Bohol	2 743.73	620	308	1 722 000
	Cebu	2 847.11	600		1 709 000
	Negros Or.	1 192.87	599		715 000
VIII		9 658.39	399		3 857 000
	Eastern Samar	192.25	359		690 000
	Leyte	3 618.12	460		1 664 000
	Northern Samar	1 858.53	360		669 000
	Southern Leyte	192.02	458		88 000
	Western Samar	3 797.47	360		1 367 000

continued on opposite page

Table 2. continued

IX-A		57.46	296		17 000
	Banian	57.46	296		17 000
IX-B		18 592.60	453		8 418 000
	Zamboanga del Norte	1 494.18	370		553 000
	Zamboanga del Sur	17 098.42	460	204	7 865 000
X		5 487.29	438		2 407 000
	Agusan del Norte	2 662.07	460		1 224 000
	Misamis Occ.	814.78	450		366 000
	Surigao del Norte	1 174.34	360		432 000
	Misamis Or.	837.10	470		394 000
XI		5 442.79	791		4 305 000
	Surigao del Sur	926.44	600		556 000
	South Cotabato	565.06	501		283 000
	Davao del Norte	1 018.18	750		764 000
	Davao del Sur	1 777.23	1 000		1 777 000
	Davao Oriental	1 155.88	800		925 000
XII		5 262.73	824		4 340 000
	Lanao del Norte	2 690.27	800		2 153 000
	Maguindanao	2 337.61	850		1 987 000
	Sultan Kudarat	234.85	851		200 000
	GRAND TOTAL	195 831.89	870		170 431 000

[a] Average production = total production ÷ total hectarage.
[b] Average production based on studies undertaken by Chong et al 1982.
Sources: BFAR Fishery Statistics of the Philippines, 1981. pp. 292-293, Chong et al 1982.

Table 3. Yield of milkfish farms by size and by province (1978).

Province	Small farms — 6 ha (kg/ha per year)	Medium farms — 6-50 ha (kg/ha per year)	Large farms — 50 ha (kg/ha per year)
Cagayan	296	239	—
Pangasinan	527	666	—
Bulacan	796	1 136	987
Masbate	337	113	16
Iloilo	433	905	1 195
Bohol	149	327	—
Zamboanga del Sur	163	207	—
Philippines	423	580	1 056

Source: Chong et al 1982.

Table 4. Yield of milkfish farms by province (1978).

Province	Average yield (kg/ha per year)		
	All farms	High-yielding farms	Low-yielding farms
Cagayan	253	424	153
Pangasinan	589	900	341
Bulacan	1 066	1 886	560
Masbate	95	432	35
Iloilo	1 110	I 616	621
Bohol	308	962	177
Zamboanga del Sur	204	427	116
Philippines	761 (n=324)	1 429 (n=97)	266 (n=227)

Note: High and low yields have been defined relative to the average yield. Those farms with above-average yield are grouped as high-yielding farms and those with below-average yield are grouped as low-yielding farms.
Source: Chong et al 1982.

Table 5. Projected supply of milkfish (tons).

Year	Marine[a] (capture fisheries)	Aquaculture[b]		
		Brackishwater fishponds	Fishpens	Total
1981	195	155 092	56 000	211 287
1982	240	168 625	61 975	230 840
1983	295	183 338	68 588	252 221
1984	363	199 336	75 906	275 605
1985	446	216 730	83 000	300 176
1986	549	236 446	83 000	319 995
1987	676	257 999	83 000	341 675
1988	831	281 493	83 000	365 324
1989	1 022	307 127	83 000	391 149
1990	1 257	335 095	83 000	419 352

[a]Projection was computed based on 1977-81 projection data using an average growth rate of 23%.
[b]Projection was computed based on compounded growth rate using 8.7% for 1981-85 and 9.1% for 1986-90.

Table 6. Projected demand of milkfish.

Year	Population[a]	Demand (tons)		
		Domestic[b]	Export[c]	Total
1982	49 836 983	124 592	926	125 518
1983	50 925 789	127 314	951	128 265
1984	52 016 230	130 041	977	131 018
1985	53 108 304	132 771	1 002	133 773
1986	54 163 971	135 410	1 028	136 438
1987	55 208 592	138 021	1 053	139 074
1988	56 242 166	140 605	1 078	141 683
1989	57 264 694	143 162	1 104	144 266
1990	58 276 176	145 690	1 129	146 819

[a]NCSO data, medium assumption.
[b]Based on annual per capita consumption of 2.5 kg of fresh/frozen/chilled milkfish.
[c]Method of projection used was the linear regression based on NCSO Foreign Trade Statistics, 1977-81.

projected to increase to 10021 in 1985 and 11291 in 1990 based on BFAR historical data (Table 6).

As shown in Table 7, the country is expected to experience a surplus of milkfish of 166 403 t in 1985, which is expected to increase further to 272 533 t in 1990. This surplus may be attributed to: (1) wide adoption of intensive culture by fishpond operators, (2) further improvement of culture methods, (3) increased credit assistance, and (4) accelerated technology transfer. However, the IFDP has targetted this surplus in milkfish production as an alternative to fill in the gap in marine fisheries production, which is expected to stabilize over the plan period as a result both of the near depletion of marine resources due to overfishing and of the high cost of some types of marine operations due to increasing fuel prices.

Marketing System

Local marketing of milkfish is generally handled by brokers, who absorb about 90% of total fish production. The brokers in turn distribute the fish to different market outlets, i. e., to wholesalers, cooperatives, retailers, and consumers (GOPA Consultants 1983). The BFAR reported that in 1981 some 3267 t of frozen and processed milkfish valued at ₱27 million were transported to the different market outlets.

Table 7. Milkfish supply and demand situation, 1982-90 (tons).

Year	Total supply	Total demand	Surplus
1982	230 840	125 518	105 322
1983	252 221	128 265	123 956
1984	275 605	131 018	144 587
1985	300 176	133 773	166 403
1986	319 995	136 438	183 557
1987	341 675	139 074	202 601
1988	365 324	141 683	223 641
1989	391 149	144 266	246 883
1990	419 352	146 819	272 533

About 77% of the total milkfish transported came from Region VI (Table 8). The majority of the operators generally sold their produce to different market outlets situated within their province. However, about 50% of fishpond production from Pangasinan was sold in Northern Luzon, while 20% of the production of Iloilo was sold in Metro Manila and other parts of Luzon (GOPA Consultants 1983).

Moreover, a marketing study conducted by the Philippine Fisheries Development Authority (PFDA) showed that milkfish is partly sold outright at the farms, where buyers pick up the harvested fish at preset prices arranged with the fishpond owners. This is especially true in cases wherein large supplies of milkfish are sold to only one buyer. However, the study likewise showed that a major percentage of milkfish production is delivered by the fishpond operators to the various wholesale markets, where brokers sell the products for them at 4% commission. In cases wherein the brokers transport the fish to the market, a 5% commission is charged by the brokers.

Pricing

The price of milkfish fluctuates in accordance with the prevailing fish supply. When the supply is abundant, which often occurs from April to October, prices are relatively low. A peak in prices is usually observed from January to March. According to the Aquaculture Development Project Technical Assistance Study financed by the Asian Development Bank (ADB), the average retail price paid for milkfish was highest in Dagupan City at ₱16.00/kg and lowest in Metro Manila at ₱12.80/kg.

On the other hand, according to PFDA data, the national average wholesale price of milkfish in 1982 was ₱10.30/kg while retail prices ranged from ₱11.45 to ₱17.40/kg, or a markup of 11.69% over the wholesale price.

Export Performance

Philippine export of milkfish has improved significantly. From a recorded export of 74.5 t in 1977, it increased to 564.5 t in 1980, or a more than 600% increase. However, a slight decrease to 528 t was experienced in 1981 (Table 9).

Table 8. Volume of frozen and processed milkfish transported from point of origin, 1978-1981 (kg).

Region	1978	1979	1980	1981
I			—	—
II	—	260	21 053	—
III	—	—	—	—
IV	671 282	85 790	67 724	97 450
NCR		700	—	—
V	67 659	18 530	52 138	221 595
VI	3 029 304	9 451 142	403 547	2 518 817
VII	1 605	12 483	—	58 960
VIII	—	11 200	—	3 000
IX-A	70 092	31 794	15 939	—
IX-B	17 275	—	127 785	250 555
X	28 351	167 009	15 864	20
XI	32 239	93 557	12 164	8 992
XII	451 168	39 352	142 329	107 625
Total	4 368 975	9 911 817	858 543	3 267 014

Source: BFAR Statistics of the Philippines, 1977-81.

Table 9. Philippine export of milkfish by product form (tons).

Type	1977	1978	1979	1980	1981
Live (fingerlings)	—	17	15	13	1.3
Frozen/chilled	74.5	150	323	551	526.4
Dried	—	—	—	—	.02
Canned	—	4	2	.6	—
Total	74.5	171	340	564.5	527.72

Source: BFAR Fishery Statistics of the Philippines, 1977-81.

The major traditional export markets for milkfish are the United States, Canada, Japan, and Singapore, which account for about 90% of the country's milkfish exports. There are four milkfish products being exported, namely, live fingerlings and frozen, dried, and canned fish. The majority of milkfish exported are in the frozen/chilled form. Live fingerlings ranked second, followed by canned, and lastly by the dried form (Table 9).

The international price for fish varies considerably, depending on the type of product being sold and on its destination. On a per product form basis, canned milkfish cost the most at an average price of ₱20.30/kg (at 1980 prices). Live fingerlings, which ranked second, cost ₱18.70/kg (Table 10). In terms of destination, Singapore paid more (₱37.60/kg) for live fingerlings than Taiwan (₱24.00/kg). The USA paid the highest price for canned milkfish (₱24.10/kg), followed by Hongkong (₱21.20/kg) and Saudi Arabia (₱17.40/kg). For frozen/chilled milkfish, most prices fell between ₱20 and ₱29/kg except for the USA, which bought at ₱15.50/kg, and the Netherlands, which paid ₱18.15/kg (Table 10).

Table 10. Export price of milkfish by country of destination.

Country	Price (₱/kg)
Live (fingerlings)	
Singapore	37.60
Taiwan	24-00
Frozen/chilled	
Belgium	20.60
Canada	22.00
England	21.50
Japan	29.10
Hongkong	22.90
Netherlands	18.15
Saudi Arabia	24.40
Singapore	20.50
USA	15.50
Dried	
USA	1.80
Canned	
Hongkong	11.20
Saudi Arabia	17.50
USA	24.10

Source: BFAR Fishery Statistics of the Philippines. 1977-81.

PROBLEMS CONFRONTING THE INDUSTRY

Various problems and risks confront the milkfish industry. Seasonal and geographical distribution of fry and fingerlings is the most common constraint. Operators are faced with other problems that are beyond their control and considered inherent in the area of operation, including frequent typhoons and flooding, the presence of acid sulphate soils, and extreme tidal fluctuations. Moreover, the lack of technical assistance seriously contributes to low production yields.

Inadequate credit, particularly for fishpond development and reconstruction, is another bottleneck for prospective operators. The inadequacy of financial assistance could disrupt the operation and thus incur more costs to the operator. Other constraints are related to marketing. These include deficient ice and storage facilities, an inadequate transport system, and limited processing plants for fish surplus. Poor market facilities cause further deterioration of fish, thereby forcing operators to sell their products at a low price and sometimes on credit.

POTENTIALS

The potential for expanding the milkfish industry in the Philippines cannot be overemphasized. There are indications which show that production targets for milkfish are realistic and can therefore be attained, among which are:

- Among the more progressive operators, milkfish production in ponds of 2000 kg/ha per year is easily attainable. Intensively fanned fishponds in Bulacan, Pangasinan, and Iloilo have repeatedly attained production performance of 3 t/ha per year (ICLARM-BAEcon-FIDC Milkfish Production Function Survey).
- Research is continuously discovering new technologies and improving existing ones.
    1. Research on induced spawning of milkfish and fry rearing under controlled conditions is actively gaining momentum. A series of experiments are being conducted at the SEAFDEC Tigbauan Research Station in an effort to increase the catch and survival of fry caught from the wild, induce maturation of captive milkfish, and develop techniques to induce spawning and rearing of larvae. All these studies could lead to an increased and more stable supply of milkfish fry.
    2. Polyculture of milkfish with other commercially important species such as prawn (*Penaeus monodon*) is now receiving wide attention. This production technique offers further possibilities for increased yield and efficiency. SEAFDEC is undertaking a research study on the production and economics of integrated farming of shrimp (*P. indicus*), milkfish, and poultry in brackishwater ponds which is already showing encouraging results.
- Support facilities, e.g., ice and cold storage plants, fertilizer and feed plants, fry banks, and hatcheries, are now being and will be established by both the government and the private sectors. Problems associated with transport, unavailability, and high cost of inputs and post-harvest handling activities are

expected to ease up with the presence of these infrastructure facilities, especially in areas where intensive culture will be promoted.

- Government programs to develop the industry further are in the pipeline. The ADB Aquaculture Development Project, which is currently being negotiated by the government, is aimed at intensifying production of existing brackishwater areas through provision of credit for fishpond reconstruction and cost of inputs, e.g., fry, fertilizer, etc. Likewise, extension and training programs are continuously being strengthened and improved to support the industry.

CURRENT DIRECTIONS

To attain the goals of the industry, government planners in cooperation with the private sector may consider the immediate implementation of the following important activities:

- *Effective technology transfer*

  Quite apart from the research findings of our institutions, there exists within the industry a wealth of applicable technology that can be harnessed to spread the benefits of science to the smaller operators in the interest of increasing their incomes, optimizing the use of given resources, and improving nutrition in the rural areas. There is a pronounced need for a mechanism for the effective industry-to-industry transfer of technology to supplement BFAR extension workers. A meaningful step toward this objective was taken recently when the fishpond federation officially agreed to make available portions of the ponds of active members for demonstration purposes, as detailed and formalized in a memorandum of agreement between the Philippine Federation of Fishpond Producers (now the Philippine Federation of Aquaculturists, Inc.), BFAR, and FIDC.

- *Responsive credit*

  The availability of institutional credit from government and private banks has stimulated industry development, albeit not yet at the desired pace, scope, and magnitude. However, surveys have shown that less than half of the total number of fishpond operators finance their development operations from funds borrowed from these institutions. Meanwhile, the repayment rate of rural bank credit has been a low 30%.

- *Efficient marketing*

  Improved marketing of milkfish can lower the prices and at the same time increase the producer's returns. The increase in income would come from a reduction of losses due to wasteful practices and unscrupulous trading manipulations. Moreover, an improved monitoring system of markets and prices of milkfish for the information of the fish farmers should be undertaken. At the same time, a system better than the currently practised open bidding system should be implemented to protect the fish farmers.

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WORKSHOP RECOMMENDATIONS

INTRODUCTION

The organizers of the conference deemed it necessary and relevant to hold a special workshop among the participating scientists, academicians, technicians, planners, administrators and fish-farmers toward the end of the conference. As a venue for the exchange of information and experiences, the workshop was a timely opportunity for the participants to assess the status of the milkfish aquaculture industry and milkfish research. Although a number of results, technological innovations and experiences have been accumulated since the First International Milkfish Aquaculture Conference, the workshop revealed that there is still much to be done in order to gain greater control of factors that will lead to better production. The outcome of the workshop is expected to provide planners, policy makers, and research institutions a more rational and scientific basis for planning milkfish aquaculture research and development.

ECONOMICS

The focus of the discussion concentrated on the issues of: (1) the lack of reliable data on the industry at both the macro level (national and regional) and the micro level (individual producers); (2) specifically, what kind of data need to be collected; how it shall be collected; the relative costs of different kinds of data collection; and how the data would be used; (3) what role the economist can play in future research on the milkfish industry; and (4) appropriate economic research methodologies.

It was concluded that, given the availability of data and the amount of economic research done to date, it is not possible or appropriate at this time for economists to make specific evaluations or recommendations to scientists or policy makers concerning the efficiency of production and marketing in the present industry. Nevertheless, the following recommendations are made:

I. Macro Data

Attempts should be made, particularly by the relevant national agencies and also possibly with external donor funding, to collect on a continuous basis secondary data on input prices, output prices, production, quantities of inputs, costs of marketing, retail prices, and product exports of the aquaculture industries in Asia, including milkfish.

II. Micro Data

More farm-level data need to be collected, but, as large baseline surveys can be expensive, time-consuming, and often out-of-date by the time the data are analyzed, the first step is to define how the data will be used.

III. Production Function

It was also decided that further research on the development and analysis of a production function approach to an initial understanding of existing milkfish operations, at the level of the individual operator, has important value in the economic analysis of the industry.

IV. Methodology

It was suggested that efforts be made to develop a "new" research methodology for milkfish encompassing two features not commonly found. First, the identification of the research problems of the industry and research to evaluate new culture techniques must be more multidisciplinary, involving biologists and economists. Second, the research must broaden its scope and not necessarily focus on a single commodity such as milkfish, but instead investigate the entire brackishwater aquaculture production and marketing system.

V. Training and Research

It was noted that, as a profession, fisheries economics is small in Asia relative to agricultural economics, and that the number of economists involved in the area of research is small. It is therefore suggested that more support be given to fisheries research, especially aquaculture research, and for the training of fisheries economists.

ARTIFICIAL PROPAGATION

The topics discussed were (1) induction of spawning, (2) induction of gonadal maturation, (3) larval rearing, and (4) sperm cryopreservation. The current status, available information, and problem areas encountered in the induction of spawning and gonadal maturation were discussed. Areas for further investigation were pointed out, as follows:

I. Induction of Spawning

A. Selection of spawners

1. Oocyte staging is required, and the usual procedure of intra-ovarian cannulation and measurement of the diameters of oocytes sampled are recommended.
2. The size of the spawner should be considered for practical reasons, since small fish are easier to handle. However, fecundity as a function of size may pose a constraint to selecting small-size breeders.

B. Hormones

A standardized procedure for induced spawning of milkfish is still lacking due mainly to the limited availability of fish for induced spawning trials.

1. To facilitate standardization, uniform preparation is suggested to be used by various institutions carrying out similar experiments for easy comparison of results. All relevant information in the experiment should be reported, e.g., fish weight, environmental conditions, dosage, time of injection, time interval between injections, and time to stripping or natural spawning.
2. Single hormone preparations such as HCG are preferable for practical reasons, but application may be limited to fish with oocyte diameters of around 0.8 mm or higher. Fish with oocyte diameters from 0.66 mm to 0.8 mm may still require salmon or carp pituitary homogenate as priming injections.
3. Differences in the response to hormone injections of fish grown at different salinities should be considered in staging fish for induced spawning. Those grown in brackish water may require an initial oocyte diameter of 0.72 mm before successful induction of spawning.
4. Possible differences between the responses of wild fish and captive stock should be considered, particularly as regards dosage needed.
5. Further studies on standardization of induced spawning procedures should therefore be carried out, particularly in view of the expected increase in the availability of captive broodstock for such purposes.

C. Time for stripping

1. Behavioral markers to indicate the best time for stripping seem to be inadequate since markers such as abdominal distention, drinking, and extrusion of calcium deposits indicate only hydration and not ovulation. The observed egg dribbling of injected milkfish may be a good reference point for the determination of the best time for stripping. Whether dribbling is a normal phenomenon is not known; studies should be conducted to investigate if egg dribbling will initiate spawning behavior in males through release of a pheromone.

2. Environmental triggers for natural spawning are not known and should be investigated.
3. Whether milkfish is a total spawner or an intermittent spawner is not known and should be studied.
4. Requirements for natural spawning regarding number of spawners, sex ratios, and space should be determined.

II. Induction of Gonadal Maturation

A. Nutrition

1. The quantity and quality of food and feeding regime for broodstock have to be worked out.
2. The nutritional requirements of broodstock are not known. As a start, diets may be formulated based on chemical analysis of the vitellogenic eggs.
3. Heavy feeding on a carbohydrate-lipid-rich diet in the initial stages of gonad development is proposed, to be followed by a lower rate of feeding with a protein-rich diet at the final stages of gonad development.

B. Environmental requirements

Gonad development seems to be independent of salinity.

1. Temperature, however, may be important. Similarly, photoperiod may be important. The effects of temperature and photoperiod on gonad development in milkfish should therefore be investigated.
2. The requirements for rematuration after spawning and the length of time required for rematuration are not known and should be investigated.
3. Space also appears to influence gonad development. The minimum requirement for swimming space should be determined.

PHYSIOLOGY

Discussion in the workshop covered the following stages: (1) eggs and larvae, (2) fry and fingerlings, and (3) juveniles and adults. Possible physiological factors affecting the survival and growth of milkfish at the different stages were discussed, and physiological studies were recommended as follows:

I. Eggs and Larvae

Not much is known about the physiology of eggs and larvae. Recommended studies are:

A. Environmental factors

1. Studies on salinity tolerance and optimum salinities at different stages of egg and larval development are needed. Efforts should be focused on the critical period in larvae. Factorial studies of salinity and other environmental factors such as temperature and oxygen should be done. The use of salinity in sorting viable eggs from dead ones needs to be investigated,

since viable eggs may float while dead eggs settle at the bottom at a given salinity level.

2. Factorial studies on tolerance and regulation of temperature and oxygen demand are needed to determine optimum levels during incubation and larval rearing.
3. The use of artificial diets may necessitate an appropriate design for incubation and larval rearing tanks that prevents settling of powdered feed and fouling of the water.

B. Organismic response

1. Studies should be made on the respiration and oxygen demand of eggs and larvae to determine the optimum stocking density.
2. Digestion studies such as determination of digestive enzymes, digestibility of feedstuffs, and assimilation of certain food organisms need to be done.
3. Studies on the circulatory system of larvae are required to understand the mechanism of osmoregulation.

C. Foods and feeding

1. Studies on suitable natural foods for larvae such as those that are digested by the larvae and can be mass produced should be done.
2. Studies are needed on the onset and timing of feeding by larvae.
3. Food preferences need to be known to determine suitable foods for larvae at different stages of development.

II. Fry and Fingerlings

A. Environmental factors

Factorial experiments on temperature, salinity, oxygen, and other factors are needed. These may have practical applications in reducing mortality during storage and transport.

B. Organismic response

1. Studies on respiration and oxygen demand are necessary to determine optimum stocking density.
2. Studies on digestive enzymes and digestibility of feedstuffs should be done.

C. Handling techniques

Stress markers should be detected by examining (1) changes in physical appearance; (2) physiological parameters such as Na, Cl, Ca, lactic acid, occult blood, and glutamic oxalo-acetic transaminase in the mucus, and during schooling; and (3) reduction of stress during harvest and transport by environmental manipulation.

III. Juveniles and Adults

A. Reproductive physiology

Basic studies are required.

B. Hormones and tranquilizers

To reduce mortality or stress in spawners caught by hook and line, apparently caused by circulatory system problems, hormones and tranquilizers should be investigated.

C. Digestibility of feedstuffs

Studies on digestibility of various feedstuffs are needed.

FRY ECOLOGY, COLLECTION, STORAGE, AND TRANSPORT

A knowledge of ecology is basic to a better understanding of milkfish. Milkfish life history still has big information gaps, particularly for the larval and sub-adult stages. SEAFDEC and other research institutions should undertake ecological studies. The fishermen are a good information source regarding the habits of milkfish; their reports should be verified by experimentation and then the results disseminated. Specific recommendations follow:

I. Fry Occurrence

How do milkfish larvae get from the spawning grounds to the fry collection grounds? There is some indication that fry may actually be carried passively by currents (passive migration hypothesis). At the same time, fry movement seems to be an active migration from open waters to sheltered nursery grounds. A very strong argument in favor of active migration is the very narrow size range of milkfish fry in shore waters (93% are 12-15 mm in length). It seems that only the larvae >10 mm in length undertake the shoreward journey. Studies are needed on milkfish larval behavior as well as the oceanographic conditions around the spawning and collection grounds to properly characterize fry migration. The environmental factors that influence fry abundance in shore waters need finer definition to improve fry fishery in terms of prediction of the place and time of abundance. An alternate to the exploitation of shore fry grounds is the exploitation of possible offshore fry resources. To do this, precise information on the vertical and horizontal distribution of offshore fry is required. It is interesting to note here that offshore fry exploitation is a rational scheme if passive migration is the dominant mechanism of fry occurrence. Fishing would be governed by chance. However, if milkfish fry actively migrate to coasts, collection should be confined to shore waters. It was reported that in the shores near the SEAFDEC Igang floating cages, the fry catch increased but the fry that were collected were smaller than usual and tended to die easily. Unfortunately, no fry sample was taken. This observation should be verified, as it may provide crucial data regarding active or passive migration as well as prove useful to the National Bangus Breeding Project of the Philippines.

II. Ecology

The ecology of the surf zone should be studied not only in terms of physical and chemical characteristics but also of biological interactions. This is important for resource management and conservation. The various species of fry that occur with milkfish should be utilized for aquaculture where possible.

III. Gear and Technology

The milkfish fry collection gear technology in the Philippines is presently at a high level of development. Some minor innovations that increase the catch or lower the mortality in certain localities should be transferred to and adopted in other localities where suitable. Fry collection, storage, and transport practices in the Philippines usually result in high mortalities prior to stocking in ponds. Techniques developed in Taiwan that result in very low mortality should be adopted in the Philippines and other countries.

CULTURE TECHNIQUES

The group examining culture techniques came up with the following recommendations:

I. Pond Engineering

Further engineering modifications on the modular pond system are still required, although this technique is already being practised by progressive fishpond operators. It allows better water management, provides a sturdier structure, especially against calamities like typhoons, and facilitates the more efficient culture of different cultivated species, either through mono- or polyculture.

A. Layout

Proper pond layout to suit specific stocks and production systems needs to be investigated.

B. Structures

Determination needs to be made of the most efficient and economical structural details of pond structures like dikes, gates, pipes, culverts, and canals.

C. Pumps

Proper and economic use of pumps in pond management should be followed.

D. Construction

The most efficient and economic methods of pond construction should be determined.

II. Acid Sulfate Soils

While a method to neutralize acid sulfate conditions in brackishwater ponds is now available, studies should also be directed to conditioning acid sulfate soils in freshwater pond areas.

III. Pond Management

A. Fertilization

Fertilization techniques and fertilizer management should be standardized.

B. Stocking

Appropriate stocking rates and pond management techniques should be determined, then standardized, especially under polyculture with compatible as well as with predatory species.

C. Feeds

Laboratory formulated diets or feeds should be tested through pilot studies in ponds, or given to the private sector for commercial application. The plankton or deep water method should be verified, then modified to suit local conditions.

IV. Economics and Marketing

The economics of deep-water methods should be studied. Special attention should be given to the economics of feeds and feeding and fertilizers and fertilization. Marketing studies should be undertaken to help the milkfish industry.

V. Diseases

With the intensification of pond operations, studies on diseases prevalent in ponds are recommended.

VI. Cooperation

An agency consisting of representatives from the private sector, the government, and research institutions and universities is proposed to facilitate solutions to the problems of fish fanners.

NUTRITION AND FEED DEVELOPMENT

Traditional aquaculture systems depend primarily on natural food bases. The upper limits of productivity under these systems have been reached by many progressive fish farmers. Technological advances for the enhancement and intensification of aquaculture productivity require a shift from natural food to artificial feeds. These advances can be achieved through a systematic research program on milkfish nutrition and feed development, active participation by all parties concerned, and the exchange of information, as presented below:

I. Research Directions

A. Nutrient requirements and metabolism

Research studies should focus on nutrient requirements and the metabolism of proteins and amino acids, lipids and essential fatty acids, and labile antioxidant vitamins. Information derived from these studies will allow feed manufacturers to develop nutritionally adequate grow-out diets for milkfish aquaculture.

B. Feed development

Research on feed development should be centered on larval and broodstock feeds. The development of larval feeds is particularly relevant since rapid advances in research on milkfish reproductive physiology is expected to cause a marked increase in the production of hatchery-bred fry in the near future. It was observed that feed manufacturers are well equipped to do R & D work on the development of milkfish grow-out feeds on a production scale. However, this does not preclude research agencies from conducting studies on grow-out feed development, although this may be limited to the pilot or experimental scale.

C. Digestive physiology

It is recommended that research studies be conducted on digestibility, digestive enzymes, nutrient bioenergetics, assimilation, and nutrient transport. These studies will further improve the data base concerning milkfish nutrition and feed development.

D. Nutritional deficiency diseases

The occurrence of nutritional deficiency diseases is expected to increase as milkfish aquaculture becomes more intensified. It is therefore necessary to develop the ability to diagnose diseases of milkfish that are caused primarily by nutritional deficiences. To achieve this goal, it is recommended that joint research studies on these diseases be conducted by fish nutritionists and fish pathologists.

E. Other research areas

Research work should also be conducted on the utilization, resource management, and quality control of local feedstuffs. Studies on substitution of high cost feedstuffs with low cost ones should also be done on a continuing basis. The economics of milkfish aquaculture productivity during the transition from low technology fish farming systems that require natural food bases to high technology systems that utilize manufactured feeds should be the subject of thorough research and should provide feedback information for the continued improvement of manufactured feeds.

II. Sectoral Roles

During the Workshop it was realized that the active participation of various sectors is necessary to promote steady technological advances in milkfish aquaculture. The sectors and their roles are:

A. Donor agencies

It is recommended that donor agencies such as IDRC, JICA, ICLARM, FAO, and USAID provide assistance in the form of funds, particularly for research equipment, manpower training, and information exchange programs such as conferences and workshops.

B. Research organizations

It was recognized that regional and national research organizations, most of which are funded by governments, remain at the forefront of generating research data on milkfish nutrition and feed development.

C. Universities

The university's most important role is in manpower training, although it was recognized that some universities have the capability to generate research data as well. It is recommended that the universities develop curricula that include basic concepts and recent advances in aquaculture nutrition and related sciences in order to catalyze and promote technological advances in the milkfish aquaculture industry.

D. The industrial sector

1. The various elements of the industrial sector that includes feed manufacturers, fish producers, and aquaculturists are the end users and beneficiaries of milkfish nutrition research data.
2. It was observed that there is some hesitancy on the part of milkfish aquaculturists to use manufactured feeds. Given this guarded attitude, a concerted multisectoral effort involving the research sector, feed manufacturers, and milkfish aquaculturists may hasten the development of economically feasible milkfish feeds. However, it is important to define in greater detail the role of each sector in such collaborative efforts to avoid complications arising from conflicts with the internal policies, practices, and traditions of each sector.
3. Many progressive aquaculturists favor manufacturing their own fish feeds using cottage or village scale facilities consistent with and limited to their individual requirements and production schedules. It is recommended that governments establish local feed analysis laboratories to provide a system for quality control of feedstuffs and feeds.

III. Information Exchange

A. Journals

The necessity for rapid exchange of information on milkfish nutrition was recognized at the workshop. The publication of research results in international journals of wide circulation and readership is deemed an effective mechanism for such an exchange.

B. Conferences

It was also observed that international, regional, and national aquaculture conferences provide an opportunity for the exchange of research results and experiences in milkfish nutrition. It is therefore recommended that the International Milkfish Aquaculture Conference be held on a periodic and regular basis.

C. Workshops

1. Regional workshops on aquaculture nutrition should also be organized within the framework of the policies and budgets of SEAFDEC member countries and donor agencies such as IDRC, JICA, ICLARM, FAO, and UNESCO.

2. National workshops on aquaculture nutrition should also be encouraged. Multisectoral representation at these workshops would promote a more dynamic flow of information and interaction between the research sector, the feed manufacturing sector, and aquaculturists.

PATHOLOGY

The group investigating milkfish pathology arrived at the following recommendations:

I. Description and Documentation of Diseases

A. Infectious disease research

1. Milkfish diseases in brackish water need to be explored, with priority given to bacterial and isopod diseases.
2. Milkfish infections in fresh water likewise need investigation, especially the parasite *Lernea* sp., fungal diseases, and Microcystis toxicosis.
3. Upgrading of diagnostic methods for prompt identification of pathogens must be done.
4. Researchers should study the influence of physiological factors such as pH, temperature, salinity, and stocking density in promoting or inhibiting the growth of pathogens in rearing systems.
5. We must assess the relationship of the host condition — in terms of critical growth stages, weight reduction, and mortality— to the effect of pathogens.

B. Nutritional disease research (please refer to the recommendations of the group examining Nutrition and Feed Development)

II. Prevention and Control

A. Identification of possible sources of pathogens, e.g., food, water, fish flora, etc.

B. Minimization of physical stress

C. Studies on effective drugs, fish tolerance to the chemotherapeutant, and practical administration techniques

D. Manipulation of salinity and stocking density

E. Immunization using endogenous pathogenic species

III. Relationship of Stress to Disease Development

A. Identification of stress factors introduced in culture such as handling, seining, transport, pollution, gas supersaturation, lesions produced by parasites, etc.

B. Practical methods of determining secondary levels of stress

C. Methods of minimizing stress during transport and harvest

CHAIRPERSONS AND PARTICIPANTS

CHAIRPERSONS OF THE SCIENTIFIC SESSIONS AND WORKSHOPS

Scientific Session	Chairpersons	Rapporteurs
Country Papers	T. E. Chua	R. D. Guerrero III
Artificial Propagation	J. V. Juario	J. F. Nacario
Physiology	R. P. Ferraris	R. R. Coloso
Culture	H. R. Rabanal	J. E. Banno
Nutrition and Feed Dev.	L. V. Benitez	F. P. Pascual
Pathology and Ecology	C. M. Kuo	A. L. Sanchez
Industry	C. MacCormac	K.C.Chong
Workshop		
Artificial Propagation	T.J. Lam	C. L. Marte
Culture	H. R. Rabanal	J. E. Banno
Fry Ecology, Collection Storage, and Transport	G. Kawamura	T. U. Bagarinao
Economics	C. MacCormac	K. C. Chong
Nutrition and Feed Development	L. V. Benitez	I. R. Gorriceta
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