

PROJECT: A.I.D./csd-2780

INTERNATIONAL CENTER FOR AQUACULTURE
RESEARCH AND DEVELOPMENT SERIES NO. 4
MARCH 1973

ARTIFICIAL SPAWNING of MULLET and CULTURE of MULLET and MILKFISH in TAIWAN



**International Center for Aquaculture
Agricultural Experiment Station
AUBURN UNIVERSITY**

R. Dennis Rouse, Director

Auburn, Alabama

COVER PHOTOGRAPH. Traditional method in Taiwan of stacking milkfish in baskets prior to marketing.

ARTIFICIAL SPAWNING of MULLET and CULTURE of MULLET and MILKFISH in TAIWAN

H. R. SCHMITTOU¹

INTRODUCTION

TAIWAN is advanced in various aquacultures. Its fish farmers are especially noted for their cultures of milkfish in brackish water and poly-cultures of Chinese carps in fresh water. Its research biologists have been among the leaders in developing shrimp culture and have been the most successful in artificially reproducing and raising mullet to food size.

Aquacultural facilities were toured in Taiwan during June 1971. The itinerary was developed by Mr. T. P. Chen, Director, Fisheries Division, Joint Commission on Rural Reconstruction. Mr. Chang-Jyi Chiou served as interpreter.

This report includes a summary on milkfish culture and the techniques used in artificially spawning and raising mullet in Taiwan.

CULTURE OF MULLET

The discussions of milkfish and mullet cultures were derived from observations and conversations with researchers and farmers in the field and from published literature.

Aquacultural potentials for milkfish and mullet are greater than those for most species. Both are hardy and respond well to management in confined environments. Both tolerate adverse conditions; the mullet tolerates colder temperatures, but the milkfish can live at much higher temperatures and salinities. Both have excellent consumer acceptance in the areas where cultured. Both are herbivorous, feeding primarily on benthic and planktonic organisms that can be cheaply produced.

In Taiwan no farms were visited where mullet was actually being cultured. Dr. I. C. Liao and his staff of Tungkuang Marine Laboratory, who were the first to successfully spawn mullet and raise the fry to fingerling size, were interviewed.

The techniques used in the artificial spawning and raising of fingerling mullet are summarized in this report. Very little is presented on mullet culture.

The striped mullet (*Mugil cephalus* Linnaeus) inhabits marine, brackish, and fresh waters of such diverse locations as India, Taiwan, Japan, United States, Israel, and the Soviet Union. It is a valued food fish in most of those areas.

The adaptability of mullet to varied environments, as well as its food habits, hardiness, market value, and other characteristics make it a popular pond fish in Taiwan.

In total production and value for all Taiwan aquacultures, mullet ranks third (2,200 metric tons and NT \$44 million²), milkfish first (19,000 metric tons and NT \$400 million), and oysters second (12,000 metric tons and NT \$121 million).

Mullet spawn at sea. It is believed that spawning occurs in the offshore waters of southern Taiwan. It is known that schools of mullet migrate southward into the Kuroshio Current from November to February. The peak of the migration is in late December and early January. Fish taken during the migrations have mature sperm and almost mature ova. The migrating fish are 4 to 5 years old with body lengths averaging 42 to 45 centimeters.

Fingerlings 2.5 to 3.5 centimeters long are collected from estuaries and coastal waters along the western coast from December to March. Usually the mullet are stocked in fresh-water ponds at 2,000 to 3,000/hectare in combination with the Chinese carps. Annual yields of mullet/hectare range up to 150 kilograms without fertilization, 400 kilograms with fertilization, and 1,500 kilograms with feeding.

Striped mullet can tolerate water temperature extremes from 4° to 35° C, but the optimum water temperature for growth is about 23° C. Salinities of 0.1 to 38 p.p.t. are tolerated by adults. Young fry will not tolerate salinities below 17 p.p.t.

The annual demand in Taiwan for stocking ponds is for about 7 million mullet fingerlings. Some years the demand is not met. For this and other reasons, research was begun to artificially spawn and raise mullet for stocking size. This work began in 1963, and involved the cooperative efforts of the Taiwan Fisheries Bureau, the Taiwan Fisheries Research Institute (TFRI), and the Institute of Fishery Biology, National Taiwan University. Their early work on induced spawning resulted in producing fry, but no fry survival. In 1967 one fry out of millions hatched survived for 23 days. The work was transferred to the newly constructed Tungkuang Marine Laboratory of the TFRI in 1968 where the work was supported primarily by the Rockefeller Foundation. That year, 2 fingerlings (1.0 and 1.1 centimeters in size) were kept alive for 30 days. The following year a total of 431 fingerlings that ranged in size up to 28 centimeters and 217 grams 200 days after hatching survived. In 1970 approximately 50,000 fry reached a length of 1 centimeter (27 days).

The techniques and procedures for artificially spawning and raising mullet to fingerlings were as follows (Dr. I. C. Liao, Director, Tungkuang Marine Laboratory):

¹Assistant Professor, Dept. of Fisheries and Allied Agriculture; serving as Chief of Party, AU-Government of Philippines Inland Fisheries Project, Manila.

² NT (New Taiwan) \$40.00 = \$1.00 U.S.



The culture of mullet is becoming increasingly popular in Taiwan since successful methods of producing fry in hatcheries have been developed.

1. Brooder mullet weighing 2 to 3 kilograms each were collected by commercial fishermen during the spawning migration lasting from November to January.

2. Brooders were selected for sexual maturity, and were held on board the fishing boat in oxygen-plus-water-filled plastic bags.

3. After the boat docked, the brooders were transferred to holding tanks.

4. An injection of 2.75 to 5 mullet pituitary glands mixed with 20 to 50 rabbit units (RU) of synaborin was given each female mullet after about 1 hour in the tank.

5. A second injection using the same amount and combination of materials was given within the next 24-hour period.

6. The females were examined at 2-hour intervals for ovulation.

7. Where ovulation was noted, sex products were taken simultaneously from both sexes by stripping, and the dry method of fertilization was employed (approximately 65 per cent of the females ovulated; 65 per cent fertilization rate was obtained).

8. Fertilized eggs were transferred to plastic tanks of 0.5 to 1 ton volume, containing water 22.5° to 24.5° C and 30 to 34 p.p.t. salinity.

9. Hatching occurred in 34 hours at 24.5° C and in 54 hours at 22.5° C.

10. Salinity of water was gradually reduced by the addition of fresh water from the 6th to the 45th day following hatching; during that period, salinity was reduced from approximately 32 to 3.4 p.p.t. Salinity must not drop below 17 p.p.t. during the first 15 days following hatching.

11. For raising newly hatched fry to fingerlings, two types of facilities were used: indoor tanks of 0.5 cubic meter capacity; and outdoor pools 7 x 5 x 1.5 meter, with 52.5 cubic meter volumes.

12. The third day after hatching, the mouth is formed. Fry are fed to satiety on the third and fourth days with oyster larvae, on the fifth day with rotifers. By this time the yolk-sac is absorbed. On subsequent days, they are fed with rotifers and *Artemia nauplii*.

13. Fry show a positive phototrophic response to light at intensities of 600 to 1,400 lux (56 to 130 foot candles).

14. Fry reach 5 millimeters in 19 days; scales begin to

develop on the 23rd day; soft-rayed fins appear on the 25th day; body completely scaled on the 27th day; fingerling ready for stocking in production ponds in 40 to 45 days.

Embryonic development of *Mugil cephalus* at temperatures ranging from 20° to 24.5° C is summarized as follows:

Stage	Time after fertilization	Comments
1-cell	1 hr. 30 min.	1st cleavage-egg 0.7 m.m. diameter
4-cell	1 hr. 50 min.	2nd cleavage
8-cell	2 hr. 10 min.	3rd cleavage
16-cell	2 hr. 30 min.	4th cleavage
32-cell	2 hr. 50 min.	5th cleavage
late segmentation	3 hr. 50 min.	blastodisc 3-storied blastomeres
blastula	8 hr.	periblast distinct
gastrula	9 hr. 30 min.	blastodisc expanding over yolk sphere
	11 hr.	germ ring formed
	14 hr.	blastodisc covering ¾ of yolk sphere
embryonic body	15 hr.	embryonic body distinct in front
optic vesicle		
myotome	16 hr. 30 min.	optic vesicles apparent; myotomes number 3-4
otic vesicle	17 hr. 10 min.	pair of otic vesicles apparent; myotomes 6-7
	32 hr. 40 min.	melanophores on oil globule
brain division	33 hr. 40 min.	brain divisions (fore, mid, hind) apparent; pulsating rear of embryo separating from yolk
	48 hr.	embryo covering ¾ yolk sphere
membranous fin	50 hr.	embryo body covering all yolk sphere; membranous fin apparent in rear part
	54 hr.	tail end of embryo grows to optic cups
hatching	59 hr.	embryo emerges tailfirst through chorion; fry at hatching about 3.0 m.m.

CULTURE OF MILKFISH

The milkfish (*Chanos chanos*), although cultured almost exclusively in Taiwan, Indonesia, and the Philippines, is the most important marine and brackish water species cultured in the world as far as total production is concerned. It is by far the most important species of fish cultured in Taiwan from the standpoints of food produced and economics. The production in 1969 of 18,995 metric tons of milkfish was greater than for any other single species. It was 33 per cent of the total Taiwan aquacultural production of 57,064 metric tons. Monetary value of the 18,995 metric tons was placed at NT \$395.5 million or about 43 per cent of the total value of aquacultural production.



Basket of milkfish is weighed prior to sale. This is the most important fish species cultured in Taiwan with approximately 19,000 metric tons, with a market value of NT \$395.5 million (about \$9.9 million U.S.), produced from ponds during 1969.

Commercial Harvest

Catches of adult milkfish on the high seas have not been reported. Reports are common of an occasional catch near shore. Schools of large fish have been observed offshore with their dorsal fins above water—a characteristic of milkfish. Large fish have been caught by long-lines and trawls operating from harbors in Taiwan. Milkfish have also been taken with stake traps, liftnets, seines, harpoons, and even explosives. However, the catching of milkfish by means other than harpooning is accidental and there is no commercial operation for harvesting natural stocks of adult milkfish.

Biological Information

Distribution. Milkfish are distributed throughout the tropical and subtropical waters of the Indian and Pacific Oceans. They are not found in the Atlantic Ocean.

Life History. Very little is known concerning the life history of milkfish. Spawning occurs from April to August with a peak in late April and early May. They spawn offshore in clear, relatively shallow water where there are sandy or coral bottoms devoid of vegetation and where salinity is 32 to 33 p.p.t. Sexual maturity is thought to be at about

6 years of age. The smallest and largest gravid females ever recorded were 94 and 124 centimeters (about 9 and 12 kilograms), respectively. Recorded weights of ovaries of gravid fish have ranged from 0.5 to 1.5 kilograms. Estimated number of eggs ranged from 3 to 7.3 million/female. The high fecundity suggests low survival to sexual maturity.

The eggs are pelagic and about 1.1 to 1.2 millimeters in diameter. They hatch in about 12 hours. The fry are 3 millimeters at hatching; 5 millimeters at three days; and about 10 millimeters when 10 days old. The fry found along the sandy beaches and estuaries are 10 to 13 days old and a minimum of 10 millimeters in length. Fry are always found in clear water over sandy bottoms; they are never found in silted waters or over mud bottoms.

Feeding Habits. As fry, milkfish feed on plankton and microscopic and small macroscopic benthic organisms. Diatoms are apparently their primary food source. Feeding habits of the adults change very little from that of the fry. In their natural habit, milkfish are believed to be primarily benthos consumers, feeding on diatoms and blue-green algae. Animal organisms consumed are considered to be incidental admixtures to the vegetative diet. However, such organisms as Foraminifera, Lamellibranchiata, Gastropoda, Copepoda, larval bivalves, and eggs of fish are found in digestive tracts of milkfish. Also found are mineral particles, detritus, and fragments of multicellular vegetation. Vascular plants and certain filamentous algae are apparently taken only after the plants have begun to decay. Milkfish apparently feed, in order of preference, on organisms on the bottom, in the mid-water, and on the surface.

It is reported that milkfish are diurnal and all stages feed exclusively during the daytime.

Environmental Tolerance. Milkfish have unusual tolerance for wide fluctuations in the environment, much more than most marine animals. They are reported to tolerate ranges of salinity from 0.1 to 120 p.p.t. They can live in water up to 40° C; however, they become sluggish at temperatures below 20° C. Sudden drops in temperatures have been known to cause discoloration, temporary blindness, and shedding of skin layers.

Fry Collection and Marketing

The collection and marketing of milkfish fry for stocking into ponds are special phases of the milkfish farming industry.

Collection of Fry. The fry are necessarily collected from coastal waters since artificial means of spawning milkfish are yet to be developed. The fry are collected during the months of April to October, with a peak season in May and June. Collecting grounds are the surf and shallow areas along the sandy beaches of the southern half of the country.

Scoop nets are employed for collecting milkfish fry near the Tungkang Marine Laboratory, where about 20 collectors work. Their scoop nets are constructed of bamboo poles and coarse cloth. Each is constructed by forming the poles into an X-shaped frame and attaching the cloth to form a bag in one-half of the X frame. The other half of the frame serves as handles. The triangular scoop is approximately 2 meters wide at the base and 2 meters deep.

The nets are pushed along slowly in shallow, sandy areas in water ankle-deep to shoulder-deep. Each net is fished for 10 to 15 minutes before the catch is removed. Fish within the net are harvested by gathering the netting into a small bag of about 2-liter volume while simultaneously lifting the

gathered net, thus forcing the catch into the resulting bag. The contents are then transferred to a container of approximately 4-liter volume for transport ashore.

The contents of the 4-liter container are carefully examined for the very slender, almost transparent fry of about 10 to 13 millimeters total length. Milkfish fry and post larvae *Penaeus monodon* are transferred to a holding container also of about 4-liter volume. The desired organisms are difficult to see among the debris and undesirable organisms such as seaweed, young of other fishes, and shrimp. Two fry per haul appears to be the average catch. This separating process requires about 5 minutes, after which the fishermen return to seining. At this rate of collecting and separating, each fisherman harvests about 100 fry in a 10-hour day. One fisherman stated that he collects from 20 to 2,000 fry per day, depending on the conditions and season.

Milkfish fry come into the shallow waters only during periods of high tides. Best catches coincide with the highest tidal levels at full and new moons. Also better catches are obtained when winds are parallel to the coast rather than when perpendicular. Fry collecting was reported to be poor during storms, but better than normal during soft rains.

Fry Markets. Fry collectors sell to dealers specializing in marketing fry to fish farmers. Fry are brought to a market in Taiwan in clay jars of about 8 liters. The fry are counted into concrete holding vats 1 meter wide, 1.5 meters long, and 8 centimeters deep. Each vat holds without aeration approximately 30,000 fry in clear seawater. The fry are fed twice daily with small amounts of wheat flour. The fry collectors receive about NT \$40 (\$1.00) per 100 fry. The fry dealer in turn sells to farmers at about NT \$60 (\$1.50) per 100. Of course, prices fluctuate with fry availability. The dealer at the largest market had sold in excess of 300,000 fry on the day prior to this visit and had marketed up to three times that number in a single day. All fish sold are individually counted by men singing aloud the running count.

Culture Methods

Ponds. There is an estimated 19,500 hectares of milkfish ponds in Taiwan. These are distributed primarily in the tidal flats along the west coast of the Chai-Nan Plain. About 80 per cent of all the milkfish ponds are in that area, perhaps because it has good topography, good soils, and is protected from strong winds and high tides that result from storms. After World War II, many milkfish ponds were constructed by converting basins of abandoned salt ponds that existed along the coast. In recent years, however, culture ponds have been constructed specifically for the purpose of raising milkfish. Most of the sites are in reclaimed mangrove swamps that are relatively poor land for other purposes.

The tidal flats are level and thus present no problems so far as topography is concerned. The soils are primarily of tight clays suitable for ponds. Ponds can be filled and drained easily. Neap and spring tides, which determine pond bottom elevations, are 0.69 and 0.85 meter, respectively. Optimum range for pond bottom elevations is approximately 0.0 to 0.50 meter above sea level. Pumping to completely fill or drain is usually necessary in ponds with bottom elevations above 0.5 meter or below -0.2 meter.

Water of good quality is also no problem. Pollution is not significant in the area. Optimum salinity for culture is considered to be between 10 and 32 p.p.t. Milkfish acclimate easily to changes in salinity and tolerate extremes of 0.1 to 120 p.p.t. Poor growth is obtained above 70 p.p.t. Optimum

salinity is determined not only by reaction of fish, but also by salinity effect on the pasture algae. The fish can tolerate much greater changes in salinity than the food organisms can. During the wet season, pond salinities may range downward from 50 p.p.t. in May to 5 p.p.t. in September, and then may rise to over 70 p.p.t. in the dry season from October to May.

Temperatures around 32° to 25° C are considered optimum, but the milkfish become sluggish at 20° C, paralyzed at 13° C, and die at 12° C. The upper lethal level is at 41° C.

Oxygen requirement of milkfish is apparently low; a liter of clear water at 25°C is sufficient to support 1,000 fry without aeration. However, suffocation is not uncommon where fish are in silty water of low oxygen content. Optimum pH is thought to be from 8.0 to 9.0.

Milkfish farms vary considerably in size and arrangement, but all consist of at least one of each of the following: water supply canal; nursery pond; production pond; and wintering pond.

Production ponds may be from one to several hectares in area. Water depth usually is about 30 centimeters and seldom exceeds 60 centimeters. These ponds are easily made larger or smaller by simply adding or partially removing a dike. Secondary dikes are low and narrow. Passages between ponds are made or eliminated in only a matter of minutes by simply removing a section of dike separating the two.

Wintering ponds appear as supply canals and perhaps would be mistaken as such except for the slanting, straw-thatched bamboo, wind-breaks. The windbreaks help shield the ponds from winter winds prevailing from the northeast. These ponds are usually about 5 meters wide, 100 meters long, and 1 meter deep. They are not as subject to rapid changes in temperature and salinity as the much shallower nursery and production ponds.



Workers are constructing a framework of bamboo poles over which is placed a layer of rice straw. When completed, this structure provides an effective windbreak and reduces fish mortality in wintering ponds.

Stocking Nursery Ponds. Fish farmers stock the newly collected fry into nursery ponds at densities of 300,000 to 500,000 per hectare. After 2 to 3 weeks, or as needed, the fry are transferred to production ponds. The fry are expected to triple in length in 3 weeks from about 13 millimeters to 40 millimeters.

Management of Production Ponds. Milkfish culture has been compared to cattle farming in that good growth of pasture is the basis for efficient production of both. The pasture for milkfish is the pond benthos consisting primarily of blue-green algae and diatoms. Milkfish production is considered to be directly proportional to benthos production. Rather definite standard techniques are used by the farmers to produce pasture benthos in the ponds.

The preparation of the pond bottom and subsequent growing of the pasture are programmed to fill the 5-month off-season period from harvesting in mid-October to stocking in mid-March.

The growing season in Taiwan is from March to October. Three harvests are routinely obtained from production ponds during each growing season. These crops are produced in the same pond and each overlaps the other to some extent.

Approximate dates for each operation are as follows:

- October 15..... Ponds are left to dry after fish are harvested.
- November 1..... All except the wintering ponds are practically dry; necessary repairs are made on dikes and gates.
- November 15..... Pond bottoms are raked smooth and sloped only slightly toward the drain; the pond is left to dry completely. (Open cracks develop in the clay soil as drying occurs.)
- December 1..... Sea water is flooded over the pond bottom to a depth of about 10 cm.; the water is allowed to evaporate leaving the pond dry and hard. Drying produces the firm surface required for maximum benthos production and adds valuable amounts of organic and inorganic materials that enrich the soil after the water evaporates.
- February 1..... Organic materials such as rice bran, chicken manure, straw, grass, sugar cane, night soil, and/or inorganic fertilizers are spread over the pond bottom; sea water is again flooded over the bottom to a depth of about 10 cm. and again allowed to evaporate.
- March 1..... The fertilizing-flooding process is repeated.
- March 7..... Water depth is increased to about 15 cm. with additional sea water. Tobacco wastes or crumbles of tea (*Camellia*) seed cake at a rate of 180 kg./ha. are broadcast over the pond to eradicate any fish that might be present. Shallow water depths are maintained to favor benthos growth over that of plankton.
- March 15..... A last fertilization treatment is given prior to the first stocking about March 20. A profuse growth of pasture benthos exists at this stage.
- March 20..... The first stocking is made with 3,000 fingerlings/ha. The fingerlings average about 12 to 15 cm. They are stocked from overwintering ponds after having been cultured in production ponds from June to October of the previous season. These fish constitute the last half-crop of the previous year and the first crop of the current season. They will be harvested for market in late June.
- April 1..... Organic and inorganic fertilizers are applied.
- April 15..... Another application of fertilizer is given; water depth is increased from 15 to 20 cm.

with addition of sea water. The second stocking is made with 5,000 fry/ha. The fry which are 1 to 4 cm. in size are stocked as obtained or from nursery ponds and are young-of-the-year fish. These fish will be harvested in mid-September and compose the one full crop produced in the season.

- May 1..... An application of fertilizer is made.
- May 15..... An application of fertilizer is made if needed.
- June 1..... A supplemental feeding program is begun using rice bran and soybean cake.
- June 15..... The third and last stocking is made with 3,500 fry/ha. These fry are also young-of-the-year fish and are stocked from the nursery. These fish will be harvested in October and the smaller ones transferred to wintering ponds.
- June 30..... The first harvest is made which consists of the fish stocked in March.
- September 15..... The second harvest is made which consists of the fish stocked in April.
- October 15..... Pond is drained and marketable fish are sold and sub-marketable fish, consisting primarily of fingerlings from the June 15 stocking, are transferred to an overwintering pond.

Harvesting. Milkfish are removed from the ponds generally in three harvests: the first in June; the second in September; and the third in October. In June, the overwintered fish stocked in March are harvested. They average about 250 grams per fish. Gill nets of monofilament mesh are used. Mesh size is such that only marketable fish are taken.

The second harvest is in September when the fish stocked in April are harvested. Gill nets are again used to selectively harvest fish, 150 grams and larger.

Total production per hectare is reported to average about 1,800 to 2,000 kilograms/growing season. However, the 1969 Fisheries Yearbook published by the Taiwan Fisheries Bureau listed 16,298 hectares in milkfish production and 18,995 metric tons produced (1,165 kilograms/hectare).



Milkfish pond being harvested by fishermen with gill nets. Size of net mesh permits fish that are below marketable size to pass through.

Survival of Different Sizes of Milkfish. Survival of milkfish is apparently very good although the fish appear to be fragile. Disease and parasites are considered incidental by both the farmers and the technical people. They consider mortality to be due primarily to predation and mechanical causes. The following is the expected mortality for different sizes of fish under specific conditions:

<i>Mortality</i>	<i>Fish size and conditions</i>
1 to 2 per cent.....	Fry transported from collecting grounds to market and then from market to nursery.
20 per cent.....	Fry of 10 mm. to harvest size of 150 g. in production ponds.
2 per cent.....	Fingerlings of 12 to 15 cm. to harvest size of 250 g. in production ponds.
2 per cent.....	Fingerlings of 12 to 15 cm. in overwintering ponds.

ITINERARY

June 2, 1971.....	Arrived Taipei, Taiwan
June 3.....	Joint Commission on Rural Reconstruction (JCRR) Taoyuan Fish Propagation Administration
June 4.....	JCRR
June 7.....	Chupei Fish Culture Station
June 8.....	Tsengwen Tidal Land Milkfish Farms Markets for milkfish fry Privately owned freshwater fish farms
June 9.....	Washan Tou Fish Hatchery Markets for milkfish fry
June 10.....	Tungkang Marine Laboratory
June 11.....	JCRR Departed Taipei, Taiwan