Milkfish (*Chanos chanos*) Culture: Situations and Trends

Franklin S. Martinez¹, Mei-Chen Tseng²* and Sin-Ping Yeh²

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**ABSTRACT**

In this article, we present an overview of milkfish (*Chanos chanos*) culture, in order to provide basic information on its life history, reproductive biology, fry production, culture methods, and genetics as well as its commercial importance. Milkfish is a warm-water marine species, and its culture is widespread in the Asian-Pacific region; it is a unique species in the family Chanidae. Currently milkfish is an important brackish water aquaculture species in Southeast Asia and represents an important component of the fisheries sector and national economy in Indonesia, the Philippines, and Taiwan; in Taiwan, annual total production has surpassed 450,000 metric tons since 2000. However, milkfish production is faced with limitations, the most significant of which is the unpredictable and limited supply of fry. Milkfish production comes mostly from aquaculture, and the availability of fry for stocking plays an important role in the success and development of the industry. Traditionally milkfish production relied on the capture of fry from the wild; but important attempts have been made to develop milkfish broodstock-hatchery technology, and significant successes have been achieved in the artificial propagation of this species.

**Key words**: Milkfish, *Chanos chanos*, Life history, Reproductive biology, Culture methods.

**GENERAL BIOLOGY**

The milkfish (*Chanos chanos*) belongs to the order Gonorynchiformes and is the only species of the family Chanidae (Leis and Reader, 1991). Milkfish are widely distributed throughout the tropical and subtropical Indo-Pacific oceans, being found on the coast of Africa, as far east as the Pacific waters of Central America, and as far south as Hawaii, Mexico, southern Australia, and New Zealand (Nelson, 1994; Lee, 1995).

In the life history of the milkfish, different stages can be described based on their morphological characteristics and ecological requirements (Fig. 1) (Lee, 1995). The larvae and juveniles spend their lives in inshore estuarine areas and then migrate into rivers in the direction of fresh water (Lin et al., 2003; Pillay and Kutty, 2005).

The natural spawning season extends from April to September in Taiwan (Tucker, 1998). Spawning probably occurs near the sea surface (30–40 m in depth), and the female produces millions of eggs that hatch within 24 h into yolk sac larvae (Landau, 1992); these are essentially planktonic and their distribution mainly depends on water movements. When larvae begin exogenous feeding, they become more-active swimmers which makes possible their migration from the spawning grounds to coastal waters. Fry are primarily selective planktivores and are mostly found in aggregation areas in superficial water close to shore. Metamorphosis occurs when the fry have left the aggregation areas and then they grow into juveniles, which are primarily

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1 Department of Tropical Agriculture and International Cooperation, National Pingtung University of Science and Technology, Pingtung, Taiwan 912, R.O.C.
2 Department of Aquaculture, National Pingtung University of Science and Technology, Pingtung, Taiwan 912, R.O.C.
* Corresponding author. E-mail: mctseng@mail.npust.edu.tw
benthic algal filter-feeders. At this point, juveniles are found in large quantities in coastal estuaries, mangrove areas, coastal lagoons, and swamps and begin moving upriver into lakes. Then juveniles develop into subadults at different sizes (200~4500 g) and at different ages (1~4 years). Most subadult fish leave the inshore environment and return to the ocean where they survive on a diet of plankton and eventually spawn; but other milkfish remain in fresh water (Lee, 1995).

Milkfish spawn in clear oceanic waters, usually at less than 40 m in depth over sand or coral about 30 km offshore during the warm months of the year (Landau, 1992). Despite this species being able to tolerate a wide range of environmental conditions, there are many factors which affect milkfish’s selection of spawning grounds; temperature is one of the most important factors, with limits reported to be from 15 to 40°C, but the ideal temperature is between 20 and 33°C with an optimum for spawning of 28°C (Landau, 1992; Lee, 1995). Other factors such as currents and wind may also influence the selection of spawning areas in order to ensure the survival of eggs and larvae (Lee, 1995).

The natural spawning seasons differ according to milkfish populations (Fig. 2); the reproductive status can be determined based on different criteria; but histological examination of gonadal development is considered the most accurate method of determining spawning seasons (Lee, 1995). Milkfish are able to spawn more than once during the annual spawning season (Lee et al., 1997). Prijono et al. (1988) demonstrated that spawning occurred on nine occasions within 4 months after stocking in a group of wild brood stock (specimens with a weight

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**Fig. 1.** Life history of milkfish represented by seven developmental stages from embryo to adults (modified from Lee, 1995).

**Fig. 2.** Spawning season (months) of different milkfish population (Lee, 1995; Tucker, 1998).
The genetic diversity of milkfish has mainly been investigated in the Philippines and some others Pacific Islands (Lee, 1995). In order to study the genetic variation of milkfish populations, Lee (1995) evaluated adult specimens which were collected from 14 locations: the Philippines (Sulop, Zamboanga, Cayagon de Oro, Argao, Ormoc, Hamtique, Mercedes, and San Thomas), Equatorial Pacific Islands (Palau, Tarawa, Fanning Island, and Christmas Island), and the Hawaiian Islands (Hawaii and Oahu). Every sample was monitored for 20 enzymes and protein systems representing the gene products of 38 gene loci by starch gel electrophoresis. Cluster analysis was used to analyze the data from the electrophoresis in order to estimate the genetic associations among groups. The results showed that the Philippine group was closer to the Equatorial Pacific Island group than to the Hawaiian Island group. Moreover, a series of studies was conducted to evaluate variations in vertebral numbers of milkfish fry, and at least eight different populations were identified across the Indo-Pacific Ocean: India, Thailand, Philippines-Taiwan-Indonesia, Tahiti, Kiribati, Tonga, Hawaii, and Panama (Lee, 1995).

### CULTURE METHODS

The milkfish is a marine inhabitant commercially cultured in brackish-water ponds and oceanic waters as well as in hyper-saline lagoons (Lin et al., 2003). Milkfish can tolerate salinities of 0–158 ppt (Lin et al., 2001). Fry, juvenile, or later stages of development can survive well in fresh water, which indicates that they can be cultured in freshwater ponds or stocked in cages in freshwater lakes and reservoirs (Alava, 1998; Lin et al., 2003). Marine or freshwater adaptation by euryhaline teleosts is a complex process involving a set of physiological responses related to ionoregulatory requirements; nevertheless, the milkfish is considered to be an efficient osmoregulator with a high capacity for adaptation to freshwater production systems (Lin et al., 2003). Apparently, small milkfish tend to adapt better to fresh than to hyper-saline water and larger milkfish find hyper-saline water less stressful than fresh water (Ferraris et al., 1988).

Alava (1998) demonstrated that salinity had significant effects on the growth and feed conversion rate (FCR) of milkfish fry. The highest growth and lowest FCR were observed in fish reared in fresh water (Fig. 3).

![Fig. 3. Effects of salinity on growth and the feed conversion rate (FCR) of milkfish fry. Different letters indicate a significant difference at $p < 0.05$ (modified from Alava 1998).](image-url)
According to this author, the maintenance of ionic and osmotic equilibrium at lower salinities (of 0~16 ppt), probably requires less energy than in seawater at 34 ppt resulting in better growth; this is probably related to the habitat preference in the development of wild fry; which normally terminate their pelagic phase of life and begin moving to estuarine or freshwater environments at 18~21 days old.

Many commercial farms in the Philippines and Taiwan now stock between 0.1 and 4.0 fish/m² depending on the intensity of the production systems. The movement from extensive to intensive systems has been achieved with the increasing use of fertilizers and feed, and provision of extra systems such as aeration and pumps (Sumagaysay-Chavoso and San Diego-McGlone, 2003).

Table 1 describes the milkfish culture methods, the stocking density, and the yield production for the major milkfish producer countries (the Philippines, Indonesia, and Taiwan). Milkfish is commonly cultured in different systems as described by Lee (1995).

- **Shallow-water culture.** Production ponds have a water depth of 30~40 cm. In this method, fry are stocked at a density of 1500/ha, and algae are provided as the main source of natural food in fertilized brackish-water ponds.
- **Deep-water culture.** Ponds have a water depth of 200~300 cm, fry are stocked at a density of 10,000/ha, and management is similar to that of shallow-water culture, but artificial feed is also offered at a daily feeding rate of 2~4% of biomass.
- **Pens.** In this system, fish are confined in circular, square, or rectangular pens surrounded by nets, and feeding management is like that of deep-water culture, but stocking density is higher than that used with deep-water culture (30,000 fry/ha).

### Wild seed collection

As milkfish seems to spawn in the sea near coastlines, fry (10~15 mm in length) periodically occur along sandy coasts and estuaries (Bagarinao and Kumagai, 1987; Garcia, 1988). Fry collection has been an important industry in Indonesia, the Philippines, and Taiwan (Bagarinao and Kumagai, 1987), but the occurrences vary depending on the spawning seasons according to each region (Lee, 1995).

The most common equipment for fry capture includes different types of deep nets; these nets are located in areas where large concentrations of fry occur. Villaluz (1988) and Lee (1995) described various fishing mechanisms used for capturing fry; which are classified according to their function.

- Fry barrier or fences are fixed structures that guide fry into a concentrated area depending on favorable conditions of wind and currents.
- Filters bags are mobile bag nets which concentrate fry while they are passing in the course of the water.
- Seine, scoop, or drags nets are also used in the collection of fry.

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

(FitzGerald, 2004)

<table>
<thead>
<tr>
<th>Country</th>
<th>Culture method</th>
<th>Stocking density (fish/ha)</th>
<th>Production (kg/ha/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indonesia</td>
<td>Extensive (shallow-water)</td>
<td>6000</td>
<td>300~1000</td>
</tr>
<tr>
<td>Taiwan</td>
<td>Extensive (shallow-water)</td>
<td>6000~7000</td>
<td>1800~2500</td>
</tr>
<tr>
<td></td>
<td>Semi-intensive (deep-water)</td>
<td>&gt; 25,000</td>
<td>8000~12,000</td>
</tr>
<tr>
<td>Philippines</td>
<td>Extensive</td>
<td>1500~6000</td>
<td>800~4000</td>
</tr>
<tr>
<td></td>
<td>Pen</td>
<td>30,000~40,000</td>
<td>2000~10,000</td>
</tr>
<tr>
<td></td>
<td>Cage</td>
<td>35~100 fish/m³</td>
<td>13~17 kg/m³</td>
</tr>
</tbody>
</table>

Note that the production varies within and between these countries, which can be explained by differences in production efficiency in each country.
portable nets which surround groups of fry and conduct them into a small area.

**Fry production through induced maturation and spawning of brood stock**

Even though artificial propagation has progressed in the last two decades, a source of wild fry is still required in some locations (Leis and Reader, 1991; Lee et al., 1997). Nowadays the production of fry is possible due to the capture of subadults from the wild and their rearing until they become sexually mature. Adults naturally mature during the spawning season when they reach 3 kg or more at 4 and 5 years old for males and females, respectively. Maturation can also be induced through the use of exogenous hormones such as luteinizing hormone-releasing hormone (LHRH-a), fish pituitary gonadotropin (salmon pituitary homogenate and carp pituitary homogenate), human chorionic gonadotropins (HCGs), and gonadal steroids (estradiol 17-β and 17 α- methyltestosterone), as well as through environmental stimulation, such as temperature and manipulating the photoperiod in order to increase the number of daylight hours (Lee, 1995). Milkfish seem to be a gonochoristic species. Determination of sex is important for the successful breeding in captivity; sex can be distinguished by external characteristics such as the presence of three minute opening pores in the urogenital region in females, while the males only have two main external openings (Garcia, 1988; Lee, 1995).

Once milkfish have matured, in order to accurately determine the time for spawning, it is better to induce spawning in females by the administration of exogenous hormones (fish pituitary gonadotropins, HCGs, and LHRH-a). Hormone therapy can be administered through food, pellet implants, and intramuscular and intraperitoneal injections. Different dosages have been studied; but 200 µg/kg using a pellet implant or injection seems to be a better dose in terms of fertilized spawn and fertilization rate. Fish spawn 24~48 h after treatment depending on the hormone therapy. A mature female can spawn 2 million eggs/kg of body weight per year (Lee, 1995).

Lee et al. (1997) and FitzGerald (2004) described two basic hatchery operation methods for producing milkfish fry: intensive and semi-intensive. In the intensive system larvae are stocked at a relatively high density of 20~30 larvae/l, and tanks are employed for larval rearing with the addition of separately cultured algae, rotifers, and Artemia at different stages during the culture period (Fig. 4). In the semi-intensive system, a pond is

![Fig. 4. Schematic representation of hatchery facilities needed to produce milkfish fry (FitzGerald, 2004).](image-url)
utilized, and natural growth of phytoplankton and zooplankton is stimulated through fertilization; in this system, larvae are stocked at a lower density (5 larvae/l).

Both systems begin with fertilized eggs (1.1~1.25 mm in diameter). Eggs need to be incubated in saltwater (30~34 ppt) and a range of temperatures of 26~30°C, and good aeration is also required. In the intensive system, eggs are directly stocked in the larval rearing or incubator tanks at a density of 1000 eggs/l, and then larvae are transferred to special areas to receive their starter diet (exogenous feed). In Taiwan, hatchery operators use the semi-intensive system, while the intensive system is used in Hawaii, the Philippines, and Indonesia to produce milkfish fry (Lee, et al., 1997; FitzGerald, 2004).

At optimal temperatures, the eyes become entirely pigmented and the mouth is open at 54 h after hatching; the yolk sac is almost completely reabsorbed 120 h after hatching (Bagarinao, 1986). Exogenous feed must be provided before the yolk sac is completely absorbed. Rotifers (Branchionus plicatilis) are considered the standard first feeding regimen at 10~20 rotifers/ml, but also microalgae and Artemia nauplii are used (Bagarinao, 1986; Lee, 1995). Normally 21-day-old milkfish fry (14~16 mm in length) are harvested and transferred to nursery ponds for 30~45 days of rearing prior to grow-out culturing (Lee, 1995; Hilomen-Garcia, 1997).

### NUTRITION AND FEED

In terms of feeding habits, milkfish are considered herbivorous (Hertrampf and Piedad-Pascual, 2000; Lim et al., 2002). This species is best suited for culture in the tropics because of its fast growth, efficient use of natural food, propensity to consume a variety of supplemental feeds, resistance to diseases and handling, and tolerance to a wide range of environmental conditions (Lim et al., 2002). In nature, milkfish are generally herbivorous, but in some conditions can be considered omnivorous. Lückstädt et al. (2001) and Lückstädt and Rati (2002) analyzed the stomach contents of adult milkfish fed natural food and reported that the stomach contents consisted mainly of single-cell green and blue-green algae, but also contained benthic and planktonic organisms and crustacean larvae. In captivity, various types of feed can be used such as live feed for rearing larvae and artificial or formulated feed for fry, juveniles, and later stages of development (Lee, 1995).

Like other marine fish species, milkfish do not have absolute protein requirements, but do require a balanced mixture of essential amino acids (Table 2) (Lim et al., 2002). Generally marine fish are not able to convert shorter-chain fatty acid (linoleic acid, 18:3 \( n-3 \)) and linolenic acid, 18:2 \( n-6 \) to longer-chain fatty acids, so it is necessary to provide these through the diet. Lipids and fatty acids play significant roles due to their function in maintaining cell membrane structures, stress tolerance, and proper development and functioning of neural and visual systems (Borlongan, 1992; Alava, 1998; Faulk and Holt, 2005). The polyunsaturated fatty acids, specifically eicosapentaenoic acid (EPA, 20:5 \( n-3 \)), arachidonic acid (ARA, 20:4 \( n-6 \)), and docosahexaenoic acid (DHA, 22:6 \( n-3 \)), have been shown to be essential in the diet of marine fish larvae (Faulk and Holt, 2005).

<table>
<thead>
<tr>
<th>Amino acid</th>
<th>Requirement (% of dietary protein)</th>
<th>Amino acid</th>
<th>Requirement (% of dietary protein)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arginine</td>
<td>5.2</td>
<td>Methionine</td>
<td>2.5</td>
</tr>
<tr>
<td>Histidine</td>
<td>2.0</td>
<td>Phenylalanine</td>
<td>4.2</td>
</tr>
<tr>
<td>Isoleucine</td>
<td>4.0</td>
<td>Threonine</td>
<td>4.5</td>
</tr>
<tr>
<td>Leucine</td>
<td>5.1</td>
<td>Tryptophan</td>
<td>0.6</td>
</tr>
<tr>
<td>Lysine</td>
<td>4.0</td>
<td>Valine</td>
<td>3.6</td>
</tr>
</tbody>
</table>

1 For diets containing 40%~45% protein.
Essential fatty acid (EFA) deficiency symptoms consist of poor growth, low feed efficiency, anemia, and high mortality especially in milkfish larvae (Fig. 5). Ascorbic acid is also required in larval fish diets; scoliosis, twisted gill filaments, and short operculae are some of the signs of ascorbate deficiency (Gapasin et al., 1998).

Milkfish accept a variety of diets such as meal forms and sinking particles or floating pellets. Using pellets improves the feeding efficiency due to the physical characteristics such as better stability which prevents them from dissolving and nutrients separating in the water. The most common pellet size used for feeding fish at 400 to 500 g is approximately 4~5 mm in diameter and 6~8 mm long (Lim et al., 2002). Newly hatched fry use their yolk sac as a source of nutrients; a brief explanation of first feeding was presented above, so the information provided in this part mostly concerns fry, juvenile, and adult stages.

Diets for fry usually contain a high percentage of crude protein, but this is decreased as the fish grow. For example, fry require a diet with 40% crude protein, and then at the grow-out phase, milkfish are fed herbivorous and artificial diets containing 23%~27% crude protein (Lim et al., 2002). The crude protein contents as well as the proportions of other ingredients used to prepare artificial diets for fry, grow-out, and broodstock stages are presented in Table 3. Feed peas (Pisum sativum), an abundant agricultural product, is a potential feed ingredient used in fish diets. It is a high-energy, medium-protein ingredient with a protein content of 22%~24% and 14.3 kJ/g of digestible energy (Borlongan et al., 2003). The efficiency of feed peas as a feed ingredient has been evaluated for milkfish (Borlongan et al., 2003) as well as trout (Oreochromis mykiss) (Hertrampf and Piedad-Pascual, 2000). However, they can also be used as dietary protein source for other aquaculture species.

Borlongan et al. (2003) found significant differences in both survival and FCR after 12 weeks of feeding different diets. The highest survival and lowest FCR were obtained in milkfish fed the control diet (containing fish meal, soybean meal, meat and bone meal, and copra meal as the principal protein sources) as well as D-2 and D-3 (containing 5% and 10% substitution of the total protein

![Graph](image)

**Fig. 5.** Percentage of incidence of opercular deformities among 40-day-old milkfish larvae. Control, larvae fed *Chlorella*-cultured rotifers and newly hatched *Artemia*; HUFAs only, larvae fed rotifers and *Artemia* enriched with high unsaturated fatty acids (HUFAs); HUFAs + C, larvae fed rotifers and *Artemia* enriched with HUFAs + vitamin C. For each trial, different letters for the treatment means indicate a significant difference (p < 0.05) (modified from Gapasin et al., 1998).
with pea meal, respectively). However, it was observed that milkfish fed diets with up to 15% and 20% levels of feed pea meal had better FCRs than those on the commercial feed control. (Fig. 6)

As with other aquaculture species, the feeding rate depends on the fish size and environmental conditions like water temperature, dissolved oxygen, and the presence of natural food. Normally feed is offered two or three times daily and is distributed by hand or automatic feeders according to the biomass in the ponds or cages. Supplementary feed can be offered at a rate (% of biomass) of 20% for fry and 9% for juveniles, and at 3%~% of body weight for growth to harvest size (Lim et al., 2002).

Table 3. Feed formulae for milkfish in different stages of development (Lim et al., 2002)

<table>
<thead>
<tr>
<th>Ingredient (%)</th>
<th>Fry (40% protein)</th>
<th>Grow-out (27% protein)</th>
<th>Broodstock (36% protein)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fish-meal</td>
<td>30.0</td>
<td>10.0</td>
<td>23.0</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>20.0</td>
<td>34.5</td>
<td>33.0</td>
</tr>
<tr>
<td>Shrimp meal</td>
<td>15.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat flour</td>
<td>25.45</td>
<td></td>
<td>15.0</td>
</tr>
<tr>
<td>Grains by product</td>
<td></td>
<td>48.0</td>
<td></td>
</tr>
<tr>
<td>Marine fish oil</td>
<td>8.0</td>
<td>2.0</td>
<td>2.5</td>
</tr>
<tr>
<td>Rice bran</td>
<td></td>
<td></td>
<td>21.0</td>
</tr>
<tr>
<td>Pellet binder</td>
<td></td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Vitamin mix</td>
<td>1.0</td>
<td>0.5</td>
<td>1.0</td>
</tr>
<tr>
<td>Dicalcium phosphate</td>
<td></td>
<td>1.5</td>
<td>1.0</td>
</tr>
<tr>
<td>Antioxidant</td>
<td>0.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trace mineral mix</td>
<td>0.05</td>
<td></td>
<td>0.5</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Fig. 6. Response of milkfish juveniles to the various diets after 12 weeks of feeding. The control diet (D-1) contained fishmeal, soybean meal, meat and bone meal, and copra meal as the principal protein sources. Feed pea meal was progressively substituted at 0% (D-1), 5% (D-2), 10% (D-3), 15% (D-4), 20% (D-5), 25% (D-6), and 30% (D-7) of the total protein and was compared with commercial milkfish feed (CMF). Different letters for the treatment means indicate a significant difference at $p < 0.05$ (modified from Bortongan et al., 2003).
DISEASE PROBLEMS

Diseases are more frequent in cultured animals than in natural populations; in captivity, fish begin to compete with each other for space, feed, and dissolved oxygen. Fish pathogens are often present in the water, but healthy fish can normally resist those present in culture systems until stresses become too great (Tucker, 1998). Diseases can be classified into two types: contagious (caused by bacteria, parasites, fungi, and viruses) and non-contagious (caused by inadequate environmental conditions).

Bacteria are secondary opportunistic pathogens and under normal environmental conditions cause no problems for farmed fish. Bacteria become pathogenic only when the balance of the host and environment is altered by increasing stocking densities, by inadequate nutrition, by deteriorating water quality, and by rough handling and other stressful factors (Seng and Colorni, 2002). The major bacterial infections among warm freshwater fishes are septicemia caused by *Aeromonas* and *Pseudomonas*, streptococcal diseases, enteric septicemia, and columnaris disease, the latter caused by *Flexibacter columnaris* (Lio-Po and Lim, 2002). Stress reduces the resistance of fish to infections by microbial organisms. Disease outbreaks in milkfish are no exception to this rule, and have been attributed to bacterial, mycotic, and parasitic causes; there are also handling stress-related diseases and morphological deformities in young milkfish larvae (Lee, 1995). Problems such as larval mass mortalities and incidences of deformities are still experienced. Morphological malformations have been observed in hatchery milkfish juveniles. These kinds of abnormalities are primarily a fissure on the branchiostegal membrane (associated with a deformity due to the partial or total absence of its supporting branchiostegal rays) and a deformed operculum (Hilomen-Garcia, 1997).

Hilomen-Garcia (1997) found that fry captured in the wild did not develop similar proportions of abnormalities when they were reared in tanks. Slow growth and a high mortality rate were associated with opercular and branchiostegal abnormalities (Hilomen-Garcia, 1997; Gapasin et al., 1998). Cruz-Lacierda et al. (2004) reported that infestations by the parasitic dinoflagellate *Amyloodinium ocellatum* in hatchery-reared milkfish caused 100% mortality in the Philippines. The same authors additionally described how *A. ocellatum* causes local erosion of fish skin and degeneration of epithelial cells at the sites of attachment of the parasite onto the body surface. High infestations of this parasite on fish may contribute to severe alterations of fish gills, disruption of the host's skin, and feeding of the parasites on epithelial cells of the host. In Table 4, the principal diseases in milkfish production as well as symptoms and possible control measures are summarized.

HARVESTING, MARKETING AND PRODUCTION IN THE ASIA-PACIFIC REGION

It is difficult to compare aquaculture products with wild fishery products, due to variations in terms of genetics, feed composition, and growth conditions which definitely influence certain characteristics of the final product such as texture, flavor, oil content, etc. (Lucas and Southgate, 2003). The quality of fish meat can be also affected by the harvest procedures (Tucker, 1998). In order to reduce the stress and injury to fish when they are being handled, it is very important to keep in mind some recommendations suggested by Tucker (1998).

- Stop feeding the fish before handling or harvest.
- Use non-abrasive handling materials to catch fish.
- Prevent alarming fish excessively and unnecessarily.
- Provide excellent water conditions while fish are being handled.

Free amino acids (FAAs) are partly responsible for particular tastes of seafood; the predominant FAAs in white muscle of milkfish are histidine, taurine, and glycine at 35.5, 12.8, and 12.0 µmole/g of wet weight, respectively (Shiau et al., 2001). In a starvation experiment, Shiau et al. (2001) demon-
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The histidine concentration decreased by approximately 46% after 60 days of starvation, compared to the milkfish control group, which were fed normally during the same period of time. The author also demonstrated that the body weight decreased as the fasting period increased from 0 to 60 days, and the hepatosomatic index dramatically decreased after the first 10 days of starvation (Fig. 7). Additionally, starvation resulted in important reductions in proteins and fat of 11% and 54%, respectively, in white muscle.

### Table 4. Principal disease problems in milkfish under aquaculture conditions (Lee, 1995)

<table>
<thead>
<tr>
<th>Type of disease</th>
<th>Description</th>
<th>Biological causes</th>
<th>Physical factors</th>
<th>Treatment and prevention</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bacterial infections</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red spot or vibriosis</td>
<td>- Red spot and ulcers on the body (mainly on the abdominal region) - Hemorrhage of eyes, mouth, and inner surface of gills - Pale gills</td>
<td><em>Vibrio anguillarum</em> Prevention: Lower stocking density and provision of good water quality</td>
<td>- Cold water temperatures - Overcrowding - Poor water quality</td>
<td>- Vaccination - Bacteriophage - Antibiotics - Disinfectant bath</td>
</tr>
<tr>
<td>Fin rot or columnaris disease</td>
<td>- Frayed fins - Hemorrhagic wounds - Excess of white mucus on the skin - Missing scales - Lesions in the mouth</td>
<td><em>Flexibacter columnaris</em> Prevention: Lower stocking density and provision of good water quality plus avoidance of folic acid and inositol</td>
<td>- Changes in pH and temperature, Cold water temperatures - Low dissolved oxygen - High ammonia levels</td>
<td>- Antibiotics (oxytetracycline, sulphadiazine) - Malachite green - Copper sulfate</td>
</tr>
<tr>
<td><strong>Septicemia</strong></td>
<td>- Loss of scales - Hemorrhages of the gills, anus, mouth, and fins - Skin ulcers - Accumulation of ascetic fluid</td>
<td><em>Aeromonas hydrophila</em> Prevention: Lower stocking density and provision of good water quality</td>
<td>- Stressed fish under poor water conditions</td>
<td>- Antibiotic therapy (oxytetracycline)</td>
</tr>
<tr>
<td><strong>Mycotic Infections</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Milky eye infection</td>
<td>- White adipose lid over the eyes - Fungal hyphae in lesions</td>
<td>Fungal infection Prevention: Reduce fish handling as much as possible</td>
<td>- Stress after handling (sampling, transport, harvesting) - Low water temperature</td>
<td>Bath using: - Potassium permanganate - Malachite green</td>
</tr>
<tr>
<td><strong>Parasitic Infections</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Copepoda</td>
<td>- Loss of weight - Gill damage - Inflammation and ulcers at the Point of attachment</td>
<td><em>Genus Lernae</em> Prevention: Drain and dry the bottom of ponds</td>
<td>- Overcrowding - Warm water temperature</td>
<td>Bath using: - 3%-5% NaCl - Sodium chloride</td>
</tr>
</tbody>
</table>
Reduction in the protein and crude fat composition in white muscle of milkfish during 60 days of starvation (modified from Shiau et al., 2001).

Fig. 7. Reduction in body weight and the hepatosomatic index (HSI) of milkfish during 60 days of starvation (modified from Shiau et al., 2001).

Fig. 8. Reduction in the protein and crude fat composition in white muscle of milkfish during 60 days of starvation (modified from Shiau et al., 2001).

Special care should be taken during milkfish harvesting due to consumer preferences, particularly when fish is marketable in a fresh condition. Milkfish harvesting techniques depend on the rearing method and design of the ponds. Juario (1988) and Pillay & Kutty (2005) described the harvest methodology related to the culture system.

- Completely draining the ponds is a method that very few farmers use because fish harvested in this manner may have a
muddy taste or smell; it is difficult to completely remove the mud that adheres to the fish during harvest.

- In the Philippines, farmers use special catching ponds; this method takes advantage of the tendency of milkfish to swim against the current. Water in the rearing pond is partially drained during low tide. Then, at high tide, water is allowed into the pond. During this procedure, the fish will swim into the catching pond through the gate, and then when the majority of the fish are in the catching pond, the gate is closed and fish are then seined. A small number of fish remain with this process, but these are harvested after totally draining the pond. With this system, the risk of a muddy flavor in the fish is substantially reduced.

- Other farmers usually employ gills or serine nets; these nets are commonly used to harvest fish reared in pens, but in the process, serious injury can occur and some scales could be lost, which can affect the market price in most cases. Then the ponds are drained to pick up the remaining fish after netting.

Indonesia, the Philippines, and Taiwan are the largest producers in the Asian-Pacific region (Sugiyama et al., 2004). Total milkfish production in Indonesia and the Philippines remained relative stable (between 150,000 and 160,000 MT) during 1992 to 1998 and a considerably increment (production over 200,000 MT) of milkfish production was

![Graph A](image)

**A**

- Indonesia
- Philippines
- Taiwan

![Graph B](image)

**B**

- Value (thousands USD)

**Fig. 9.** Major milkfish producing countries: Indonesia, the Philippines, and Taiwan. (A) aquaculture production and (B) values from 1990 to 2004 (FAO FishStat database, 2004).
Milkfish Culture in the Asian-Pacific Region

achieved from 1998 to 2002 particularly in the Philippines and Indonesia (FitzGerald, 2004). Milkfish production for 2002 from the major producers countries in the Asian-Pacific region is presented in Fig. 9. In Taiwan, milkfish is produced on about 10,000 ha (Chiang et al., 2004), and the production of this fish reached a peak of 77,921 MT in 2003 (Taiwan Fisheries Yearbook, 2004). Taiwan has become the most technically advanced and has reached the highest production/ha/year (8~12 MT/ha) (Chiang et al., 2004) compared with the Philippines (4~10 MT/ha) and Indonesia (< 1 MT/ha).

FUTURE PERSPECTIVES

Currently milkfish is the most important inland farm-raised fish cultured in Taiwan. Maturation of the larval rearing technology in 1984 (Lin, 1985; Liao, 2005) and the tremendous quantities of fry production not only provide milkfish farmers of Taiwan with ample supplies, but have also opened the export market to other neighboring countries like the Philippines, Indonesia, and Thailand (Chien et al. 1997). The development of more-efficient culture systems has resulted in higher milkfish production, which has been quite reliable to the present time. Wild milkfish are distributed around the world. The dispersal history of populations has still not yet been completely studied. The origin of milkfish is still a mysterious puzzle even today. For the sustainable development of milkfish culture, we must attach importance to the management and conservation of wild populations. Therefore, understanding the population structure and evolutionary history of milkfish is urgently needed research. Additionally, as far as culturing problems are concerned and avoiding disease outbreaks, we must adequately control the quality of water and supply optimal feedstuff. Simultaneously, researchers ought to promote biotechnological development to increase growth rates, improve the tolerance of fish to low temperatures, and raise the disease resistance of milkfish.

REFERENCE


虱目魚養殖之現狀與趨勢

Franklin S. Martinez¹, Mei-Chen Tseng²* and Sin-Ping Yeh²

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在這篇文章中，我們綜述現今虱目魚(Chanos chanos)的生物學研究，提供其生態生活史，繁殖學，仔魚產量，養殖方法，遺傳學上的資訊和商業上之重要性。虱目魚是虱目魚科中唯一的魚種，屬暖水性海水魚類，在亞洲-太平洋區域被廣泛的養殖，現在是東南亞地區最重要的養殖魚種。對於印尼、菲律賓和台灣而言，虱目魚養殖佔有重要的經濟價值。自 2000 年開始，台灣每年總產量超過四十五萬公噸。然而，虱目魚產量面臨極限，最主要的原因是仔魚供給上的限制。傳統上虱目魚產量是依靠野生魚苗的捕獲，但是虱目魚的種魚人工孵化場，已經成功的完成了人工繁殖。目前虱目魚產量最主要來自於人工養殖，在台灣成功和發達的企業中，虱目魚人工繁殖魚苗的外銷，在經濟上佔有重要的地位。

關鍵詞：虱目魚，生活史，生殖生物學，養殖方法。

¹國立屏東科技大學熱帶農業研究所
²國立屏東科技大學水產養殖系
*通訊作者