

The Natural Life History of Milkfish

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Most of the information on milkfish biology is related to aquaculture, for a long time within the pond context, and recently in the hatchery context. The book "Biology of Milkfish" published by the SEAFDEC Aquaculture Department in 1991 and the review paper "Systematics, distribution, genetics, and natural life history of milkfish" in *Environmental Biology of Fishes* 39: 23-41 (1994) attempted to advance the level of current understanding of the biology of milkfish by covering fundamental aspects not usually considered in aquaculture papers. The present account is taken from those two main sources and includes some ecological data in a Ph.D. dissertation by Shigeru Kumagai in 1990. Literature citations have been omitted here for brevity but given in full in the book and the review paper.

Adults

Adult milkfish are large (to 1.5 meter or 15 kg), long-lived (to 18 years), silvery and streamlined, pelagic and schooling. Not much is known about the adults in nature. Milkfish are powerful swimmers and have been seen in large schools along the coast, near islands where reefs are well developed, or in large coastal lagoons, oftentimes with dorsal fins sticking out of the water like sharks. Near-shore sightings and catches are usually limited to the few months of the breeding seasons. Adult milkfish also inhabit freshwater lakes in the Philippines, Indonesia, and Madagascar. Catches of adult milkfish from Philippine lakes and rivers have markedly declined in recent years.

Adults and juvenile milkfish in the wild eat a variety of food, most commonly cyanobacteria, diatoms, detritus, along with filamentous green algae and invertebrates such as small crustaceans and worms. Adults apparently swim through plankton masses and larval schools — they have been found with juvenile sardines in the gut, and they ingest their own eggs after spawning in floating cages. In captivity, both adults and juveniles accept artificial foods such as pelleted diets.

Reproduction of milkfish in nature is not well understood as there have been few studies. However, the milkfish has been successfully bred and propagated in captivity, with and without hormonal treatment, first at the SEAFDEC Aquaculture Department in the Philip-

pinas, and subsequently in Taiwan, Hawaii, and Indonesia. Adults reach sexual maturity in 3-5 years in nature and in large floating cages, but may take as long as 8-10 years in ponds and concrete tanks. Milkfish produce from 0.5 to 6 million eggs in 3-13 kg females. Individual milkfish may spawn more than once a year both in nature and in captivity. Spawning takes place usually at night, may be lunar periodic, and is strongly seasonal. They spawn offshore near coral reefs or small islands.

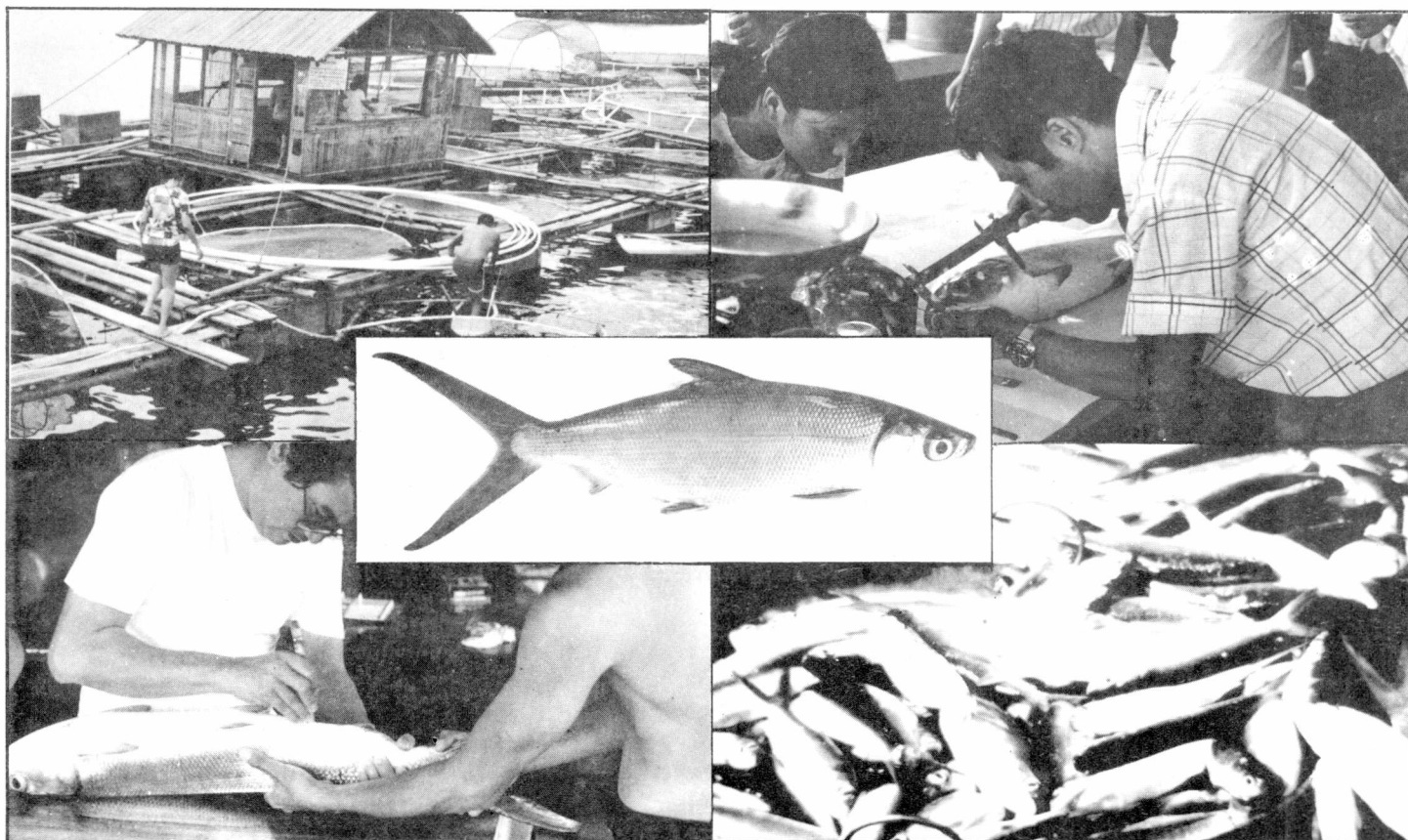
Eggs and embryos

Fertilized milkfish eggs are pelagic, spherical, 1.1-1.25 mm in diameter, with finely granulated yolk, no oil globule, narrow perivitelline space, and no structures on the envelope. Embryonic development is typical of teleosts and takes 20-35 hours at temperatures of 26-32°C and salinities of 29-34 ppt. Delsman was the first scientist to take note of milkfish eggs when he examined the oocytes and later collected 15 eggs from the Java Sea in 1926. His identification was proven correct when milkfish were induced to spawn in captivity at SEAFDEC/AQD in 1976.

Researchers at the SEAFDEC Aquaculture Department collected 1700 milkfish eggs in 188 successful (1898 total) plankton tows around Panay Island in 1976-1980, most abundantly near the surface but also in low numbers down to 30-50 m deep. Spawning locations of milkfish are clean, clear, saline, warm (25-30°C), shallow waters (less than 200 m deep) over sand or coral reefs, within 6 km offshore. These locations are thought to be selected by the need to position the eggs over water deep enough to minimize predation by benthic planktivores such as corals, and near enough to the coast to facilitate the return of larvae to inshore habitats.

Larvae

Milkfish larvae are pelagic and have been described in detail from both hatchery and plankton specimens. At hatching, the yolk-sac larvae are of 3.5 mm total length (TL); three days later at 27-30°C, they begin to feed when the eyes have become fully pigmented, the mouth has opened, and some yolk is still present. Egg size, larval size at hatching, amount of yolk, and initial mouth size are



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greater in milkfish than in many other tropical marine fishes, a size advantage that probably determines in part the survival of larvae in the wild and in the hatchery.

Milkfish larvae from newly hatched to about 15 mm TL have been collected in small numbers by plankton net tows in the Java Sea, around Hawaii, and in Ben Goi Bay in southern Vietnam. Off the western coast of Panay Island in central Philippines, 71 milkfish larvae (3-17 mm TL) were obtained by plankton net from 5-325 m deep stations 0.1-6 km offshore, and about 1500 milkfish larvae (5.8-14.6 mm TL) with a plankton net attached to the cod end of a floating set net 500 m offshore in water 30 m deep. Jeff Leis and co-workers collected 682 milkfish larvae (2.1-12.3 mm TL, preserved) from around Lizard Island and the Coral Sea in northeastern Australia, and 106 milkfish larvae (2.2-10.6 mm TL) in plankton net tows in French Polynesia. The vertical and horizontal distribution of milkfish larvae change with size and age. Off western Panay, younger larvae (less than 10 mm TL) occur mostly near the surface, but also at 20-30 m deep. Older (10 mm TL and larger) larvae occur only near the surface. Younger larvae occur both far and near shore, but older larvae are found only near shore. In the Great Barrier Reef, an

essentially similar pattern was seen with more extensive collection of larvae. The larvae probably move from the Coral Sea to the inshore juvenile habitat, probably via a combination of passive advection and active behavior. Only milkfish larvae that have attained a certain degree of morphological, physiological and behavioral development, probably at 10 mm TL and two weeks old, are able to migrate inshore.

"Fry" and the metamorphosis phase

Milkfish 'fry' or 'seed' (to the aquaculturist) are larvae approaching metamorphosis and the end of the pelagic interval. The larvae caught in the surf zone and shore waters in the Philippines, Taiwan, Japan and elsewhere are all 10-17 mm TL, 14-29 days old (average 13-14 mm, 20 days) and definitely without yolk anymore. A fishery on inshore milkfish larvae supports the centuries-old grow-out culture industry. Some 1.35 billion were collected in the Philippines in 1974, and 700-800 million are collected each year in Indonesia, and an average of 130 million a year in Taiwan.

The larvae that survive the shore waters and surf zones settle in shallow-water depositional habitats such as mangrove swamps and coralline lagoons where they metamorphose and spend a few months as juveniles. Metamorphosis in milkfish is a complex of morphological, physiological and behavioral changes, as in other fishes with indirect development. Following metamorphosis, the zooplankton-feeding larvae become benthic-feeding juveniles, opportunistically herbivorous, detritivorous, or omnivorous, depending on the predominant food types in the habitat. Milkfish in metamorphosis have never been recorded from the open sea, but have occasionally been taken from coastal wetlands in the Philippines and Tonga, and in large numbers in Sri Lanka and India.

Juveniles and sub-adults

Milkfish larger than 20 mm have acquired the characteristic shape and definitive structures of the adult of the species and are considered juveniles. They bear the complete fin-ray complement, a forked caudal fin, scales, and silvery coloration. Juveniles 2-10 cm TL are usually called 'fingerlings' in the aquaculture industry. Milkfish up to 30 cm TL have been found in such diverse habitats as coral lagoons, estuaries, marsh flats, tidal creeks, and tide pools that share the common characteristics of rich food deposits and protected, relatively shallow waters. In the Philippines, where coastal wetlands have been extensively converted into culture ponds, wild juvenile milkfish are relatively hard to find and could be collected only in small numbers. In contrast, wild juveniles 2-25 cm can be collected in large numbers where wetland areas are still mostly in the natural state and fishing pressure on inshore milkfish larvae is negligible.

Habitat area, depth, and connection with the sea apparently determine the maximum size and duration of stay of juvenile milkfish in natural nursery grounds, where food is not limiting. Where habitats are small or temporary, only small juveniles up to about 30 cm TL are found. In a 1.6 ha mangrove lagoon in Naburut Island off north-eastern Panay, milkfish larvae ≥ 10 mm were found to enter with the high tides of spring tide periods (i.e., every two weeks), grow into juveniles, stay there for 4-5 months

until they are about 25 cm TL, and then leave, again with the high spring tides. Some juveniles find themselves in large coastal lagoons, atolls, and freshwater lakes, where they grow into sub-adults but do not reach full sexual maturity (although gravid stunted females have been found in hypersaline lagoons at Christmas Island in the central Pacific). Both small juveniles and large sub-adults go back to sea when they reach the size limit supportable by the habitats.

Growth and survival data for cultured milkfish abound in the literature but are not available for wild milkfish. Milkfish grow fast particularly during the first year. Although adults are fish of the open sea, the larvae and juveniles adapt well to crowding in culture systems. Of the milkfish larvae collected inshore and stocked in ponds, about 38% are harvested at market size (200-300 g) in the Philippines and 70% in Taiwan with improved methods of handling and culture. The largely herbivorous feeding habit, wide tolerance to environmental factors, and fast

growth rate of juveniles account for the long-standing success of milkfish in aquaculture.

Summary of life history

Figure 1 is a schematic of the life history of milkfish as interpreted from many studies. The life history of milkfish is a series of migrations, but little is known about the actual movements, particularly during the period after the juveniles leave the nursery grounds, and the period after the

spawning of adults in nature. Since milkfish larvae are used in aquaculture, there have been some attempts to link the spawning grounds to the inshore collection grounds, i.e., to find the mechanism for the appearance of milkfish 'fry' en masse in shore waters. No one has been really successful. The available evidence discussed above indicates that milkfish larvae move by active migration and passive transport from offshore spawning grounds into shore waters. Then they enter and settle in mangrove creeks and swamps, coral lagoons, estuaries, and sometimes freshwater lakes. Shallow-water depositional habitats appear to be obligatory for juveniles, while freshwater habitats are optional (used if available). In the Philippines and other oceanic archipelagos where freshwater bodies are few, most milkfish probably never see freshwater.

So that aquaculturists and consumers may continue to benefit from milkfish, there must be a strong effort to protect the coastal habitats: coral reefs for milkfish spawning, shore waters for the "fry", estuaries and mangrove swamps for the juveniles, and rivers and lakes for the sub-adults.

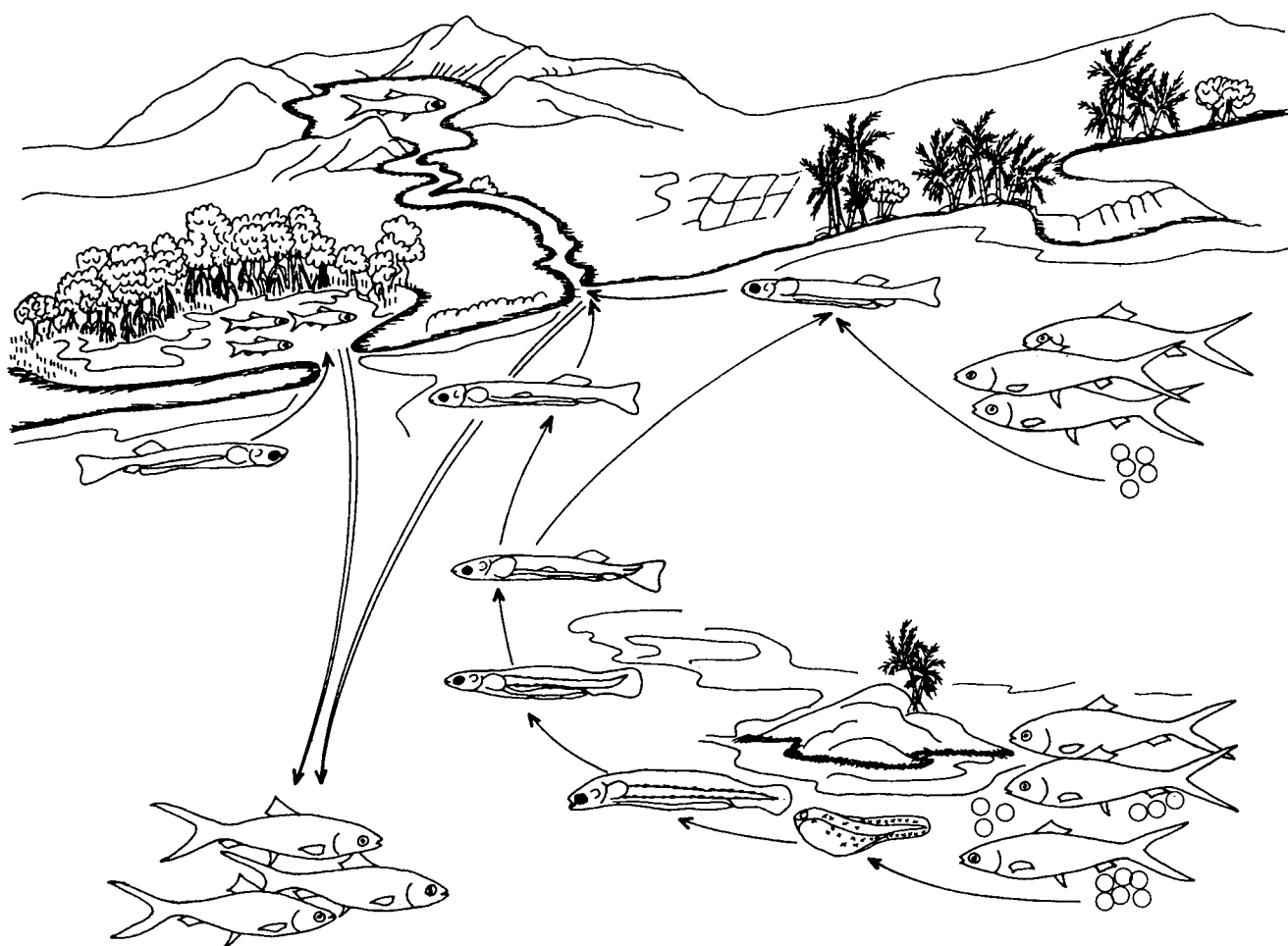


Figure 1. Schematic of the natural life history of milkfish showing respective habitats. Adults are relatively large, long-lived, pelagic, and schooling. They spawn offshore near coral reefs or small islands. The eggs and larvae are pelagic. Larvae ≥ 10 mm TL and 2-3 weeks old (commonly called "fry") move inshore by both passive advection and active migration. They pass through shore waters and surf zones and settle in shallow-water depositional habitats such as mangrove swamps and coral lagoons, where they stay for a few months as juveniles. Some juveniles may enter freshwater lakes where they grow into sub-adults but do not mature. Both juveniles and sub-adults go back to sea when they reach the size limit supportable by the inland habitats. Little is known of milkfish at sea before they reach sexual maturity at about 5 years and after their spawning migrations along the coasts. Diagram not to scale, the eggs and larvae being shown disproportionately larger than the juveniles and adults.

No longer 'the mysterious milkfish' (as in an earlier video documentary by the International Research Centre of Canada), hundreds of papers and a few books have been written about it. But much remains to be studied. The biggest gaps are in ecology, physiology and behavior, including the migration habits at sea. Stock assessment has not been done for milkfish anywhere, and population dynamics, natural birth rates and mortality rates are virtually unknown. It is difficult to study wild milkfish in the Philippines because the juveniles and adults are not fished in quantity — probably because the inshore larvae

are. The effects on milkfish population genetics of the current 'fry' fishery, the production of milkfish larvae in commercial hatcheries, and the soon-to-be possible searanching of hatchery-produced larvae will need to be monitored. So that aquaculturists and consumers may continue to benefit from milkfish, there must be a strong effort to protect the coastal habitats: coral reefs for milkfish spawning, shore waters for the 'fry,' estuaries and mangrove swamps for the juveniles, and rivers and lakes for the sub-adults.