THE POND FISHERIES OF THE PHILIPPINES[1]

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Of the various fishes commonly grown or encouraged to grow in ponds and lakes, the milkfish, or "bañgos" as it is known in the Philippines, is distinctive for its very low trophic level; in confinement it feeds mainly on the blue-green or filamentous green algae of the bottom and to a lesser extent on the submerged portions of hydrophytic spermatophytes. The pond practices in the vicinity of Malabon, where the industry is most highly developed, are designed primarily: 1) to encourage differential growth of the blue-green or green algae upon which the fish feed, at the same time maintaining aquatic conditions suitable for the fish, and 2) to exclude as nearly completely as possible all predators of this species. Nonpredacious, mildly competitive species or those of dissimilar food habits, like mullet and shrimp, are sometimes permitted and even cultured in the ponds. Any increase in production of the nonplanktonic algae can be expected to have an immediate effect in increasing the production of fish proteins, without the energy losses attendant on longer food chains, as in the case of the carnivorous species of fish. Large annual yields of milkfish are obtained in the Manila Bay region by application of the rule-of-thumb principles developed by trial and error chiefly during the past 75 years, but the basis for these various procedures has not been adequately investigated and as a result is imperfectly understood.

During the course of a survey of the Philippine fisheries made by the U. S. Fish and Wildlife Service in 1946, in which the author participated, various phases of the milkfish industry were observed. These firsthand contacts, plus the meager accounts of milkfish culture in the literature, constitute the basis for the following report.

GENERAL

The milkfish, *Chanos chanos* (Forskål), is the only living member of the family Chanidae (Fig. 63). It is a herring-like, isospondylous fish, with a highly arched back, a single soft dorsal fin, and a large tail

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cleft to the base. It ranges throughout the warm portions of the Indian and Pacific oceans, from southern Japan to Australia, and from southern California and Mexico to the Red Sea. An important food fish over most of its range, it is grown extensively in ponds in the Hawaiian Islands, Netherland East Indies, and the Malay Peninsula, in addition to the Philippines.

Culture of the milkfish has been carried on for more than 500 years in Java, where laws codified in 1400 A. D. provided punishment for anyone who stole these fish from a "tambak" or salt water pond. Likewise in the Hawaiian Islands the use of fish ponds goes back at least 300 years to the time of construction, according to legend, of a large fish pond at Pearl Harbor. The ponds in these localities, and in Batavia, Singapore, Madura, Formosa, and the southern Philippines, are scarcely more than fish traps, with gates or funnels permitting the fish to enter the ponds but not to return to the open sea (Fig. 64). Relatively recently the practice has developed of catching young milkfish (and sometimes mullet) along the coasts and placing them in the salt water ponds, where it is hoped they will grow to a larger size. No other care is given them. The occurrence of many predators tends to keep production low.

The specialized culture of milkfish in the central Philippines, however, employs different ponds for fry, fingerlings, and larger fish. Separate, yet closely interrelated, occupations have developed of catching the fry, raising the fry to fingerling stage, and rearing the latter fish to market size. As a result of this emphasis on the species, the milkfish ranks first in annual production in the Philippines. It is well known that fish and rice are the staples of the Filipino diet, and on good authority it is recognized that thousands of people, especially in the Manila region, depend on this one species of fish for their daily source of animal protein. During protracted periods of inclement weather in the southwest monsoon, when costal fisheries cannot be operated, the milkfish may be the only species on sale in the markets.

BIOLOGY

Very little appears to be known about the biology of the free-living milkfish. The adults, which reach a length of 1.5 meters, live offshore and are seldom caught except during the spawning season when they are taken in small numbers by gear operated near shore. Smaller individuals up to 0.5 meter in length enter estuaries and bays with flooding tides. A small percentage make their way into some of the fresh water lakes, where they may remain for several years and grow to a considerable size. Spawning, however, occurs only in salt water offshore along sandy coasts.

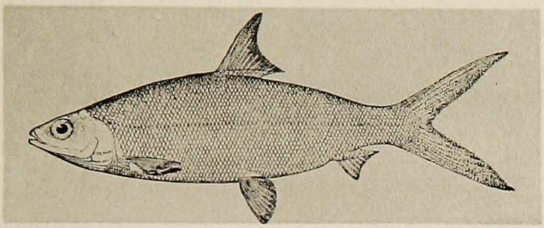

Figure 63. The milkfish or bangos, *Chanos chanos* (Forskal) (From Jordan and Evermann, 1905).

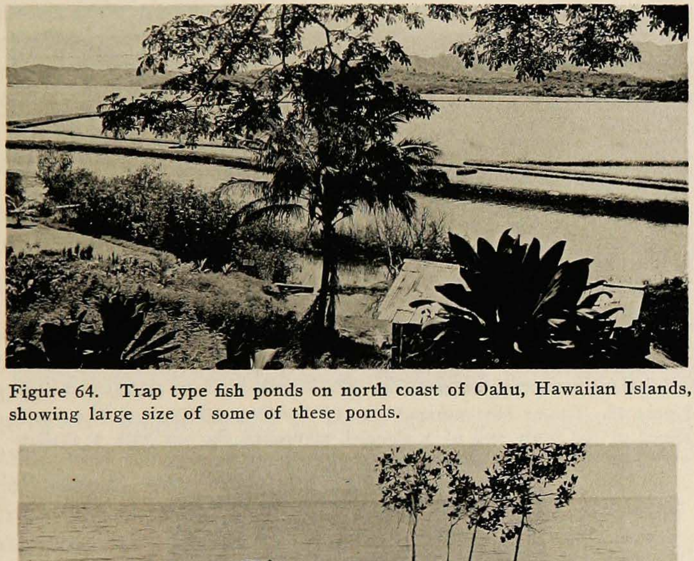

Figure 64. Trap type fish ponds on north coast of Oahu, Hawaiian Islands, showing large size of some of these ponds.

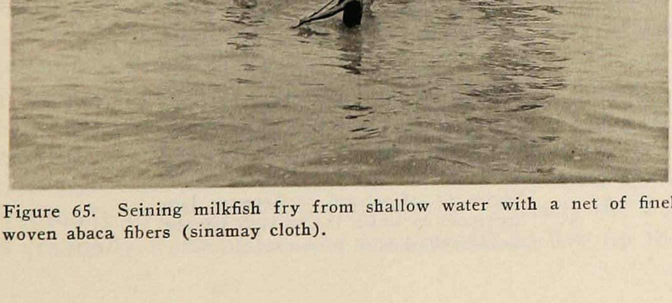

Figure 65. Seining milkfish fry from shallow water with a net of finely woven abaca fibers (sinamay cloth).

Figure 66. Funnel-shaped trap, designed to catch milkfish fry coming inshore with the flooding spring tides.

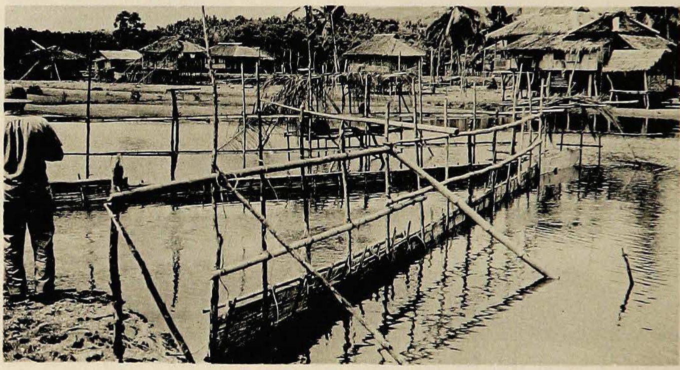

Figure 67. Larger funnel-shaped trap for catching milkfish fry. The trap is placed at the inner end of a channel connecting the sea with a shallow-water lagoon.

Figure 68. Unglazed earthenware jars (palayok) in which the milkfish fry are stored and shipped to market.

The females are said to average three to five million eggs, which are thought to be of the demersal type. Milkfish fry appear periodically along the coasts during flooding spring tides in the months March through June, but earlier in the southern Philippines than in the northern. Knowledge of the actual spawning of the adults, or of the habits and biology of the newly hatched fry before they appear along the coasts, is virtually lacking. The occurrence of these small fish only during spring tides indicates that the periodic spawning of the adults is regulated by, or at least associated with, changes in the water resulting from the monthly tidal cycle.

Milkfish fry subsist on the food reserves of the yolk sac until they reach a length of approximately 1.5 cm. The food they begin eating at this time in the ponds consists of blue-green algae and associated organisms growing on the bottom. At a length of 5 to 10 cm. the food preference begins to shift to the filamentous green algae, and proper steps must then be taken to satisfy these new dietary requirements of the fish.

CATCHING AND HANDLING THE MILKFISH FRY

Inasmuch as the coastal fisheries represent the sole source of milkfish fry for stocking the ponds, the entire pond fish industry depends on the relatively few days each year when the fry can be caught. At such times there is a feverish activity in suitable localities, with the women and children, and to a lesser extent the men, attempting to catch the small fish by various laborious and inefficient methods (Figs. 65, 66, 67).

The newly caught fry are 10 to 15 mm. long, transparent except for the eyes, and are usually mixed in with the young of other species (mullet, tarpon, barracuda, threadfin, slipmouth, *Caranx*, etc.), which they resemble closely and from which they must be separated. Where the numbers are small this is done by picking up the fish a few at a time in a clean clam shell and discarding the undesirables, or if there are many fish to be sorted, by pouring the fish into a metal sieve with meshes 1.5 mm. square, through which only the milkfish fry can pass. The unwanted fish are usually dumped on the ground, where they die and are lost to production.

The bañgos fry, after being laboriously counted by hand in many instances, are stored in unglazed earthenware jars (palayok) of 15 to 30 liters capacity (Fig. 68) at the rate of 1,500 to 3,500 per jar, depending on its size. In this condition the fish are delivered to the market and eventually to the fishponds themselves. Usually the water in the jars is gradually freshened. The fry are said to live up to 10 or 12 days in these containers. Mortality, which ranges from 5 to 20 per cent, varies with overcrowding, protozooan parasites, length of storage, temperature, etc. No accurate records are available, but it has been estimated by members of the Philippine Bureau of Fisheries that approximately 100,000 pots of fry, representing one-third of a billion fish, are caught and marketed annually.

POND PRACTICES

Before the recent war there were 60,000 hectares of milkfish ponds in the Philippines, all located along the coast, with the greatest concentration in the provinces bordering Manila Bay to the north of Manila. The ponds in this region are all shallow-water salt or brackish ponds. They are so constructed with reference to the mean low water level that they can be flooded with estuarine water during the incoming tide or completely drained at low tide by appropriate regulation of the head gates. Each operator usually has one or more large ponds for growing market fish, and one or more small ponds for growing fry or fingerlings or for keeping fingerling stock on hand, although some operators buy their small fish from culturists who do nothing except raise fry to the fingerling stage.

In preparation for receiving the fry, the ponds concerned are washed during several changes of tide to get rid of old salt accumulations, then completely drained and allowed to dry in the sun for several days up to two weeks, during which time the bottom is cleaned of debris and deposits thought to be undesirable. Brackish or salt water is admitted to a depth of 3 to 5 cm., and within three or four days there begins to form on the bottom a dense mat of algae and associated organisms, collectively called "lab-lab," which is the food of the bañgos fry. It is said to consist primarily of unicellular and filamentous blue-green algae, chiefly of the family Oscillatoriaceae, and secondarily of a great variety of diatoms, bacteria, protozoa, and entomostraca, and a small proportion of filamentous Chlorophyceae. When this growth is well started the depth of the water is gradually increased to approximately 12 cm., and the fry are added at the rate of 500,000 per hectare in the case of productive ponds. At any time the food supply becomes low, the small fish may be transferred to another pond similarly prepared. After two to three months, when the fish have reached a length of 5 to 10 cm. and have begun to change their food habits, they are transferred to larger ponds with different food conditions.

In contrast to the fry which live entirely on blue-green algae and the associated microzoa, the fingerlings and larger milkfish feed mainly on filamentous green algae and to a lesser extent on the submerged leaves of higher aquatics. Before the fingerlings are stocked in them, the large ponds are washed and sun dried as previously described, then flooded with salt water to a depth of 10 to 15 cm. With this greater initial depth of water the lab-lab complex does not develop, but there appears instead a heavy growth of filamentous green algae, known as "lumut," consisting mainly of *Cladophora, Enteromorpha, Vaucheria, Spirogyra, Chaetomorpha,* and *Oedogonium* (Herre and Mendoza, 1929). After the lumut in the growing ponds is well started the depth of water is gradually increased to 30 to 50 cm. Usually a trench about one meter deep is provided in each pond to afford protection for the fish from the hot midday sun, but this is about the greatest depth of water permitted in the ponds.

Although lumut is the main food of the growing milkfish, rooted aquatics are also eaten when they are present. These plants, known collectively as "digman," comprise *Ruppia graminea* and *Halophila beccarii,* which are said to prefer salt water, and *Nejas graminea, Halophila ovata,* and *Thalassia hemprichii,* which are said to grow best during the rainy season when the salinity of the ponds is decreased. The roots of *Lemna paucicostata* are also eaten by the fish, but since this plant grows in water which is almost fresh, it is not of wide occurrence in the milkfish ponds where the salinity is kept fairly high.

PRODUCTION OF FISH IN THE PONDS

Under favorable conditions the milkfish grow rapidly in the ponds, reaching a length of 25 cm. in four months after the fingerlings are stocked in the growing ponds, 40 cm. in eight months, and 50 cm. in a year (Seale, 1908). However, because the greatest demand is from the Filipinos of the lowest income group who cannot afford to buy big fish, the bañgos are usually marketed after they have reached a weight of 300 to 600 grams. Six to nine months are sufficient to grow fish of this size.

Either one or two crops per year are produced in the ponds. In the former instance the fish are marketed at the end of the calendar year when they have reached a weight of 400 to 600 grams, whereas in the latter instance they are marketed in September and October and again in April and May after an individual weight of 300 to 500 grams has been attained. Accepting the figures of Adams, Montalban and Martin (1932) that 900 to 1000 market fish can be raised per hectare of pond surface, the average annual yield of a productive series of ponds is thus 500 to 1000 kg. per ha., depending in part upon the system of cropping employed.

Average mortality from all causes is reported to be approximately

70 per cent in the central Luzon fish ponds (Adams, Montalban and Martin, 1932), and proportionately greater in the ponds of the southern Philippines where less care is taken of the growing fish and where predacious species are frequently abundant in the ponds. Assuming an annual yield of 750 kg. per ha., which is undoubtedly generous, the annual production of this species, excluding the relatively small proportion of market size fish caught in the coastal fisheries, would be 45,000,000 kg.; and assuming each fish weighed 500 g. at the time of marketing, the number of fish marketed—90 million—would be hardly one quarter of the estimated number of fry caught each year. Actually the 1938 census listed an annual production of only 14,530,000 kg. of milkfish.

DISCUSSION

The annual production of various species of fish depends mainly upon the trophic levels of the species (Lindeman, 1942), other conditions being equal. The primary consumers (those feeding on autotrophic plants) have a greater annual production than the secondary consumers (those feeding mainly on primary consumers), and they in turn have a greater annual production than tertiary consumers, etc. Swingle and Smith (1941) found, for example, that the production of goldfish and shiners (primary consumers) varied from 750 to 1,100 pounds per acre, of bluegills and bullheads (secondary consumers) from 500 to 600 pounds per acre, and of largemouth bass and white crappies (tertiary consumers) from 150 to 200 pounds per acre. Thompson (1941) observed approximately the same relationships among standing crops of fish in 22 Illinois ponds and lakes, noting in addition that in general five pounds of food were required to produce a pound of fish.

Because the milkfish is at the third trophic level in the energy cycle, feeding directly on the primary producers (algae and higher aquatics), it would be expected *a priori* to have a high productivity; and when this fish is raised in ponds where the food plants are abundant and enemies largely excluded, such an expectation is realized. The annual production of 500 to 1,000 kg. per ha. in the Philippines is a substantial yield, considering that it has resulted entirely from food grown in the ponds without the addition of any fertilizer. It is greater by far than the annual production of sport and commercial species in any of the lakes and ponds considered by Rounsefell (1946) and considerably greater than the carrying capacities of nearly all these bodies of water. It is greater than the average annual yields obtained by Swingle and Smith (1941) in fertilized ponds, although in this instance production would be expected to be lower because the fish concerned are from a higher trophic level than the milkfish. It is considerably less, however, than the annual yield of fresh-water ponds in southern China, where carp and other species are fattened on foodstuffs added to the ponds. Annual yields up to two or more tons per acre are reported in this fishery.

With the milkfish directly dependent on plants for its energy, any increase in the growth of these food organisms would logically result in an immediate increase in production of fish within the limits of the particular ponds. Fertilization would appear to be the next step in the Filipino system of milkfish culture, but here the problem is not the same as in other pond cultures where fertilizers have been used effectively to increase fish production. The goal in the present instance is not to increase the quantity of phytoplankton, zooplankton, or bottom organisms, but rather the amount of matted Myxophyceae and filamentous Chlorophyceae growing on the bottom. Our present knowledge of the nutritional and environmental requirements of the various groups of algae does not enable us in most instances to selectively culture in ponds the particular types desired.

In the Philippine pond system both qualitative and quantitative growth of the algae appears to result from the interaction of at least three factors: nature of the pond bottom, depth of water, and salinity, with the first mentioned factor probably the essential basis of present productivity.

Rosell and Argüelles (1936) concluded from an analysis of 33 bottom samples from milkfish ponds in the Manila Bay region that "algae seem to grow very abundantly in types of subaqueous horizons that have a high solution loss and a high content of clay, nitrogen, and organic matter. Types that are deficient in these characteristics generally have very few algae." Greatest production of algae was noted in ponds having bottoms described as "peaty clay, either compact or matted in structure" or "Slimy clay, slightly organic and gelatinous in consistency." Least production was associated with bottoms of "Sandy mud, sand-shell admixed" and "Sand, clean sand compact." This is another variation on an old theme long known to the European carp culturists (Schäperclaus, 1933), that the pond bottom is at least equal in importance to the overlying water in determining production of fish. Basic productivity varies from one region to another, depending not only on the geological origin and subsequent history of the surface deposits (regional limnology) but also on the colloid complex of the pond bottom which is so important in base exchange and retention of essential nutrients.

Variation between ponds in production of algae has been a source of considerable trouble to the Filipinos. Some ponds are so productive that it is claimed the growths of algae must be thinned out to permit the fish to move about. In others, which do not share in this exuberant growth of plants, *Oedogonium* and other kinds may be imported and placed loose in the pond, or clumps of *Cladophora* and forms with similar growth habits may be planted in the bottom, but these procedures ignore the cause of the low productivity and probably satisfy the culturists more than the hungry fish. Sometimes rice bran (tikitiki) soaked in water is used to supplement the natural food of the fish in unproductive ponds.

Drying of the ponds at regular intervals is likewise practiced by the European pond culturists (Schäperclaus, 1933) for the reason that the aerobic processes which are favored by this procedure result in an oxidation of the organic matter with a consequent liberation of plant nutrients to the colloid complex ("mineralization"), and an improvement in structure of the bottom colloids. In the short periods of drying in the Philippines it is likely that the fixation of nitrogen by blue-green algae, certain bacteria in their mucilaginous sheaths, and by the *Azotobacter*-group proceeds apace. The published reports on the Philippine practices, however, merely generalize that the drying promotes the growth of lab-lab and kills many of the enemies of the bañgos, without offering any explanations as to the mechanism of the former effect.

A statement frequently occurring in the literature is that the selective growth of the blue-greens or greens depends primarily upon the initial depth of water at the time of flooding; very shallow water encourages the Myxophyceae, whereas somewhat deeper water encourages the filamentous Chlorophyceae. Adams, Montalban and Martin (1932) caution against flooding the ponds deeper than 12 cm. after the lab-lab complex has begun a good growth, otherwise the filamentous green algae which cannot be utilized by the fry will start to develop. The fact that the same pond can be used for production of lab-lab and later for the production of lumut by altering the technique of flooding is further substantiation of the point in question.

Depth of water is obviously only one of many covarying factors influencing the growth of the algae. Although the depths are very small it is possible that differences in light penetration and temperature might contribute to the differential production of greens or blue-greens. In very shallow streams with dark bottoms, for instance, water temperatures considerably higher than those of the adjacent air were recorded by the author in the Philippines. It is quite likely that conditions at the shallower depths of water are more favorable for the growth of the nitrogen-fixing Myxophyceae and their associated bacteria. Assuming that most of the plant nutrients come from the colloid complex of the subaqueous horizon, it might be expected that the concentration of these nutrients would be greater after a given period of time in a small volume of water than in a larger (deeper) volume.

At present no fertilizers are being added to the Philippine fish ponds in an attempt to increase production of algae, and even if the fertilizers were available in adequate quantities in the islands, it is more likely they would be applied to the deficient agricultural soils than to the already productive ponds. In effect, though, there already is a type of fertilization in that the water of the fry ponds, and to a lesser extent that of the growing ponds, is replaced at frequent intervals. Where these ponds are located along streams draining population centers it is likely, although studies have not yet been made to ascertain the truth of this, that considerable quantities of nutrients are brought into the pond with each exchange of water. Gross observations on regional variation in pond productivity tend to support this view.

Although bañgos can be grown in fresh water ponds or in salt water ponds, including any part of the continuous range in salinity between these two extremes, they apparently do best in strongly brackish water because of better growth conditions there for the food plants. Roxas and Umali (1937) observed that milkfish and mullet "are unprofitable to culture in fresh water ponds, where the growth of algae, the bulk of the food of these two species, is entirely inadequate to supply their needs for rapid growth." At times, however, the water in the ponds must be fresh or nearly so to permit significant growth of such forms as *Spirogyra*, *Oedogonium*, and *Lemna*. The various components of lab-lab and lumut have different salinity tolerances, so that the composition of the association at any particular time will depend in part upon the salt content of the pond water, and this varies from pond to pond and from season to season.

SUMMARY

By way of summary, the Filipinos have developed a successful method of rearing milkfish in ponds by rule-of-thumb methods without understanding the basis for the various procedures employed. Production can be still further increased by utilizing for fish pond construction even a small portion of the 400,000 hectares of mangrove swamps in the islands. Perhaps production can also be increased by a program of careful fertilization worked out experimentally to determine the economic as well as biological feasibility. At least in an instance such as this, where the flow of energy in the food chain proceeds directly from alga to fish, the possibilities of so increasing production are sufficiently great to merit investigation.

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