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

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

INTRODUCTION

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

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

DEFINITION OF MILKFISH FRY

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

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

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

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

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

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

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

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

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

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

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

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

TIME OF FRY OCCURRENCE

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

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

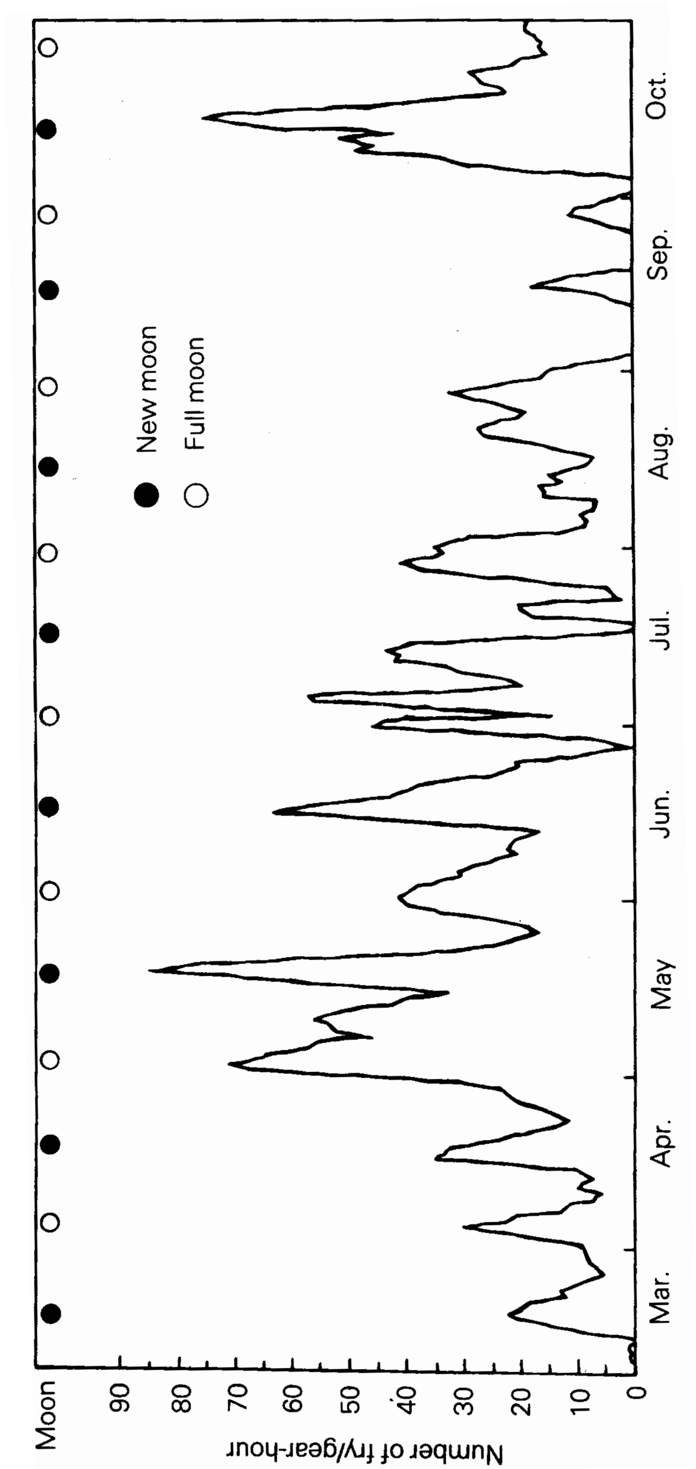

Fig. 1. The abundance of milkfish fry at Hamtik from March to October 1977, showing relation to lunar phase.

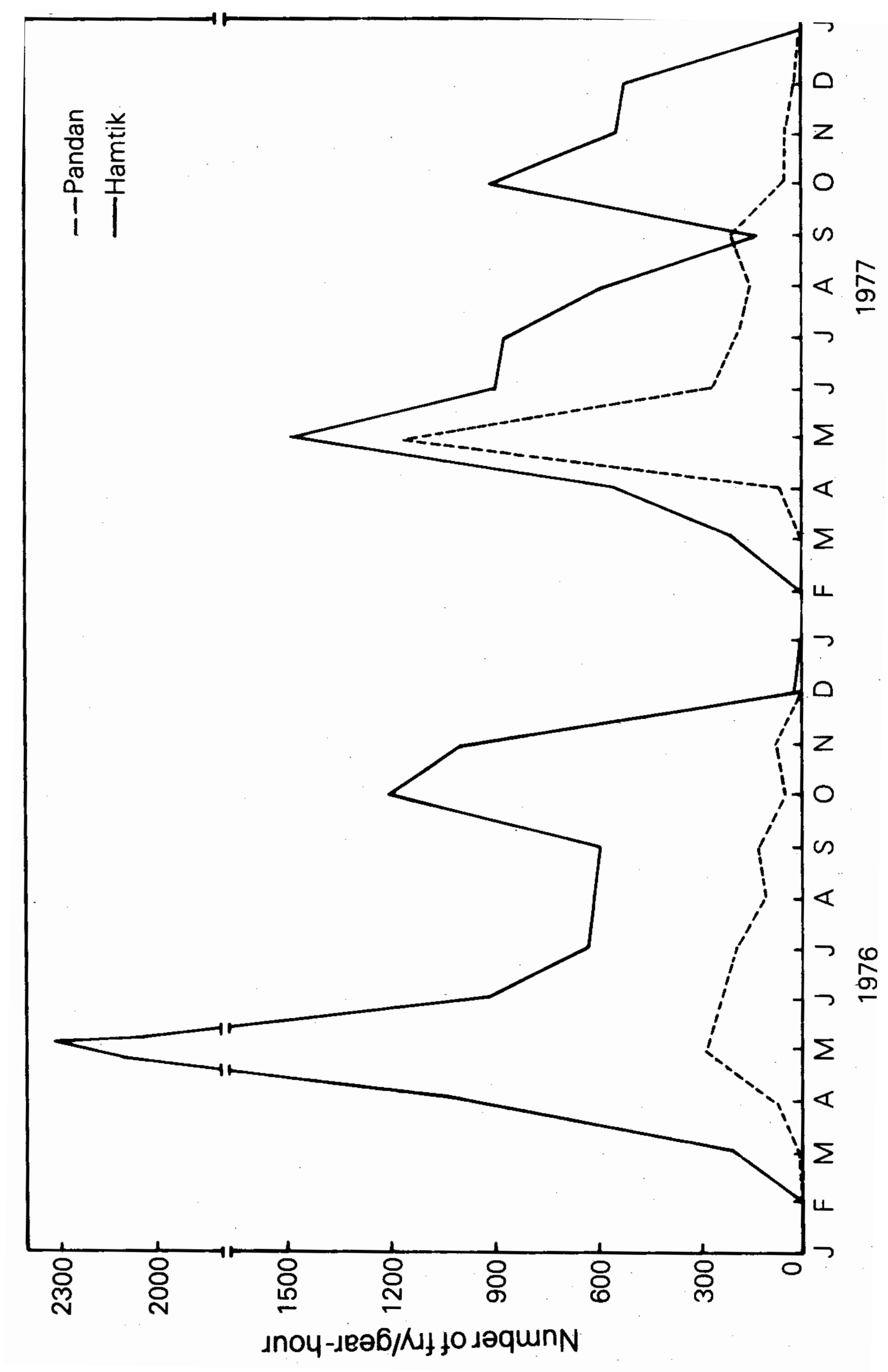

Fig. 2. The fry occurrence pattern in Pandan and Hamtik, Panay Island.

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

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

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

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

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

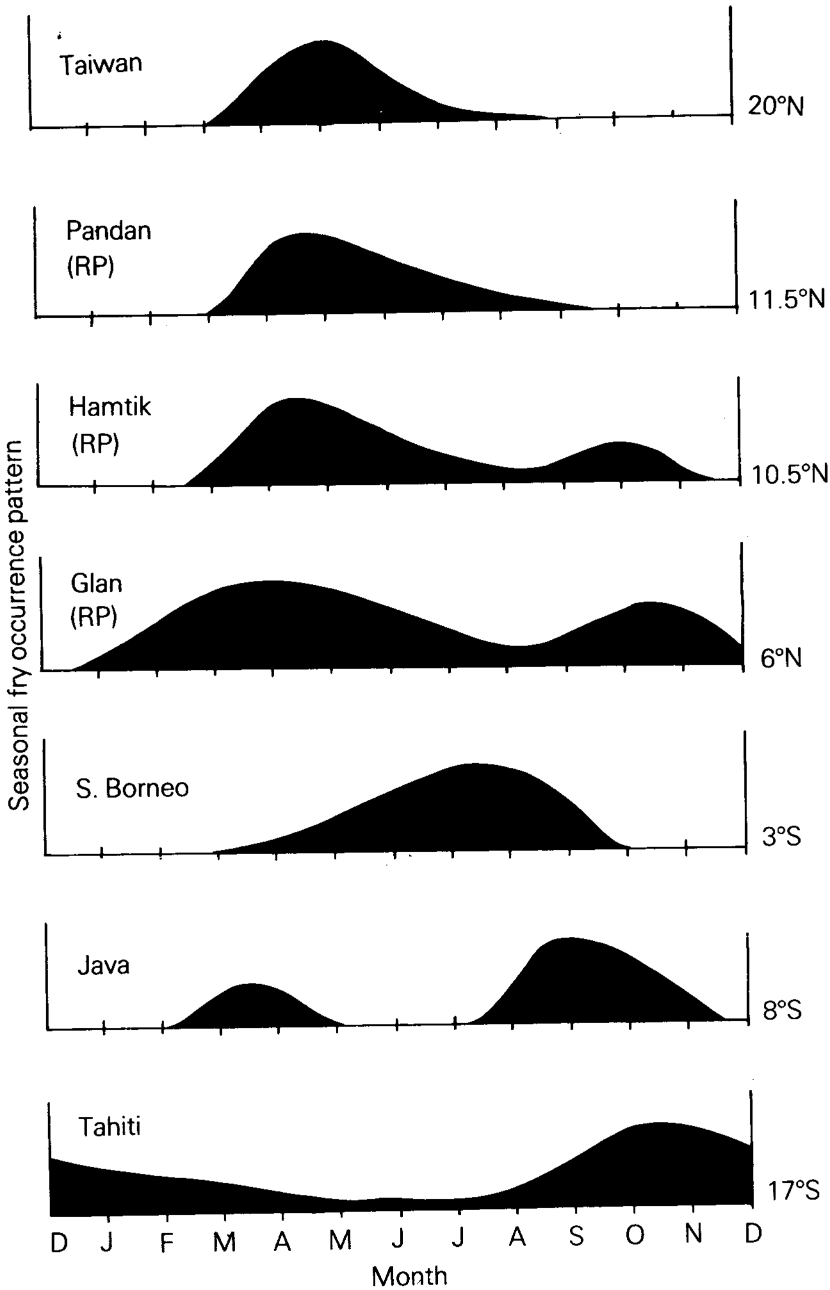

Fig. 3. Seasonal fry occurrence patterns at different latitudes (drawn from data of various authors).

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

PLACE OF FRY OCCURRENCE

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

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

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

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

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

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

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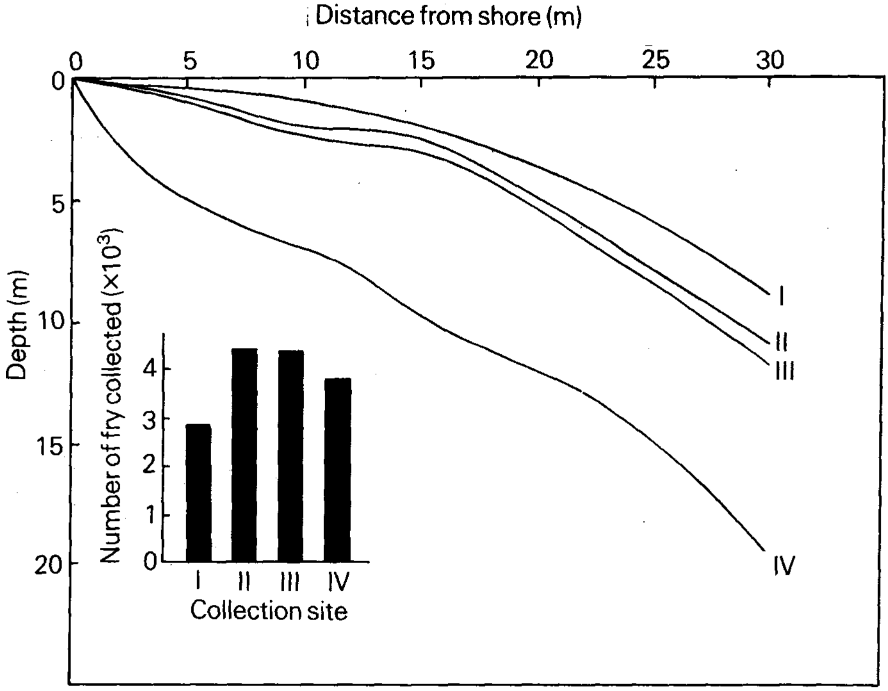

Fig. 5. Types of bottom profile from gradual (I) to steep (IV) and the corresponding milkfish fry catch.

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

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

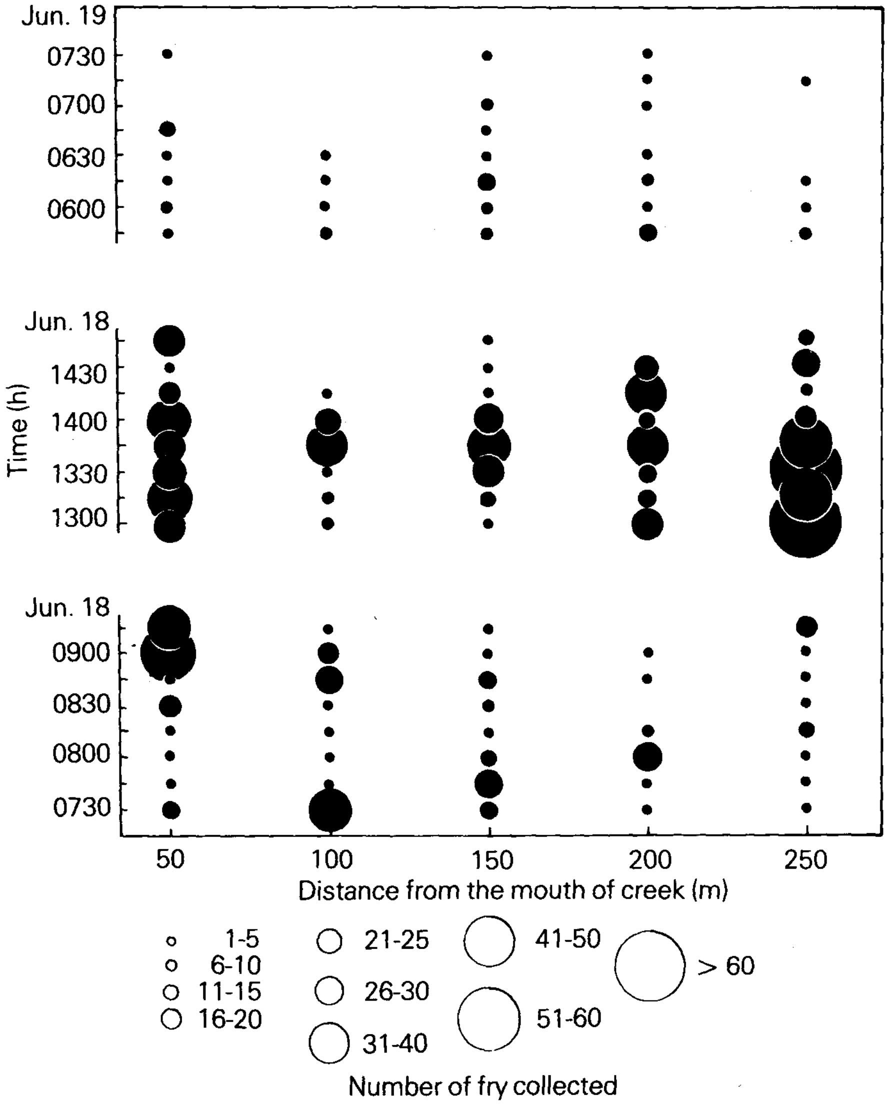

Fig. 6. The catch of milkfish fry at 5 consecutive zones adjacent to a creek mouth (which was a concessioned fry collection site). There is no clear trend of increase of fry abundance towards the creek mouth. The fry appear to arrive at the surf zone in patches.

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

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

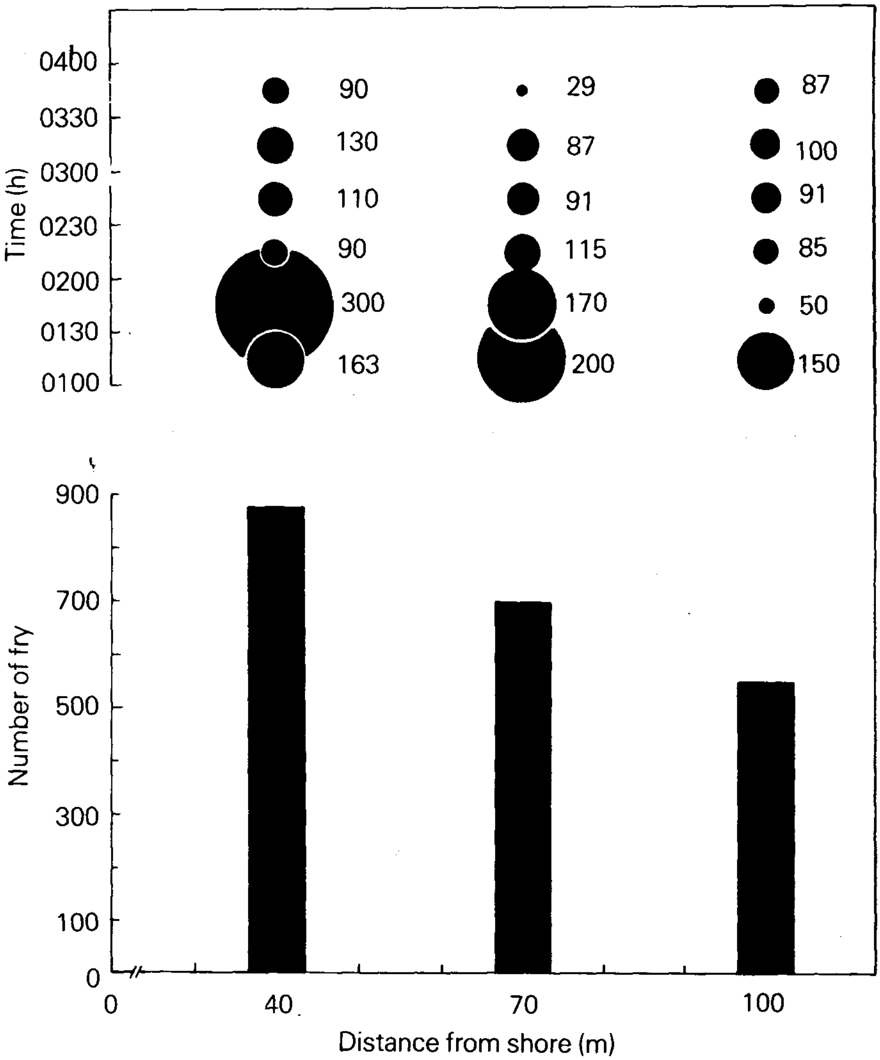

Fig. 7. The abundance of milkfish fry at distances of 40, 70, and 100 m from the surf zone in Hamtik as indicated by catch data from bulldozers. The catches at various times at these three sites suggest gradual accumulation of fry in the surf zone with time.

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

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

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

MECHANISM OF FRY OCCURRENCE

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

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

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

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