THE SENSE ORGANS AND BEHAVIOR OF MILKFISH FRY IN RELATION TO COLLECTION TECHNIQUES

Gunzo Kawamura
Faculty of Fisheries, Kagoshima University
Kagoshima, Japan

Only with some knowledge of the behavior of fish can fishing technologists objectively approach the problems of improving existing fishing techniques or of developing new ones. Behavior is the reaction of organisms to stimuli received through sense organs. This paper describes the sense organs and some of the behavioral characteristics of milkfish fry, based on studies conducted at the Aquaculture Department, SEAFDEC, Philippines and at Kagoshima University, Japan in 1979. Based on the experimental results obtained and the observations made in the Philippines, Indonesia, and Taiwan, existing fry collection techniques such as the employment of fish lamps and scare lines are considered effective and rational. Several recommendations are made for improvement of the collection gear and for research on fry behavior.

INTRODUCTION

The collection of milkfish fry from shore waters in the Philippines, Indonesia, and Taiwan is an important task crucial to the pond and pen culture industry. There is need to improve collection techniques to increase the catch, both to boost milkfish production and to provide remunerative employment to people in coastal villages. The development of fishing gear technology is not based on completely new concepts (von Brandt 1972). The highly modernized fishing gear of today is not fundamentally different from the so-called traditional or primitive fishing gear. Innovations in equipment and techniques have been due to the ingenuity of fishermen, engineers, and scientists who invent mechanisms and improve their quality and effectiveness to meet different fishing conditions and socioeconomic requirements. Although the traditional milkfish fry collection techniques are effective, these lack sound scientific bases and institutional arrangements for continuous improvement through innovation.

By knowing the behavior of fish in the vicinity or path of the gear, gear technologists can approach the problem of improving existing fishing techniques or developing new ones. Behavior is the reaction of organisms to some external stimuli received through sense organs. It is imperative, therefore, to know the sense organs and behavior of milkfish fry.

The objectives of this report are: (1) to describe the sense organs and some of the behavioral characteristics of milkfish fry from the studies made at the Aquaculture Department, SEAFDEC, Philippines and in Kagoshima University, Japan in 1979-83; and (2) to make recommendations for improving existing fry collection techniques in the Philippines, Indonesia, and Taiwan.

SENSE ORGANS OF MILKFISH FRY

Milkfish fry were caught in the shore waters of Kumano Bay, Tanega Island, Japan (Senta et al 1980). Some of them were fixed on the beach in Bouin's solution or in 2.0% osmic acid with 0.1 M sodium phosphate buffer; the others were reared in the laboratory for observation of the development of the sense organs using scanning electromicroscopy and histological techniques. All the sense organs of milkfish fry were considered functional at the time of their capture, and they could respond to optical, chemical, and mechanical stimuli.

Eye

Vision is the most important sense for the fry in feeding and in response to nets (Kawamura and Hara 1980a, Kawamura et al 1980). At the time of capture, the fry have the ability to move their eyes, and they exhibit a well developed regionally differentiated duplex retina (Fig. 1). The cell density and the thickness of the retina are highest in the temporal region (area temporalis), indicative of highest visual acuity towards the nose. Although rod density is low at this stage, retinomotor response is observed, and both photopic and scotopic vision must be possible. The adipose eyelid is not formed at the fry stage and appears only during metamorphosis. A tapetum lucidum is present in the pigment epithelium and may be functional under subdued light conditions. This is observed in nocturnal animals or fish in turbid environments (Walls 1942, Moore 1944). The S-potentials recorded from the retinae of young milkfish (12.5-14.0 cm in fork length) suggest the possession of color vision and show a spectral sensitivity with peaks at 492-522 nm and 582-621 nm (Kawamura and Nishimura 1980), although the fry have not been examined in this respect.

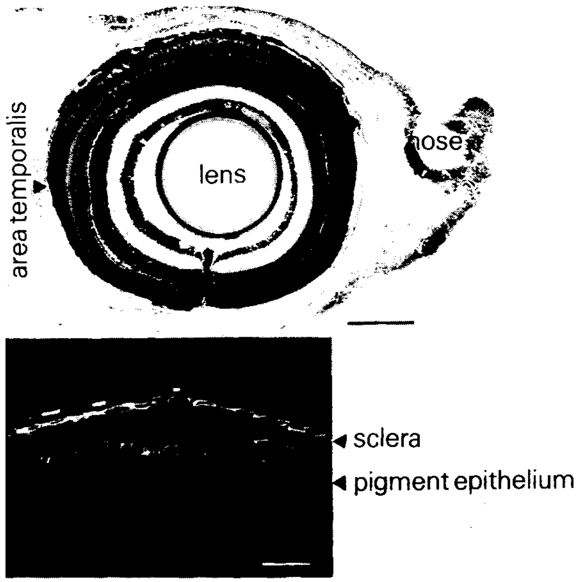


Fig. 1. Top, longitudinal section of the eye of milkfish fry showing the well developed retina with area temporalis. 4 mm thick, Azan stained; scale, 100 mm. Bottom, magnified photomicrograph of the retina of milkfish fry taken under differential interference contrast microscope. The retinal tapetum lucidum shines bright in the pigment epithelium. Scale, 25 mm.

Lateral Line

The receptor unit of the lateral line system is the neuromast, made up of ciliated pyriform receptor cells and covered with a gelatinous cupula. In larval teleosts, the system appears as free neuromasts found in the epidermis. With growth, some of these submerge into the dermis and form lateral line canals with pores; the others remain in the epidermis and are called pit organs. In adult teleosts, the canal organ functions as a mechano-receptor, and the neuromasts (pit organs) are sensitive to chemical, mechanical, and thermal stimuli (Katsuki 1978, Kawamura and Yamashita 1981). The function of the free neuromasts in larvae has not been well examined, but it is probably not different from that in adults. According to Iwai (1972), the free neuromasts become functional as mechanical receptors when the cupulae are well developed. At the time of capture, fry have numerous free neuromasts with well developed cupulae on the head and a few on the trunk (Fig. 2). During metamorphosis, the free neuromasts submerge and form canals in the dermis.

Inner Ear

The inner ear is the receptor of hearing and balance. The membranous labyrinth of fishes can be likened to a purse. Leading from the main pocket (utriculus) of this purse are loops (semicircular canals) and a side pocket (sacculus) that has yet another

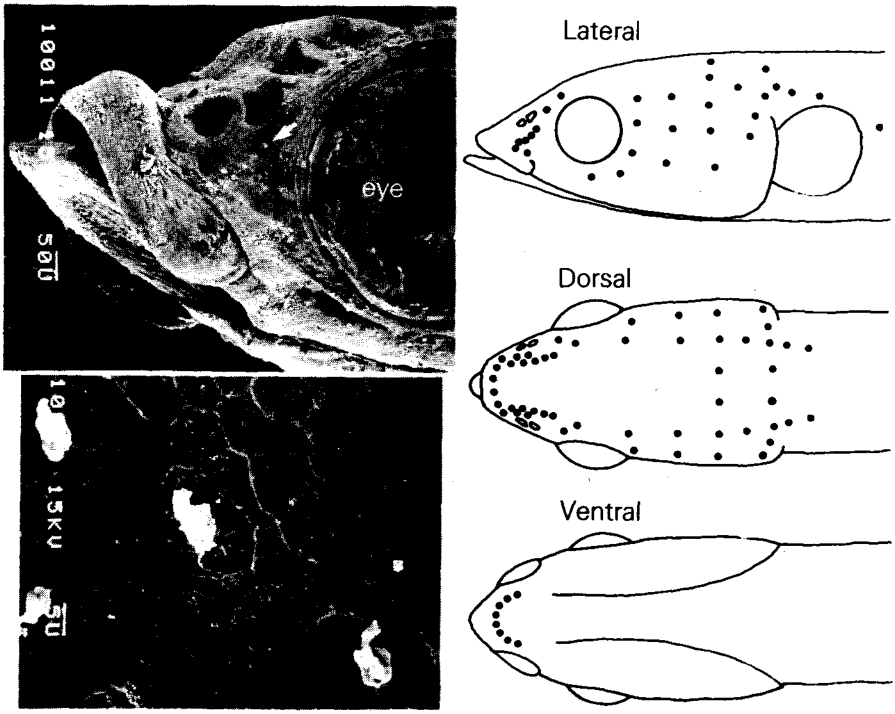


Fig 2. Left, scanning electronmicrographs showing the free neuromasts around the nares (shown by arrow) and the same when magnified. Right, the arrangement of the free neuromasts on the head and under the lower jaw.

pocket (lagena) opening from it. The main pocket and the three semicircular canals are responsible for equilibrium, and the sacculus and the lagena for hearing. At the time of capture, fry have well developed semicircular canals, but not well differentiated pockets (Fig. 3). Since there are neuromast cells with cupulae and otoliths in the main and anterior pockets, the inner ear can be considered functional enough for hearing and equilibrium maintenance.

Olfactory Organ

The olfactory organ of milkfish is a pouch that opens to the water through the anterior and posterior nares on each side of the snout. Division of the nares was incomplete in about half of the newly caught fry examined and becomes complete in all fry within 5 days after capture. The separation of incoming and outgoing water then becomes possible. The olfactory epithelium is not lamellated at the time of capture (Fig. 4). A deep fold appears 14 days after capture. Lamellation increases with growth, increasing the exposed surface area and hence the sensitivity.

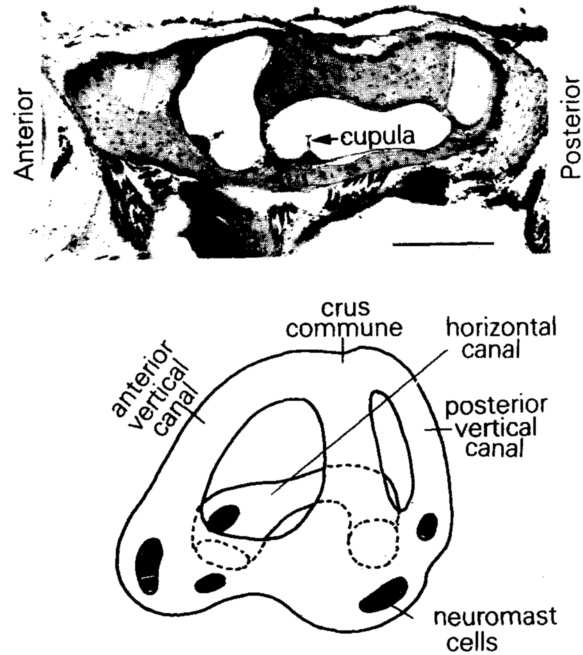
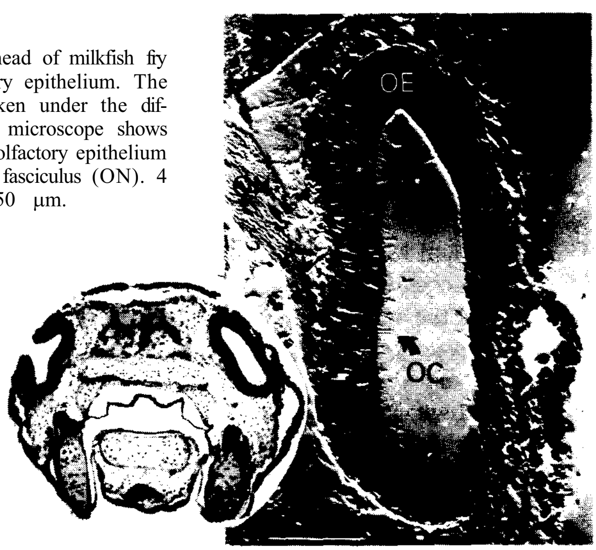


Fig. 3. Top, vertical longitudinal section of the inner ear of milkfish fry. Neuromast cells with cupulae can be seen in the main and the anterior pockets. 4 mm thick, Azan stained; scale, 200 mm. Bottom, the structure of the inner ear as reconstructed from successive sections.

Fig. 4. Cross-section of the head of milkfish fry showing the nares and olfactory epithelium. The magnified photomicrograph taken under the differential interference contrast microscope shows long olfactory cilia (OC), the olfactory epithelium (OE), and the olfactory nerve fasciculus (ON). 4 μm thick, Azan stained; scale, 50 μm.



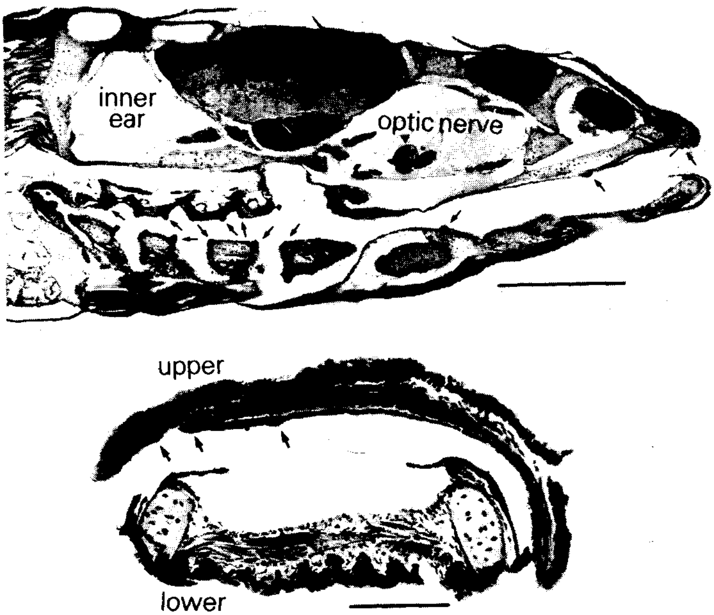


Fig. 5. Top, vertical longitudinal section of the head of milkfish fry showing the taste buds in the epithelium of the oral cavity and the gill arches (arrows). 4 mm thick, Azan stained; scale, 400 mm. Bottom, cross section at tip of mouth shows taste buds in the epidermis of the upper lip (arrows). 4 Um thick, Azan stained; scale, 100 mm.

Taste Buds

Fry at the time of capture have numerous taste buds in the epithelium of the oral cavity and the gill arches and in the epidermis of the upper and lower lips (Fig. 5). With growth, the taste buds in the mouth increase in number and size.

BEHAVIOR OF MILKFISH FRY

Distribution and Movement in Shore Waters

The depth of operation of any fishing gear is dictated largely by the vertical distribution of the desired species. Kumagai (1981) showed the vertical distribution of milkfish larvae by developmental stages from plankton net tows made in offshore waters. Buri and Kawamura (1983) compared catches between two fixed gear at different depths of operation in the mouth of the river at Hamtik, Panay, Philippines and found higher catches from the shallower gear.

The movement of the fry to the collection grounds appears to be an active process. This was first suggested by the results of the drift card experiment of Kumagai and Bagarinao (1979). Buri and Kawamura (1983) released 4060 marked fry 150-160 m offshore at Hamtik and observed active movement back to shore into collection gear and into backwaters (Fig. 6). Good fry collection grounds are usually located close to river mouths and swamp outlets. The entrance of fry into backwaters seems to take place only on suitable flood tides, 1-3 h before high tide.

There is a notable semilunar (circasyzygic) rhythm in the catch of milkfish fry; that is, more fry are caught during full moon and new moon periods (Kuronuma and Yamashita 1962, Kumagai 1981, Buri and Kawamura 1983). When the daily fry catch at Hamtik in 1980 was correlated with the lunar cycle, the catch fluctuation appeared to coincide well with a resultant rhythm composed of syzygic and semi-syzygic rhythms rather than the syzygic rhythm alone (Fig. 7). These studies on the rhythmic fluctuation of the catch of fry may later enable prediction of, and concentration of fishing effort during their peak appearance.

Schooling Behavior

Since a solitary fish behaves differently from a school, and fishing techniques have to be based on the distribution of solitary fish and on the size of a school, fishing technologists have been very interested in schooling behavior. Milkfish fry usually form a typical school in aquaria and similar captive conditions. However, it is not known whether or not the fry form a school or several schools in shore waters. Kawamura and Quinitio (unpubl.) analyzed the catch from two mobile fry sweepers operated independently within a fixed 100 m stretch of beach at Culasi, Panay, Philippines. The analysis was based on the assumption that, if the fry form a school, the catch of any gear would be governed by chance, and there would be low or no

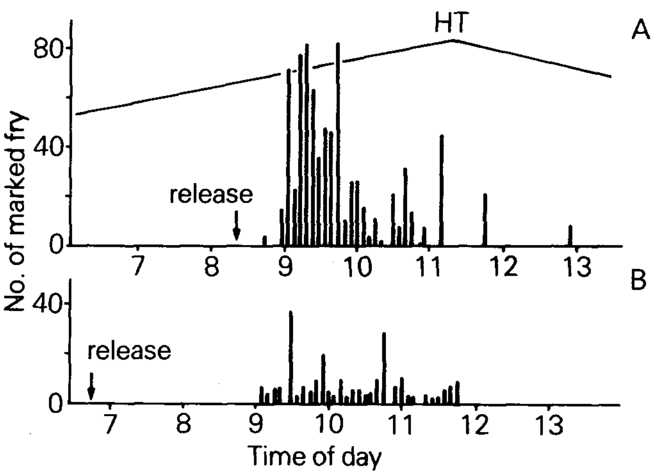


Fig. 6. Recapture of marked milkfish fry in all collection gear combined, from the first release (A, 30 April 1980) and the second release (B, 1 May 1980) at Hamtik. Time scale of B was shifted left to unite the time of high tide (HT) with that of A. The first batch (2060 fry) was released about 3 hours before high tide, the second batch (2000 fry) the following day about 5 hours before high tide. Recapture ratio was 37.2% for the first batch and 35.3% for the second batch (After Buri and Kawamura 1983).

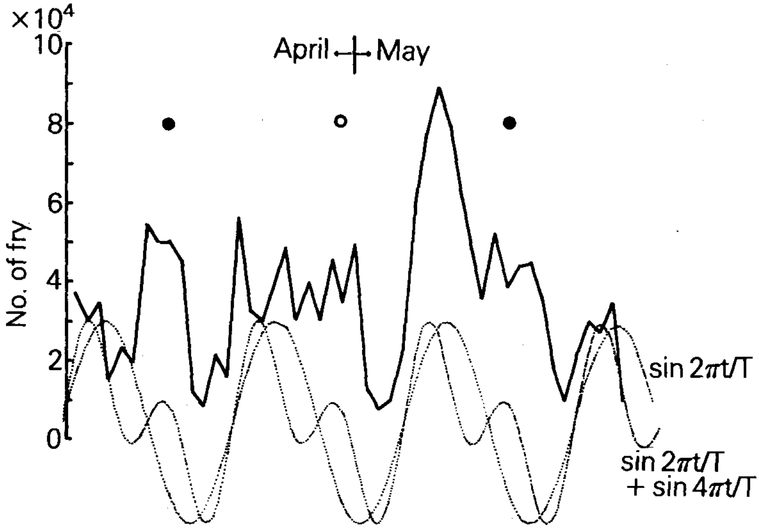


Fig. 7. Daily fluctuation of commercial milkfish fry catch at Hamtik from 7 April to 24 May, 1980 (bold line), shown with the syzygic rhythm and a resultant rhythm composed of syzygic and semi-syzygic rhythms (dotted lines). t = time in days, T = period = 14.77 days, open circle = full moon, closed circle = new moon.

correlation in catch between the two sweepers. However, although the catch was poor, relatively high correlation coefficients were obtained (Table 1), indicating that the fry disperse from an offshore school (if such exists) or form a loose aggregation in shore waters. This result is partly supported by the mark-recapture experiment of Buri and Kawamura (1983); recapture data indicated scattering of released fry over a large area, as far as 2 km from the release point.

Swimming Speed

The swimming speed of milkfish fry has been examined in the laboratory using a water tunnel. Komaki (1981) obtained a speed of 10.8 cm/s, whereas Kumagai et al (1980) observed 9 cm/s in sustained swimming and 24 cm/s in burst swimming. The swimming speed can also be estimated from the optomotor reaction (OMR). From the rotation velocity of the drum employed in the OMR experiment by Kawamura and Hara (1980b), the swimming speed was estimated to be about 9 cm/s. In the mark-recapture experiment, Buri and Kawamura (1983) found that one recaptured fry covered the distance of 150 m in 25 minutes at an average speed of 10 cm/s. Although the experimental methods employed were very different, the observed swimming speeds varied within a narrow range — 9-11 cm/s. On the other hand, the swimming ability of fish has been established to have a positive correlation with space in which to swim (Yonemori 1978). The speed of fry in shore waters may then be greater than that measured in captivity.

Table 1. Correlation coefficients of the catch of two fry sweepers operated simultaneously in independent directions (sometimes in the same direction, sometimes in counterdirection) off a fixed 100 m stretch of beach. The fry in the sweepers were counted every 30 minutes. (After Kawamura and Quinitio, unpubl.)

Date	Time	No. of operations	Total catch		Correlation coefficient	t	P
			Gear-A	Gear-B			
April 17	0700-1830	21	1063	542	0.720	4.300	<0.001
	1830-2400	10	153	174	0.106	0.301	>0.50
April 18	0800-1800	19	222	174	0.760	4.835	<0.001
	1830-0030	9	122	63	0.636	2.180	>0.05
April 21	0800-1700	18	77	46	0.766	4.763	<0.001
May 1	0900-1700	16	34	57	0.542	2.415	<0.05
May 2	0800-1700	18	192	124	0.888	7.710	<0.001

Phototactic Behavior

The use of lamps to attract milkfish fry is practised in the Philippines. The photopositive behavior of the fry was first confirmed in a tank experiment by Kumagai (unpubl.) at the Aquaculture Department of SEAFDEC. Thereafter, Kawamura and Shinoda (1980) in Japan examined the behavior of the fry in the field and in a tank and observed a change in phototactic behavior with growth. Fry exhibit strong positive phototaxis at the time of capture from shore waters. Three shifts in phototactic behavior were observed in fry grown in tanks. The photopositive behavior of the fry approaching metamorphosis became weak, and young juveniles showed photonegative behavior. About 7 weeks later, juveniles again showed photopositive behavior, whereas some 4.5 months after capture, no significant photopositive or photonegative behavior was observed. As the attracted fry can be guided by slowly moving light (Kawamura and Shinoda 1980), lamps can be used with both fixed and mobile gear. However, the light intensity has to be carefully decided upon because the fry have sensitive eyes and are repelled by light stronger than 200-300 W in experimental tanks (Kumagai, unpubl.).

Optomotor Reaction (OMR)

The OMR is an unconditioned reflex evoked by the sight or feel of movement and is of great importance in spacing and in school formation (Protasov 1970). Inside and outside a moving seine net, fish with OMR swim in the same direction at the same speed with the net and are caught when the net wings are closed (Parrish 1967).

The OMR of milkfish fry and juveniles was examined by Kawamura and Hara (1980b) at the SEAFDEC Aquaculture Department. The fish were placed in a beaker and their reactions to a moving striped paper drum were observed. When the drum was rotated in a certain direction, most of the fry turned slowly and moved in the same direction along the wall of the beaker. The OMR was somewhat weak during the first week following capture. It underwent a big change during metamorphosis, and juveniles showed perfect OMR. Although the amplitude of the OMR is somewhat low, newly captured fry in containers show very strong rheotaxis. This behavior may be evoked not only by vision but also with the aid of the already well developed free neuromasts. The role of the lateral line system in rheotactic behavior was elucidated by Inoue et al (1982).

Response to Nets

The fry collection gear presently used in various locations in the Philippines, Indonesia, and Taiwan are in principle operated by filtration, similar to plankton and larval nets. However, as Bridger (1956) reported, marine fish larvae visually avoid plankton and larval nets towed slowly in the daytime. The importance of vision in the response of fish to stationary and moving nets is well established (Ochiai and Asano 1955; Hiyama et al 1957; Kanda and Koike 1958a, b; Kanda et al 1958; Blaxter et al 1964). The fry have well developed eyes and feed on plankton mainly by vision (Kawamura and Hara 1980a). Therefore, although the amplitude of the OMR is somewhat low, the fry can respond to the collection gear by vision.

The responses of milkfish fry to moving and stationary nets were observed in a tank by Kawamura et al (1980) at the SEAFDEC Aquaculture Department. Since juvenile milkfish have color vision (Kawamura and Nishimura 1980), nets of different colors and mesh sizes were tested on the fry in an experimental procedure similar to that of Kusaka (1957). An experimental wooden tank (240 × 60 × 60 cm), painted blue on the inside, was filled with seawater to a depth of 20 cm. Black nylon twine of 0.53 mm diameter was stretched vertically on a blue-painted wooden frame at intervals of 5, 10, and 20 mm, and white nylon twine of the same diameter at 5 and 20 mm.

To observe fry response to a stationary net, 200 fry were driven to one end of the experimental tank and were blocked by a net set 60 cm from the wall. The number of fry which passed through the mesh was counted; this was taken as a measure of the visibility of the net to the fry and as a measure of the strength of the net avoidance response. Fry blocked by a stationary net turned around and formed one or two schools inside the net. Then a small or large part of the school passed through the mesh. It was evident that black and white twine had different effects on the fry; the fry easily and very quickly escaped through the white twine but were retained for a much longer time in the black.

For observation of fry response to moving nets, the fry were driven to one end of the tank where the net had been set beforehand next to the wall. The net was then moved at 3.5-4.0 cm/s toward the opposite wall. The number of fry that were passed by the net (i.e., not herded) was counted. The response of the fry to the moving net varied slightly with the mesh size and color of the twine. The fry swam forward in a relatively dense school, keeping a distance of about 10-45 cm from the moving black twine; they formed a loose school, keeping a distance of 3-45 cm from the moving white twine.

The response of fry to moving mosquito nets of white, black, and blue color was also observed in the tank. The fry reacted by turning away from and swimming in front of the nets, keeping a good distance ahead. However, the difference in the response of the fry to nets of different colors was not clear, probably because the underwater visibility of the nets varied with the space light, i.e., whether the fry were surface or contour-lighted.

The experimental results adequately show the importance of vision in net avoidance and indicate that fry can be driven by suitably visible nets. This implies that the wing parts of existing fry collection gear can be replaced with larger mesh netting such that the gear can be made larger in scale without undue increase in bulk.

FRY COLLECTION WITH INNOVATED GEAR

Based on the response of milkfish fry to stationary and moving nets, Kawamura and Quinitio (unpubl.) conducted fry collection experiments using fry gear with no wings or gear in which the wings were made of larger mesh netting. The experiments were done along the shore of Culasi, Panay Island, Philippines in April-May 1980. Fry sweepers and double stick nets were used in the experiments. The ordinary sweeper has wings and a cone made of fine mesh (0.8 mm) nylon netting. The two innovated sweepers used in the experiments had exactly the same parts and dimensions as the ordinary one, except that one innovated sweeper had wings made of dark green coarse mesh (2 cm) nylon netting, while the other had no wings. The ordinary double stick net uses fine mesh (*sinamay*). The innovated net had only the central part made of *sinamay* and the two ends of dark green coarse mesh (2 cm) nylon netting. The innovated and control fry gear were operated simultaneously along a fixed 100 m stretch of beach, sometimes in the same direction and sometimes in opposite directions. These were frequently exchanged among the operators to minimize bias in the catch data. The number of fry caught was counted every 30 minutes.

The results are summarized in Table 2 and show a lower catching efficiency for the innovated sweeper. Analysis of the catch data shows that in the innovated sweeper the bamboo frame itself and the large mesh netting of the wings have a considerable fry driving effect. At the same time, the filtration effect of the fine mesh wings of the ordinary sweeper is significant. It was seen that the innovated sweepers can be operated faster than the ordinary one due to reduced underwater resistance. This is reflected in the lower ratio of live fry to total fry for the innovated gear (Table 2). The innovated sweeper can be operated at a lower towing speed and will consequently be less tiresome for the fishermen.

The innovated double stick net had almost the same catch as the ordinary one. This suggests that the two sides of the net function not as a filter but as a driving device.

The catch obtained in the experimental collection does not warrant further catch analysis nor conclusive explanation. However, it seems reasonable that the wings of mobile fry gear should be made of coarse mesh netting, at least in certain collection grounds. Such improvement decreases the underwater resistance of the gear and enables fry collectors to operate bigger gear to cover more area for a longer time with less fatigue.

RECOMMENDATIONS FOR IMPROVEMENT OF FRY COLLECTION TECHNIQUES

Milkfish fry collection gear is variously designed to meet the requirements of particular collection grounds and to utilize locally available materials. Various items have been described by Kumagai et al (1980), Villaluz et al (1982), and Kawamura et al (1983). The following discussion will deal with the principles of fry capture and gear improvement.

Barriers

Fixed barriers or fences are set perpendicular to the beach across the current and fry movement. Assuming that the fry are distributed mostly at the surface and associate with floating materials in shore waters, fry barriers could be set floating at the water surface to move with the changing tide. Where longshore currents are pronounced, barriers could be set oblique to the shore to guide and concentrate the fry shoreward.

Scare Lines

The drive-in technique to catch milkfish fry using scare lines (*blabar*) is applied only in Indonesia. Since the milkfish fry are driven well by mobile gear (see above), the use of scare lines is an effective technique, especially in extremely shallow waters where larger mobile gear cannot be operated.

Table 2. Results of fry collection with innovated and existing gear (After Kawamura and Quinitio, unpubl.).

Gear[a]		Date, time	No. of operations	No. of fry: Alive	No. of fry: Total	Ratio: Alive/Total	x^2	P	Underwater (visibility) of gear (cm)
Control		17 April	21		1063		129.23	0.001	20-40
E1		0730-1830		—	542	—			
Control		17 April	10		153		1.10	0.250	unknown
E1		1830-2400		—	174	—			
Control		21 April	18	45	77	0.58	7.81	0.01	200
E1		0800-1700		22	46	0.48			
Control		2 May	18	179	192	0.93	14.63	0.001	200
E1		0800-1700		109	124	0.88			
Control		18 April	19		222	–	5.82	0.010	20-40
E2		0800-1800		—	174				
Control		18 April	9		122		13.72	0.001	unknown
E2		1830-0030			63				
Control		22 April	16	41	46	0.89	28.70	0.001	200
E2		0830-1630		5	7	0.71			
Control		1 May	16	34	34	1.00	5.81	0.010	200
E2		0900-1700		51	57	0.89			
Double stick net	Control	19 April	16		285		1.40	0.100	200
	Exp.			—	314	—			

[a]E1 - sweeper without wings,
E2 - sweeper with coarse mesh wings.

Fixed Filter Nets

This type of gear, found only in the Philippines, has V-shaped wings to guide the fry to a posterior bag of fine mesh netting. It is commonly set in the mouths of rivers, creeks, and similar places where fry come in with the high tide. Since a large portion of the fry population in shore waters enters rivers and creeks, it would be good practice to excavate the river mouth to attract and guide the fry to a place where the actual capture is made. This will make fry collection in backwaters possible, a definite advantage when the sea is rough and collection from the open shore is difficult. To minimize damage to fry due to strong currents, the posterior end of the filter net should form a deep bag to allow the trapped fry some room in which to swim around.

Skimming Nets

Skimming nets are handy enough to be operated even in places that are very rocky, or with obstructive mangrove roots. The larger skimming nets in Indonesia and Taiwan have a container at their posterior ends that retain the fry. In the Philippines, this container could be adopted and affixed to certain mobile gear to facilitate scooping of fry from the net and to minimize damage. In Taiwan, a specially modified skimming net without frame is operated at the water surface from a boat; it has a pocket at its posterior end where the fry are scooped.

Fry Sweepers

Fry sweepers or fry bulldozers are especially developed and very popular and effective on Panay Island, Philippines. While the sweepers exhibit large variations in construction and in scale, they all basically have a surface skimming net with rigid wings that drive the fry (see above) and prevent their escape. The posterior end should form a deep pocket to enable the fry to stay in the net without becoming injured.

Seine Nets

Double stick nets are operated in waist-deep water in the Philippines. A longer (15 m) fry seine net (1 m deep) without a bag is operated like a beach seine at Culasi, Panay Island. Its warps can be replaced with scare lines to drive the fry. The fine mesh netting, except for the central part where final scooping is done, can be replaced with coarser mesh netting to reduce towing resistance. A container can be attached at the central part of the seine net to facilitate scooping.

According to Villaluz et al (1982), recent modifications of the fry catching gear in the Philippines are directed to areas farther from shore. However, offshore exploitation may not be effective, as fry are concentrated in shore waters. Further fry exploitation should focus on shore waters; the following information is required:

- the behavior of fry in the vicinity of the gear to employ suitable catching and handling techniques,
- the vertical distribution of fry in shore waters at different times of day in different fry grounds to employ suitable depths of operation for more economic and effective fishing, and

the movements of fry in shore waters to enable effective operation of the collection gear.

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