The Efficiency of Mollies, *Poecilia mexicana*, as Live Bait for Pole-and-Line Skipjack Fishing: Fishing Trials in the Tropical Central Pacific

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ABSTRACT—Cultured mollies, Poecilia mexicana, *were tested as live bait for pole-and-line skipjack tuna,* Katsuwonus pelamis, *fishing. Fishing trials were conducted in American Samoa, Tuvalu, and the Gilbert Islands in June and July 1978. Fishing in American Samoa was poor. Overall, 80 schools were chummed and 3,151 tuna (mostly skipjack) were tagged, including 1,018 in 1 day on mollies alone around Funafuti. The ratio of mollies chummed to tuna tagged was 1:17; under a commercial effort, a ratio of 1:59 could have been expected. Mollies performed as well as or better than wild bait* Spratelloides delicatulus. *Small mollies seemed to work as well as larger ones. The mollies were cured of bacterial infections by treating them in the baitwells with an antibiotic. After 2 weeks aboard the vessel, the remaining mollies weakened and began dying; they had been fed on tuna fish meal and dietary defiency is the suspected cause. Because mollies tend to crowd in the neck of the baitwells, modification of baitwells warrants consideration in future work. Lures designed to simulate mollies may also be important.*

Introduction

It is generally agreed that limited bait supplies prevent further expansion of skipjack tuna, *Katsuwonus pelamis*, pole-and-line fisheries in the central and western tropical Pacific. A tuna baitfish workshop was held in Honolulu in 1974 to address this problem and bring together current knowledge (Shomura, 1977). The recommendations concerning cultured baitfish species called for further field tests and for evaluation of species suitability for pole-and-line tuna fishing. This study tested the desirability of the cultured mollie, *Poecilia mexicana* (Pisces: Poeciliidae), in pole-and-line tuna fishing aboard a modern, well equipped Japanese live-bait vessel.

Poecilia mexicana was tried as live bait in several preliminary trials around American Samoa in 1974 and 1975 and results indicated that this species was a suitable baitfish for skipjack tuna (Baldwin, 1977b). The Office of Marine Resources, American Samoa Government, pursued the culture of this species. More extensive sea trials using cultured *P. mexicana* were conducted in American Samoa and Fiji in January, February, and March 1978 aboard a modern well equipped west coast live-bait vessel, *J-Ann* (Vergne et al., 1978).

In Hawaii, other potential alternate live baits have been tried, e.g., tilapia, *Tilapia mossambica*, (Shomura, 1964) and threadfin shad, *Dorosoma petenense*, (Iverson, 1971), but the shad tests proved inconclusive. Although tilapia showed promise, further interest and subsequent funding for the project has waned.

June and Reintjes (1953) provided a practical field guide to the baitfishes of the central Pacific and Baldwin (1977a) gave an excellent review of baitfish literature. In this report, skipjack tuna refers to *Katsuwonus pelamis* and yellowfin tuna refers to *Thunnus albacares*, as given by Klawe (1977).

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Materials and Methods

Mollies used in the fishing trials were cultured and reared in enclosures located at Pago Pago International Airport in American Samoa (Fig. 1). The enclosures were constructed by staking and fencing with synthetic plastic screen material having a mesh size of approximately 1.5 mm. The mollies were seined from the enclosures and placed in 2,300-l capacity fiber glass tanks (described by Iverson and Puffinburger, 1977) at a density of about 25 mollies (37 g) per liter of brackish seawater (25 ‰). A water soluble antibiotic (Furacin[1], Eaton Laboratories) was mixed in at a ratio of 0.1 g/l of water as a prophylatic. Oxygen was provided through two large airstones in each tank according to methods described by Baldwin (1970). Dissolved oxygen in each tank was kept at levels above 6 ppm by this system.

The two holding tanks were mounted on a flatbed truck with the oxygen system and the fish were transported to Pago Pago Harbor about 15 km from the culture site (about 35 minutes). Upon arrival, the fish were gravity fed from the transport tanks down an enclosed plywood chute into one of two floating receivers (holding pens). One receiver measured 6.5×6.5×2 m in depth, the other was 3×3×2 m in depth. Both receivers were constructed of wood and had working platforms around the perimeters. They were floated by means of 220-l (55-gallon)

[1]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

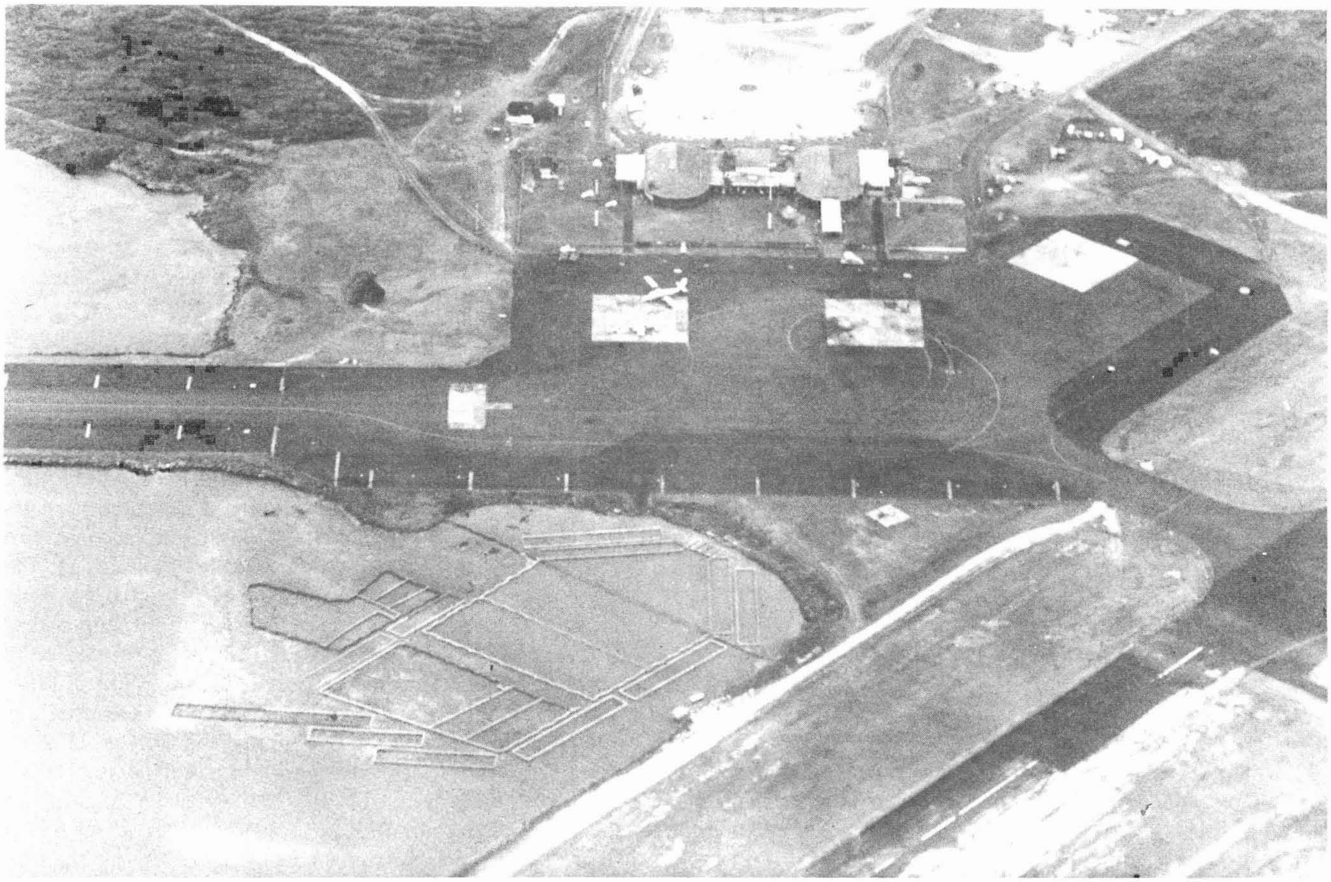

Figure 1.—Aerial view of mollie culture complex (bottom half of photograph).

oil drums. Each receiver consisted of an outer bottom section made of 6-mm galvanized screen which protected an inner prefabricated nylon net of 4-mm mesh size.

To load the baitfish into the baitwells, the receivers were brought alongside the vessel and the baitfish transferred with buckets. Approximately 373,000 mollies (507 kg) were loaded aboard the *Hatsutori Maru* on 16 June and another 134,000 (202 kg) were loaded on 21 June (total, 710 kg). Two size groups were represented: Baitwell No. 1 contained about 66,000 (46 kg) smaller mollies ($\bar{x}$ SL = 27.0 mm; $\bar{x}$ WT = 0.7 g)[2]. The other four wells contained about 442,000 (663 kg) larger mollies ($\bar{x}$ = 36.2 mm; $\bar{x}$ WT = 1.5 g).

[2]SL = standard length; WT = weight.

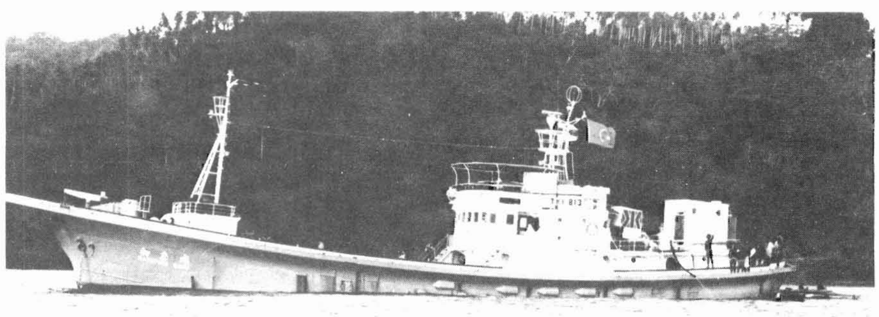

Figure 2.—Japanese live bait pole-and-line fishing vessel, *Hatsutori Maru*. Name on vessel is misspelled.

The vessel used for the fishing trials was a Japanese sampan, *Hatsutori Maru* (Fig. 2). At the time of the trials, it was under charter to the South Pacific Commission (SPC) for a 3-year period to conduct a skipjack tagging program throughout the Pacific basin. Through mutual agreement between SPC and American Samoa Government, these tests were incorporated into her planned schedule. The crew consisted of nine Japanese (including the captain) and nine Fijians. In addition three SPC scientists and the author were aboard during these fishing trials. The vessel specifications are as follows: Launched, 12 November 1967; gross tonnage (metric), 192; length overall, 42 m; registered length, 34 m; beam, 6.7 m; draught, 3.2 m; speed, 11.8 knots max.; range, 6,000 miles. Detailed specifications and the vessel layout are given by Kearney and Lewis (1978). The bait tank (baitwell) capacities beginning from the bow are: No. 1, 13.9 m^3; No. 2, 14.0 m^3; No. 3, 13.7 m^3; No. 4, 16.8 m^3; and No. 5, 16.1 m^3. Each well is pumped independently of the others and all have open seawater circulation. The vessel is also equipped with a saltwater spray system with individual adjustable nozzles located at intervals (about 0.5 m apart along the gunwales) around the stern, the bow, and along the entire length of the port side (Fig. 3). The fishermen used fiber glass fishing poles with mono filament lines and leaders. The lures were the traditional squids with chrome heads and white (or white and red) feathers partially skirted with processed cat's (feline) skin. Most fishermen used a #2.3 lure (Japanese numbering system) for the smaller tuna and a #2.5 for the larger tuna.

Night baiting for wild baitfishes was done using two submerged lights (each 1 kW), one hung off the port side near the bow and the other hung from a skiff containing a diesel powered generator and positioned about 100 m behind the stern of the vessel. The bait was captured by a Japanese style stick held lift net (bōuke ami) pulled in from the starboard side of the vessel. An illustrated account of the Japanese night baiting method is given in the JAMARC report (Anonymous, 1976).

There are two chumming stations on board the *Hatsutori Maru*; one tank (station) is located on the port bow and the other on the port stern. Bait was transferred from the baitwells to the chumming tanks in buckets as needed. Usually, chumming commenced from both stations as the vessel approached a school of tuna. When the fish were observed to break at the surface along the "chum line," the vessel was slowed to a stop while making a half circle so that the port side was positioned at more or less a right angle to the "chum line." The water spray system was then turned on as the tuna approached the vessel and fishing commenced.

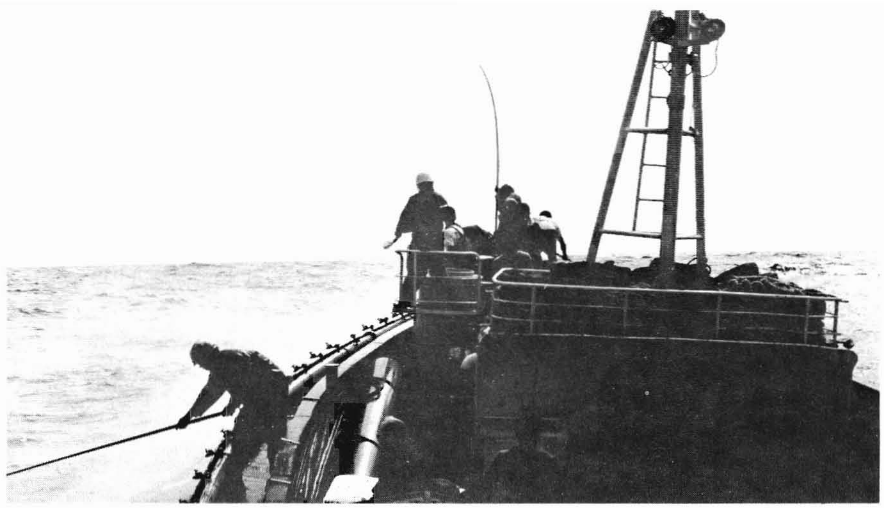

Figure 3.—Spray system along the port gunwales of the *Hatsutori Maru*. Chummer has just thrown some live mollies.

On those occasions when wild bait was available, it would be chummed from the bow (or stern) while mollies were stimultaneously chummed from the stern (or bow). On the following day, the order would be reversed, and so forth. Fish caught on the stern were kept separated from those caught on the bow and amidships.

Buckets of mollies loaded aboard the vessel were periodically sampled and weighed to provide estimates of weight and numbers chummed. When night baiting for wild bait, random buckets were sampled and weighed and the species composition recorded. In addition, dead bait from each well was collected and weighed every 6 hours to estimate mortality. In rough seas, however, this proved difficult because many of the dead baitfish would be washed overboard before they could be collected. Bait transferred from the baitwells to the chumming tanks were recorded in numbers of buckets, each bucket containing an average of 3.0 kg of fish.

Results

Mollies as Baitfish

The mollies used in these trials were exposed to considerable stress and rough handling from the initial seining, transporting, and loading into the baitwells on 16 or 21 June in American Samoa. On 22 June a large percentage of the mollies in baitwells 1, 2, 3, and 4 aboard the *Hatsutori Maru* were apparently infected by a bacterial pathogen and possibly fungus. Each of these wells was treated with a water soluble antibiotic (Furacin water mix) by adding about 0.1 g antibiotic per liter of water and turning off the pumps for about 40 minutes. The same treatment was repeated the following day and no further disease problems were encountered again.

Mollies which were regurgitated by tuna poled aboard the vessel often survived when they were picked up and placed back into a baitwell. Several times live mollies were removed from the stomachs of tuna and placed back into the baitwells where they swam away, apparently quite able to survive.

The mollies were fed dry tuna fish meal once or twice each day aboard the *Hatsutori Maru*. The constricting neck at the top of each well and the tendency of the mollies to crowd at the sufrace when being fed made efficient feeding difficult. If the food was spread on the surface, it was instantly consumed by the fish nearest to the surface. When the fish meal was made into a wet mash and sunk, the fish still would crowd together in the neck of the well attempting to reach the surface.

The baitwells on the *Hatsutori Maru* are designed for alternate use as reefer holds to freeze tuna and subsequently the walls of the wells are lined with freezer coils. To remove the bait from the wells, a stick-held crowder net was used to concentrate the fish at the surface where they were more accessible. Once the crowder was initially used, the mollies tended to avoid it by swimming downward and hiding between the coils and in the corners of the wells. This made it ultimately necessary to drain the baitwell and scoop the remaining mollies (about 30 percent) out by hand. Similar problems were encountered on the *J-Ann* even though the *J-Ann's* baitwells were not lined with coils but had smooth interiors.

For the most part, fishing was conducted with the vessel stopped and the behavior of the mollies when chummed facilitated this method of fishing. The mollies would initially remain motionless for several seconds upon hitting the water, then swim either singly or in small groups back underneath the water spray and alongside the hull of the vessel. This usually brought the tuna close in under the spray in reach of the lures. Often after fishing a school for several minutes the biting would slow down considerably. When this happened, the captain would ease the vessel ahead briefly, flushing out the mollies close to the hull. The maneuver usually initiated a renewed feeding response and subsequent vigorous biting. This method was often repeated several times while fishing a school and proved to be quite effective to renew the biting response.

When pursued or attacked by tuna, the mollies would often repeatedly jump from the water, sometimes somersaulting through the air. At no time were the mollies observed to dive. Sometimes small aggregations of mollies would venture 1-2 m from the vessel but would always return, particularly when being chased by feeding tuna. One night while the *Hatsutori Maru* was drifting, I scooped over a bucket of mollies back aboard the vessel. The mollies were apparently attracted by the vessel's lights and remained alongside after having been chummed several hours earlier while fishing a "sundown school."

Several schools were chummed with small mollies ($\bar{x}$ SL = 27.0 mm; $\bar{x}$ WT = 0.7 g) than those normally used ($\bar{x}$ SL = 36.2 mm; $\bar{x}$ WT = 1.5 g). No distinguishable differences in the behavior of these two size groups or their respective catchability were detected. Several other schools were chummed with a mixture of these two size groups and again no differences were noted.

I covered the chrome and skirt of several squids of different sizes with dried dark skin of mahimahi and fished these lures next to the traditional lures on several occasions. In two schools, the dark colored lures received more strikes than the stock lures. In other schools the modified lures performed as well as or better than the traditional lures.

Survival of Mollies

Of the 710 kg of mollies loaded aboard the *Hatsutori Maru*, about 506 kg (includes 27 kg mixed with sprat) were chummed (Table 3) and about 203 kg were lost to mortality or otherwise, i.e., human error, pump failure, and overflows. Most of the mortality occurred after 2 July. Total mortality through 1 July was 7 percent ($\bar{x}$ daily mortality, 0.44 percent). From 2 July through 5 July mortality increased significantly and about 71 percent of the remaining mollies (215 kg) were lost.

On 2 July, the pump to well No. 3 was accidentally turned off for an undetermined time causing the mollies to crowd at the surface in the neck of the well (in distress, mollies come to the surface and gulp air). The dissolved oxygen was apparently depleted and the mollies began dying. After the problem was remedied, the mollies appeared weak and lethargic, crowding in the neck of the well. During the night the mollies plugged the outlet manifold causing the baitwell to overflow.

The following day (3 July) mortality continued in this well and the mollies in well No. 1 began showing similar symptoms, crowding at the surface in the neck of the well. High mortality subsequently began in this well also and this condition continued in both wells until all the bait was used during chumming just before dark on 5 July. Even in their weakened state, the mollies were very effective as baitfish. I examined 10 dying fish from each well and found one symptom in common; all had enlarged gall bladders full of dark green fluid. Externally the fish appeared healthy and normal, certainly not emaciated.

General Fishing Results

Table 1 provides a daily summary of schools chummed and/or fished ("fished" indicates that fish were caught from the school). Overall, 80 schools were chummed and 30 schools were fished (38 percent). The average size of skipjack tuna caught was 2.9 kg; for yellowfin tuna the average size was 1.8 kg. A grand total of 11,210 kg (95.5 percent) of skipjack tuna and 505 kg of yellowfin tuna was caught. Of 4,187 tuna caught, 3,151 were tagged and released. Most of the other fish encountered were rainbow runner, *Elagatis bipinnulata*, and though these schools were never fished for more than a few minutes, they usually came quickly to the vessel and were easily caught. Only several mahimahi, *Coryphaena hippurus*, were caught, these trolled. Although the major goal of this cruise was to tag tunas, these trials were considerably more successful than those undertaken by the *J-Ann* (Vergne et al., 1978) as shown in Table 2.

Table 3 gives the fishing results according to the type of bait used. On 5 days, both mollies and captured wild bait (round herring or sprat, *Spratelloides delicatulus*)[3] were chummed (sprat from the bow simultaneously with mollies from the stern and vice

[3]The Hawaiian name is "piha."

versa on alternating days). Twenty-one schools were chummed in this fashion and nine were fished (43 percent). More tuna were tagged on mollies than on sprat in five schools and more tuna were tagged on sprat than on mollies in four schools. From the nine schools, 515 tuna (1,329 kg) were tagged on mollies versus 386 (858 kg) tagged on sprat.

Most schools took longer to follow the chum line to the boat than was previously experienced by the *Hatsutori Maru* with schools chummed on wild bait in other island groups (J. P. Hallier, South Pacific Commission, Noumea. Personal communication during these trials). Usually it took 30-60 seconds from the time the school first broke the surface on the chum line until the school reached the stern of the vessel and could be fished. This was true even when both mollies and sprat were chummed.

Stomach analyses were performed on decked tuna taken from almost every school fished (Table 4). Poled skipjack tuna and yellowfin tuna frequently regurgitated mollies as they were pulled aboard. The stomachs of most tuna examined contained mollies (RF, 78 percent)[4] (Fig. 4). The stomach of one large skipjack tuna contained 133 (200 g) mollies. Most fish examined from schools chummed with *S. delicatulus* contained the same (RF, 63 percent).

Almost all schools were located by the presence of birds (schooling terminology used here adapted from Scott, 1969). Schools encountered 20 km or more from land tended to be fast moving breezers accompanied by high flying birds; often the birds would disperse when a school was chased down. Schools encountered less than 20 km offshore tended to be jumpers or foamers, slower moving, and accompanied by greater numbers of birds than offshore schools. The stomachs of inshore fish usually contained more food items and more biomass (other than chum) than stomachs examined from offshore fish. In general, offshore schools bit better than inshore schools.

[4]RF =relative frequency.

Table 1.—Daily summary of fishing results by *Hatsutori Maru*.

Date	Locality	Bait	No. schools chummed	No. schools fished	Kg bait chummed	Kg tuna tagged[1]	Kg bait: Kg tuna
June 17	American Samoa	Mollies	7	0	33	0	
June 18	American Samoa	Mollies	5	0	24	0	
June 19	American Samoa	Mollies mixed with *Spratelloides gracilis*	1	1	27	165	1:6
		Mollies	4	1	39	58	1:1
June 21	American Samoa	Mollies			3	0	
		Stolephorus	1	0			
		devisi			9	0	
June 25	Nearing Funafuti	Mollies	8	6	125	2,518	1:20
June 26	Funafuti	Mollies	3	2	24	299	1:12
June 27	Funafuti	Mollies	13	4	57	1,672	1:30
June 28	Funafuti	Mollies	5	1	15	118	1:8
June 29	Funafuti &	Mollies			18	84	1:5
	Nukufetau	*Spratelloids*	7	4			
	Nukufetau	*delicatulus*			30	124	1:4
June 30	Nukufetau &	Mollies			12	25	1:2
	Funafuti	*S. deli-*	4	1			
		catulus			21	70	1:3
July 1	Funafuti	Mollies					
		S. deli-	1	1	15	164	1:11
		catulus[2]			18	192	1:11
		Mollies	6	2	51	1,617	1:32
July 2	Funafuti	Mollies	6	4	21	302	1:14
July 4	Steaming	Mollies			12	314	1:26
	toward Tarawa	*S. deli-*	4	1			
		catulus			24	118	1:5
July 5	Between Tarawa	Mollies			30	742	1:25
	& Onotoa	*S. deli-*	5	2			
		catulus			39	354	1:9

[1]Includes both skipjack tuna and yellowfin tuna.
[2]Depleted *S. delicatulus* in first school.

Figure 5 shows the general course of the *Hatsutori Maru*.

American Somoa Fishing Results

Five days were spent fishing and baiting (Table 5) around American Samoa where generally fishing was very poor. High winds (20-30 knots) and heavy seas made spotting of birds difficult. The surface water temperature averaged 28.0°C. Eighteen schools were chummed but only three were fished (17 percent). One of the fished schools was chummed with a mixture of mollies and round herrings (*S. gracilis*). Although 80 buckets (120 kg) of the anchovy *Stolephorus devisi* were captured by night baiting in Pago Pago Harbor during the early morning of 21 June (Table 5), only one school of tuna was spotted that day and it did not respond to chumming by either mollies or anchovies. Most schools would not even bite trolled lures and several schools followed along with the vessel for several minutes, ignoring the trolled lures. Overall, only 74 (223 kg) tuna were tagged in American Samoa waters (Kearney and Hallier, 1978).

Table 2.—Comparison of fishing results using mollies between the west coast vessel *J-Ann* and the Japanese vessel *Hatsutori Maru*.

Vessel	Kg mollies chummed	Kg tuna caught	Kg mollies: Kg tuna
J-Ann[1]	1,834	[3]17,542	1:10
Hatsutori Maru[2]	479	[4]10,236	1:21

[1]Commercial fishing effort, 6 January-14 March 1978.
[2]Tagging effort only, 17 June-5 July 1978.
[3]Includes trolled fish.
[4]Does not include trolled fish.

Table 3.—Fishing results by *Hatsutori Maru* according to type of bait used.

Type of bait	No. schools chummed	Kg bait	Kg tuna[1]	Kg bait: Kg tuna
Mollies	80	479	7,913	1:17
Spratelloides delicatulus	21	132	858	1:7
Mollies *Spratelloides gracilis* mixture	1	27	165	1:6

[1]Based on tagged fish only.

Table 4.—Food items found in stomachs of tuna examined from 23 schools. Data presented were randomly subsampled from larger stomach analyses samples to facilitate conciseness.

		Number of food items in stomach					
School No.	Tuna	Mollies	Sprat	Other fish	Squid	Shrimp	Other crustaceans
3	Skipjack	65	18				
	Skipjack	37	6				
16	Skipjack	7		2			
	Skipjack	20					
19	Skipjack						
	Skipjack	13					
20	Skipjack	10					
	Yellowfin	15				P[1]	
21	Skipjack						
	Yellowfin	8					P
22	Skipjack	3					
	Skipjack	4					
23	Skipjack	3		P			
	Skipjack	7					P
24	Skipjack					1	P
	Skipjack						
29	Skipjack			4			1
	Yellowfin	2		P			P
42	Skipjack	1					
	Yellowfin	7		1		TNC[2]	P
45	Skipjack	4					
	Yellowfin	41			1		P
52	Skipjack						P
	Yellowfin				1		1
53	Skipjack	7	1				
	Yellowfin						2
54	Skipjack						
	Skipjack	19	25	P			
58	Skipjack	8	17			TNC	2
	Skipjack					TNC	1
59	Skipjack	53	55	P	1		
	Skipjack	38	31	1	1		
61	Skipjack	28		P			2
	Skipjack	2		1			
65	Skipjack	50		2	2	TNC	1
	Skipjack	13				TNC	1
68	Skipjack	4		P			
	Yellowfin	1		P	1		
70	Skipjack	4		2	P	TNC	1
	Skipjack	7		1	5		P
72	Skipjack	34	149	1	1		
	Skipjack	50	13				
78	Skipjack	5	14	1			1
	Skipjack	5	2	P			
80	Skipjack	49	2	5			
	Skipjack	21					

[1]P = present but not counted.
[2]TNC = too numerous to count.

Table 5.—Night baiting results by *Hatsutori Maru*.

Date	Locality	(No. buckets) and kg	Species	Composition
June				
18	American Samoa, Fagasa Bay	(1) 1.5	*Bregmaceros* sp.	0.95
			Pranesus pinguis	0.03
			Spratelloides delicatulus	0.02
19	American Samoa, Aoa Bay	(9) 14	*Spratelloides gracilis*	0.99
			Pranesus pinguis	0.01
21	American Samoa, Pago Pago Harbor	(80) 120	*Stolephorus devisi*	1.00
29	Tuvalu, Funafuti lagoon	(322) 483	*Spratelloides delicatulus*	0.92
			Bregmaceros sp.	0.07
			Pranesus pinguis	<0.01
			Archamia lineolata	<0.01
July				
3	Tuvalu, Funafuti lagoon	(386) 579	*Spratelloides delicatulus*	0.90
			Archamia lineolata	0.10
			Pranesus pinguis	<0.01

Tuvalu and the Gilbert Islands Fishing Results

On the evening of 21 June the *Hatsutori Maru* left Pago Pago heading north towards Funafuti (capital of Tuvalu, former Ellice Islands) for 2 days, and resumed fishing 25 June. The water temperature had increased to 29.0°+C and the wind velocity had reduced to 1-5 knots. A total of 1,018 (2,247 kg) skipjack tuna and yellowfin tuna were tagged on 25 June using mollies; eight schools were chummed and six were fished. We fished in the vicinity of Funafuti through 2 July and night baited twice in Funafuti lagoon, catching adequate quantities of sprat, *S. delicatulus* (Table 5). During the mornings and afternoons, most schools encountered around Funafuti and Nukufetau (an atoll north of Funafuti) were hesitant or slow to bite, whether being chummed with sprat or mollies. However, at about 1700 hours each day we encountered schools about 8 km offshore which bit very well until almost dark. Most of the fish tagged around the Funafuti area were caught from these "sundown schools" (Kearney et al., 1978).

On 3 July we left Funafuti lagoon, running all day towards the Gilbert Islands to the north. We resumed fishing on 4 July using the last of the remaining bait in a "sundown school" 5 July) Kearney and Gillett, 1978). The total number of tuna tagged in the vicinity of Tuvalu and the Gilberts was 3,077 (8,713 kg). Sixty-two schools were chummed and 28 were fished (45 percent).

Discussion

It is significant that during these trials the mollies performed as well as or better than the wild bait, *S. delicatulus*. The latter are considered an important baitfish in the Palau skipjack tuna fishery (Wilson, 1977), the Papua, New Guinea fishery (Smith, 1977), to a lesser extent in the Hawaiian skipjack fishery (Yoshida et al., 1977), and in other areas where they occur in reasonable abundance (Baldwin, 1977). Many Okinawan fishermen consider *S. gracilis* as being superior to anchovies

Figure 4.—Mollies cut from the stomachs of tuna poled aboard the *Hatsutori maru*. Each pile represents one stomach.

(Smith, 1977). Sprat are generally regarded as an excellent baitfish (Baldwin, 1977; Wilson, 1977; Smith, 1977), but fragile (Baldwin, 1977; Wilson, 1977). In this regard, we kept *S. delicatulus* alive for 3 days but mortality was high and increased with time.

The rate at which tuna schools approached the vessel was the same whether chumming with mollies alone or both mollies and sprat (one from the bow, the other from the stern or vice versa). Furthermore, gut analyses showed no significant preference for either the sprat or the mollies; the tuna seemed to feed equally on both when both baits were chummed. Mollies, then, are at least equally desirable to the tuna as sprat.

Much has been said regarding the desirable characteristics of a good baitfish (Hester, 1974; Smith, 1977; Yuen, 1977), and there appears to be disagreement about the size of a good baitfish. Smith (1977) reported a size of 60-80 mm as being desirable; Yuen (1977), on the other hand, recommended a size of 20-60 mm.

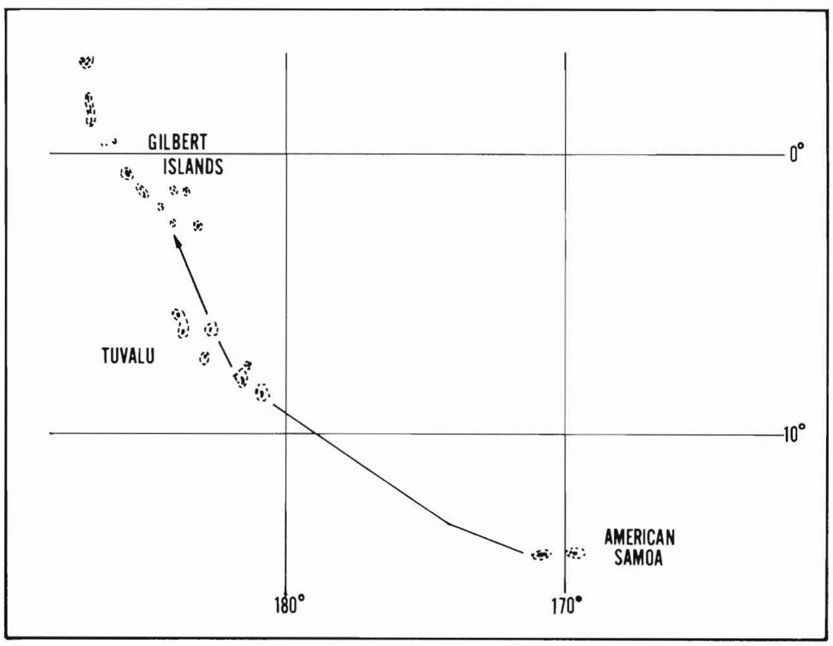

Figure 5.—Course taken by the *Hatsutori Maru* from American Samoa to Tuvalu and the Gilbert Islands.

Size is an important factor in considering a cultured baitfish such as mollies. The faster the bait can be utilized, i.e., the smaller the size, the higher the production rates. Although the results of chumming with smaller mollies were not mentioned in the report by Vergne et al. (1978), there were no differences noted between the smaller mollies and the larger ones during either the *J-Ann* trials or the *Hatsutori Maru* trials. The smaller mollies tested aboard the *Hatsutori Maru* were around 27.0 mm SL, at the lower end of the range recommended by Yuen (1977) and much too small to be an attractive bait according to Smith (1977).

During the *J-Ann* trials, particularly around American Samoa, most skipjack tuna and yellowfin tuna caught were full of very small anchovies (probably *Stolephorus buccaneeri*) which were no more than 20 mm SL. Many of the tuna caught around Funafuti on this trip were full of small caridian shrimp with lengths about 10-15 mm TL. Optimum baitfish size may vary according to seasonal changes or with lunar cycles and is a subject calling for further studies.

Hester (1974) and Yuen (1977) gave durability as one of the characteristics of an effective tuna bait, although Smith (1977) simply assumed that a good bait is hardy anyway. Ikebe and Matsumoto (1938) stated that a baitfish should be selected for its desirability first and secondly for its hardiness, but this seems obscure. A bait must be able to withstand being captured, being transferred into the baitwells, and the trip to the fishing grounds. In the Hawaiian pole-and-line fishery, an annual average of 22 percent of all nehu caught die before they can be used (Yoshida et al., 1977).

During the *J-Ann* trials, balls of pelagic anchovy (*S. buccaneeri*) were twice captured and placed into the baitwells but both times the bait died before they could be used (Vergne et al., 1978). Hardiness, then, precludes attractiveness since dead bait is not considered usable.

Lewis (1977) examined the restrictions caused by weak bait on the Papua New Guinea skipjack pole-and-line fleet. He recommended more effort towards reducing mortality rates of bait species presently being utilized, thus freeing the fleet of the present day-to-day mode of operations.

Considering the above, perhaps the most important attribute of mollies is their hardiness. Few species of fish can be taken from the stomachs of their predators, placed into water, and swim away, especially after the predator has laid on deck for some time. Not only can mollies withstand handling many times over, but they can be easily cured of bacterial infections while in the baitwells by treating with antiobiotics, as was proven both on the *J-Ann* and the *Hatsutori Maru*.

The mortality problems we experienced the last several days aboard the *Hatsutori Maru* were probably the result of nutritional deficiencies since the mollies were fed straight tuna fish meal (50 percent protein). Mollies, being omnivorous, probably need other nutrients for long-term survival. Although they are fed with straight tuna fish meal in the rearing ponds, a variety of naturally occuring food items are available to them and they browse continuously. Mollies were held on the *J-Ann* for over 30 days with no such problems, but they were fed with a commercially prepared fish food (Trout Chow, Ralston Purina) as well as with fish meal.

The hardiness and durability of the mollies cannot be disputed, but their tendency to stay near the surface of the water in baitwells can lead to problems of oxygen depletion. Their tendency to crowd in the neck of the well is most noticeable when they are given food.

My observations indicate that olfaction triggers this surfacing response. Mollies are topfeeders in nature and the cultured stocks reared in American Samoa have been further conditioned to feed at the surface. Baitwell design will have to be taken into consideration if mollies are to be used; wells with larger surface areas should be considered. This would also allow for better feeding efficiency and lessen the problems now encountered with oxygen depletion. The addition of aeration or modification of the water circulation system may also prove valuable in alleviating these problems.

This report is based on tagging effort results only and not on a commercial fishing effort. Kearney (1978) assessed the fishing power of the *Hatsutori Maru* tagging operation relative to a commercial effort in Fijian waters. He found that when fishing commercially, the *Hatsutori Maru* could be expected to catch 3.47 times the catch of a tagging operation. Tables 1 and 3 are based only on tagged fish. If our tagged catch ratio (kg bait chummed:kg tuna tagged), 1:17, is multiplied by 3.47, then under a commercial effort the ratio could be expected to have been 1:59. If, in this tagging effort, we also include those fish dropped on deck during the tagging operation, the ratio is 1:21 (Table 2) and the corrected ratio expected for commercial fishing would be 1:73 (21 ×3.47).

The ratio of bait used to tuna caught in the Hawaiian commercial pole-and-line fishery is estimated to be about 1:29 (Yoshida et al., 1977)[5] and this fishery is based on the anchovy (nehu), *Stolephorus purpureus*, which is considered a superior live baitfish by Hawaiian fishermen. The breakeven price for a bucket of nehu (one bucket = 6.4 kg or 14.2 pounds, Hida and Whetherall, 1977) is $30.12 or $4.71/kg ($2.12/pound) (Crumley, 1977) and Wetherall (1977) calculated the average opportunity cost of nehu (1968-73) to be $67.88/bucket or $10.52/kg ($4.78/pound). Although Vergne et al., (1978) calculated the cost of producing 1 kg of mollies (*P. mexicana*) in American Samoa at about $26.40 ($12.00/pound), this cost analysis was based on a fiscal evaluation reflecting a highly experimental project designed only to produce as many mollies as possible to conduct sea trials, regardless of cost. Herrick (1977) has calculated cost projections on culturing a similar species, *P. vittata*, based on two levels of production: Production of 3,000 buckets (8,100 kg) per year (one bucket of mollies equals 2.7 kg) would cost $12.93/bucket; production of 30,000 buckets (81,000 kg) per year would cost $3.69/bucket ($1.37/kg). He further stresses that the ultimate economic feasibility of mollie

[5]The ratio was derived by applying Yoshida et al. (1977) annual average nehu mortality factor of 22 percent to all bait caught. Nehu makes up 95 percent of the bait catch in Hawaii.

culture enterprise will hinge upon their relative effectiveness as bait. The results of these trials clearly indicate that mollies are an effective baitfish and may even be more effective than some good wild baits used in the Pacific, e.g., *S. delicatulus*.

The results of the fishing trials conducted in American Samoa and Fiji by the *J-Ann* during January, February, and March 1978 (Vergne et al., 1978) were considerably lower than those obtained by the *Hatsutori Maru*, even though the latter represented a tagging effort. The *J-Ann* obtained a mollie live bait to tuna ratio of 1:10 while that of the *Hatsutori Maru* was 1:21 (Table 2). The *J-Ann* fished 30 percent of the schools chummed; the *Hatsutori Maru* fished 38 percent of the schools chummed.

While there were probably a number of reasons for the variation in the results of the two vessels, I feel the most important ones were: 1) The captain and crew of the *J-Ann* had had no previous fishing experience in the tropical central Pacific, 2) their gear was too heavy for skipjack fishing in clear tropical waters, and most important of all, 3) the vessel was not equipped with a water spray system.

The Japanese are the principal exploiters of tropical central and western and, to some extent, eastern Pacific skipjack tuna resources, harvesting two-thirds of the world's catch, mostly by live bait pole-and-line fishing (Yoshida et al., 1977). Their methods represent the state of the art for the pole-and-line fishery for a major portion of the tropical Pacific Ocean. The importance of the spray system in the pole-and-line skipjack tuna fishery is discussed by Yuen (1969) and Hester (1974).

Fishing around American Samoa was poor with June being recognized by local fishermen as part of the off-season. Not only do the skipjack tuna schools bite poorly (only 17 percent bit in these trials) but they move north during the austral winter. This agrees with other researchers (Uda and Tsukushi, 1934; Aikawa, 1937; Sasaki, 1939) who reported a seasonal difference in the response of skipjack tuna. Schools bit much better after we had run north for 2 days and reached warmer water. On this leg of the trip, 45 percent of the schools chummed bit.

Even though schools often would not bite in the morning or afternoon, the "sundown schools" often bit very well. Suehiro (1938) reported that morning was the best time for pole-and-line skipjack tuna fishing. In a study of the skipjack tuna response to live bait in the Hawaiian pole-and-line fishery, Yuen (1959) concluded that biting response was not affected by the time of day or weather conditions. These findings contrast greatly with our "sundown school" phenomena encountered around Funafuti. Suehiro (1938) also reported that offshore skipjack tuna schools responded better to pole-and-line fishing than schools close to shore and Yuen (1959) found that large skipjack tuna bit better the further away they were from land. In general, our results were similar to theirs, i.e., offshore schools usually bit better than inshore schools.

Often, when chumming with mollies, schools followed the chum line up to the stern of the vessel and fed actively on the mollies, but would not take the lures. Yuen (1969) believed that each skipjack tuna caught by pole-and-line represented an error in discrimination by the fish, i.e., the lure was mistaken for a live fish (chum). In a subsequent work, Yuen (1977) discussed how catch rates can be increased by causing the tuna to make mistakes and suggested that altering the lures to look more like the bait being chummed may increase the catch.

My observations were that the traditional chrome and white feathered squids are quite dissimilar in appearance and color to the mollies. This may have accounted for so many schools feeding on the chummed mollies but not taking the lures. The lures which I modified with dark mahimahi skin looked much more like a mollie than the stock lure. The fact that the modified lures worked as well as or better than the stock lures indicates that lure design is an important factor in the concept of using cultured mollies as live bait.

Hester (1974) stated that acceptability of a baitfish species must cover both mortality and effectiveness. These results show that mollies, *Poecilia mexicana*, are acceptable live bait for pole-and-line tuna fishing. Their hardiness will allow presently limited day fleets in many island groups to extend their range, giving them the efficiency which they presently lack because of the fragility of wild bait. Mollies are easily cultured and if smaller mollies are further demonstrated to be as effective as larger sizes, production rates can be increased significantly. Investigations directed towards lure design and modification of present baitwell configurations should parallel the development of this new resource.

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