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Technique for Estimating Trawl Efficiency in Catching Brown Shrimp (*Penaeus aztecus*), Atlantic Croaker (*Micropogon undulatus*) and Spot (*Leiostomus xanthurus*)

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TECHNIQUE FOR ESTIMATING TRAWL EFFICIENCY IN CATCHING BROWN SHRIMP (*PENAEUS AZTECUS*), ATLANTIC CROAKER (*MICROPOGON UNDULATUS*) AND SPOT (*LEIOSTOMUS XANTHURUS*)

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ABSTRACT Mark-recapture experiments conducted in a small 17.5 ha lake in Barataria Bay, Louisiana, were used to estimate the efficiency of a 4.9-m (16-foot) otter trawl in capturing brown shrimp, Atlantic croaker, and spot in water 1.5 m deep. The trawl was observed to sweep an area 2.5 m in width. Trawl efficiency was determined to be approximately one-third to one-half for brown shrimp, one-fourth for Atlantic croaker, and only 6 percent for spot.

INTRODUCTION

The shrimp trawl, often used as a biological tool to estimate the standing crop of shrimp and slow-swimming demersal fish, is not 100% efficient. Loesch (1962) estimated that in Mobile Bay during the months of July, August, and September, an area equal to 1.1 to 1.7 times the total area of Mobile Bay was swept each month by shrimp trawls. During each of these months more shrimp were landed than the estimated standing crop in the area at any one time. This indicates that the shrimp trawl is inefficient at capturing shrimp, that shrimp grow at an extremely fast rate during these periods, or that both of these contributed to this observation.

No study with which we are familiar effectively quantifies the efficiency of a type of collecting gear for capturing a given species. Watson (1976 in press) found that electrical trawl efficiency on burrowed brown and pink shrimp varied from 35% with one net having a small electrical field to 54% with another net having a larger electrical field. Each net was within 5% of its estimated efficiency as predicted from laboratory experiments. Seidel (1972) estimated that working shrimp boats caught approximately one-fourth to one-half of the shrimp in the area covered. Gear efficiency probably varies not only for each species but also for different length classes within each species and with the design of the gear, the method used, the water temperature, the tidal stage and time of day, the behavior of the organism, the turbidity of the water, the bottom type, etc. (see Ko et al. 1970 for a discussion of shrimp behavior near a moving net). While the gear efficiency estimates in this study are pertinent only to the area and the conditions of the study, they may be applied to similar physical environments.

This study estimates the trawl efficiency for two species of fish, *Micropogon undulatus* and *Leiostomus xanthurus*, and one species of shrimp, *Penaeus aztecus*. Trawl locations are given in Figure 1. Water depth ranged from 1 to 1.5 m over a muddy bottom during the period of maximum utilization of the estuaries by juveniles of these species (May 1971, May 1972).

Gear efficiency is defined as the percentage of the organism in the test area (path of the trawl) captured by the gear being used.

METHODS

Laboratory Experiments

Short-term, mass fish-marking experiments have been conducted successfully by the use of compressed air and fluorescent pigments (Jackson 1959; Phinney et al. 1967). Benton and Lightner (1972) used similar techniques and found a 5% mortality after blasting them at 240 pounds per square inch (psi). Preliminary laboratory experiments were conducted to ascertain the optimum pigment-application pressure and the retention time of the imbedded particles. Initially, we marked penaeid shrimp and croaker with fluorescent pigment using 80, 100, and 120 psi pressure from an unmodified paint spraygun. The dry granular pigment was obtained from Wildlife Supply Company[1] of Saginaw, Michigan and was sandblasted into the test organisms. Eight penaeid shrimp were marked at each test pressure and placed in separate aquaria for observation. Controls consisted of 24 shrimp, handled in a similar manner except for spraying, that were divided equally among three aquaria. After 2 days no fluorescent granules were observed on the fish or shrimp when irradiated with UV light. Because there was some clogging of the spray apparatus, the intake stem of the aspirator was removed for subsequent marking. Shrimp were next sprayed at 115, 135, and 155 psi; all retained some detectable fluorescent pigment after 3 days. These results were not considered suitable for field studies, so higher application pressures were tested. One shrimp sprayed at 135 psi molted after the pigment application, but retained the fluorescent dye for at least 3 days after molting. Apparently the dye granules were "sandblasted"

[1] Wildlife Supply Co., Saginaw, Michigan, produces a specially designed air blast gun for marking.

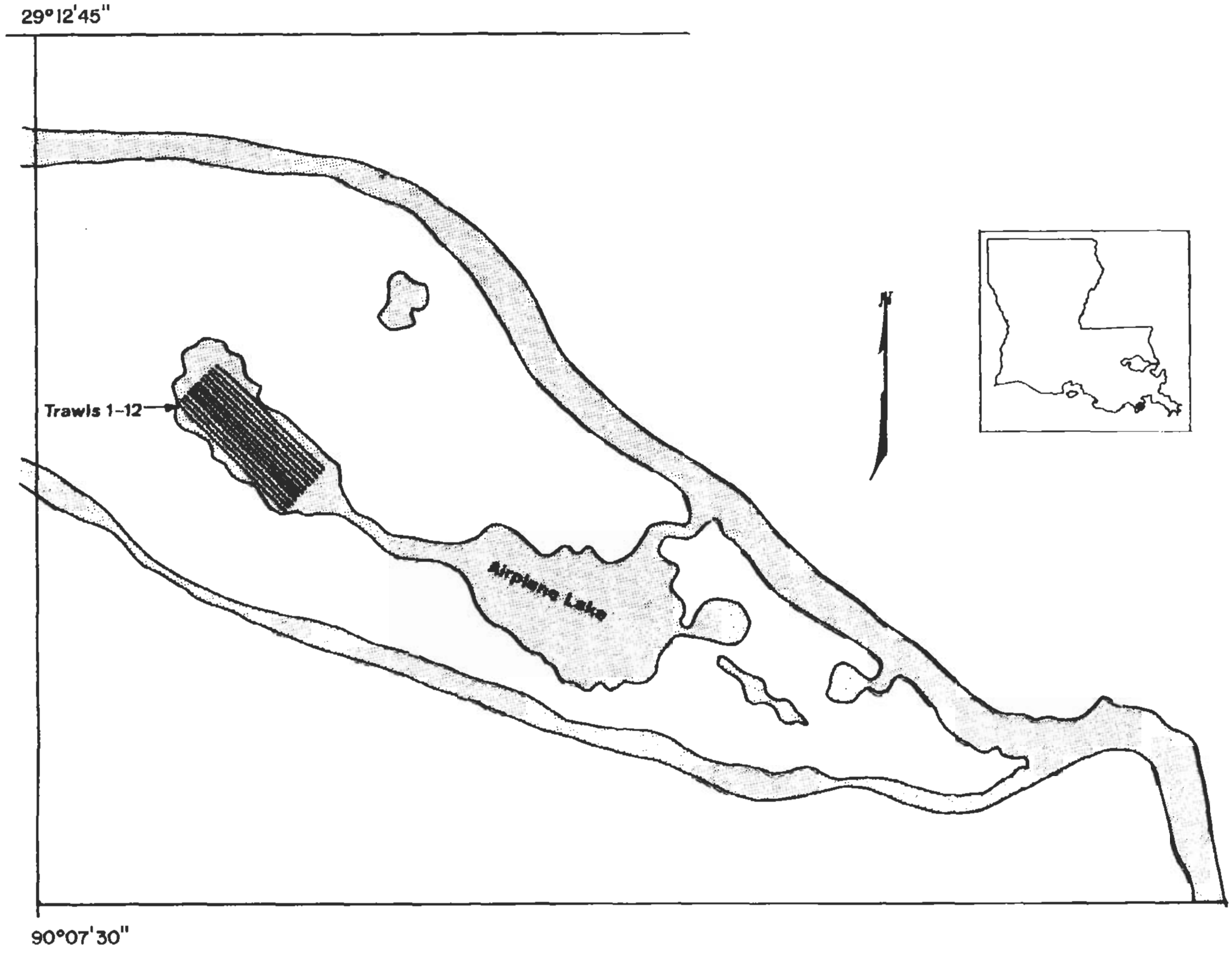

Figure 1. Airplane Lake, Louisiana, and trawl stations for 1972.

through the exoskeleton into the flesh of this individual. Benton and Lightner (1972) stated that pigment granules were located in the exoskeleton, in the paired appendages and tissues of test animals. Many shrimp retained this mark for 2 months while undergoing several molts.

To conserve air and to obtain a more uniform application of dye, a double stage regulator was used for the remaining test pressures (earlier experiments employed a single-stage regulator). Eight shrimp were marked at 165, eight at 200, and eight at 245 psi. One day later, all of the shrimp sprayed at 245 psi were dead; three that were sprayed at 200 psi had molted, and one of the 200-psi shrimp had disappeared (presumably cannibalized). Six days later all live 200-psi test shrimp were sacrificed; all had retained their marks. In another trial, pigment was applied to ten shrimp at 215 and then at 230 psi; about half the shrimp died within hours. Thus, it was decided to apply the pigment at 200 psi. Similar experiments revealed that an application pressure of 150 psi was optimum for marking spot and croaker.

During 1971, 100 shrimp caught near Airplane Lake, Louisiana, on May 13 were marked and kept in 75-liter containers as controls. The containers were new plastic garbage pails that had been aged in seawater. While being held at Grand Isle, Louisiana, the four containers of shrimp were aerated with a Silent Giant aquarium aerator; four battery-powered aerators were used during the trip to Baton Rouge. On May 14, ten shrimp were examined and nine had retained their mark. On May 15, 10 more were examined, all of which had their mark. The marked shrimp were then transported to Baton Rouge for further observation; however, most of the shrimp died en route. During the same period, 101 unmarked shrimp were also kept, most of which also died en route to Baton Rouge. The method of control proved faulty in that live shrimp were sacrificed; no record could be made of shrimp that molted and were cannibalized.

Field Experiments

The inner lobe of Airplane Lake, a small 17.5 ha marsh pond in the Barataria Bay area of Louisiana, was sampled to estimate the populations of the subject species. A sample of the population of each species was obtained by trawl capture in 12 parallel, 200-m drags. Stakes were placed to designate capture and release sites and to mark each trawl area. Trawling began on one side of the lake and progressed systematically across the lake in order to avoid trawling in previously sampled areas (see Figure 1). Nine and one-half and 12 200-m tows were made in 1971 and 1972, respectively. Sampling began at 0700, and each drag lasted approximately 3 minutes.

Live animals in a small dip net were held in the air about 1/2 m from the nozzle of the spray gun and marked. The spraying procedure lasted approximately 30 seconds. Benton (personal communication) said about spraying, "A trough was constructed with plastic webbing. Shrimp were placed in the trough, and the trough was agitated during spraying so that the shrimp were more evenly covered. The spraying procedure was completed in about 10 seconds." After the animals were marked, they were put in water-filled, plastic garbage cans and observed for a short period. Animals showing no sign of injury were released in the same area from which they were captured.

The recapture method consisted of making parallel, 200-m drags, covering the distance in 3 minutes. Twelve drags were made daily for 7 days. A 16-foot Boston Whaler with an 80-hp Mercury outboard motor was used to tow the trawl. Because it is a cul-de-sac, the lake is not affected by tidal currents. Shrimp, croakers, and spot were separated from the rest of the catch and transported to the field station near Grand Isle, a 15-minute boat ride. They were examined on a tray under ultraviolet light in a specially built darkbox. Each shrimp could be individually handled under the light to separate the marked from the unmarked.

The population of each species was calculated using the Peterson method, $\hat{P} = m(u + r)/r$ (Robson and Regier 1971) where P is the total number of shrimp (or fish) in the population, m the number of marked shrimp in the population, u the number of unmarked shrimp captured in the sample, and r the number of marked shrimp recaptured in the sample. $\hat{P}$ is the estimate of P. This estimate was assumed to be a measure of true population in the lake.

Another estimate based on the swept area of the trawl was derived by the proportion method. Because a 4.9-m (16-foot) trawl does not sweep an area 4.9 m wide, the net's true opening had to be ascertained. First, the distance between floats attached to the trawl boards while trawling was measured by observers in the water. Second, various lengths of twine were tied to the boards. (Twine shorter than the width of the net opening broke, while twine longer than the width did not.) Third, the net opening was measured by a person swimming beside the boards as the net was towed. The average of all computing methods was 2.5 m. Twenty-two measurements were obtained and varied from 1.5 to 3.0 m.

Stakes 100 m apart marked the trawl route and 200 m were covered per sample. Thus each haul swept 500 m² of the lake bottom. In 12 such hauls the trawl covered 6,000 m² of the lake bottom, sampling almost one-tenth of the total of 62,480 m² in the inner lobe of the lake. If the trawl is assumed to be 100% efficient and the distribution of the species uniform, then the total population of the species may be calculated. For instance, 695 spot were captured in this swept area on the first day, consequently we estimated that there were 7,237 spot in the entire inner lobe of the lake.

$$\frac{6{,}000 \text{ m}^2}{62{,}480 \text{ m}^2} = \frac{695}{x}; \quad x = 7{,}237$$

To determine distribution of shrimp over the lake bottom, an analysis of variance (Table 1) in a random block design was computed on the total 1972 shrimp catch data (Table 2) for each 200-m drag. Blocking removed any differences among days. Shrimp were significantly more abundant near the shore (stations 1 and 12, which are within 10 m of the shoreline), but no differences in density were found among stations 2–11. Because all areas of the lake were sampled equally (Figure 1) and each day's sampling covered the same areas, we feel that the greater densities nearshore do not affect the trawl-efficiency estimate.

Only 423 shrimp were marked in 1972 (as compared to 1,522 in 1971), apparently because fewer shrimp were

TABLE 1.

Analysis of Variance of 1972 Shrimp Catch (Data from the 12 Trawl Stations)

Source	df	Mean Square	F
Days	3	18,631	26.6**
Trawls	11	2,297	3.2**
Trawls 1 and 12 vs 2–11	1	19,729	28.2**
Trawls 2–6 vs 7–11	1	1,988	2.8
Error	33	699	

**Significant at 0.01 level

TABLE 2.

Shrimp catch data 1972 (no. of shrimp)

Date	1	2	3	4	5	6	7	8	9	10	11	12
22 May	33	19	18	53	33	46	45	25	08	15	65	63
23 May	182	105	113	110	102	74	89	96	70	87	88	138
24 May	127	98	126	113	83	100	84	95	76	92	108	237
25 May	185	127	129	166	120	94	134	117	107	103	43	140
TOTAL	527	349	386	442	338	314	352	333	261	297	304	578

present on the day that they were being collected for marking than on subsequent days.

Each day the mark-recapture and swept-area estimates were calculated. The efficiency of the trawl was estimated by dividing the swept-area estimate by the mark-recapture estimate.

On May 16 the estimate of shrimp population using the swept area method was 34,423 and using the population mark-recapture method was 86,588; therefore the estimated trawl efficiency was 34,432/86,588 = 39.8%.

RESULTS AND DISCUSSION

Atlantic Croaker and Spot

Trawl efficiency was calculated for the Atlantic croaker in 1971 and for the spot in 1972 (Table 3). The percent efficiency is an estimate of the percentage of croaker and spot which the trawl captures from the total population calculated to be present in the area swept by the trawl.

The mark-recapture population estimate and the swept-area population estimate would be equal if the trawl were 100% efficient. But if the estimate derived from the swept area is only one-fourth that derived from mark-recapture, and if the mark-recapture estimate is assumed to be the true population, then we can conclude that for the test species and test conditions the trawl is 25% efficient.

It appears that the trawl is more efficient for capturing croaker than it is for spot. This could be related to the differing ecological niches of these two species. The croaker feeds on, and remains close to, the bottom most of the time while the spot is usually found at moderate depths (Nelson 1969). Because the trawl fishes approximately the bottom meter of the water column, the croaker is more vulnerable to capture than the spot. Also, the spot may more successfully avoid the trawl than the croaker.

We estimated that the trawl captured 26% of the croakers and about 6.5% of the spot in the area fished, under conditions that existed at the time (Table 3). Only one sample was utilized for croaker because of the paucity of recaptures in samples on subsequent days. The three estimates for spot show some variation in the estimated efficiency (Table 3).

Shrimp

Only the first day or two of shrimp recaptures in 1971 can be used in claculations (unless corrections are made) because on each successive day the number of marked-recaptured shrimp dropped drastically, causing the population estimate from the mark-recapture to increase rapidly (Table 4), while the population estimate from the swept area remained fairly constant. If the population estimate from the swept area remains constant, one would expect the same consistency among the marked-recaptured shrimp, unless the shrimp were losing their marks, or were being selectively eliminated from the overall population either by differential rate of mortality, by migration, or by shedding of the mark. It is suspected that shrimp were losing their marks at the rate of about 15% per day.

The estimated population of brown shrimp (Table 4) in the swept area varied only from 34,423 to 30,714 on May 14, 15, and 18, but the number estimated from mark-recaptures increased sharply from 86,588 to 146,496. Based on these figures, the efficiency of the 4.9-m trawl, which opened to 2.5 m wide while fishing, varied from 40% to 21%. We assume that the data of the first two days are the most reliable, and that the trawl was about one-third efficient for brown shrimp under these conditions.

Estimated population in the swept area during May 1972 varied from about 13,000 to 15,000 (about half that of May 1971); it increased slowly during the sampling time. The percent efficiency of the trawl varied from about 27% to 13% in 1972. Because the population from the swept area remained fairly constant, while the number of marked shrimp recaptured decreased with time during the two successive years, it might be assumed that something was happening to the marked shrimp. Most control shrimp in earlier experiments retained their marks, but they were not exposed to predation, except cannibalism.

When the shrimp population as calculated by the swept area method consistently decreases while the population as calculated by the mark-recapture method increases rapidly (Table 4), then some of the marked shrimp are disappearing from the population in the lake. Although trawl efficiency is expected to remain constant, calculation using these data suggests that it decreased from 39.8% to 8.4% in 10 days of sampling (Table 4).

We presumed that the trawl efficiency would not vary consistently (becoming less efficient each day) as was indicated by using the data that assumed no marks were lost (Table 4). We then calculated an estimated 10% mark loss

TABLE 3.

Population Estimates and Percent Efficiency of Trawl from Mark-Recapture

Species	Date	Number Marked At Large	Number Marked Recaptured	Number Unmarked Captured	Swept Area (m^2)	Swept Area Estimate No. Fish	Mark-Recapture Estimate No. Fish	Trawl Efficiency (%)
Atlantic Croaker	13 May 1971	149						
Atlantic Croaker	14 May 1971		3	156	4750	2065	7,798	26.5
Spot	22 May 1972	695						
Spot	23 May 1972	695	6	715	6000	7237	83,516	9.0
Spot	24 May 1972	689	3	498	6000	5217	115,063	4.5
Spot	25 May 1972	689	4	404	6000	4249	69,972	6.1

TABLE 4.

Population Estimates and Percent Efficiency of Trawl from Mark-Recapture of Brown Shrimp, *Penaeus aztecus*

								If 10% Marked Lost Each Day			If 15% Marked Lost Each Day		
Date	Number Marked at Large (m)	Number Marked Recapt. (r)	Number Unmarked Captured (u)	Swept Area (m^2)	Pop. Swept Area	Pop. Mark-Recapt.	% Trawl Efficiency	Number Marked at Large (m)	Pop. Mark-Recapt.	% Trawl Efficiency	Number Marked at Large (m)	Pop. Mark-Recapt.	% Trawl Efficiency
1971													
14 May	1522	46	2571	4750	34,423	86,588	39.8	1370	77,941	42.8	1294	73,617	46.7
15 May	1476	33	2446	4750	32,608	110,879	29.4	1192	89,544	36.4	1061	79,704	40.9
18 May	1443	23	2312	4750	30,714	146,496	21.0	845	85,786	35.8	632	64,162	47.9
19 May	1420	14	1804	4750	23,913	184,397	13.0	740	96,094	24.9	518	67,266	35.5
24 May	1406	9	1376	4750	18,218	216,368	8.4	434	66,788	27.3	224	34,446	52.9
1972													
23 May	423	11	1243	6000	12,996	47,799	27.2	381	43,326	30.0	360	37,571	34.6
24 May	412	5	1334	6000	13,943	110,334	12.6	333	89,177	15.6	297	79,537	17.5
25 May	407	6	1459	6000	15,256	106,159	14.4	295	72,029	21.2	248	60,553	25.2

13 May 1971 — 1522 shrimp marked
22 May 1972 — 423 shrimp marked

per day (Table 4) and found that estimated trawl efficiency still decreased daily. Presuming that a greater loss of marks must be occurring, we calculated the estimated trawl efficiency assuming a 15% mark loss. When a daily loss of marked shrimp was calculated, the percent trawl efficiency for 1971 varied (not regularly) from 36% to 53% with an average of 44.8% (Table 4). Using these data it seems that the shrimp trawl we used was from one-third to one-half efficient under the conditions that existed. Population estimates of brown shrimp in subdelta Louisiana estuarine areas based on sampling with a 4.9-m trawl should incorporate this one-third to one-half efficiency estimate.

With refinements, we believe this method can be used to estimate the true population of aquatic animals present in an area at any given time. This study was designed to determine approximate trawl efficiencies for shrimp, croakers, and spot in the area. Similar procedures for other species in different habitats at other times of the year would be expected to yield different gear efficiencies. A larger trawl and increased turbidity may improve gear efficiency. We do believe that the method holds some promise for determining the percentage of fish a particular gear captures.

CONCLUSIONS

One important point emerges from these results, i.e., the 4.9-m otter trawl is much less than 100% efficient. It captured approximately 26% of the croakers, 6% of the spot, and 30–50% of the brown shrimp from the study area. These species are probably more susceptible to capture than are most others because they are slow-moving demersal forms. Biomass estimates based on swept area using trawl data are therefore minimal and a conversion factor must be applied before estimating the true standing crop.

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