ARTICLES

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DEVELOPMENT OF THE ELECTRO-SHRIMP TRAWL SYSTEM

By Norman L. Pease* and Wilber R. Seidel**

The Gear Research Unit of the Exploratory Fishing and Gear Research Base in Pascagoula has developed an electrical shrimp trawl capable of catching nocturnally active species of shrimp during the day. As part of the project, over 1,000 shrimp were stimulated with various electrical fields to determine the necessary characteristics--a minimum field of 3.0 volts at 4 to 5 pulses per second. The staff then designed and built a prototype electro-shrimp trawl system.

In the system, the vessel's generator produces alternating current, which is transmitted by an electrical cable to an electronic pulse generator on the trawl door; here the current is converted to direct current and is then released at a specified pulse rate to an electrode array on the trawl.

Fishing trials on the mud bottom in the north Gulf of Mexico indicated that the system could catch, during daylight, 96 to 109 percent of the shrimp caught at night by a nonelectrical trawl. In the southeastern Gulf, on a calcareous sand-shell bottom, the catch rate was 50 percent.

The shrimp industry in the Gulf of Mexico has grown impressively during the last three decades. In 1934, the exvessel landing value of shrimp was $1.9 million; by 1966, it had grown to $82.8 million. During this period shrimping techniques were refined, such as double-rigged trawling (Knake, Murdock, Cating, 1955), and vessel design was improved (Juhl, 1966). Additional modifications, such as the change from cotton to synthetic webbing, helped increase the strength and useful life of trawls. Various designs of tickler chains, mud ropes, and rollers were developed by fishermen to help increase the catch or to adapt the shrimp trawl to fishing areas not previously worked. New shrimp handling and processing equipment afloat and ashore have been designed and developed for the commercial fishing industry ("Fish Boat," 1966a, 1966b). Collectively, these innovations have contributed to the expanding shrimp industry.

Trawling for the pink shrimp (Penaeus duorarum) and the brown shrimp (P. aztecus), however, has continued to be regulated by the shrimp's daily activity cycle. These shrimp burrow in the bottom during daylight, apparently for protection from predators, and come out at night to forage for food. Commercial fishing, therefore, is restricted to night trawling when the shrimp are available--effectively reducing the fleet's fishing activity at sea almost 50 percent.

To increase the fleet's efficiency, it was necessary to find a method that would catch shrimp while they are normally burrowed in the bottom and not available to conventional gear. The BCF Gear Research Unit at Pascagoula proposed to develop equipment that would permit the expansion of the existing night shrimp fishery into a 24-hour-a-day fishery. The harvesting system would use electricity to make shrimp come out of the

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ottom involuntarily, where they could be aptured.

SHRIMP BEHAVIORAL STUDIES

Higman (1956) established that a pulsed irect current produced definitive behavior atterns in shrimp and that increasing the rength and duration of electrical impulses duced variations in behavior. Kessler 965) used capacitor discharge pulses to de- rmine the threshold electrical voltage eded to produce a hopping response in hrimp.

In 1964, the BCF Gear Research Unit be- an shrimp behavior studies to determine ptimum electrical requirements needed to timulate burrowed shrimp (Klima, MS). hese studies were made in the eastern Gulf f Mexico on different bottom types using arious electrical voltages and pulse rates. ver 1,000 burrowed shrimp were stimulated lectrically to determine the best combina - ion of voltage and pulse rate needed to force hrimp out of the bottom. SCUBA divers laced individual shrimp on the bottom and llowed them to burrow. Then a diver using 16-mm. movie camera filmed an entire equence: from the initial activation of the lectrical field to the shrimp emerging rom the bottom and swimming up into the ater.

A frame-by-frame analysis of all the re- ultant film footage was used to determine e elapsed time each shrimp took to reach position 3 inches above the bottom. Under ptimum electrical conditions, the average me to reach this height was 2.0 seconds. e determined that the width of the electri- al field in front of the trawl should be 8 feet using the 2-second interval and a trawl ragging speed of 4 feet per second (2.5 nots). In relation to the trawl speed and the idth of the electrical field, the optimum lectrical characteristics were found to be .0 volts at 4 to 5 pulses per second.

Upon completion of this phase of the proj- ct, the engineering staff began designing and abricating components for the system.

DESCRIPTION OF SYSTEM

The use of continuous direct current in seawater would require large amounts of electricity from generators of prohibitive size and cost. Therefore, the electro-shrimp trawl system uses a pulsed direct current field to force shrimp out of the bottom. The system has a power control panel, power supply cable, pulse generator, electrode ar- ray, and a 40-foot Gulf of Mexico shrimp trawl (fig. 1). Alternating current from a ship's generator is converted to a capacitor discharge pulse by the underwater pulse generator, which can be attached to either the port or starboard trawl door when using a single trawl.

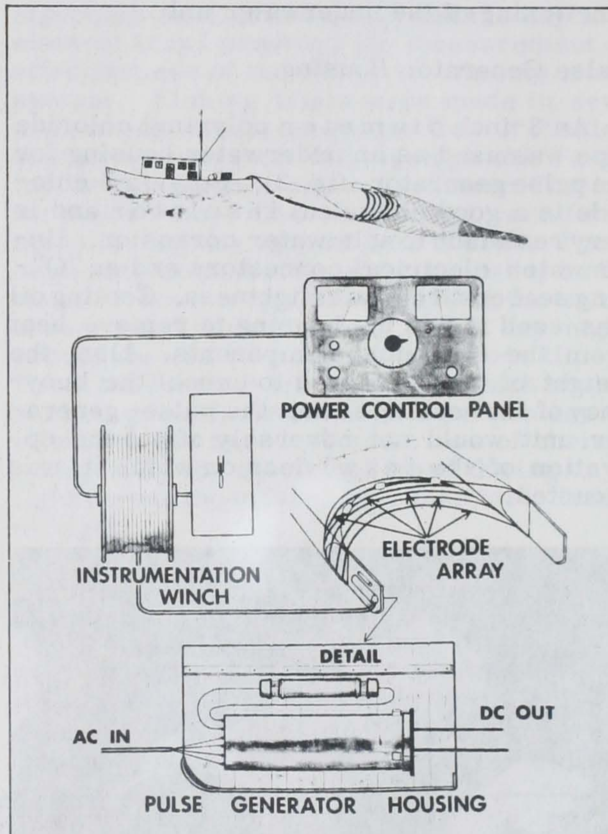

Fig. 1 - Basic components of the electro-shrimp trawl system.

When towing 2 trawls simultaneously, the pulse generator for each trawl should be attached to the inboard door to facilitate its handling. The output of the pulse generator is supplied to the electrode array, which is towed in front of the footrope on the trawl and creates the electrical field. This low voltage field causes an involuntary "jump- ing" response in shrimp that are burrowed during daylight and not available to nonelec- trical shrimp trawls. The jumping response forces the shrimp out of the bottom.

Power Control Panel

The power control panel was used to check the alternating current input, capacitor voltage, and pulse rate of the underwater pulse generator. Alternating current was supplied to the underwater unit through a variable transformer. A direct-current voltmeter on the control panel showed voltage readings on the output of the pulse generator. Although 2 conductors in the power supply cable were required for this voltmeter, it was useful because it provided a continuous check on the functioning of the underwater unit.

Pulse Generator Housing

An 8-inch diameter polyvinyl chloride pipe was used as an underwater housing for the pulse generator (fig. 2). Polyvinyl chloride is a good electrical insulator and is very resistant to salt-water corrosion. Underwater electrical connectors and an "O"-ring seal ensured watertightness. Cooling oil was used inside the housing to remove heat from the electrical components. Also, the weight of the oil served to cancel the buoyancy of the housing so that the pulse generator unit would not adversely affect the operation of the trawl door on which it was mounted.

Fig. 2 - The pulse generator and its underwater housing.

Power Supply Cable

A neoprene-coated power supply cable (fig. 3) containing 4 American wire gage No. 12 wires was used during field tests and fishing trials of the electrical trawl. Two conductors supplied alternating current from boat to pulse generator. The other 2 conductors were used to return voltage readings from pulse generator capacitor bank to direct-current voltmeter on the control panel.

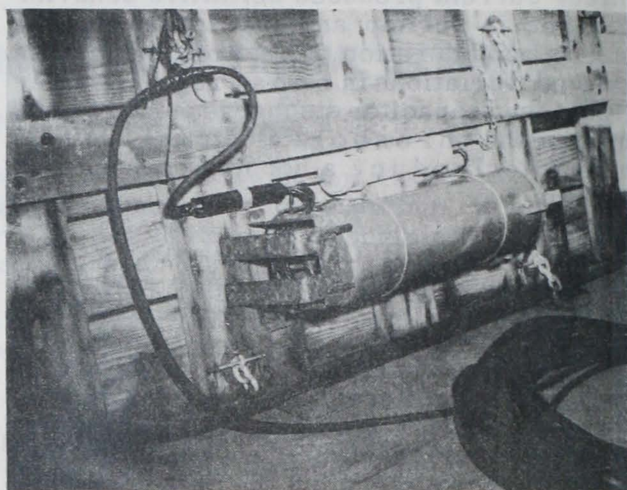

Fig. 3 - Power supply cable coiled beside the trawl door on which the pulse generator is mounted.

Electrode Array

Through the shrimp behavior studied, it was determined that an array about 8 feet deep was needed to provide the necessary stimulation time for a trawl moving 2.5 knots. Therefore, the electrode array comprises 5 parallel bare conductors spaced 2 feet apart from each other at the center of array (fig. 4). Any noninsulated, flexible, copper alloy cable, about $\frac{3}{8}$-inch diameter, can be used for the electrode material if it is durable enough to withstand the constant chafing of the ocean bottom. During the field

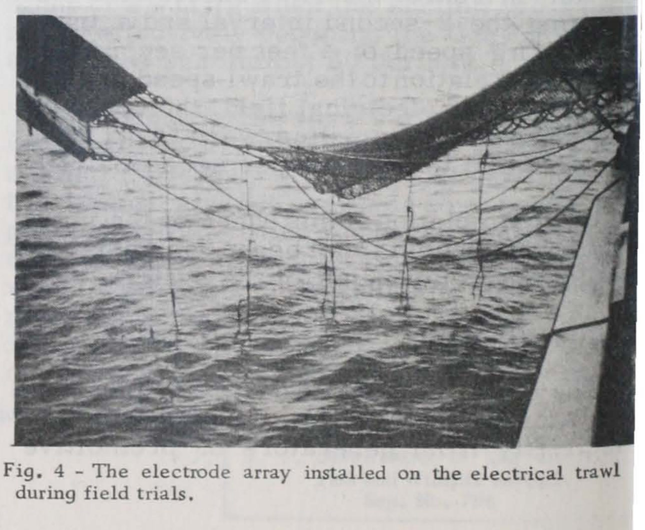

Fig. 4 - The electrode array installed on the electrical trawl during field trials.

trials, we used a wire with 6 strands--3 strands of insulated stainless steel wire for strength and 3 of noninsulated copper wire for current carriers. The strength and electrical characteristics of this wire proved satisfactory.

Operating Characteristics of System

The pulse generator was designed to satisfy the electrical characteristics developed during behavior studies. The minimum field voltage occurs at the center of the electrode array because the electrodes are farthest apart at this point. Because of the electrode array's shape, space between electrodes decreases toward each end of the array; this results in an increased field voltage in these areas. The alternating current power requirement of an electro-shrimp trawl system is 110 volts and 20 amperes. The ship's generator should provide a minimum of 3 kilowatts for each electrical trawl. A 12- or 32-volt system cannot be used to power this electro-shrimp trawl system.

ENGINEERING FIELD TESTS

Field tests of a prototype electro-shrimp trawl were performed aboard the R/V "George M. Bowers". SCUBA divers on towed diving sleds made observations and film recordings of gear performance. These showed that the electrode array and the underwater pulse generator housing were compatible with the trawl and did not adversely affect the trawl performance. Operational tests were made during several cruises to check the system's operation and reliability. Several component changes and minor design modifications were made before the unit was ready for fishing trials.

FISHING TRIALS

Methods

The George M. Bowers was rigged with 2 standard 40-foot Gulf of Mexico shrimp trawls (Bullis, 1951). The electro-shrimp trawl system was installed on the starboard trawl, and a standard $\frac{3}{8}$-inch galvanized chain tickler was attached to the port trawl. Loop chain was hung on the footrope of the electrical net to cause it to tend bottom close enough so that electrically stimulated shrimp would be caught at a minimum vertical distance of 3 inches off the bottom. An equal amount of chain was added to the nonelectric net.

Except for these modifications, the 2 trawls were identically rigged so that differences in the amount of shrimp caught in the 2 nets could be attributed to the electrical system on the starboard trawl. Other factors that could affect catch rates were minimized by comparing a large number of drags in one area.

To determine the catching ability of the electric trawl, both trawls were dragged simultaneously day and night. Comparison of the individual trawl catch rates for the nighttime nonelectric trawl and the daytime electric trawl provided the measurement of effectiveness of the electro-shrimp trawl system. Fishing trials were made in several areas within the major Gulf of Mexico shrimp grounds off Mississippi and Texas for brown shrimp, and off southern Florida for pink shrimp. One-hour drags were first made during daylight on each area. Then, beginning immediately after sunset, additional 1-hour drags were made in the same area worked during the day. This day-night procedure was repeated numerous times. From the 24-hour test cycles on each major shrimp ground, we obtained a percentage of effectiveness based on catches of shrimp caught by the electrical trawl during daylight versus those taken by nonelectric trawl at night.

Results of Fishing Trials

Table 1 is a summary of the shrimp catches and catch rates for the electric and nonelectric trawls in the 3 major grounds. A comparison of average catches taken during the fishing trials is presented in fig. 5.

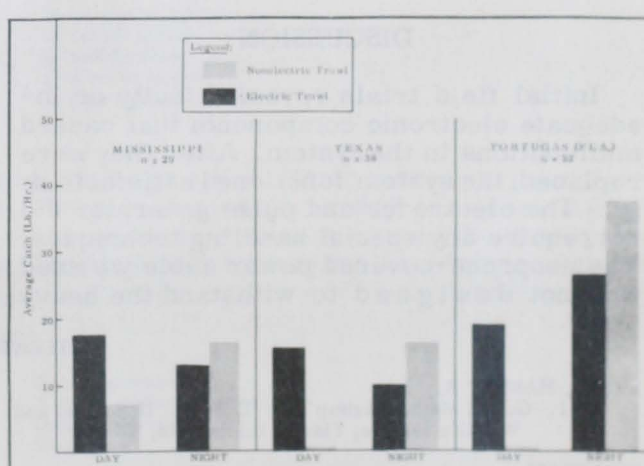

Fig. 5 - Average catches made during fishing trials with the electro-shrimp trawl.

Table 1 - Summary of Trawl Catches Taken During Comparative Fishing Trials with the Electro-Shrimp Trawl

Time	Trawl	Mississippi Grounds			Texas Grounds			Tortugas Grounds		
		Drags	Total Catch	Catch Rate	Drags	Total Catch	Catch Rate	Drags	Total Catch	Catch Rate
		Number	Lb.	Lb./1 Hr.	Number	Lb.	Lb./1 Hr.	Number	Lb.	Lb./1 Hr.
Day	Electric	19	336.5	17.7	18	278.5	15.5	29	548.5	18.9
Day	Nonelectric	19	139.5	7.3	18	9.5	0.5	29	24.5	0.8
Night	Electric	10	130.0	13.0	20	197.8	9.9	23	609.5	26.5
Night	Nonelectric	10	162.5	16.3	20	324.0	16.2	23	866.5	37.7

In the 2 northern Gulf grounds off Mississippi and Texas, the average daytime shrimp catch with the electric trawl was 17.7 and 15.5 pounds per hour, respectively. On the Tortugas shrimp grounds, the average daytime catch by the electric trawl was 18.9 pounds per hour. Nighttime nonelectric averages for the three grounds were 16.3, 16.2, and 37.7 pounds per hour, respectively. All shrimp weights are with heads on.

Table 2 - Day-Night Effectiveness of Electro-Shrimp Trawl System

Catch Comparison	Mississippi Grounds	Texas Grounds	Tortugas Grounds
	......	(Percent)	.....
Daytime electric trawl/nighttime nonelectric trawl . . .	109	96	50
Nighttime electric trawl/nighttime nonelectric trawl . . .	80	61	70

Table 2 presents the effectiveness of the electrical shrimp trawl obtained by comparing the average catches from each fishing ground (daytime electric trawl/nighttime nonelectric trawl). Off Mississippi and Texas, the daytime electric trawl caught 109 percent and 96 percent of the nighttime nonelectric catch, but on the Tortugas shrimp grounds the catch rate dropped to 50 percent.

DISCUSSION

Initial field trials revealed faulty or inadequate electronic components that caused malfunctions in the system. After they were replaced, the system functioned satisfactorily. The electrodes and pulse generator did not require any special handling techniques. The neoprene-covered power cable we used was not designed to withstand the heavy strain or chafing normally encountered with trawling gear. Therefore, we were cautious and controlled the cable by hand to complete our tests, but we recognize its limitations for commercial use. An armored cable that also could function as the trawl warp would be the best solution. Several wire manufacturers are now developing a cable suitable for this purpose.

Klima demonstrated that electrically stimulated shrimp emerge faster and jumped higher from a mud substrate than from any other bottom type. This was substantiated during our fishing trials where the catch ratio was highest on the mud substrate common to the shrimp grounds in the northern Gulf. The catch ratio was reduced almost 50 percent on the Tortugas shrimp grounds, where the substrate is primarily calcareous sand-shell material.

The nighttime electric trawl catches were consistently less than nighttime nonelectric trawl catches (table 2). Based on comparable catch data, about 20 to 40 percent of the available shrimp were not being caught with the electrical trawl system when it was dragged at night. We were not able to obtain data that specifically indicate the reason for this lower catch ratio. Studies of the nocturnal behavior of pink shrimp, however, have shown that they come out of their burrows during the night to forage on the bottom (Fuss, 1964). If we assume that shrimp were foraging during the nighttime fishing trials, they could use the time interval required during daytime to emerge from the bottom to swim out of the electrical field. Those shrimp located in the area of the approaching trawl wings would thus have the opportunity to evade the trawl.

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OLD ITALIAN FAVORITE BECOMES NEW SEAFOOD SLIMMER

Taking a cue from the Italians, a new low calorie salad, Sea Garden Antipasto, is stealing the show at luncheons these days. Maine sardines are featured in this production, but equally talented standby stars are ready to go onstage. Lobster, tuna, crab, pickled herring, or shrimp may be substituted for sardines to present a seafood spectacular. The sardines and mushrooms are marinated and chilled in a low-calorie French dressing mixture made interesting with soy sauce, ginger, garlic, and wine vinegar before being served on lettuce leaves with a variety of crisp, garden-fresh vegetables.

Sea Garden Antipasto is one of many new ideas that make dieting fun with fish and shellfish in a new, 16 page, full-color booklet, Seafood Slimmers, just released by the United States Department of the Interior's Bureau of Commercial Fisheries. It is available for 25¢ from the Superintendent of Documents, Washington, D. C. 20240.

SEA GARDEN ANTIPASTO

3 cans (3-3/4 or 4 ounces each) Maine sardines
2 cans (4 ounces each) button mushrooms
Marinade
6 large lettuce leaves
24 cucumber slices
18 celery sticks
12 radish roses
12 tomato wedges
6 green pepper rings

Drain sardines and mushrooms. Place in shallow baking dish. Pour marinade over sardines and mushrooms and chill for 30 minutes. Prepare vegetables and chill. Remove sardines and mushrooms from marinade. Drain. Arrange all ingredients, except the marinade, attractively on lettuce leaves, dividing the ingredients evenly among the 6 servings. Serves 6. Approximately 130 calories in each serving.

MARINADE

1/2 cup low calorie French dressing
1/4 cup soy sauce
2 tablespoons wine vinegar
2 tablespoons water
1 clove garlic, crushed
Dash powdered ginger
Dash pepper

Combine all ingredients and mix thoroughly. Makes approximately 1 cup marinade.