Scuba Diving Methods for Fishing Systems Evaluation

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ABSTRACT—The scuba diving methods and operational procedures used by the Harvesting Technology Group, Pascagoula Laboratory, Southeast Fisheries Center, National Marine Fisheries Service, NOAA, during the development of new fish trawl technology are described. Procedures for using diving sleds for efficient transport of divers to and from the trawls to facilitate on-the-net observations of operational bottom and mid-water trawls are provided. Procedures are described for the static deployment of bottom and mid-water trawls in fishing configuration, as required during the development of electric trawling systems. Diving safety is discussed as it relates to the use of a diving sled and to both operational and static deployment of fish trawls.

INTRODUCTION

The validity of new fishing system concepts or improvements to existing techniques is normally determined through the development of prototype hardware for operational evaluation. The applicability of scuba (self-contained underwater breathing apparatus) diving techniques for observing and evaluating operational fishing gear were recognized in the early 1950's by gear research units of the Bureau of Commercial Fisheries. Scuba diver observations provided an effective and expedient method for directly identifying components of prototype fishing systems requiring modifications or adjustments to optimize their operational performance. Development of new fishing technology (e.g., electrified trawls) and the determination of capture efficiency values for these and conventional trawls created a need for gear research diving methods for both static and dynamic deployment and evaluation of fishing gear.

This report documents some of the scuba diving methods and trawling systems deployment techniques used by the diver/scientists of the Harvesting Technology Group, Pascagoula Laboratory, Southeast Fisheries Center, NMFS, NOAA, during developmental research and evaluation of several new fishing systems. The examples used relate primarily to the diving methods associated with the development and evaluation of an electric shrimp trawl and an electric mid-water fish trawl.

DYNAMICALLY DEPLOYED TRAWLS

Observations of operational fish trawls were initially attempted by swimmers holding onto tow ropes and positioning themselves at the surface above trawls being fished in shallow water. Considerable improvement in trawl observation techniques were realized by the introduction of diving sleds for towing scuba divers adjacent to the trawls (Sand, 1956; Hold, 1960). Detailed evaluations of operational trawl mechanical characteristics and fish/gear interactions were achieved when divers began working directly on the net following the determinations that most trawls were extremely stable with taut webbing (High and Lusz, 1965). The descent to operational trawls has been accomplished by the divers seizing and pulling themselves down a floatline attached to the trawl (High and Lusz, 1966; Hemmings, 1969) or by moving down the towing warps (Caddy, 1968; High, 1969).

Refinements of diving methods incorporating the use of both diving sleds and on-net operations provided considerable flexibility in positioning divers for recording fish/gear interaction behavior and evaluation of trawl design and experimental hardware. The transport of divers to and from an operational trawl by use of a diving sled reduces the time required to reach the net, providing maximum use of bottom time for collecting observational and measurement data. Diving sled transport also provides additional operational safety advantages: the divers descend and ascend as a group, being easily spotted at the surface by a pickup skiff on completion of a dive, thereby eliminating the difficult task of locating individual divers surfacing downstream of the trawl's path; the hazardous technique of descending along trawl warps ahead of the trawl mouth can be avoided; and protection from possible shark attack is provided by the sled frame, a particular psychological advantage to divers. The following methods were developed for making in situ diver observations on bottoms and mid-water trawls during fishing operations.

Diver Observation Methods for Operational Bottom Trawls

Scuba diving on and around operational fishing trawls requires proper preparation and briefing of the operations team, familiarization with the fishing gear being observed, and the use of good judgment on the part of the divers and all other supporting personnel to ensure effective and safe operations. Bottom trawl observations can be accomplished using the fishing

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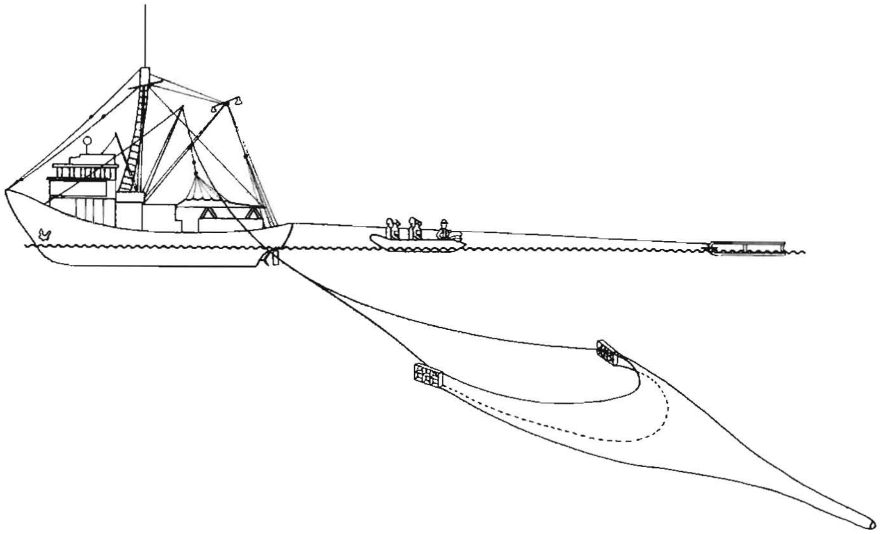

Figure 1.—Correct position of fishery vessel, trawl, diving sled and dive support skiff to allow sufficient distance for divers to enter the water and board the diving sled.

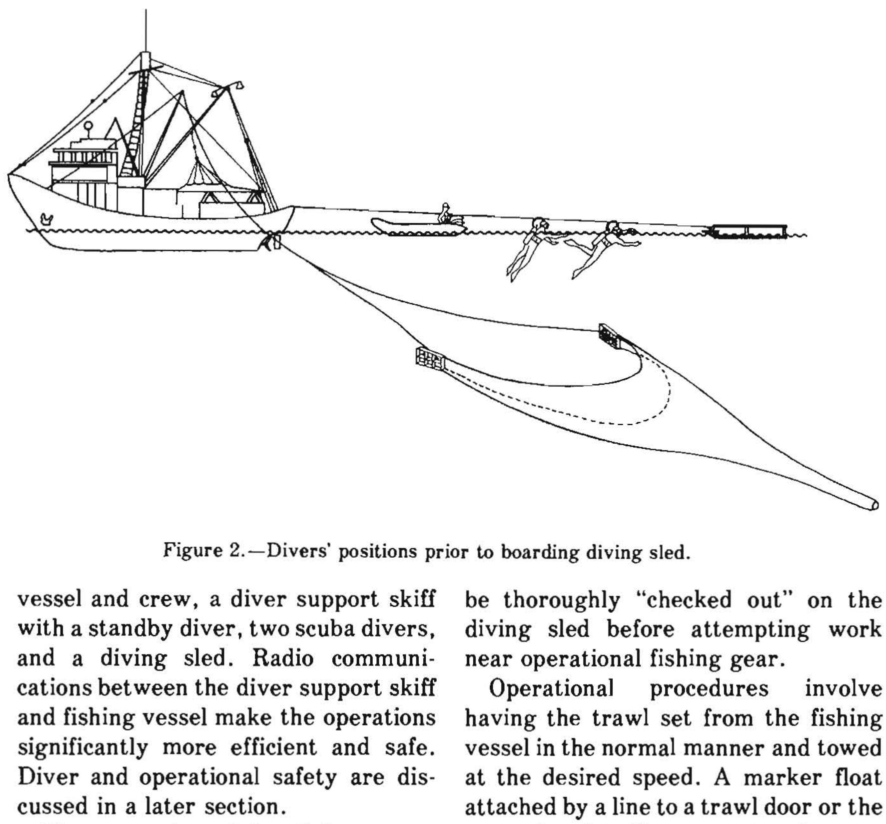

Figure 2.—Divers' positions prior to boarding diving sled.

vessel and crew, a diver support skiff with a standby diver, two scuba divers, and a diving sled. Radio communications between the diver support skiff and fishing vessel make the operations significantly more efficient and safe. Diver and operational safety are discussed in a later section.

The area selected for diving operations should have clear water, trawlable bottom, and to maximize diver bottomtime, a water depth less than 8 fathoms (48 feet; 17 meters). Bottom trawls are normally towed at speeds of 2-3 knots. Diver operations are extremely difficult at towing speeds exceeding 3-3.5 knots. Divers should be thoroughly "checked out" on the diving sled before attempting work near operational fishing gear.

Operational procedures involve having the trawl set from the fishing vessel in the normal manner and towed at the desired speed. A marker float attached by a line to a trawl door or the net cod end facilitates surface location of the trawl's position on the bottom. The diving sled is deployed from the fishing vessel and positioned on the surface at a distance estimated to be 1-3 fathoms (6-18 feet; 2-6 meters) behind the trawl headrope.

The two divers board the diving sled by having the support skiff maneuvered ahead of the sled a sufficient distance to allow the divers time to enter the water and position themselves for boarding the sled (Fig. 1). The skiff moves in close to the sled towline from the downwind side. When the divers are ready to enter the water, the bow of the skiff is turned away from the towline as the motor is taken out of gear. Once the divers are in the water and clear of the propeller, the support skiff motor is engaged and the skiff circles around, taking up a position following behind and to one side of the dive sled path. The divers position themselves 20-30 feet (6-9 meters) apart along opposite sides of the dive sled towline facing the oncoming diving sled (Fig. 2). The diver acting as sled pilot is in the forward position. When the sled reaches the sled pilot, the sled pilot grabs the passing diving vane while kicking in toward the sled (Fig. 3). This action pivots the sled pilot behind the vane to a position parallel with the sled facing the direction of travel. The sled pilot then grabs the sled frame and slides aboard, assuming a prone position at the sled controls. The observer boards the sled in the same manner from the observer side of the diving sled. (A third diver, when needed, would also board from the observer side in the same manner and assume a position on the center of the sled between the other two divers.) When the two divers are in position aboard the diving sled, the pilot releases the diving vane control restraints, which hold the vanes in the up position, and assumes control of the sled. After signaling the support skiff and checking that the observer diver is ready, the pilot flies the sled downward for a brief dive to check sled position in relation to the net (Fig. 4). When the divers surface following this position check, the observer conveys any necessary sled towing line adjustments to the support skiff operator for relay by radio to the fishing vessel. After the necessary towing line adjustments are completed, the divers descend to the net. If the net is small(<20-foot headrope) or data being obtained requires that the net shape not be deformed, the dive sled is landed on the net and the observer diver disembarks and moves to the observation position by pulling himself hand-over-hand across the webbing. The pilot flies the sled off the net to a standby position several feet above the net until the observer signals he is ready for pickup. The sled is then flown back onto the net and the observer diver moves back along the webbing and reboards the sled. When working on larger nets or where changes in net configurations are not critical, the dive sled can be landed and parked on the net by being tied to the webbing, thereby freeing the pilot so he may leave the sled to move about on the net and also function as an observer (Fig. 5). At the termination of this type of operation, the divers reboard the sled, release the tie-down lines, and ascend to the surface. The support skiff then moves in close to the sled, and, on signal from the divers, the motor is taken out of gear. The divers kick free off the back of the sled and swim over to and board the support skiff. The diving sled and trawl are then retrieved by the fishing vessel crew.

Diver Observation Methods for Operational Mid-Water Trawls

Operational and diver support requirements, diving sled operations, and observation techniques used with mid-water trawls are similar to those described for use with bottom trawls. The major operational differences with mid-water trawls, besides their generally large size, is the necessity of fishing them in deep water [> 12 fathoms (22 meters)] over a smooth bottom for a 40-foot (12-meter) midwater trawl to avoid snagging the net on the bottom. Trawling speeds are usually a minimum of 2.5 knots and are not constant since net position (depth monitored by a headrope net sounder) is controlled by vessel speed. Divers working on a mid-water trawl should constantly monitor their depth gauges to detect any changes in net depth because the bottom and other references to vertical position are usually lacking. Operations should be planned so that the mid-water trawl headrope is not fished deeper than 5-7 fathoms (9-13 meters). This will provide for a maximum of diver bottom time and allow descent along the net side walls, as is often required to make fish/gear interaction observations, while retaining some latitude for the usual net

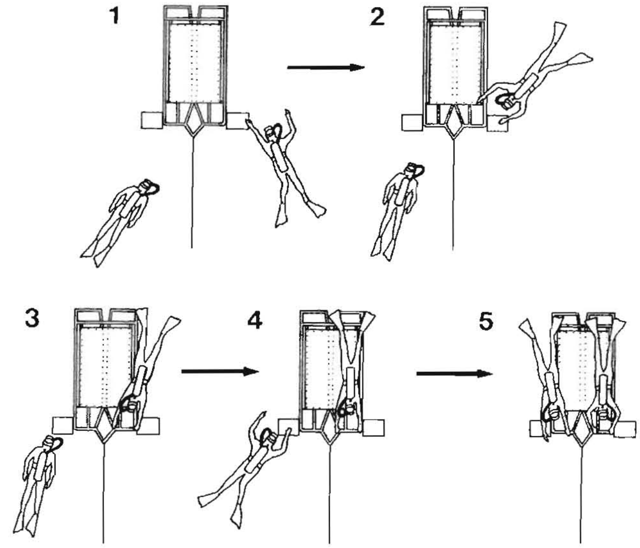

Figure 3.—Procedure used by divers for boarding a moving diving sled.

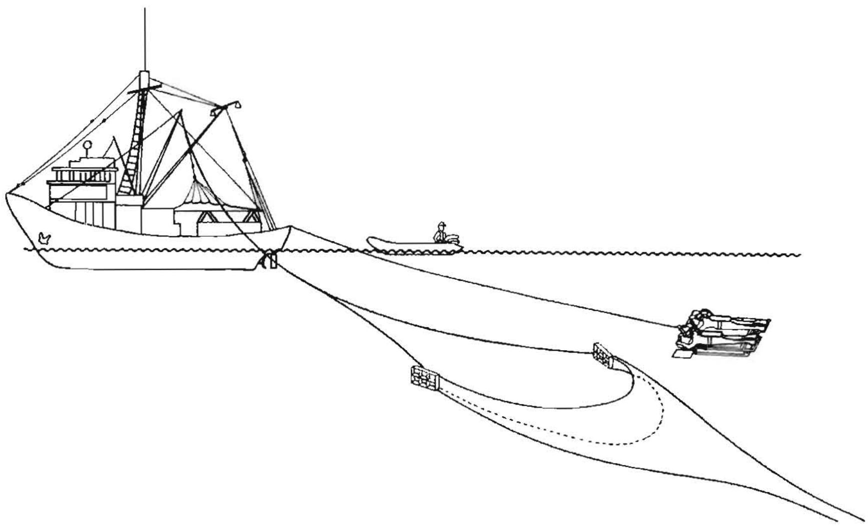

Figure 4.—Divers descend to the moving trawl aboard the diving sled.

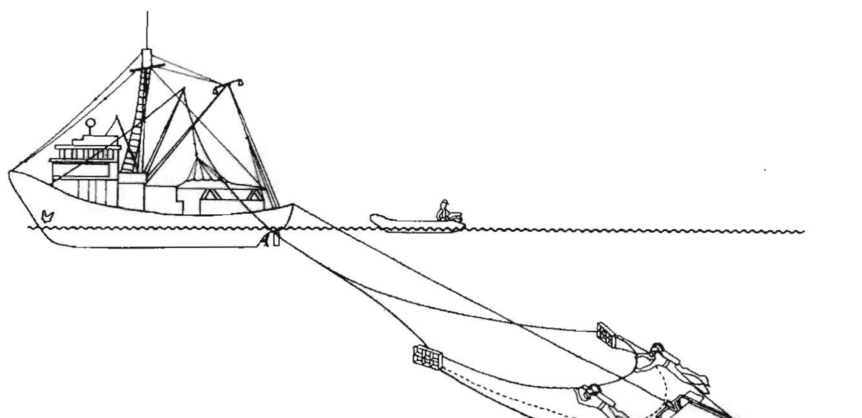

Figure 5.—The diving sled is secured to the trawl and divers are free to move about on an operating trawl.

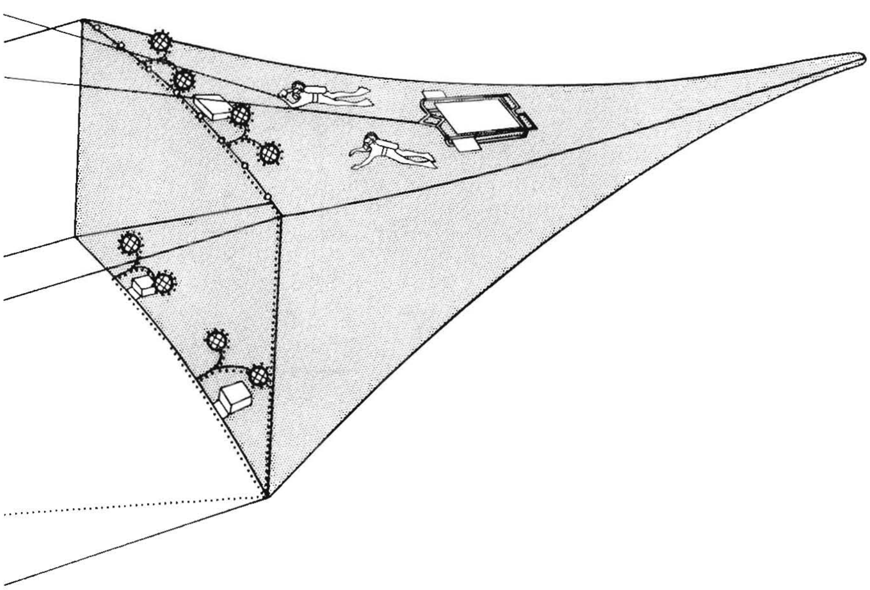

Figure 6.—Diver and sled position on an operating electric mid-water trawl. Divers are positioned safely behind trawl electrodes at a location that allows observation of fish behavior.

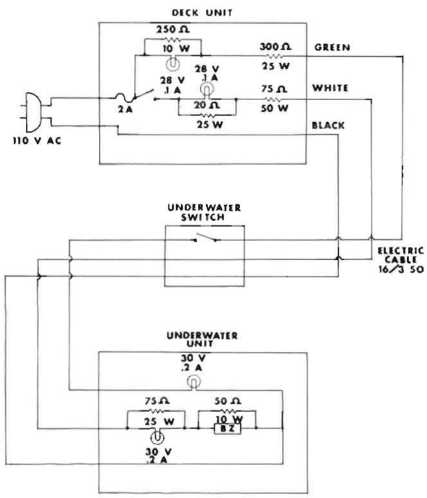

Figure 7.—Schematic diagram of diver safety light system.

depth changes. A diving sled can be landed and parked, as previously described for bottom trawls, on a 40-foot (6.5-meter) or larger mid-water trawl, with almost no effect on the trawl (Fig. 6). Divers moving about on a mid-water trawl may be tempted to pass over the net side wall and ride on the footrope to improve their observation position; this is extremely dangerous and should never be attempted or permitted because a diver could lose his hold and be swept back into the net.

During the development and evaluation of a prototype electric mid-water trawl, a diver safety/signal system and underwater flashing light/buzzer switching unit, connected by electrical cable to a surface monitoring unit aboard the fishing vessel, was attached to the diving sled tow rope. Details of the safety/signal system are shown in Figure 7. The buzzer signal was especially effective underwater as one diver did not have to continuously watch the signal light to monitor signals. This signal system permitted the divers to direct times the electrical power, controlled from the fishing vessel, should be turned on and off, thus allowing the divers to move about the net safely without the danger of shock. This on-trawl electrical system control helped to improve the diver observations of fish response to the trawl and electrical stimulus field.

Considerable diver bottom time can be spent riding a mid-water trawl without encountering a pelagic fish school, even in areas where numerous schools can be sighted at the surface. This situation was improved through the use of mid-water artificial structures (Klima and Wickam, 1971; Wickham and Russell, 1974) to attract and hold schools of coastal pelagic baitfish in the study area. Conical shaped structures, similar to those used by Wickham, Watson, and Ogren (1973), were anchored individually by weights and were spaced at ¼-mile intervals in several rows. The mid-water trawl, with divers on the net, was towed along one of these lines of fish attraction structures during an observation. This technique significantly increased the chance of sighting fish schools during the dive.

STATICALLY DEPLOYED TRAWLS

Development of electric fishing systems requires verification of the capability of prototype electrical stimulus generating components (pulse generator, transmission, and electrode hardware) to produce electric fields of sufficient strength and spatial dimensions to meet experimentally determined stimulus specifications in the extremely low electrical resistivity of seawater (e.g., 0.213 ohm meters at 25°C, 30 ‰ salinity). Prototype systems should meet design specifications prior to initiating their operational evaluation.

Prototype electrode components for the electrical shrimp trawl (Seidel, 1969) were initially evaluated by deploying the electrode array in shallow water (<1.5 meters). Shallow water tests permitted waders or skin divers to position sensing probes for measuring electric field strengths to determine whether minimal stimulus power specifications (Klima, 1968) were being achieved. This technique was useful during development of electrical system components; however, stimulus strength values obtained with this method were somewhat elevated due to electrical field confinement by the close proximity of the air/water surface boundary in shallow water. To accurately determine electric stimulus field strengths and spatial distribution patterns during fishing operations, it was necessary to develop techniques for statically deploying the prototype electric fishing systems in their operational environment and fishing configurations. The following procedures were used to statically deploy an electrified bottom trawl and mid-water trawl to obtain in situ electrical field strength measurements.

Static Deployment Procedures for Bottom Trawls

Static deployment of a bottom trawl (e.g., electric shrimp trawl) can be accomplished using two scuba divers, a diver support skiff and standby diver, and the fishing vessel. A deployment site should be selected which has clear water, a water depth of 4-8 fathoms (7-15 meters), and a clean hard bottom. A marker buoy attached by line to a trawl door facilitates location of the trawl on the bottom. The trawl, with the cod end untied, is set from the fishing vessel in the normal manner and towed into the prevailing current. When the deployment site is reached, the brakes of the trawl winch are released on signal, allowing the warps to go slack and the trawl doors to drop in position on the bottom. This should leave the net horizontally spread in full fishing configuration. Fishing vessel headway is reduced simultaneously with the winch brake release signal. When the fishing vessel is properly positioned, the anchor is set and sufficient line played out to hold the vessel (Fig. 8). During anchoring, the trawl warps must be adjusted to keep them clear of the ship's propellers. Once the fishing vessel is anchored, divers verify the proper door spread and net opening and make any adjustments needed to obtain the required net configuration. Normally, the trawl doors drop in place with the trawl footrope spread in fishing configuration. Trawl webbing usually overruns the footrope. The divers must pull the webbing back and stretch it taut by setting an anchor behind the cod end and pulling the net into shape either by hand, or, when deploying a very large net, with a block and tackle. Divers make additional webbing adjustments using lines attached to small anchors or floats. When the electrical shrimp trawl was used, divers made minor adjustments to the electrode catenary and spacing to match the exact fishing configuration observed during trawling operations. The prototype electric shrimp trawl has a 25-foot (7.5-meter) headrope overhand extending above the electrode array, which requires that the net mouth be floated open to permit divers access to the electrodes. Once the trawl is satisfactorily deployed, electrical field strength measurements can be initiated (Fig. 9). An electric probe linked by coaxial cable to an oscilloscope aboard the fishing vessel is used to collect electric field strength data. Details of electric probe construction are given by Klima (1968), Seidel (1969), and Watson (1974). The accuracy and efficiency of the field strength measurements are facilitated by using support skiff radio and diver safety signal system communication with the fishing vessel. The diver safety signal system was described previously.

Measurement procedures involve using divers to position the probe between the electrodes at selected positions predetermined by the measurement scheme. When the probe is set for a measurement, the divers signal the vessel and receive a confirmation signal before the pulse generator is turned on. After the field strength and pulse configuration measurements are obtained from the shipboard oscilloscope, the pulse generator is turned off and the divers are given an "all clear" signal to which they, in turn, give a confirmation signal before moving the probe to the next position. When all electrical measurements are completed, the probe and signal light are placed aboard the dive skiff. Before returning to the fishing vessel, the divers recover all anchors, floats, and lines used for statically deploying the net.

The net recovery procedure is generally the reverse of that used during deployment. The fishing vessel hoists the anchor while the towing warp slack is regulated to keep lines clear of the propeller. When the anchor is secured aboard, the vessel is held into the current as towing warp slack is taken up on the winch and the power cable slack pulled in. The vessel then moves ahead and, after towing speed is attained, the winch retrieves the net as during normal fishing operations.

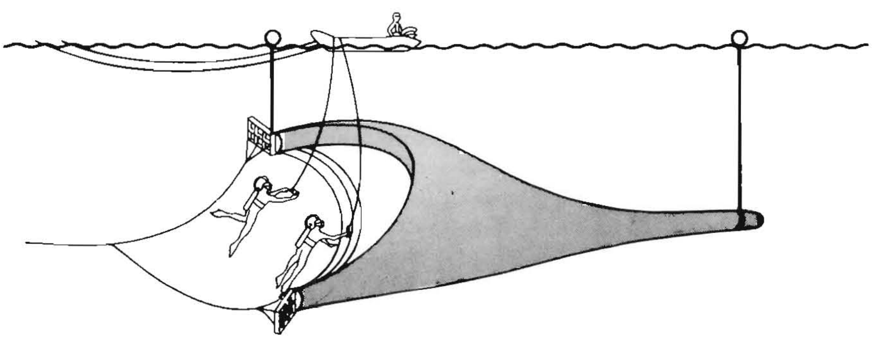

Figure 9.—Statically deployed electric shrimp trawl showing diver and support skiff position for making electrical field measurements.

Static Deployment Procedures for Mid-Water Trawls

A prototype electric mid-water trawl was constructed (Seidel and Wickham[1]) to evaluate the feasibility of developing a system based on this concept for resource assessment sampling for coastal pelagic school fish. Measurement of in situ electric field characteristics for comparison with design specifications established by Klima (1972) and Seidel and Klima (1974) was accomplished by statically deploying the mid-water trawl, suspended in mid-water to avoid electrical field dispersal distortion at the bottom and water surface interfaces.

Static mid-water deployment of the prototype 40-foot (12-meter) electric mid-water trawl requires three 2-man diving teams, an air compressor with a minimum of 12 air bottles, two diver

[1]Seidel, W. R., and D. A. Wickham. Feasibility for development of an electro-fishing midwater trawl. Manuscript.

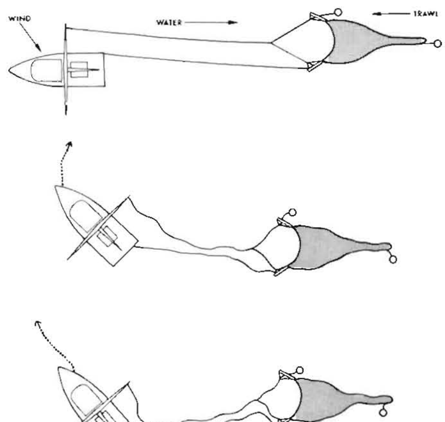

Figure 8.—Procedure for statically deploying a trawl from a fishery vessel.

support skiffs, and the fishing vessel. Deployment operations are started once the fishing vessel is anchored. The deployment area should be preselected for relatively clear water, smooth unobstructed sand/shell bottom, current velocity less than 0.5 knot, and a water depth 6-7.5 meters greater than the desired vertical net opening. These criteria allow as much nondecompression diver bottom time as possible, since water depth significantly affects duration of bottom time. Net deployment in water exceeding 80 feet (24 meters) may require an additional pair of divers because of bottom time restrictions. Our mid-water trawl development operations were conducted in 20-23 meters of water off Panama City Beach, Fla. This location is also advantageous because of the Navy decompression facility nearby.

The trawl is rigged for deployment by replacing the doors with equivalent length 4- x 4-inch (10- x 10-cm) wooden spacers. Floats (automobile innertubes) attached by measured drop lines are spaced along the leglines and top corner side seams of the net to provide buoyance and establish the spacing between the net and water surface. The net is set using a skiff to pull the net off and away from the anchored fishing vessel's stern until sufficient towing warp is available to permit the net to be spread. A mid-water trawl can be spread without using the leglines; however, we used them for attaching our electrical field measurement transect guidelines and for providing a frame of reference for static observation on fish response to the electric field. The net should be aligned so the prevailing water current flows toward the trawl mouth. Once the net is sufficiently clear of the fishing vessel, the cod end of the net is temporarily secured in place by a line attached to a Danforth-type anchor set in the bottom, and the location is marked by a buoyed retrieval line. The two skiffs, each with a line on one of the wooden door spacers, are then used to pull the spacers apart to spread the leglines. Towing warps may have to be slackened slightly to obtain a spread equivalent to that obtained when the net is fishing. When the desired separation is obtained, the spreaders are temporarily held in position by lines attached to small Danforth-type anchors. The towing warps are then slackened so divers can unshackle them from the spacers. When released, the towing warps are retrieved on the fishing vessel winch. The electric mid-water trawl is now attached to the fishing vessel only by its electrical power supply cable. It is critical at this point that secure anchor attachments be made at the two spacers and the net cod end to prevent the net from breaking free due to changes in current direction or sea state. The electrical power cable must be secured at the point where it clears the spacer attachments to prevent it from dragging or pulling the net as the fishing vessel moves on anchor. The power supply cable must be monitored regularly aboard the fishing vessel while the net is deployed to make sure the cable has sufficient slack as the vessel swings on anchor. We used screw anchors (telephone pole guy-wire anchors with shaft length shortened to 4 feet or 1.2 meters, set in the bottom by the divers) as attachments for the main electric mid-water trawl securing lines. A two-man diver team is able to set a screw anchor in sand, using a cross bar for twisting leverage while continuously shaking the anchor shaft. Once the net is secured at the three critical points, net spreading and other adjustments can proceed. The net at this stage of deployment is laterally collapsed. The electrical transformers, attached to the footrope, usually rest on the bottom and the webbing extends vertically to the headrope floats just below the surface. Divers working near the net at this time should use caution to avoid being tangled in the slack webbing. A screw anchor is placed in the bottom, 50-75 feet (15-23 meters) away from the net on each side at an angle of 30-35° from parallel to the net footrope, to allow spreading open the net. A guideline from the net to the screw anchors and a buoyed screw anchor retrival line make for quick relocation of the screw anchors by the divers. Block and tackle attached to each end of the footrope and the respective screw anchor are used by the divers to spread open the bottom of the net. Deflated innertube floats are then attached to the electrical transformers mounted on the footrope. An air bottle with an innertube filling attachment can be used to inflate the floats underwater until a slight positive buoyancy is obtained. The footrope is then securely tied with lines to the screw anchors and the block and tackle units removed. A second set of screw anchors is then set in the bottom about 25 feet (7.5 meters) farther out at the same angle from the footrope screw anchors. Block and tackle are now attached to each end of the headrope and to the second set of screw anchors. Four innertube floats are attached to each end of the headrope at the legline attachment eye splice by droplines adjusted in length to position the net at the desired depth below the surface. When tension is brought against the headrope and floats with the block and tackle, the net spreads open and the headrope flattens out. The headrope is then securely tied with lines to the screw anchors and the block and tackle units removed. A line on each side of the net running between footrope and headrope eye splices is used to lift the footrope sufficiently to obtain the fishing configuration vertical net opening. Block and tackle are sometimes required for this operation. This adjustment usually results in the footrope being raised approximately 10 feet (3 meters) above the bottom. Other minor adjustments in line tensions can then be made to square the net opening to obtain the desired configuration. Webbing in the belly of the net is pulled taut and adjusted by changing the attachment position and dropline lengths of the floats along the net top side seams and by the use of lines attached along the top and bottom side seams and secured to the bottom by small Danforth anchors. The net is now fully deployed and only marked transect lines remain to be positioned to guide electrical probe positioning during field strength measurements (Fig. 10).

Transect lines marked at predetermined intervals are tied across the top and floor of the net at one-meter (0.3-foot) intervals, starting at the electrode grids and extending out ahead of the webbing for 3 meters (0.9 foot). Lines ahead of the webbing are attached to the net corner pieces and suspended leglines. The vertical measurement positions are established

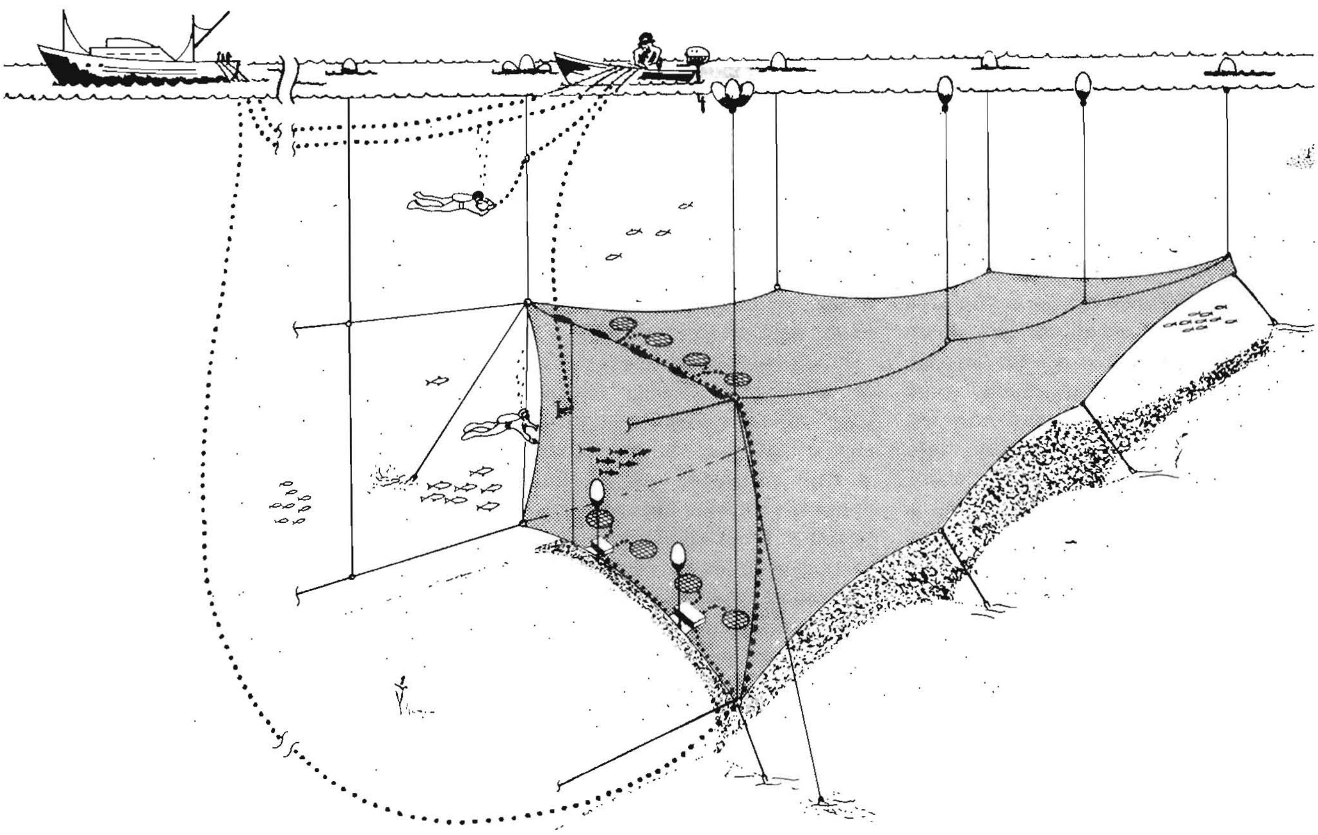

Figure 10.—Statically deployed electric mid-water trawl showing diver and support skiff positions for making electrical field measurements.

by suspending a movable vertical marked line between corresponding locations on top and bottom horizontal transect lines.

An electric probe attached by coaxial cable to an oscilloscope aboard the fishing vessel is used to obtain field strength measurements. Details of the electric probe are given by Seidel and Wickham (Footnote 1). The measurement procedures involve attaching the electric probe to each position on the vertical measured line for measurements at each transect point. At the completion of each vertical measurement series, the vertical lines and electric probe are moved to the next transect station. The vertical series are repeated until the field strength pattern is determined sufficiently for the field strength configuration plot for the net to be calculated at various pulse generator output voltage levels. The weight of the vertical line and probe is supported by an attached buoy.

The diver safety signal light described previously is used during field strength measurements. This signal system improves diver operations significantly by allowing the divers to remain submerged at depth, where they have only to swim horizontally out of the electrical field during a series of measurements.

Net retrieval is accomplished by having the divers recover all the Danforth and screw anchors, including the power cable anchor, except for those holding the two spreaders and cod end. A line is run from the fishing vessel and securely tied through the cod end choker line rings for retrieving the net. The divers then release the cod end from its anchor and as the webbing is pulled toward the fishing vessel, the spreaders are released. The net is dragged cod end-first back to the fishing vessel and pulled aboard. During net retrieval the electrical power supply cable is also pulled aboard. The divers extract and pick up the last screw anchors while the net is being retrieved. Once the net is onboard the fishing vessel, the floats, transect marker lines, and other deployment rigging are removed, readying the net for fishing trials or storage.

DIVER OPERATIONS AND SAFETY

The materials and mechanical operations associated with fishing systems make their in situ evaluation a potentially hazardous diving operation. These activities can be accomplished safely, however, by trained and properly prepared diver/scientists.

Standard diving safety practices are observed by divers working on or around fishing gear (U.S. Department of the Navy, 1973; U.S. Department of Commerce, 1975). In addition, procedures are established on a precautionary basis for any potentially hazardous situation anticipated for a particular project. Diver preparation for fishing gear evaluations includes a thorough familiarization with the diving gear, support equipment, and operating procedures as well as the waters where the diving operations will be conducted.

Immediately preceding any diving activities, the captain, mates, deckhands (engineers, if special demands will be made on vessel equipment, e.g., electrical power demand surges), scientific party members, skiff operators, and divers would be briefed on the operational objectives, workplan, and their responsibilities. Arrangements are made for the use of portable transceiver radios whenever possible, because direct verbal communications are essential for safe, efficient operations.

Diving operations conducted directly over-the-side from a fishing or research vessel should be permitted only when the propulsion engines are off-line, for accidental clutch engagement could cause a diver to be sucked into the propeller blades. Diver safety lines should also be used because water currents, vessel wind drift, or a combination, can often rapidly separate divers from a vessel, even on anchor. The necessity for having a large vessel locate and pick up divers in the water at sea should be avoided because maneuvering is difficult and potentially dangerous to the diver. Divers working directly beneath the vessel hull must use caution because a vessel riding in a sea swell can move downward in the water rapidly, resulting in a heavy blow, cuts, or abrasions to the careless diver.

Diving operations for the purpose of fishing systems evaluations are usually conducted at sea using a small skiff deployed from a fishing or research vessel. Experiences with over-the-side operations using skiffs of a variety of designs and materials in a wide range of sea conditions have indicated that the inflatable skiffs are best for diving operations. Inflatable skiffs are relatively light for their size and not difficult to store (either below or on deck), deploy, or retrieve from a large vessel. The air cushion structure of the inflatable skiff results in little damage to either the deploying vessel or skiff when they are slammed together by the sea swell when laying alongside for the transfer of people and gear. This cushion effect reduces the chance of serious injury should someone have a hand or leg caught between the skiff and vessel. The inflatable skiffs reduce the chance of injury when divers in full gear climb in and out of the skiff. Transfer of people between a vessel and skiff can be accomplished safely using a Jacobs Ladder. Diving gear and other equipment can be transferred hand-to-hand or by using a rope for passing gear in or out of the skiff.

Inflatable skiffs usually do not move astern easily, especially with a load of divers and diving gear, and adequate propulsion should be provided to permit effective maneuvering. Our experience indicates a 15-foot (4.5-meter) inflatable skiff should be powered with at least a 25-hp outboard motor with an extended foot when being used as a dive skiff at sea.

Divers preparing to use a diving sled or work on operating trawls where they will be towed through the water should make sure all their diving gear is firmly secured and positioned to minimize chances for snagging on the sled or in trawl webbing. Life vest CO_2 cartridge release cords should be secured to prevent their being snagged and inadvertently fired, deploying the vest. A full wet suit is recommended since being towed through even relatively warm water (e.g., 80°F; 26.7°C) results in rapid body heat loss and chilling. The wet suit also affords some protection from jellyfish stings. A weight belt is usually unnecessary because the diver is always in contact with either the diving sled or trawl.

Special attention should be directed toward tightly securing air bottles in the backpacks. The air tanks of a towed diver are subject to considerable water pressure when traveling at trawling speeds (>2.5 knots), which can cause improperly secured air tanks to slip out of the backpack. If an air tank slips out of a backpack during a towed dive, the diver may be able to hold onto the tank and mouthpiece or the mouthpiece may be pulled out of the diver's mouth and all the gear could be lost. In either case, the diver and his buddy should abandon the diving sled or net and return normally to the surface, buddy-breathing if necessary, for pick up by the dive skiff. Divers should be restricted to non-decompression diving when working on diving sleds or nets as a safety precaution.

Prior to attempting any work with a diving sled, the divers should be thoroughly checked out on the sled, initially as observers with an experienced pilot and then as a sled pilot. The checkout dives should include making controlled 360° rolls, since a sled may occasionally invert when being banked steeply as required for making extensive horizontal maneuvers. Diving sled operations require that each diver carefully monitor water depth and descent and ascent rates to avoid the chance of pressure squeeze or embolism resulting from unnoticed depth changes. Regular shallow breathing is preferable to slow deep breathing and divers should never hold their breath on the diving sled or the trawl. The sled pilot must also control depth rate changes so that should an observer diver have difficulty equalizing inner ear pressure, the pilot can be signaled to make the necessary depth or rate change adjustments to correct the situation.

Divers encountering bottom obstructions (wrecks, rock ledges) while on the diving sled or riding a trawl can easily avoid contact by abandoning the net or sled before impact. The forward motion of a diver stops almost immediately upon release of the towing surface and he can then surface normally.

Divers working on trawls should always use the buddy system, remaining within visual range (separation distance being determined by water clarity) and check each other frequently for changes in location and signs of trouble. A diver can move around on a net and up to the doors by pulling himself forward hand-over-hand up the webbing and leglines. Extreme caution should be used when hanging onto trawl doors to avoid being pinched by moving hardware. Hanging onto the cod end or trailing behind the net is not advisable because of potential for shark attack. Fish/gear interaction observations can be made through the trawl webbing or from the headrope or net wings. A diver should never cross over into the net mouth or maneuver beneath a net. Slack webbing on a trawl should be avoided because it is extremely easy to tangle gear in these areas. A diver should remain calm if his gear becomes tangled in the webbing and immediately signal his buddy for assistance. A diver also has the option, if necessary, of using his knife to cut entangling webbing loose or ditching his gear and swimming to the surface buddy-breathing or in free ascent. If a diver moving about on a net should lose contact with the net and not be able to regain his hold, the diver's buddy should also abandon the net and they should ascend together normally to the surface where they can signal the dive skiff for pick up.

Diving operations associated with the static deployment of nets usually require sequentially operating teams of two or more divers to effectively utilize available daily non-decompression bottom time for task accomplishment. Pre-dive briefings should be conducted to plan detailed work assignments and event sequences. During the actual net deployment, each diver team should brief the succeeding team of divers on the details of the work accomplished and identify any problems encountered or anticipated. The lead divers for each team statically deploying a fishing net must be thoroughly familiar with the net design to properly identify net component sections and to effectively pick up and continue with the work of the preceding team.

The most hazardous period when statically deploying a fishing net occurs while it is being spread and there is slack webbing in the net. Divers should use caution when working with slack webbing because tangling diving gear in the webbing is deceptively easy with any contact. The safest procedure for working with slack webbing is to have one member of the dive team handle the work near the webbing with the buddy diver providing support while remaining clear to provide assistance should the diver tangle his gear in the webbing. Diving gear badly tangled in slack webbing can be freed by cutting the webbing. The diver may also ditch his gear to untangle the webbing or to accomplish free ascent to the surface. Divers conducting hard physical labor under water, such as setting screw anchors and tightening net restraining lines, should use caution to avoid overexertion and oxygen debt buildup. If the statically deployed net is left in position for several days, a potential shark hazard might develop when fish are gilled in the webbing at night. Divers should use appropriate discretionary judgment whenever large numbers of fish are being gilled in the net. Net retrieval activities are relatively routine, but again the divers should avoid overexertion while recovering anchoring hardware and use caution when working near slack webbing.

Our experiences have documented the important role played by the properly trained diver/scientist in the development and evaluation of fishing systems. A diver/scientist is in a position to obtain many insights into gear operational characteristics and make observations of fish/gear interaction obtainable in no other way. The diver/scientist, as a trained observer skilled in specific disciplines, is also able to provide critical technical observation reports for use by non-diving scientists. Contract diving services should be used, however, to supplement or replace diver/scientists during certain types of diving operations. Projects requiring considerable underwater construction, such as during deployment of large nets or test hardware, can effectively utilize contract diving services. A contract diver can also be trained as a diving sled pilot to assist in routine operational net evaluations. Often a diver/scientist diving sled pilot is desired to provide additional skilled observational talent on the net. A properly trained diver/scientist should be the preferred option whenever technical or scientific measurements and observations are required.

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