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# An Automated Unmanned Fishing System to Harvest Coastal Pelagic Fish

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*ABSTRACT—Coastal pelagic fish resources of the Gulf of Mexico are basically unutilized with the exception of menhaden, which are harvested extensively. The other fishes of the coastal pelagic group represent a resource which has been estimated to be nine times larger than the menhaden resource, but cannot be profitably harvested by traditional purse seining techniques. The various species do not naturally form large schools as do the menhaden, and are often found in shallow water over rough bottom areas which limit the use of purse seines. Described is an automated fishing system that offers a method to effectively harvest the coastal pelagic fish resource. This system would be unmanned from harvesting through processing; the only manpower or vessel requirement would be to service and maintain fishing platforms and to offload the processed products.*

## INTRODUCTION

Harvesting coastal pelagic fish in the Gulf of Mexico consists primarily of purse seining for menhaden (*Brevoortia* sp.) for reduction to industrial products, mainly fish meal and oil. There are indications that the catch of menhaden in the Gulf has reached or perhaps surpassed the level of sustainable yield. At best, this species is only the third, and perhaps only fifth, most abundant coastal clupeid in the Gulf of Mexico (Bullis and Carpenter, 1968).

Other latent pelagic resources of the Gulf offer excellent opportunities to the fishing industry. They include herrings, anchovies, and jacks, which are available from the coast to the edge of the Continental Shelf. Personnel of the National Marine Fisheries Service (NMFS) at Pascagoula, Miss., have estimated the standing stock of coastal pelagic fishery resources to be over 11 million tons (Klima, 1970). For example, stocks of Atlantic thread herring (*Opisthonema oglinum*) have been estimated at about 1 million tons (Bullis and Thompson, 1967).

Attempts to harvest latent coastal pelagic fish have been generally unsuccessful because the fish avoid mid-water and bottom trawls (Klima, 1970). Their behavior makes capture with standard purse seines ineffective. Unlike menhaden, these pelagic fish are usually found in numerous small schools (2-5 tons), making it economically unfeasible to use purse seines for capture. When large schools are found, they often divide into smaller groups that are extremely fast and difficult to encircle with a purse seine (Butler, 1961). In addition, purse seines have not been suitable for harvesting coastal pelagic fish in some areas because rough bottoms and shallow water inhibit extensive seine-type operations.

Economic factors are compounded because coastal pelagic fish are not highly concentrated and range over vast areas. When used for reduction into fish meal or fish protein concentrate (FPC), the fish must be harvested inexpensively by capturing large quantities in a relatively short time, close to a processing plant. Various techniques have been tested to locate schools; the most successful has been the use of aircraft with spotter pilots. Present harvesting techniques and gear are inefficient, but dockside processing of the catch has evolved to almost total automation. As a result, the cost of acquiring the raw material is the dominant factor controlling the price of the end product. The Southeast Fisheries Center of NMFS and its predecessor agencies have proposed the development of automated fishing systems as a potential solution to the problem of economically harvesting coastal pelagic fish.

## SYSTEM DESCRIPTION

There are an estimated 1,000 unused oil rig platforms and structures in the Gulf of Mexico and several thousand more which are oil producing units. Recreational fishermen have demonstrated the usefulness of these platforms

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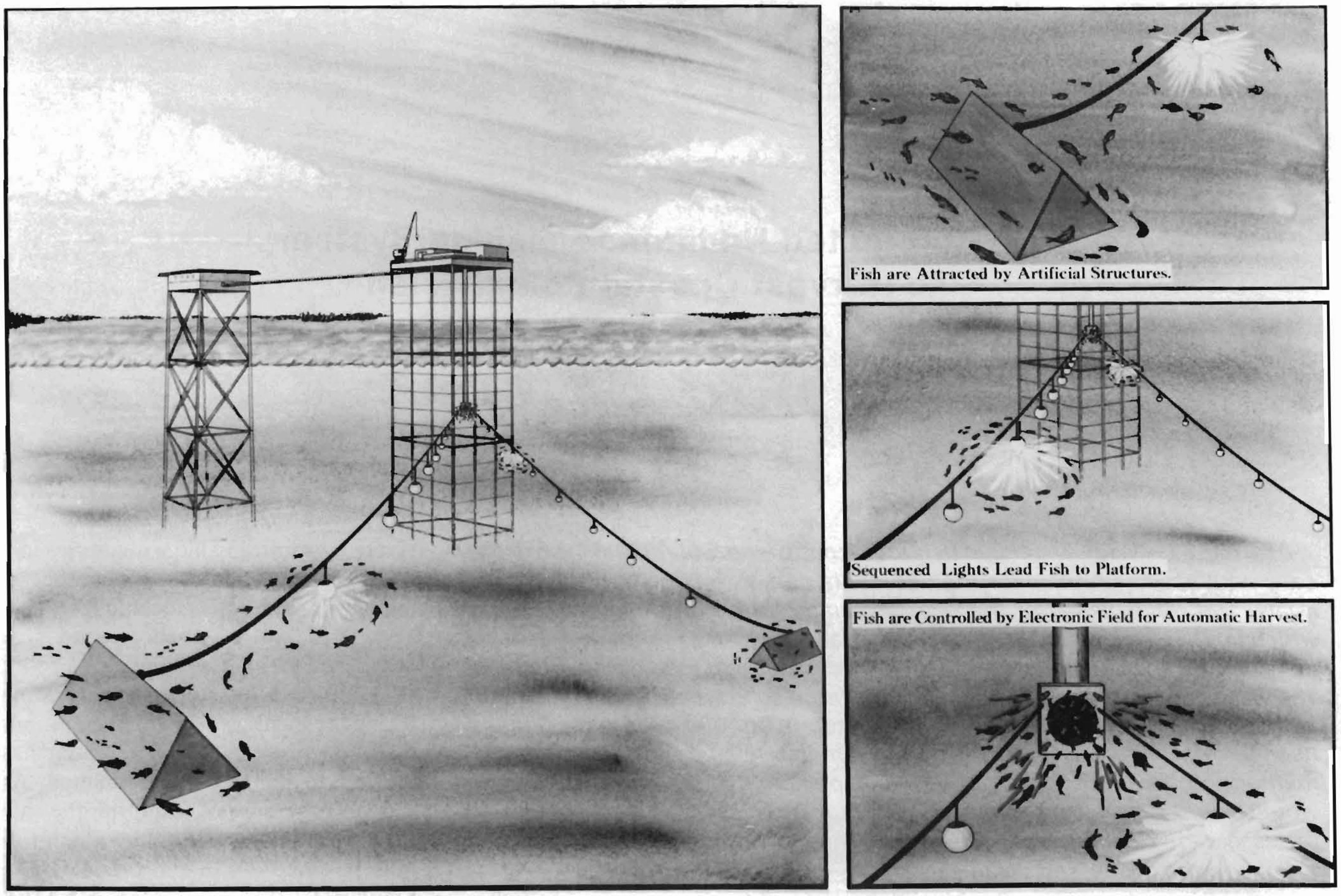


**Figure 1.—Artist's concept of an automated fishing station on an offshore oil platform.**

as attractors of food fish such as red snapper, lemonfish, grouper, and drum, and it is known that coastal pelagic fish are also attracted in great numbers. These platforms are an integral component of the proposed automated unmanned fish harvesting system, although in areas without such platforms groups of man-made underwater structures could be used.

The proposed system would be based on the unused oil rig platforms as attractors of coastal pelagic fish. The fish that congregate around and under the platforms would be periodically harvested with the aid of attraction lights and electrical fields. An automatic processing vessel or barge, with attraction and harvesting equipment installed on it, would pump the fish from the electrical field into onboard automatic processing machinery where the fish would be converted into fish meal and oil. An alternative to this approach would be to install electrical hardware and automatic processing machinery on the platform itself (Fig. 1). Fish would be periodically pumped into automatic processors and the resulting fish meal or FPC stored on the platform to await collection by a shuttle boat.

Additional small attraction devices could be deployed outward from and around the oil platforms to increase fish concentrating capability. Through the use of sequential lighting or main attraction lighting, either under the platforms or aboard the processing barge, the fish could be concentrated and harvested from the electrical field.

There are advantages and disadvantages to the barge and platform processing techniques. An automatic processing barge would offer more flexibility and mobility to the overall harvesting operation and the initial cost perhaps would be less. However, permanently fixed processing and harvesting equipment on each platform would offer the capability for continuous fishing at multiple locations which might offset any increased initial capitalization.

## SYSTEM COMPONENTS

### Attraction Devices

In many parts of the world, commercial fishermen have harvested pelagic fish that congregate around floating objects (rafts, logs) and near fixed structures (Hunter and Mitchell, 1967). Evaluations of artificial floating objects reported by Hunter and Mitchell (1968) revealed that pelagic fish are attracted more to submerged three-dimensional structures, resembling small tents, than to horizontal or vertical plane surfaces.

Klima and Wickham (1971) and Wickham and Russell (1974) experimented with structures patterned after Hunter and Mitchell's (1968) successful design. Their studies indicated that artificial structures were effective for concentrating coastal pelagic fish in the Gulf of Mexico. During a 20-day observation period, 25 metric tons of fish were attracted to a structure on one occasion, and in six other instances at least 5 metric tons of fish were attracted. The studies revealed a very rapid rate of initial attraction, indicating that the fish could be harvested at frequent intervals.

Field studies to determine the attraction of coastal pelagic fish to night-lights were reported by Wickham (1971a, 1973) and Wickham and Seidel (1973). A single light used in conjunction with a conventional purse seine yielded approximately 4,000 pounds of fish in 3 hours. Multiple lights, properly spaced, appeared to act as independent attraction points and it was demonstrated that fish attracted to one could be led by sequentially illuminating the series of lights. A single moving light also proved successful in leading fish. Use of artificial structures in conjunction with light attraction significantly increased the density of fish concentration.

## Control Techniques

Laboratory experiments were conducted by Klima (1972) to identify the electrical characteristics needed to induce electrotaxis as a means of controlling and leading fish. He used a modified electric shrimp pulse generator which produced pulsed direct current in the form of capacitor discharges at a rate of 5-75/second. An index of optimal responses was obtained for selected species (Table 1).

Table 1.—Effective combinations of voltage (per 10 cm) and pulse rate (per second) for inducing electrotaxis in the species studied and the approximate amperes (per square meter) (Klima, 1972).

| Species | Volts | Pulses | Amps | Fish length (mm) | |
|---|---|---|---|---|---|
| | | | | Range | Average |
| Coastal pelagic fish | | | | | |
| Scaled sardine | 1.5 | 15-55 | 62.5 | 100-145 | 118 |
| | 3.0 | 8-28 | 86.5 | 100-145 | 118 |
| Spanish sardine | 1.5 | 35-45 | 43.3 | 85-180 | 130 |
| | 3.0 | 15 | 86.5 | 85-180 | 130 |
| Round herring | 3.0 | 25-45 | 86.5 | 80-150 | 104 |
| Silver anchovy | 3.0 | 35-45 | 98.3 | 85-110 | 96 |
| Butterfish | 1.5 | 35 | 41.3 | 80-100 | 118 |
| | 3.0 | 45 | 86.5 | 80-160 | 118 |
| Chub mackerel | 1.5 | 15 | 53.8 | 125-240 | 180 |
| Bumper | 1.5 | 15 | 57.0 | 135-230 | 173 |
| Rough scad | 1.5 | 15-25 | 42.3 | 120-145 | 133 |
| Thread herring | 1.5 | 15 | 62.5 | 80-185 | 146 |
| Round scad | 1.5 | 15 | 43.3 | 90-170 | 148 |
| Bottom fish | | | | | |
| Spot | 1.5 | 15-35 | 43.3 | 90-250 | 120 |
| Longspine porgy | 1.5 | 25-35 | 43.3 | 100-160 | 128 |

Klima (1972) reported that guiding or leading coastal pelagic fish to the anode was easily accomplished within a uniform electric field. Nonuniform fields—a gradation of voltage which increases as the fish approach the anode—caused the fish at the outer edges to undergo a fright reaction because of the low-voltage gradient. Fish in the center of the field underwent electrotaxis and swam toward the anode until the voltage increased sufficiently to cause tetanus. Fright and tetanus responses are undesirable for leading fish; however, fish can be led considerable distances without these responses in a uniform field. Thus an electrode array should be designed to produce an electric field as close to uniform as is possible in the area where electrotaxis is wanted.

The behavior of fish in an electrical field is dependent on the voltage applied, pulse rate, and length of the animal, since the voltage potential increases proportionately with length. To substantiate the accuracy of electrical characteristics established in the laboratory, an intermediate-size pulse generator and test electrode array were constructed to conduct in situ tests (Seidel and Klima, 1974). Fish were attracted into the electrode array and their responses to various combinations of electrical fields and pulse rates were evaluated to determine the requirements of an electrical system which could succeed in the full-scale commercial harvesting of coastal pelagic fish.

The tests conducted by Seidel and Klima (1974) enabled them to compute the size of an electrode array to harvest commercial quantities of coastal pelagic fish, and the electrical field and pulse generator characteristics necessary to produce the proper stimulation to lead and control the fish. Pulse generator and electrical system criteria established by these tests were used subsequently to design and purchase a pulse generator with an output capability of 120 kw into a load resistance of 0.02 ohm at variable pulse rates and pulse widths. The system, now installed on the RV *Oregon II* (Fig. 2), provides the capability to lead and control pelagic fish in commercial quantities so that rapid, efficient capture and harvest can be accomplished.

## Pumping and Processing Equipment

Most of the pumping and processing equipment required to complete the automated fishing system is available commercially. Adaptation of an electrode array and possibly a small secondary pulse generator around the pump intake, however, might be required. The most feasible system output appears to be pelletized fish meal similar to that produced in several South African countries. This processing method alleviates the requirement for aerating the fish meal as part of the drying process and also prevents combustion. It would also expedite transfer and handling of the product between the platform and service vessel and at the shore facility.

## Concept of Operation

The two methods available for using the automated concept to commercially harvest coastal pelagic fish already have been briefly discussed. The first method uses an automated fish processing barge to service fish concentrations and harvesting sites. The harvesting and processing vessel would service several sites in an area nightly or at whatever time interval is determined to be optimum. Installed on the vessel would be a pulse generator, electrode array, fish pump, fish processing equipment, and other hardware, including storage facilities, necessary to accomplish automated harvesting and processing of the fish. A minicomputer would be necessary at each site to properly activate the concentrating and holding lights. The lights would be automatically turned on about sundown and, if a series of satellite structures were used, the computer would also activate sequential lights to lead fish from the satellite structures to the main platform. The

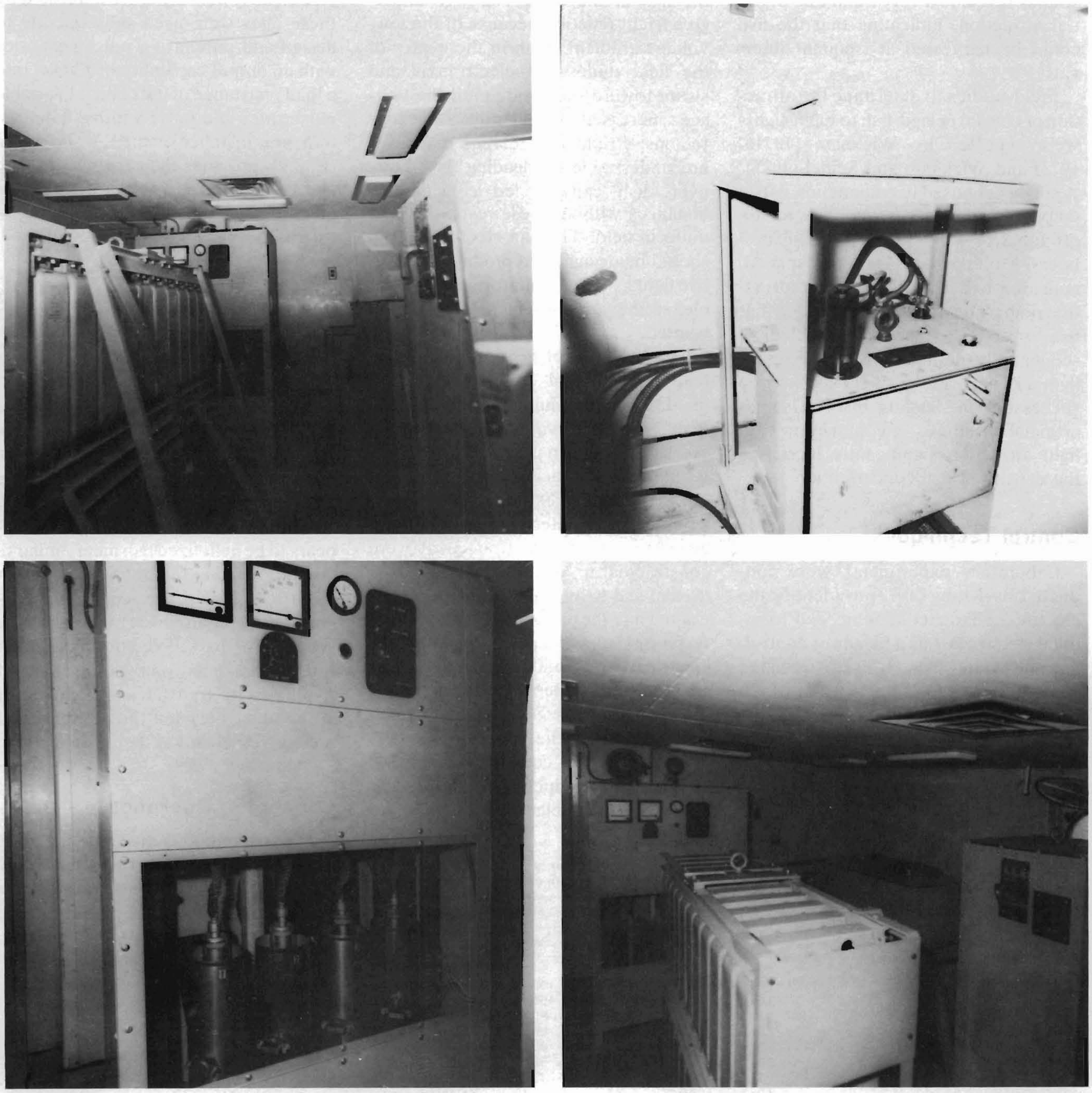

**Figure 2.—120 kw pulse generator on FV *Oregon II*. Components shown (left to right, top to bottom) include: input/compensating pulse capacitors and rectifier unit, output transformer, main control unit, and a composite picture including the variable input transformer in background.**

fish would be held by the main light for harvest by the processing vessel.

The second method identified for harvesting coastal pelagic fish is to make each major offshore oil platform an independent automated fishing system. To do this, each platform would be equipped with a pulse generator, electrode array, attraction light, fish pump, and automated processing equipment. Again, a minicomputer would be necessary to activate the sequential leading lights from the satellite structures to the main holding light and to properly sequence the electrical field, fish pump, and processing equipment. A small sonar system could be used to evaluate fish biomass at the pump inlet to enable the computer to determine the feasibility of activating the pumping and processing operation.

The automated fish harvesting platform offers an advantage in that the complete sequence of fish harvesting and processing events could be repeated several times a night at each platform, whereas with the automated processing barge, the vessel probably could harvest fish from each platform location only once each night. Additional studies are needed to determine the length of time a group of fish can be held after sundown before they lose interest and leave a light field. If fish can only be held from 2 to 3 hours after sundown, a service vessel may be able to visit only one to two locations each night and would need to harvest a larger volume of fish at each stop. To decide which method is most economical, the potential production of an area and the probable rate of production will have to be determined and compared against system costs. The possibility of combining any of the subsystems or procedures suggested in the two systems described above also should be considered.

## PRESENT CONSTRAINTS

Using abandoned oil rigs as platforms for automated fishing systems will cause concern among the recreational fishermen of the Gulf Coast. Oil rigs are a known habitat for many species of fish that are sought by sportfishermen, and sportsmen may experience a feeling of encroachment by the commercial fishing industry. Because of their distance offshore, however, many rigs are inaccessible to the average sportsman. Careful selection of potential sites and proper management controls should obviate the sportsmen's concern. In addition, selectivity characteristics of the electrical field on different species of fish and the predator/prey zonation of fish around lights at night can also be used advantageously to harvest only the smaller, coastal pelagic commercial species.

Selection of productive sites will be difficult, requiring definitive predictive capabilities. Surveys conducted by NMFS research vessels will supply inputs as will industry catch/effort records.

Even though submerged objects and lights are effective fish attraction devices, one question still arises, "How frequently can a harvestable quantity be attracted?" Results of tests conducted by Klima and Wickham (1971) and Wickham and Russell (1974) suggest that the pelagic fish populations congregating around attraction devices are transient schools that constantly move into and away from the structures. This implies that the leading away of one congregation will not impact subsequent operations. With regard to the effects of environmental and biological variables, Wickham (1971b) reported that experimental fishing trials were required to define their effects on production levels.

Fish near attraction devices generally can be led by sequential or moving lights without regard to species or size. However, Klima (1972) reported that the response of a fish in an electrical field depends upon voltage and the length of the animal, because the voltage potential increases proportionately with length. Evidence from the same study indicates a combination of electrical factors that induce electrotaxis in one species may induce fright or no response in another. Further study of fish behavior in electric fields may identify optimum voltages or voltage gradients that would induce the desired effect on target species while repelling unwanted species. For example, it has been shown that in a light field predators tend to remain in the darker fringes and therefore probably would only be exposed to the fringe area of the electric field, which is not effective in leading or controlling fish.

If many discrete harvesting platforms are used, the possibility exists that the pumping and processing systems will be activated when an insufficient quantity of fish is concentrated at the nozzle intake. Sonar systems have been successfully used to locate living marine resources and tests are being conducted to establish techniques to quantify biomass. A sonar-type device, scanning the area immediately surrounding the pump nozzle, could provide biomass measurements to be used by a small computer for operating decisions.

Fish meal currently is produced in a powdery form that requires several aeration cycles for drying. Present techniques are not readily adaptable to the suggested automated processes or to wind exposure. Shipboard processing ventures have adapted techniques used at shore-based plants, but manpower is required. Attempts to apply vat storage aeration techniques generally have been unsuccessful. As an alternative, fish meal could be pelletized or processed into a press cake form after the addition of butylated hydroxytoluene or bacteria retardants to facilitate storage.

System maintenance would require different expertise than is presently existent in the industrial fishery, but neither the reliability of the equipment nor the periodicity of maintenance should represent serious problems. Most of the components should be commercially available by the time a system is operational. Developmental research and pilot plants will have demonstrated system integrity and resolved the inherent problems associated with design and construction of the various components. The establishment of effective operational control procedures, development and testing of the software required to operate the system, and troubleshooting and identifying problems will represent the more critical factors in system development.

The exact cost of an automated fishing system is unknown. It is reasonable to assume, however, that the cost would be less than the investment required to purchase and equip a purse seining fleet to catch a comparable harvest. At this time, the apparent savings is in manpower—instead of the normal 8-9 man crew on each of many purse seine vessels, only one seagoing crew would be required on each of a few automated service barges or shuttle boats. Dockside manpower would also be reduced since the catch would already be processed. Another cost factor to be considered is the possible addition of a transfer system to enable shrimpers to periodically offload their discards for processing into fish meal and oil. This would be advantageous to both parties and its feasibility for offering a solution to the sizeable shrimp discard problem should be investigated.

## BENEFITS

The automated fishing system is a potential method for realizing the economical utilization of the estimated 11 million tons of latent coastal pelagic fishery resources in the Gulf of Mexico. Many of these resources are unexploited because they cannot be harvested with existing gear. The proposed automated fishing system should obviate many of the problems which have prevented significant harvest of this latent resource, and result in a substantial increase in the industrial fishery harvest while at the same time reducing harvesting and processing costs. The length of the fishing season, presently limited to about 6 months for menhaden, could be extended due to the availability of coastal pelagic fish in various areas of the Gulf of Mexico throughout the year.

Obviously the system must be designed, developed, and tested before the actual cost savings can be quantified; however, several cost reduction factors seem apparent. The expansion of the potentially harvestable resource base will increase harvest production and should remove some of the seasonal restrictions. Automated systems will significantly reduce manpower requirements. Fleets of purse seine vessels will not be necessary; therefore, seagoing crews will not have to be employed. At a time when fuel supplies are becoming critical, reduction of the fishing fleet will definitely reduce fuel requirements and costs. Landings of processed fish meal and oil will reduce the size of the shore-based labor force and offer an alternative solution to meeting pollution standards associated with shore-based facilities.

Implementation of the automated fishing concept could potentially increase raw fish stock production of fish meal and oil by as much as 25 percent. At this rate, based on the 1974 Gulf of Mexico menhaden fish meal production of approximately 593,000 metric tons, the automated fishing system could represent an increase in meal production of 148,000 metric tons and 30-35 million dollars annually, not including oil.

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