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Nightlighting, an ancient fishing technique, is updated to help 20th century fishermen concentrate fish for harvest.

A Self-Contained Subsurface Light Source System For Fish Attraction

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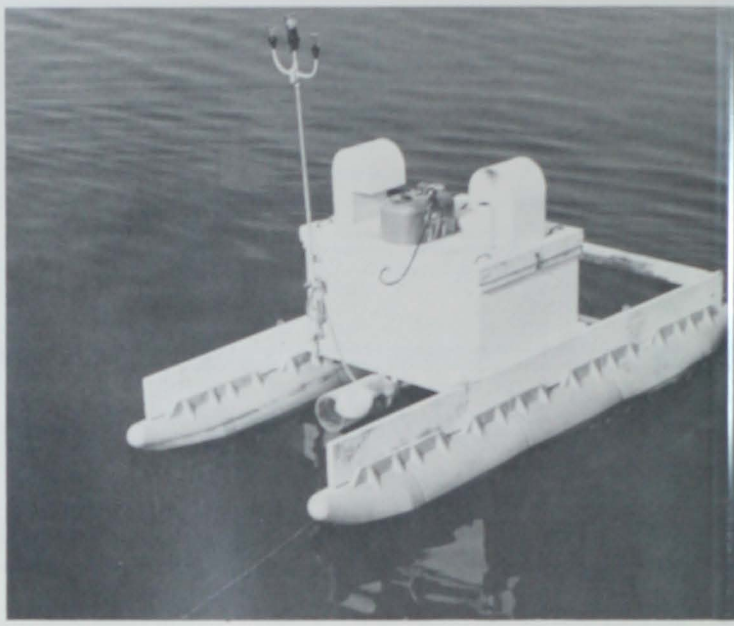

Figure 1.—The prototype unit of the catamaran configuration (FLAC). The attraction lamp swing arm can be seen in the "up" position between the pontoons.

ABSTRACT

A light source system is described which has potential for use in commercial fisheries utilizing nightlighting techniques for concentrating fish for harvest. Design criteria are provided for two prototype platform configurations of the system, a modified spar buoy and a catamaran. Each configuration is designed to meet operational requirements for specific types of potential fishing applications. At-sea operational field trials and evaluations of the prototype platform are discussed.

INTRODUCTION

Nightlighting techniques have been used to attract and concentrate fish for capture since ancient times (von Brandt, 1972). Light sources have evolved from hand-held torches to the gas- and electric-powered lamps used today. Fish attraction lamps are usually deployed by mounting them directly on the fishing vessel, drifting the lamps powered by battery or attached umbilical power cord away from the vessel on a float, or using portable gas- or electric-powered lamps in manned skiffs. These techniques impose disadvantageous restrictions on the activities of the fishing vessel when the lamps are in use. They limit the number of lamps and size of the area in which lamps from a single vessel can be deployed or require an increase in manpower to support them.

As a result of our field experience in the development and evaluation of light attraction fishing techniques (Bullis and Thompson, 1967, 1970; Wickham, 1970, 1971a, 1971b, in press), we recognized a need for a self-contained, unmanned fish attraction light source which could be anchored, moved by power, or drifted freely without requiring close attention from a fishing vessel. A light source system of this type was also required for development of a netless harvesting system (Klima, 1970, 1971). The National Marine Fisheries Service proposed this netless system as a potential approach to economically harvesting the estimated 4 million tons of latent coastal pelagic finfish resources in the Gulf of Mexico (Bullis and Carpenter, 1968). A desirable feature for a light source to be used with the netless harvesting system would be the capability for operation as a single unit or as one of a multiple series of units operated sequentially (Wickham, 1971b). Duncan (1952) patented an unmanned fishing lure for use with purse seines. This was an automatic chumming device with surface mounted lamps which could be used for fish attraction. Our self-contained light source system was conceptualized primarily for the attraction of fish with light. It employs an underwater lamp to eliminate light loss at the air-water interface, thereby maximizing the attracting range and effectiveness of the light source. The prototype units described in this report have been used to attract and control aggregations of mixed coastal pelagic fishes (i.e. sardine, herring, scad, anchovy, etc.) in concentrations

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as large as 4.5 metric tons (10,000 pounds) during preliminary field trials in the northeastern Gulf of Mexico.

SYSTEM DESIGN CONCEPT

Our basic design criteria for the self-contained, subsurface, fish attraction light source system was to provide a stable, buoyant platform containing an electric generator for powering an underwater fish attraction lamp and requisite supporting components. Two platform configurations of our light source system, a modified spar buoy (fish light attraction buoy—FLAB) and a catamaran (fish light attraction catamaran—FLAC), were designed to test operational requirements for specific fishing applications. These system configurations were built and tested in prototype form (Figure 1). Design considerations for both prototype configurations are presented in this report. Platform configurations different from the prototype models are possible within the basic system design, but all variations require the common components shown schematically in Figure 2.

The light source system was designed around a portable electric generator which supplies power to an underwater lamp and accessory support equipment. We used a gasoline-powered 2.5 kw, 115-volt a.c. generator, with an electric starter and battery charger, enclosed within a vented water resistant compartment. Modifications to the generator to allow installation in a closed container were minor and involved mounting the manual start and kill switches externally, extension of the exhaust pipe to vent outside the enclosure, and attachment of a copper fuel line from the carburetor to an externally vented spill-proof fuel tank.

The externally mounted generator "on-off" indicator lamp and an a.c. enclosure ventilation exhaust fan are powered directly by the generator. The generator also supplies power to the a.c. switch-controlled fish attraction lamp.

A regulated battery charger on the a.c. generator was used to charge a heavy duty (i.e., ≥ 80 ampere-hour) automobile-type storage battery. This storage battery supplies power to the system's d.c. components which include the safety flasher lamps, d.c. enclosure ventilation exhaust fan, and the starter for the generator motor. Our prototype systems were operated under manual control; however, an optional d.c. powered automatic timer or radio controlled switching unit could be included for remote operation.

The design concept of the light-source system will be further clarified by the illustrations of the FLAB and FLAC units (Figures 3 and 4) and the following brief functional description of each component. The d.c. powered components of the system are primarily for operational safety. Power from the high amperage-hour storage battery is supplied to the system's d.c. components whenever the d.c. switch is in the "ON" position. If the generator power fails, the flasher lamps located above the unit provide a warning to boat traffic and permit relocation of the light source system at night. The d.c. exhaust fan is essential to force-draft fresh air through the generator enclosure to remove any potentially explosive fuel fumes and to insure sufficient fresh air before starting the generator drive motor. Generator mountings and other hardware within the enclosure must be constructed to permit free air circulation so that fuel fumes cannot be trapped in dead air spaces. As a safety precaution, the generator starter can only be activated after the d.c. switch is turned on and the d.c. exhaust fan is in operation. The d.c. storage battery would also be used to supply power to an automatic timer or remote control switch.

The attraction lamp and additional safety features are powered directly by the a.c. generator. Whenever the generator is in operation, the generator "on-off" indicator lamp and the a.c. exhaust fan are operational. The generator indicator lamp provides a method for remotely checking whether the system is functioning properly. The a.c. exhaust fan prevents the buildup of heat and fumes within the generator enclosure when the generator is operational and helps to insure an adequate fresh air supply to the generator motor. The attraction lamp is activated only when the a.c. switch is in the "ON" position. We have utilized single attraction lamps with our prototype units; however, several floating satellite lamps attached by umbilical power cords could be operated from these units. All a.c. electrical components are grounded to the water to reduce shock hazard during operational handling—extreme caution should be used when the lamp system is operated on deck for checkout.

We selected a subsurface fish attraction lamp for our light source system to eliminate the air-water interface

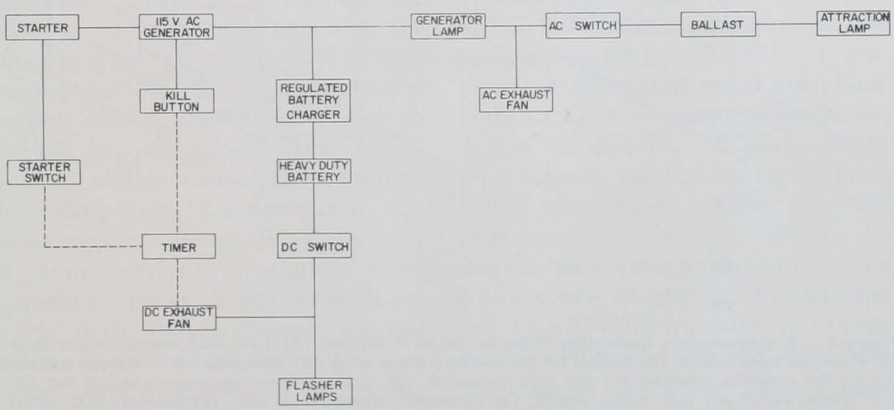

Figure 2.—Schematic diagram of the components for the self-contained light source system.

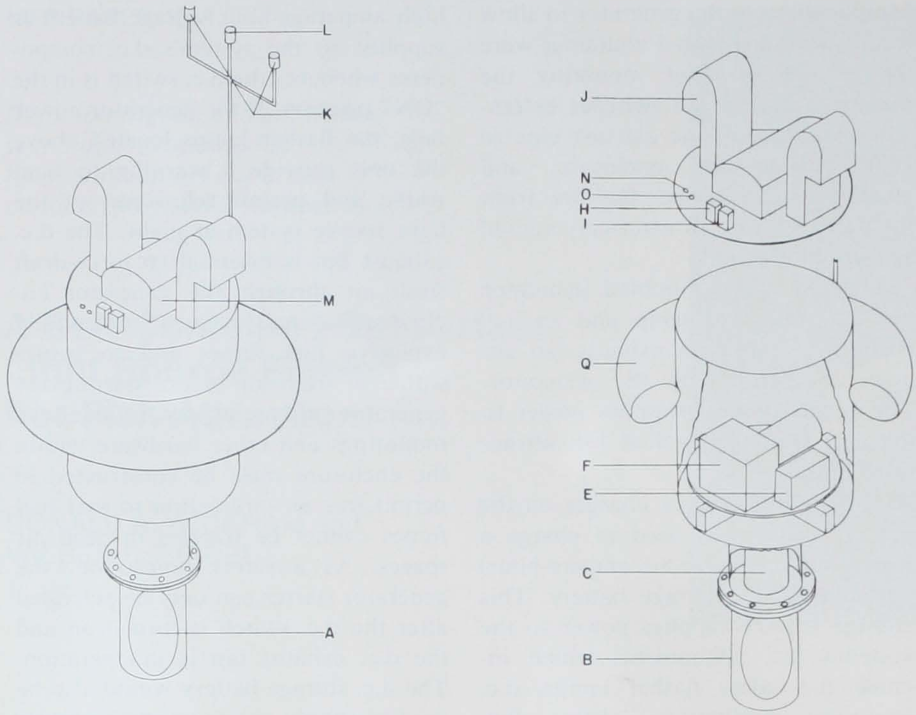

Figure 3.—A diagrammatic illustration of the prototype FLAB unit; (A) 1,000-watt mercury vapor lamp, (B) Plexiglas lamp shield, (C) Ballast for the mercury vapor lamp, (E) Heavy duty D.C. storage battery, (F) 2.5 KW gasoline powered 110 volt A.C. generator, (H) D.C. power switch, (I) A.C. power switch, (J) Generator enclosure air vent, (K) Flashing, D.C. safety lamps, (L) A.C. generator operation indicator lamp, (M) Gasoline tank, (N) Generator kill button, (O) Generator starter button, (Q) Flotation collar.

losses from reflection and refraction which reduce penetration of surface light into the water. This approach makes the subsurface lamp more efficient than a comparable surface lamp and is capable of creating a larger area of illumination with an increased underwater range of lamp visibility. A subsurface lamp also avoids the placement of a bright light source above the surface, which might create a hazard to navigation. Another advantage of using an underwater attraction lamp was the creation of a uniform 360-degree horizontal light field which provided the fish with an unobstructed view of the light source. Illumination efficiency was increased by using mercury vapor lamps which have their strongest light emission between 480 and 580 millimicrons, the range of wave lengths which have the greatest transmission in sea water.

To reduce the cost of our prototype underwater light system, we utilized a ballast unit and lamp from a conventional street light. The lamp was mounted in a rubber, watertight, mogul base socket in direct contact with the water. This underwater lamp socket is available from Hydro Products, Inc.[1] A clear, heavy walled, plexiglas, openend cylinder was used to shield the lamp from mechanical damage.

PLATFORM DESIGN CONSIDERATIONS

The two prototype platform configurations of our light source system were designed and evaluated to test different operational requirements for specific fishing applications.

Fish Light Attraction Buoy (FLAB)

The spar buoy configuration was designed for fixed station operation. Lamp systems with this configuration were intended to function as the basic unit either individually or as one of a string of sequentially operated lamps used to attract and lead fish to selected harvesting sites. Each FLAB unit can be modified to power several satellite attraction lamps thereby reducing the

[1]Use of trade names in this publication does not imply endorsement of commercial products by the National Marine Fisheries Service, NOAA.

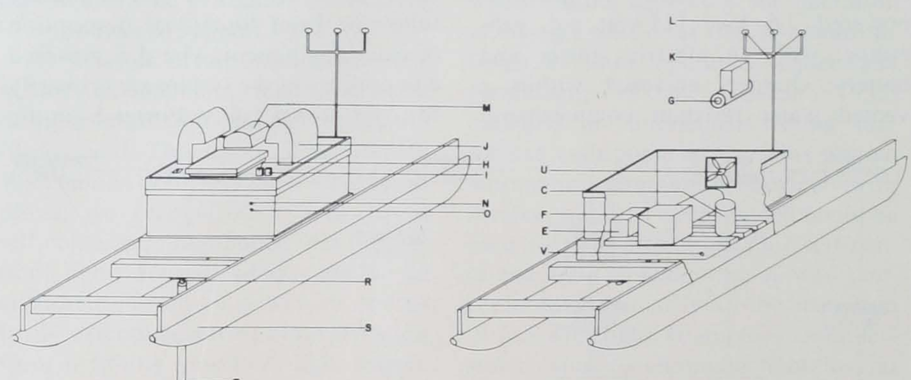

Figure 4.—A diagrammatic illustration of the prototype FLAC unit, (A) 1,000-watt mercury vapor lamp, (B) Plexiglas lamp shield, (C) Ballast for the mercury vapor lamp, (E) Heavy duty D.C. storage battery, (F) 2.5 KW gasoline powered 110 volt A.C. generator, (G) D.C. generator enclosure exhaust fan, (H) D.C. power switch, (I) A.C. power switch, (J) Generator enclosure air vent, (K) Flashing D.C. safety lamp, (L) A.C. generator operation indicator lamp, (M) Gasoline tank, (N) Generator kill button, (O) Generator starter button, (R) Universal joint, (S) Flotation pontoons, (T) Underwater lamp swing arm extension, (U) A.C. enclosure exhaust fan, (V) Generator enclosure drain plug.

number of power units required for sequentially operated lamp strings.

The primary consideration in the design of the FLAB unit was to achieve a buoy system with good stability since motion in the tilt or roll axis had to be minimized to prevent the underwater lamp from moving about quickly and creating a fright-escape reaction in the light attracted fish. The forces involved in providing buoy stability are illustrated in Figure 5. A floating body is in equilibrium when the weight and buoyancy forces act along the vertical axis of the body. The best stability is obtained when the center of gravity is below the center of buoyancy.

The modified spar buoy configuration utilized for our prototype FLAB unit provides a platform stable in the tilt or roll axis. It was designed to maintain two-thirds of the unit's volume below the surface and maintain the center of gravity below the center of buoyancy. Since the center of buoyancy shifts to a new position as the buoy tilts or heels, surface buoys have to be designed with a wide range of stability accompanied with maximum righting moments at high angles of tilt. We installed a flotation collar around the buoy to increase the displacement of the buoy as it tilts and thus increase its righting moment. When the buoy is tilted from vertical, this collar greatly increases displacement on the low side of the buoy and simultaneously raises the center of buoyancy, thereby increasing the righting moment and opposing the tilt forces. The flotation collar also contributes to a large horizontal cross section which, along with a high weight to size relationship, damps vertical motion caused by sea surge. In addition, the flotation collar acts as a protective bumper when the buoy is being serviced on station. Consequently, almost all motion of FLAB occurs in the vertical direction and this motion is well damped for normal sea operation by proper weight distribution and a relatively large cross sectional area.

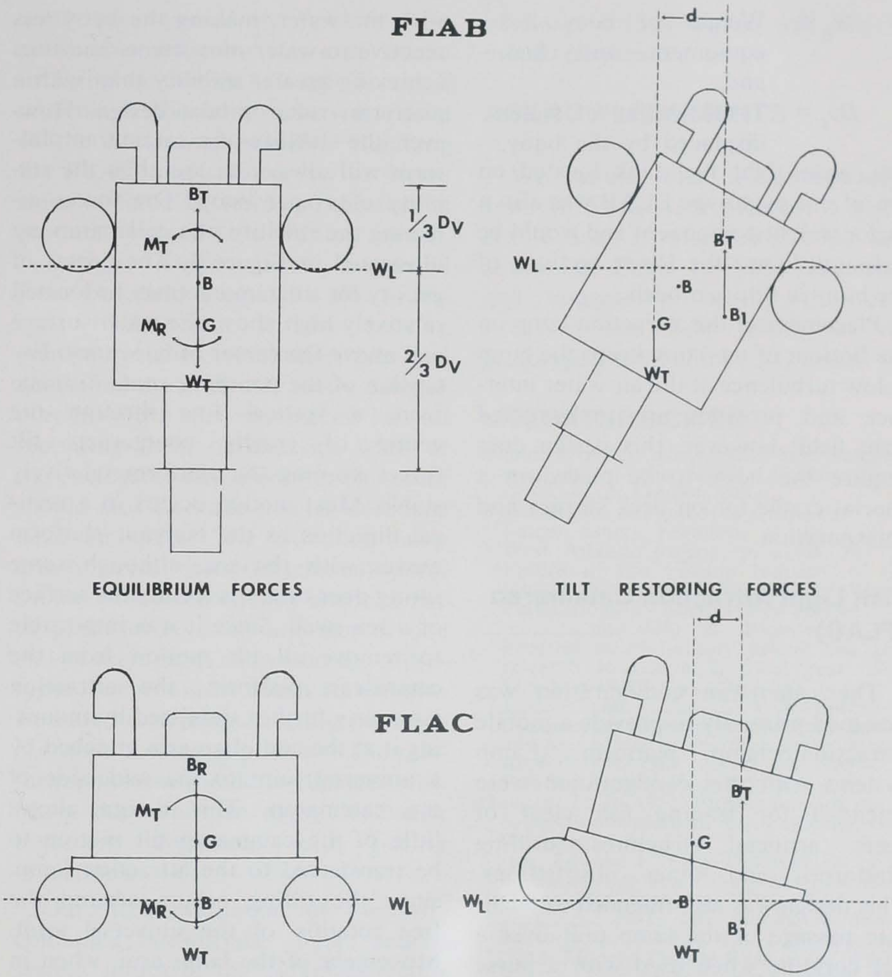

Figure 5.—A schematic diagram of the forces involved in stability for the FLAB and FLAC platforms. (B) Center of buoyancy, (BT) Total buoyancy, (G) Center of gravity, (WT) Total weight, (MT) Tilting moment, (MR) Righting moment, (WL) Water line, (Dv) Displacement volume, (d) moment arm length, (B_1) New center of buoyancy resulting from tilt.

The stability of the FLAB unit is dependent upon a low center of gravity. Since the system generator is the heaviest single component, it was placed on the bottom of the main buoy body to keep its weight contribution as low as possible. A heavy flange pipe housing and the attraction lamp ballast were placed beneath the main displacement body to obtain the desired buoy water line and to provide a low center of gravity. We designed the FLAB platform with two-thirds of its volume submerged and one-third above the water line, without the flotation collar, utilizing the equation:

$$Dv_1 + Dv_2 + ... + Dv_n - W_1 - W_2 - ... - W_e = 1/3\ Dv_t$$

or

$$Dv_t - W_b - W_e = 1/3\ Dv_t$$

and

$$2/3\ Dv_t = W_b + W_e$$

where

Dv = Weight of water displaced by the volume of each buoy section,

W = Weight of each buoy section,

W_e = Weight of buoy equipment and fuel.

W_b = Weight of buoy less equipment and fuel, and,

Dv_t = Total weight of water displaced by the buoy.

The water-tight fuel tank located on top of our prototype FLAB was also a major weight component and would be redesigned into the lower sections of the buoy in future models.

Placement of the attraction lamp on the bottom of the buoy keeps the lamp below turbulence at the air water interface and provides an unobstructed light field; however, this design does require the buoy to be placed in a special cradle for on deck storage and transporation.

Fish Light Attraction Catamaran (FLAC)

The catamaran configuration was designed primarily to provide a mobile attraction lamp platform. Lamp systems with this configuration were intended for leading fish clear of reefs, artificial structures, drilling platforms, and other obstructions. This design was also intended to facilitate passage of the lamp unit over a net corkline when used with a purse seine or other conventional fishing gear. The FLAC unit can also be modified to power several satellite attraction lamps and has potential for development into a remote controlled self-propelled fish leading unit.

Our primary consideration in the design of the FLAC unit was to develop a platform with high mobility and the ability to pass over net cork lines. Stability on station was also required to reduce motion transmitted to the underwater attraction lamp, thereby minimizing the fright-escape reactions in the light-attracted fish created by sudden movements of the lamp. The degree of stability obtained with a mobile surface platform is directly related to maintaining the unit in an upright attitude so that it will not capsize. By using the catamaran principle, a relatively small amount of surface area is in direct contact with the water, making the buoy less reactive to water movements and thus achieving greater stability than with a platform, raft, or boat design. However, the stability of a catamaran platform will always be less than the stability of a spar buoy. The forces affecting the stability of a catamaran are illustrated in Figure 5. The center of gravity for a catamaran may be located relatively high above the water surface and above the center of buoyancy. Extension of the pontoons some distance from a vertical line through the center of gravity counteracts tilt forces keeping the platform relatively stable. Most motion occurs in a vertical direction as the buoyant platform moves with the sea, although some tilting does occur as it rides the surface of a sea swell. Since it was impossible to remove all tilt motion from the catamaran platform, the attraction lamp was further stabilized by mounting it at the end of an arm attached by a universal joint to the underside of the catamaran. This design allows little of the catamaran tilt motion to be transferred to the attraction lamp, since the tilting occurs around the free rotation of the universal joint. Movement of the lamp arm, when in the vertical position, is damped by weight and water resistance at its distal end. The universal joint also permits the attraction lamp to be raised horizontally between the pontoons and stowed under the catamaran body when the FLAC unit is being towed at sea, passed over net cork lines or transported by trailer.

SYSTEMS EVALUATION AND CONCLUSIONS

Prototype units of both the spar buoy and catamaran configuration of the light source system were constructed and field tested at sea to evaluate design and operational concepts.

The modified spar buoy configuration (FLAB) was designed primarily for fixed station operation. Field evaluations with FLAB anchored on station indicated that in the tilt or roll axis the prototype unit was acceptably stable. Vertical motion in the buoy was a function of sea swell height, although the response magnitude and rate were noticeably dampened by the flotation collar. In a strong current, FLAB would heel over slightly (i.e., $< 10°$ - $15°$ in a 2-knot current) as the lower section moved with the direction of the water flow (Figure 6). During these tests, the anchor line was attached above the buoy's center of gravity. A more vertical orientation could have been maintained under these high current conditions if more attention had been given to the methods and position of anchor line attachment. A bridle arrangement could be used effectively in maintaining a vertical buoy position when deployed in swift currents. On several occasions, FLAB was released from anchor and allowed to drift freely at night to facilitate purse seine capture of fish that had accumulated around the attraction lamp. Some difficulty was encountered in removing FLAB from the purse seine since it was not possible to either tilt the buoy or sink the net floats sufficiently to float the buoy over the cork line. Consequently, after each set FLAB had to be brought alongside the seiner and lifted out of the net with the ship's boom. Relatively calm seas (i.e., $<$3-foot swell) were required for handling FLAB since it had to be carried on deck in a special cradle and deployed and retrieved over the side with the vessel boom.

Design changes recommended for the prototype FLAB unit involve improving the number and placement of pad eyes on the buoy to facilitate handling and anchoring. The control switches, ventilation fans and ducts, and the generator motor exhaust port should be moved from the buoy enclosure access lid to the upper outside section of the buoy. The prototype FLAB can be constructed from surplus material and locally available off-the-shelf components. A production model based on this

Figure 6.—The prototype FLAB unit anchored on station in a current greater than two knots.

system however, should have the buoy body specifically designed and components carefully selected to reduce the size and weight of the unit. A properly designed spar buoy would permit the lamp system to be further optimized for sea keeping ability and specific fishing applications.

Sea trial evaluations of the mobile platform catamaran configuration (FLAC) indicated this unit, with the attraction lamp stowed horizontally between the pontoons, could be towed at speeds up to 10 knots in relatively choppy seas. When FLAC was anchored on station or allowed to drift free with the lamp arm in the vertical fishing position, the attraction lamp was acceptably stable. During the static position test, the catamaran body rocked around the lamp arm universal joint, stepping over the surface chop and riding up and down the sea swell. Little of this motion was transmitted to the lamp. When FLAC was being towed to lead fish accumulated around its attraction lamp, the lamp arm swung back and up slightly as the towing speed was increased. This presented no problem since towing speed had to be kept relatively low to prevent the rate of lamp movement from exceeding the swimming speed of the fish. Experiments on the use of a moving lamp to lead coastal pelagic school fish for capture with a purse seine are reported by Wickham (in press). No difficulty was experienced in bringing the FLAC unit across a corkline if the lamp arm was raised to the horizontal position. Handling the FLAC unit created few problems since it could be towed to the fishing grounds behind the fishing vessel.

Design improvements suggested from our field trials with the prototype FLAC unit involve moving control switches, ventilation fans and ducts, and the generator motor exhaust port from the enclosure access lid and mounting them on the side walls of the enclosure. The generator enclosure should also be made smaller to reduce dead air space. The attraction lamp arm-universal joint attachment point should be located directly at the center of platform rotation and not at one end of the unit as shown on the prototype. A mechanical winch should also be added to facilitate raising the lamp arm to a horizontal position. The platform pontoons should be replaced with heavy duty units to resist the rough treatment associated with fishing operations.

Our field evaluation of the self-contained subsurface light source system indicates the catamaran configuration offers the greatest potential and flexibility for use in most anticipated fishing applications. The FLAC platform is simpler to construct and units based on this design could be easily built by fishermen, using materials and system components readily available in most locations. The FLAB configuration appears to be more suitable for specific fishing applications such as the establishment of lamp strings which will not be moved frequently.

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