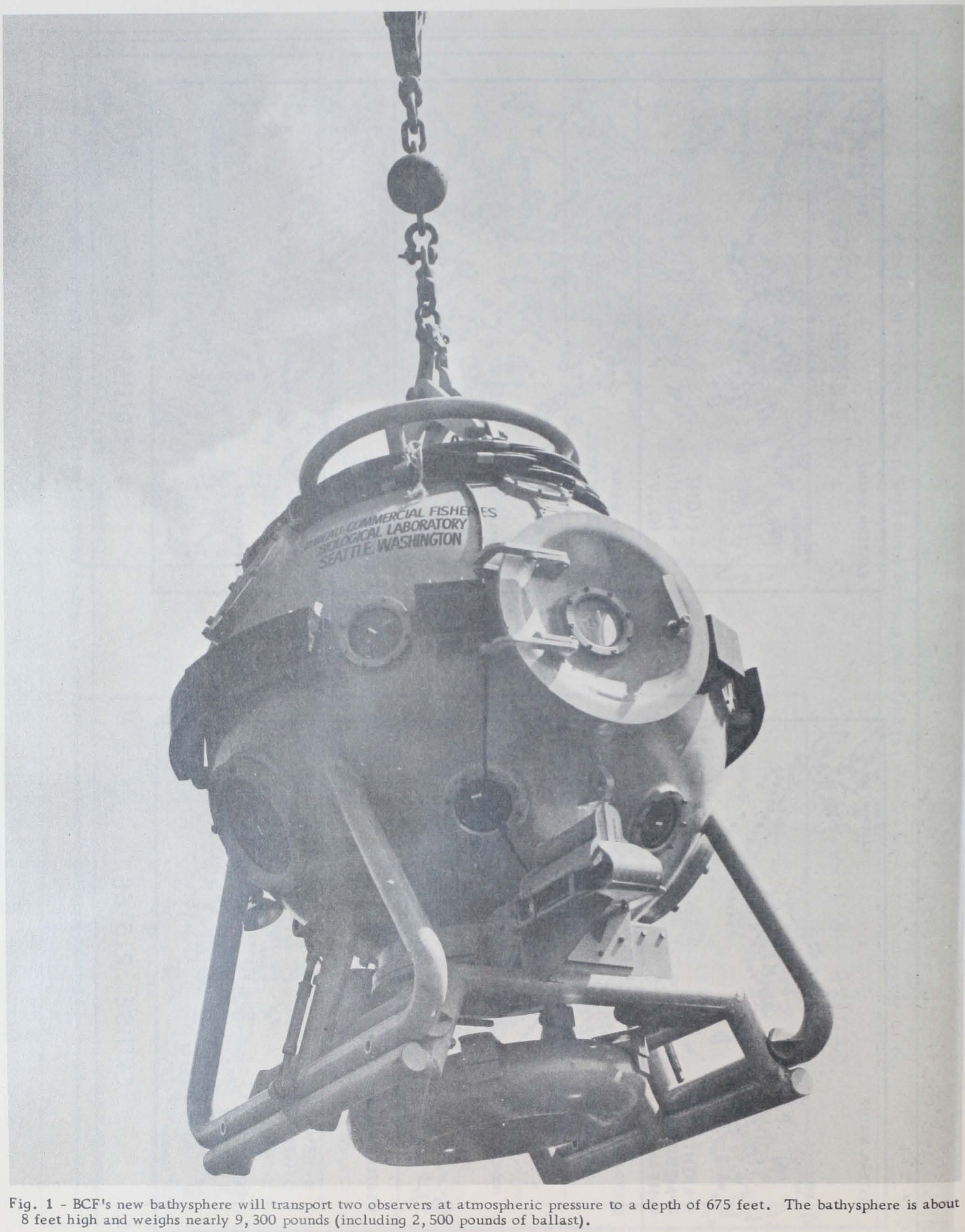

Fig. 1 - BCF's new bathysphere will transport two observers at atmospheric pressure to a depth of 675 feet. The bathysphere is about 8 feet high and weighs nearly 9,300 pounds (including 2,500 pounds of ballast).

A BATHYSPHERE FOR FISHERY RESEARCH

John R. Pugh and Richard B. Thompson

The Bureau of Commercial Fisheries (BCF) Biological Laboratory in Seattle, Wash., has acquired a bathysphere and a support barge for fishery research. The system will be used in studies to determine the behavior of commercially important marine organisms in their natural environment.

BATHYSPHERE

The bathysphere (fig. 1) was constructed by the Ocean Engineering Division of Reading and Bates of Tulsa, Okla. It is designed to transport two observers at atmospheric pressure to a depth of 675 feet. The sphere is constructed of special steel-plate alloy; the walls are 0.625-inch thick, and the total weight, including the ballast, is about 9,300 pounds. The inside diameter is 5 feet 6 inches. The overall height, including a sturdy-steel framework that supports the bathysphere, is about 8 feet. The bathysphere has two access hatches--one on the side to facilitate entry on deck and horizontal mating with a deck decompression chamber, the other on the bottom to permit divers to exit or enter the pressurized bathysphere at depth. Both hatches have double doors--an external one to withstand sea pressure, and an internal one to withstand interior pressure during lock-out dives. Sixteen portholes (six, 12-inch; ten, 6-inch) provide excellent viewing in all directions. Neoprene bumper pads spaced around the horizontal centerline between the ports help protect the bathysphere during operations at sea. Two fixed quartz iodide lights, each 750 watts, provide illumination for underwater viewing. Electricity for the lights is supplied by surface generators.

Life-support equipment in the bathysphere includes a 48-hour oxygen supply for two observers, and the necessary equipment for removal of carbon dioxide. There is also an auxiliary air supply that can be used: (1) in an emergency, such as failure or contamination of the regular oxygen supply, or (2) for pressurizing the bathysphere at shallow depths (less than 100 feet) for lock-out dives, or (3) by divers with "Hookah" attachments working outside the bathysphere. During dives of long duration, the breathing mixture can be supplied from surface compressors. One instrument allows the observers to monitor the percentage of oxygen in the bathysphere; another allows them to check the carbon dioxide level. A hardwire communications system provides direct contact between the bathysphere and the support barge. One depth gauge allows the observers to monitor their rate of descent or ascent; a second gauge allows them to monitor the pressure in the bathysphere when pressurization is required for lock-out dives.

The bathysphere is about 600 pounds buoyant. Sufficient ballast to make it sink and to stabilize it (about 2,500 pounds) is attached by a $\frac{3}{8}$-inch diameter cable, 100 feet long, to an electrically powered submersible winch fastened to the support frame on the sphere's underside. Under normal operating conditions, the winch cable is wound tight, and the ballast is carried close to the bottom of the sphere. In an emergency, the ballast can be jettisoned, allowing the bathysphere to return to the surface. The bathysphere is also equipped with a release mechanism on the main lifting cable; the occupants can free the sphere from the cable if it becomes fouled.

Flexibility of operation was a major consideration in the bathysphere's design. The submersible winch attached to the support frame is controlled from within the sphere and allows the occupants to position it at various distances above the ocean floor--depending on length of ballast support cable--while remaining independent of the motion of the surface vessel. By directing crane operator to slacken main lifting-cable, and by reversing drive motor on submersible winch, the occupants can leave the ballast on the ocean floor to serve as an anchor. The bathysphere

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U.S. DEPARTMENT OF THE INTERIOR
Fish and Wildlife Service
Reprint No. 873

will rise toward the surface, allowing the occupants to make observations and a controlled ascent up to the length of the winch cable. Since the winch is electrically powered, the occupants can winch the bathysphere back to the bottom if they desire.

SUPPORT BARGE

In Puget Sound, the bathysphere is transported and supported by a self-propelled barge (fig. 2), which is 104 feet long, 31 feet wide, and displaces 240 gross tons. (However, the sphere can be supported by any vessel that has adequate deck space and is capable of lifting about 5 tons.) The barge is equipped with a diesel-powered, friction-driven crane that has a 15-ton lifting capacity. The crane drum holds about 1,200 feet of nonrotating $\frac{7}{8}$-inch cable with a rated breaking strength of 32,000 pounds. About 1,100 square feet of uncluttered deck space forward of the crane provides ample room to stow or support the bathysphere.

The barge requires a minimum crew of three--a helmsman, an operating engineer, and a deckhand. During diving operations, when the barge is securely moored, the engineer operates the crane and the helmsman and deckhand tend the bathysphere. Usually, two or more biologists serve as observers in the bathysphere and assist the barge crew wherever needed during station changes and mooring operations.

PRELIMINARY TESTS

In June 1969, the bathysphere, unmanned, was successfully tested to a depth of 1,500 feet. The BCF research vessel 'Miller Freeman' (fig. 3) transported the sphere to Jervis Inlet, about 60 miles north of Vancouver, B.C., the only nearby site in protected waters with suitable depth. The bathysphere was lowered and raised with the conventional trawling winches, cable, and gantry permanently installed aboard the vessel.

The purposes of the tests were: the final acceptance trial under the terms of the contract; to demonstrate the bathysphere's structural integrity, and to show its ability to withstand pressures at depths far greater than those at which it will be used in fish behavior research.

The first manned dives were conducted at the BCF research station at Manchester, Wash., on Puget Sound, from September 30 to

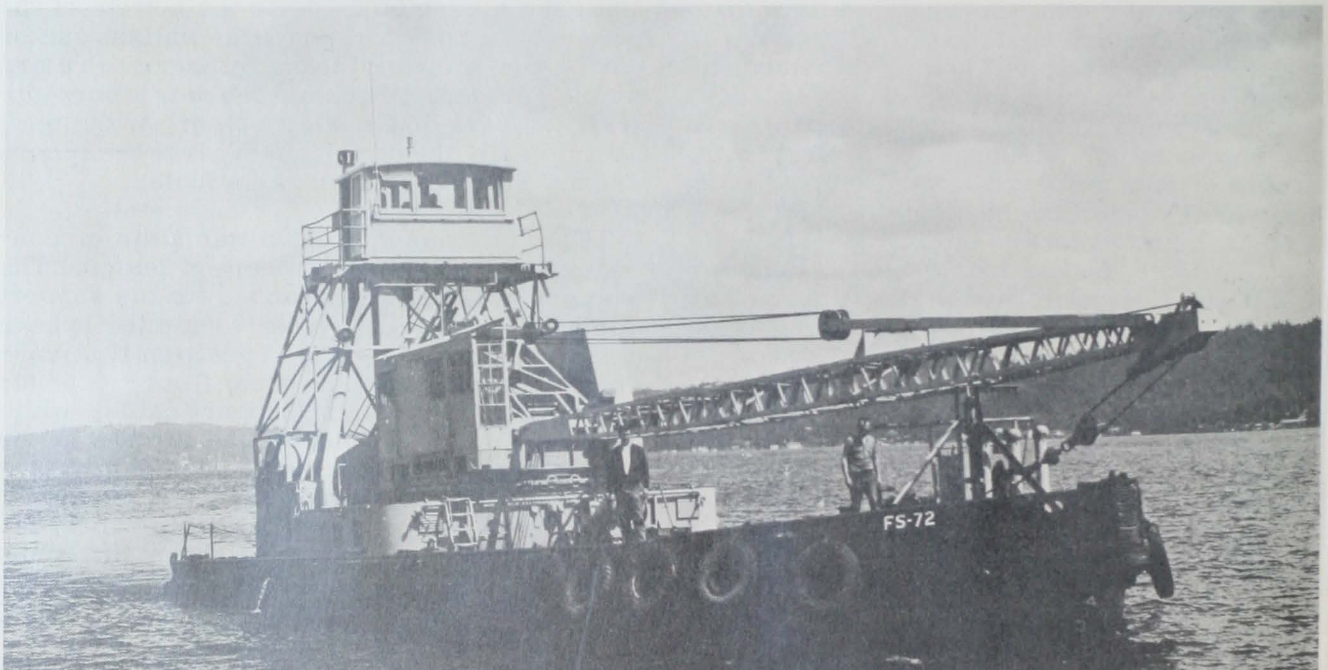

Fig. 2 - The bathysphere's self-propelled support barge, a converted airplane salvage barge, 104 feet long, has a cruising speed of about 8 knots; it carries two scientists and a crew of three. The crane on the barge is capable of lifting 15 tons.

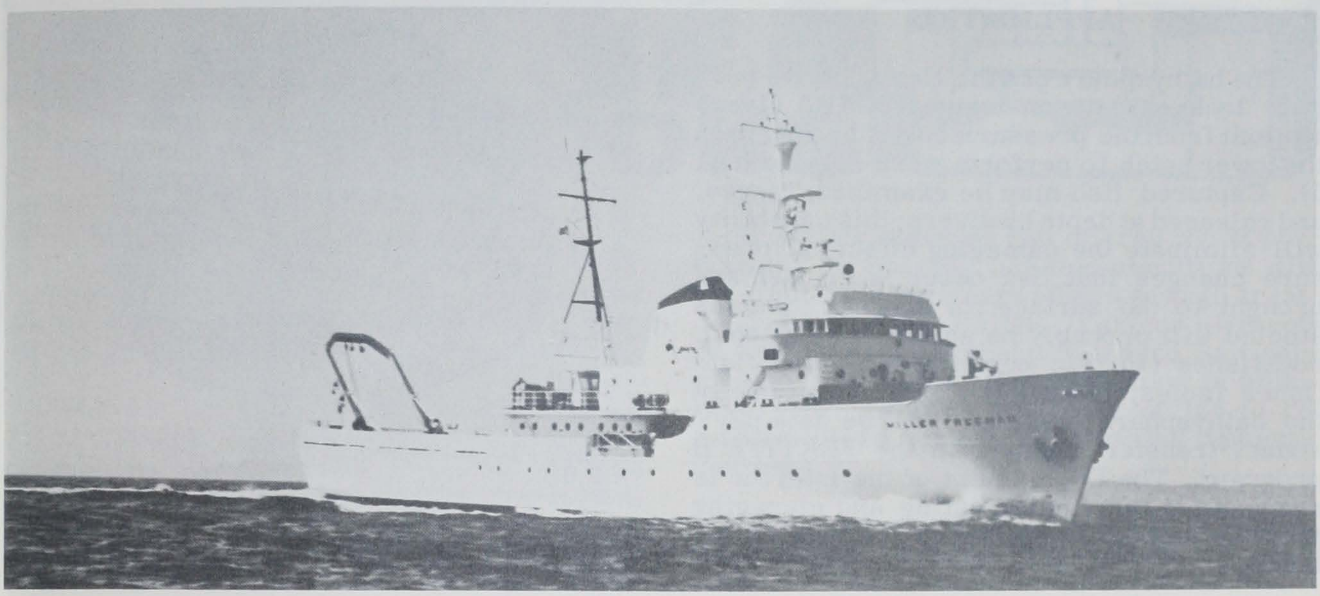

Fig. 3 - The bathysphere can be lowered and raised with the trawling winches, cables, and gantry that are permanently installed aboard the 215-foot Miller Freeman, the Seattle Biological Laboratory's research vessel.

October 8, 1969. The various safety devices and life-support systems of the bathysphere were tested. All systems functioned according to design.

There were additional tests to determine the ability of observers to recognize objects of unknown size and to estimate the distance of various objects from the bathysphere. The results showed that each of four observers tended to underestimate both the size and the distance of objects from the bathysphere.

Another test at Manchester was designed to determine underwater viewing capability from the bathysphere. It showed that the cone of vision through the view ports decreased from about 120° when the bathysphere was above the surface to about 90° underwater. An example of the underwater view through one of the 12-inch ports is shown in figure 4. There was variation caused by the diameter of the viewports; also, the cone of vision varies according to the porthole used because the arrangement of instruments restricts observer's ability to place his eyes close to the inside surface of some portholes. Since the portholes tested were in favorable locations, a 90° cone of vision probably is the maximum attainable viewing capability. The 16 viewports spaced around the bathysphere provide a good view in all directions.

Fig. 4 - Sea anemones (Metridium) attached to concrete blocks as observed at a depth of 40 feet from one of bathysphere's 12-inch viewports.

APPLICATION

The bathysphere has the flexibility to permit "lock-out" dives; trained SCUBA divers can exit from the pressurized sphere through the lower hatch to perform work outside (fig. 5). Captured fish may be examined, tagged, and released at depth by divers; this capability will eliminate the damaging effects of pressure changes that can occur when fish are brought to the surface for tagging. Species studied will probably be shellfish (scallops), rockfishes (Pacific ocean perch), and flatfishes (soles, flounders). The initial use of the bathysphere, however, will be as a personnel-transfer capsule in the TEKTITE II program. The Department of the Interior is responsible for implementing and managing program now underway in the U.S. Virgin Islands.

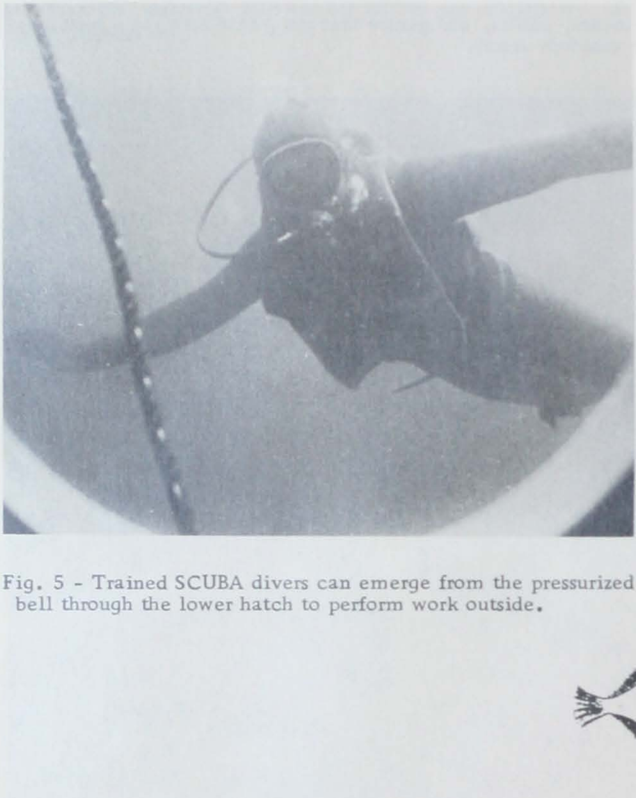

Fig. 5 - Trained SCUBA divers can emerge from the pressurized bell through the lower hatch to perform work outside.

Fig. 6 - The weathervane scallop ('Patinopecten caurinus') will be the object of study in one of the bathysphere's first applications. Scientists hope observations on scallop behavior will explain inconsistency of commercial catches.

As one of the first practical applications for the bathysphere locally, we propose to study the natural behavior of weathervane scallops, Patinopecten caurinus (fig. 6) on commercial dredging grounds near Bellingham, Wash. On the basis of reports from commercial scallop fishermen, we believe the species may be exhibiting some natural evasive reaction to scallop dredges. A difference between their day and night behavior is also suspected. Perhaps these responses can be observed from the bathysphere. We will look for natural behavior patterns--such as burrowing, prolonged or erratic swimming, mass migrations, and reactions to changes in light intensity, tidal flow, turbidity, and temperature--which might help explain the inconsistency of scallop catches. Future observations on rockfish and flatfish may take the bathysphere onto the Continental Shelf.