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The Use of Underwater Television in Fisheries Research

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The Use of Underwater Television in Fisheries

Research

by

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There are many problems in fisheries research which can be answered best by direct visual observations underwater. Such observations have always proved difficult to make. Recently a new technique, using underwater television became available. The equipment was developed at the National Research Council by W.F. Torrington and his assistants, W.E.M. Dale and T.R. Smith.

#### Development

Underwater television was first used at Bikini atoll in 1947. During the same year brief tests were made at Cornell University. More recently underwater television equipment was developed independantly and almost simultaneously in Canada and Great Britain. In Canada, development began in 1949 and the first tests were made in 1951 in the Ottawa River, Rideau Canal and Lake Ontario. In the United Kingdom, the Electrical and Musical Industries Research Laboratory carried out tests in 1949 in the Aquarium of the Zoological Society of London and demonstrated with a large variety of marine animals the quality of the picture which might be approached. Following this preliminary work the Council of the Scottish Marine Biological Association obtained a grant from the Development Fund of the Treasury to carry on further studies. This equipment is now almost ready. Some work has been carried out with the prototype equipment. In 1951 the British Admiralty announced that underwater television had been used in locating and raising the submarine H.M.S. Affray. Since then further tests have been carried both by the Royal Navy and by British fisheries research workers.

In Canada, the first use of underwater television in fisheries research was made in 1952 by Dr. Jean-Paul Guerrier, Chief Limnologist of the Canadian Wildlife Service. He was able to determine the suitability of various areas

of the bottom of Lake Minnewanka, Banff National Park, as spawning grounds for lake trout (Cristivomer namaycush) and to locate their eggs on the bottom. The first tests of the equipment in salt water were made at the Pacific Biological Station, Nanaimo, and at the Pacific Naval Laboratory, Esquimalt, B. C. in October 1952.

#### Description of Equipment

The equipment consists of six units together with two generators and transmission and power cables. The total weight of the equipment is 1600-1800 lbs., and when packed for transportation about 2400 lbs. Because of its weight and the care required to protect the electronic units from shock and vibration in transportation, the equipment is classed as transportable rather than mobile. It is compact enough to operate in a tent, on the back of a truck or on a 30 foot vessel.

The equipment is made up of the following units: camera unit, master control unit, main viewing unit, auxiliary viewing unit, remote control unit and voltage regulator unit. Two portable gasoline driven 110 volt 60 cycle AC generators of 2 kilowatts and 3-4 kilowatts output provide the power.

#### (1) Camera Unit (figs. 1 and 2)

The camera tube in the Canadian and in the original model of the British Admiralty equipment is an Image Orthicon; in the Scottish Marine Biological Association's equipment a Cathode Potential Stabilised Emitron is used.

The camera is enclosed in a watertight steel cylinder, 3 feet long and 16 inches in diameter. The cylinder also contains three electric motors and a 50 lb. lead weight. This weight serves partly to offset buoyancy and partly, by having its position changed, to incline the nose of the

cylinder up or down. Fitted to the stern are two propellers driven by electric motors. One drives the unit backwards or forwards, the other swings it from side to side.

A battery of four 25 candlepower automobile spotlights are mounted on the front of the casing and provide adequate illumination.

All movements of the cylinder, control of the lights and adjustments and operation of the camera are remotely controlled from the surface. Camera adjustments include focusing the camera, changing the lens opening, and changing the lens from the normal two inch lens to a five inch lens for close-ups.

Out of water the camera unit weighs about 300 lbs., in water it is just buoyant. Weights suspended from a length of chain beneath the unit cause it to sink until the weights touch bottom, the cylinder then regains its buoyancy and remains at a distance from the bottom determined by the length of the chain.

Images picked up by the camera are transmitted through coaxial cable to the viewing units in the ship. In addition to the coaxial cable there is a 21 pair cable providing power and control circuits for the operation of the camera, lights and propulsion motors. The cable is approximately 500 feet long and weighs about 400 lbs. Wooden floats were lashed along the cable to give it some buoyancy and to reduce its drag on the camera unit.

(2) Master Control Unit (fig. 3)

Through this unit the operator regulates all the electronic operations of the equipment, including the synchronization, the quality of the image on the screen, the focusing of the camera and the changing of the lens opening and of the lenses. This unit is about 3 feet long, 1½ feet wide and

2 feet high. It weighs about 150 lbs.

(3) Main Viewing Unit (fig. 3)

The main viewing unit allows for continuous observation of the bottom. The image is displayed on a 6" x 8" screen. This unit has the standard controls for brilliance, tube focus etc. The unit is about 3 feet long, 1½ feet wide and 2 feet high and weighs about 75 lbs.

(4) Auxiliary Viewing Unit (fig. 4)

The screen in this unit is 3" x 4". The unit is fitted with a special synchronized movie camera, which permits permanent records to be made quickly and easily. The unit is 3 feet long, 1 foot wide and 2 feet high and weighs about 75 lbs.

(5) Remote-Control Unit (fig. 4)

This unit controls the movement of the camera unit, backwards or forwards, from side to side, up or down. It is a small unit about a foot on each dimension and weighs about 50 lbs.

(6) Voltage Regulator and Power Supply Unit

This unit is about 2½ feet long, 2 feet wide and a foot high, weighing about 150 lbs.

(7) Generator Units

Power is provided by two portable 110 volt 60 cycle AC generators, driven by air-cooled gasoline engines. One 2 kilowatt generator provides power for the electronic equipment, the other, a 3.5 kilowatt generator, provides power for the propulsion motors. The units weigh about 200 lbs. and 350 lbs. respectively.

Operation of the Equipment

In operation the camera unit is suspended about six feet off the sea bottom. In this position it views an area about 6 feet wide; the distance

forward it scans depends upon the turbidity of the water. Under moderately clear water conditions, it can "see" up to 15-20 feet. It was found most satisfactory to tip the nose down so that the distance viewed forwards was 6-10 feet. All objects were then in sharp focus.

Barnes (1952) using the prototype of the equipment being developed for the Scottish Marine Biological Association reports that in tank experiments, using a  $2\frac{1}{2}$  inch lens with a water turbidity of 73% (of the transmission value in air, measured by a modified Petterson instrument) adult cod of 18" in length were distinguished by their ordinary structural features at 16 feet. In a turbidity of 63% the twitching of the antennules of a moderate sized crab could be readily seen at 6 feet, the lens magnification available allowing more detail to be seen than would be possible by direct visual observation at this distance and under these conditions. For the purpose of comparison it may be stated that the turbidity of the sea in this area (off Millport) was about 86% during the course of the experiments.

The light construction of the present camera unit limited operations to depths of less than 100 feet. In depths down to 50-60 feet it was found that artificial illumination was not necessary, and even if used did not improve the clarity of the images. However at depths of more than 60 feet, and of course during night operations at any depth lights were necessary. The images produced were comparable in clarity with those obtained in shallow water. The diffused light underwater caused little or no shadows to be cast. The images hence seemed somewhat flat in appearance. By the use of lights stronger shadow effects were produced, making the images appear more natural to our eyes. Extremely clear pictures were obtained at all depths. Objects on the bottom and sessile plants and animals were seen very clearly. Fish could be identified readily and did not appear unduly

disturbed by the equipment during the daytime. The use of lights during night operations did disturb some fish, particularly herring. Schools of these fish dispersed quickly when the lights were switched on. Other fish appeared to be attracted by the lights. Herring, ratfish, lingcod, greenling, sea-perch, rockfish, sculpins and flatfish were seen.

#### Limitations of the Equipment in its Present Form

The equipment in its present form has several limitations which curtail its usefulness.

1. Depth - The depth to which the equipment can be used is determined primarily by the strength of the camera cylinder and by the effectiveness of the sealing glands where the electrical cables enter the cylinder. The present equipment is limited by these factors to depths of less than 100 feet. However, it would be a relatively simple matter to design a casing and probably also a junction box capable of withstanding greater pressures. There is nothing in the operation or make-up of the equipment that would impose a depth limit, provided that the casing and the watertight seals round the cable junction and propeller shafts were sufficiently strong.

2. Field of Vision - The field of vision when compared to what would be visible to the human eye was naturally somewhat reduced, but was adequate. The calculated angular field of view is about  $30^{\circ}$ . The display of the images on the 6" x 8" screen, made it difficult to scrutinize the finer details of the picture. With the present mechanism for moving the camera, it was not possible to obtain a general view of a large area and then to move the camera forward sufficiently to obtain a good close-up of a small area for detailed study. The turbidity of the water reduces the field of vision and the clarity of the images. However the effect is probably no more than similar conditions would produce in other methods of making underwater

observations.

3. Underwater Mobility - The propulsion motors give a certain degree of mobility to the camera unit. However under certain circumstances, such as when the camera is used in a weed bed or where there is a current, the control was not sufficiently positive to overcome the drag produced on the camera or cable. Faster acting more powerful propulsion motors would have made it possible to follow more readily moving objects. It was found difficult to keep a swimming fish in view long enough to be certain of its identification.

4. Motility - The weight of the equipment and the inherent sensitiveness of the electronic units to shock and vibration militate against its use under rigorous field conditions.

#### Comparison with Other Methods of Underwater Observation

There are three methods of making direct visual observations underwater. These are: (a) Diving - under this heading are included, diving with conventional suit with air supplied from the surface and with the aqualung equipment with a self-contained source of compressed air; (b) Underwater photography and (c) Underwater television. The three methods will be compared under the following headings:

- |                      |                      |
|----------------------|----------------------|
| 1. Risk              | 5. Mobility          |
| 2. Depth             | 6. Underwater Vision |
| 3. Temperature       | 7. Permanent Records |
| 4. Time of Immersion |                      |

1. Risk - One advantage shared by both underwater television and underwater photography over diving is that there is no risk to the observer's life. This permits these methods to be used under a great variety of conditions.

2. Depth - Here again underwater television and underwater photography have the same advantage over diving, in that there is no limit to the depth to which they can be used, provided that the mechanical construction of the instruments is sufficiently strong to withstand the high pressures at depths.

3. Temperature - Neither underwater television nor underwater photography are limited by water temperature. In some forms of diving, particularly in aqualung diving, temperature is a limiting factor. For aqualung work the lower limit is about 45°F. Thus for aqualung diving both the times of the year when operations are possible and the depths of operation are prescribed by this temperature limit.

4. Time of Immersion - One of the great advantages of underwater television is that there is practically no limit to the time the equipment can remain immersed. This makes continuous long period observations possible. The time underwater photographic equipment can remain immersed and in position is limited by the amount of film carried and the necessity of changing it periodically. The time a diver can remain in position is limited by the depth of the dive and the water temperature. The deeper the dive and the colder the temperature the less time the diver can remain down.

5. Mobility - With regard to mobility underwater, diving possesses the advantage over the other two methods. If the diver does not descend in quite the desired spot, he can fairly readily change his position without returning to the surface. The diver can also survey a greater area of the bottom. He can change his position so as to view an object from all angles and from all distances. He has the further advantage in that he can use his hands to examine objects. Underwater television has the advantage over underwater photography because continuous observations are immediately available, allowing adjustments in position to be made at once. The underwater photographic

camera must be positioned "blind" and must be returned to the surface and the film developed before errors in positioning are discovered.

6. Underwater Vision - This heading may conveniently be divided into three sub-headings:

- (a) Sensitivity to Light and Colour
- (b) Field of Vision
- (c) Perception of Movement

(a) Sensitivity to Light and Colour. The underwater television camera is estimated to be at least three times as sensitive to light as the underwater photographic camera. This confers a tremendous advantage on underwater television. It permits its use without artificial light and the attendant risk of disturbing aquatic fauna to a greater depth and under more adverse light conditions than is possible for underwater photography. When lights are necessary the intensity of light required to produce a clear image by underwater television is much less than would be required in photography. The human eye underwater is probably as sensitive to light as the television camera. In addition, the human eye can see objects in three dimensions and in their natural colours. This is a great advantage over the two dimensional, black and white presentation of the television and photographic cameras. Underwater three dimensional and colour television are possible, but intense illumination would be required.

(b) Field of Vision. The diver possesses the advantage both in the size of the field of vision and in the ability to compensate readily by movements of the head and body for any reduction in the field of vision imposed by the helmet or face mask. Although the size of the field of vision as determined by the characteristics of the camera lens in both underwater television and underwater photography would be essentially similar, underwater

television possesses the advantage over underwater photography. The immediate and continuous presentation of objects seen by the television camera allows adjustments in positioning and focusing to be made at once, compensating somewhat thereby for the limits imposed on the field of vision. The adjustments that can be made and the compensation attained are not as great or as readily made as those of the diver.

(c) Perception of Motion. Here again the diver possesses the advantage over the other two methods. He is able to perceive motion at once and to keep readily a moving object in his field of vision. In the actual perception of motion, the television camera is probably the equal of the diver. However it was found difficult with the present equipment to keep moving objects within the field of vision. This at times made it difficult to identify even moderately slow swimming fish, rapidly swimming fish tended to blur.

(d) Permanent Records. Both underwater television and underwater photography possess the advantage over diving in securing permanent records of observations. Photography is the only method by which permanent records of visual observations can be made. The diver must depend on underwater photography to secure permanent records of his observations and is thus subject to the limitations of the method. Permanent records can be made of underwater television observations by photographing the screen. The method has the advantages possessed by underwater television but is limited by the technical difficulties of photographing the television screen. Both the diver and the television operator can select their subjects whereas in underwater photography one is frequently "shooting blind".

Application of Underwater Television to Fisheries Research

During the tests of underwater television at the Pacific Biological Station, an opportunity was provided for most members of the staff to witness the equipment in operation. Later members were asked how the equipment might be used in their investigations and to discuss the general limitations in its application to their problems. The following section is based largely on the opinions expressed.

The application of underwater television to fisheries problems will be discussed under the following general headings:

1. Bottom Surveys
2. Gear Experiments
3. Observation and Behaviour Studies

(1) Bottom Surveys - Underwater television in its present form is well suited for making qualitative surveys of bottom fauna and for locating the attached demersal eggs of certain species of fish (herring, lingcod etc.). Quantitative surveys would be somewhat more difficult to make. With the present equipment it is difficult to calculate the size of objects and to measure distances. It is possible that some additions or modifications could be made that would permit sizes and distances to be measured more readily.

The equipment has potentialities for making surveys to determine the population density and size composition of crab and oyster stocks. It would be useful in estimating the extent and density of herring spawn deposition below low tide level and in locating and estimating the lingcod spawn on reefs. It might also be used to determine the extent of lake spawning in sockeye salmon. For making spawning surveys particularly the equipment would have to be made more compact and rugged to permit its use from smaller boats and under more rigorous field conditions.

The equipment modified for use at great depths offers many possibilities for use in submarine geology in the investigation of bottom formations, in studying the surface form of bottom sediments and in obtaining evidence of erosion or deposition by bottom currents. For such work it might well replace completely the underwater photographic camera.

(2) Gear Experiments - Underwater television appears to be a promising means of studying fishing gear in action and of checking the operation and performance of underwater instruments. Visual observations on fishing gear in action have been extremely difficult to obtain. Some observations of this type have been made by aqualung divers, though not without considerable personal risk. Underwater photography has also been used.

The equipment in its present form could probably be used for studying the action of stationary nets such as trap nets and gill nets and behaviour of fish in approaching these structures. For studying moving nets such as otter trawls and purse seines, the equipment would have to be modified and strengthened for towing at moderate speeds and for withstanding the shock of contact with the moving net or the bottom. For such studies the built in propulsion motors would not be necessary. This would not only facilitate streamlining but would also reduce the size of the camera unit thereby simplifying handling problems. So far no tests of this nature have been carried out.

(3) Observation and Behaviour Studies - Under this category are included studies which would involve the use of television to make observations in mid-water rather than on the bottom. Here, the distance 'vision' becomes of great importance, as also does the ability of the instrument to follow moving objects. Such studies would include the observation on the schooling behaviour of fish, the checking of echo-sounder contacts to determine

the species of fish producing the response, the behaviour of fish in fishways and below stream obstructions and the swimming action of fish marked by removal of certain fins.

Television might be used in the study of the deep scattering layer. The composition of this layer has puzzled biological oceanographers and underwater sound experts for some time.

The application of underwater television to salvage work, the direction of divers and the inspection of underwater structures is obvious and needs no comment.

In summary, underwater television provides a useful tool for making bottom surveys, observations of fishing gear in action and to a lesser extent of fish behaviour. The equipment, while it can be used in its present form for these purposes requires some modification to make it more suitable for each. In particular, for making bottom surveys some modification is required so that the size of objects and distances can be measured simply and quickly, for use in gear experiments the equipment requires modification to suit the type of gear studied. For studying trap and gill nets it is probably suitable in its present form, for moving nets it requires streamlining for towing etc. For behaviour studies the equipment is limited by the distance it can "see" through the water and by the difficulty in following swiftly moving objects.

In general the potentialities of underwater television in fisheries research and aquatic research generally are far greater than those of underwater photography. Its advantages while less than those of diving in shallow water, exceed them for deep water work.

Acknowledgements

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Generating equipment was provided through the courtesy of the Superintendent of the Banff National Park and of the Manager of the Nanaimo Branch of the British Columbia Power Commission.

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The writer is also indebted to Dr. Jean-Paul Guerrier, chief limnologist of the Canadian Wildlife Service for the privilege of witnessing part of the series of tests carried out in Lake Minnewanka, Banff National Park.

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Figure 1. The camera unit in three-quarter view. It shows the battery of lights, the camera port (the lower of the two centrally placed ports), the propulsion tubes for backwards movement and the chain and weights beneath the unit for offsetting buoyancy and regulating the height of the unit from the bottom.

Figure 2. The rear view of the camera unit. The propeller for forwards and backwards motion and the small propeller for side to side turning are visible.

Figure 3. The master control unit on the right and the main viewing unit on the left.

Figure 4. The remote control unit on the left and the auxiliary viewing unit fitted with the synchronized movie camera on the right.

Figure 5. A rocky bottom.

Figure 6. A sandy bottom in an eel grass bed. This picture was taken in 15-20 feet of water without lights.



FIGURE 1



FIGURE 2

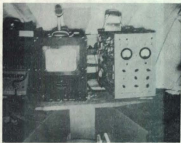


FIGURE 3



FIGURE 4



FIGURE 5



FIGURE 6

Figure 7. A jellyfish swimming through eel grass. As the jellyfish is fairly close to the camera lens, the background is slightly out of focus.

Figure 8. Sea anemonies growing a sheer rock wall in 15-20 feet of water. No lights were used. The small white marks are barnacles.

Figure 9. A Sabellid worm. Note the stout tube and the widely extended feathery tentacles. The picture was taken in 50-60 feet of water without lights.

Figure 10. A sunstar in 40 feet of water.

Figure 11. A lingcod (Ophiodon elongatus) lying on the bottom in 90 feet of water. Lights were used.

Figure 12. A rockfish (Sebastes caurinus) resting on a rocky bottom in 30-40 feet of water. No lights were used.



FIGURE 7



FIGURE 8



FIGURE 9



FIGURE 10



FIGURE 11



FIGURE 12

