

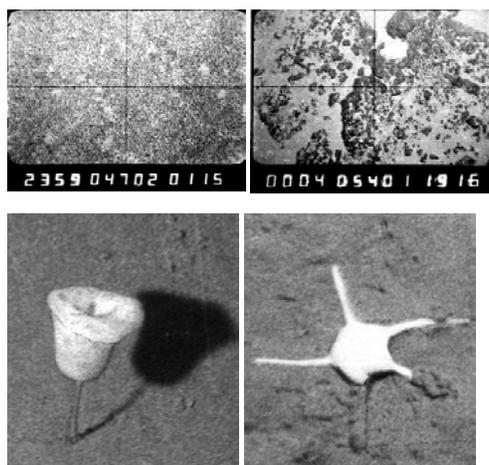
# Underwater photography - A visual survey method

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## Introduction

“Photography as a means of observing and recording data beneath the sea has been of special interest in recent years among scientists and amateurs devoted to diving. Thousands of photographs, including many thousands of feet of motion picture films of marine life and the seafloor in shallow water, scarcely require another general description. But photography in the deep sea, either near the seafloor or in mid water, has developed more slowly because there has been far less opportunity for it, the expense is greater, and it is fundamentally more difficult”. This was written in the preface of a book on Deep-Sea Photography, edited by J.B. Hersey of Woods Hole Oceanography Institute, Massachusetts, USA, published by John Hopkins Press in 1967. The first successful deep-sea photographs were those made by Maurice Ewing and his co-workers during cruises on Atlantis in 1940-48. Their subject was the seafloor and their method of clicking was to trigger the camera mechanically when its mounting struck bottom. This is the only method of triggering cameras to photograph the seafloor until the work of Edgerton and Cousteau with the sonar pinger (Hersey, 1967).



**Fig. 1:** Seafloor photographs with polymetallic nodules (top left), rock outcrops (top right) with ferromanganese crusts, a sponge (bottom left) and a star fish (bottom right) in the Indian Ocean.

Subsequently, several authors have described the techniques of underwater photography (Engel, 1968; Shulke, 1978; George et al, 1985) and some have also published exhaustive collection of underwater photographs (Heezen and Hollister, 1971). Underwater photography

has come a long way in terms of the techniques used as well as its applications. Use of underwater photography ranges from the study of the natural features such as the rocks, minerals and biological features (Fig. 1); as also man-made structures such as sunken ships and lost civilizations encountered during marine archaeological expeditions.

This chapter describes the principles, requirements and applications of underwater photography, and also briefly deals with the processing of photography data.

## Principles of underwater photography

This section has been described in detail by Thorndike (1967), of which the excerpts are given below:

### (a) Refraction and dispersion

As a light ray passes from one medium to another, it is refracted in accordance with the equation :

$$n_1 \sin \theta_1 = n_2 \sin \theta_2 \quad (1)$$

in which  $n_1$  and  $n_2$  are the refractive indices of the two media and  $\theta_1$  and  $\theta_2$  are the angles between the ray and the normal to the surface in the corresponding cases. If light passes from water into glass or plastic and then from the glass or plastic into air, this equation is used successively at the two surfaces. The situation is simplified if the glass or plastic has surfaces that are plane and parallel to each other. Then the properties of the window do not affect the final result which becomes :

$$\sin \theta_a = n \sin \theta_w \quad (2)$$

in which  $n$  is the refractive index of water relative to air, approximately 4/3.

For an optical system, viewing an object in water through a plane window, refraction gives the following effects :

1. Rays diverging from a point at a distance  $S_w$  from the window appear, after they have passed through the window, to come from a distance  $S_a$ , such that

$$S_a = S_w/n \quad (3)$$

Thus, the optical system must be focused for an air distance approximately 3/4 of the actual distance in water.

2. A ray coming to the window at any angle of incidence other than zero will leave it at a larger angle. Thus, an optical system such as a camera, which has a given angular field of view in air, will have a smaller angular field in water. In addition, an object, which would produce an image of a certain size if it were in air, produces a larger image if it is in water. The lens appears to have a longer focal length, approximately 4/3 than in air, and a correspondingly modified focal ratio of value, making the lens slightly slower.

3. Rays from points forming a rectangular grid in water do not appear arriving from a rectangular grid after they have passed into air, as there will be distortion.

4. Light of different wavelengths has different values of  $n$ ; thus, there is dispersion in water, and the three effects above will vary with the colour of the light. The most important effect of dispersion is the introduction of lateral chromatic aberration in the outer part of the field. White light passing obliquely from water to air is dispersed into a spectrum along a line extending radically out from the axis of the system.

### *(b) Absorption and scattering*

Both absorption and scattering present difficulties when optical observations are made over appreciable distances in water. Scattering is more troublesome as it not only removes useful light from the beam but also adds background illumination. Compensation for the loss of light by absorption can sometimes be made by the use of stronger light sources. The background illumination caused by scattering can be reduced by keeping unnecessary light out of the water between the object being viewed and the viewing instrument. Objects a few meters from the camera can be clearly imaged in ocean water but the clarity is sharply reduced for distances even as small as 10 m. In coastal water, the distance at which usable photographs can be obtained, or visual observations made, may be as small as a meter or two.

### **Requirements of underwater photography**

Successful underwater photography requires apparatus that fulfils the technical specifications discussed below (Edgerton, 1967):

1. The casing must be strong enough to withstand the hydraulic pressure of seawater. The pressure increases by one atmosphere for each 10 m of depth, and, at the greatest known depth, a pressure of about 1200 kg/cm<sup>2</sup> (1,160 atm) must not cause damage.

2. Provision must be made in the casing for a transparent, distortionless optical window for photography.

3. Control levers, or wires, are needed to carry triggering information, or electrical power, into the casing. These parts must also be able to withstand the great pressures experienced with depth, and their insertion must not weaken the casing. Even the smallest leak can lead to malfunctioning.

4. Light is required for deep investigations since daylight is almost completely absorbed at depths greater than 200 m in the clear water of the open sea. Light sources, such as electric lamps with batteries, must be able to operate efficiently at high pressure and low temperatures.

5. The optical aberrations discussed above must be compensated in order to obtain the maximum information from the photographs.

6. Triggering of the exposure is important.

7. Positioning of the camera at a known spot, or at a given height above the sea bottom, is very important, and often the most difficult problem in deep-sea photography.

### **Photogrammetry**

Photogrammetric techniques used in stereographic aerial surveys are applied to deep-sea stereophotography, permitting the photoanalyst to describe the subject quantitatively (Shuldt et al., 1967).

To enable the dimensioning of any subject appearing in underwater stereophotographs, each frame of a stereopair is projected and viewed so that points common to each frame are superimposed, and the left and right frames are seen with the left and right eye respectively.

Although any sampling system has limitations, the techniques described can be applied to the measurement of: (a) ripple characteristics for interpretation of the water movements they reflect; (b) bottom roughness for sonar studies; (c) grading of sediments into fine, medium, and coarse; and (d) the linear extent of such grades. Geological features can be measured, such as width and height of outcrops, size of fracture patterns, inclusions in conglomerates, size of minor structures like nodules for mineral-resource evaluation studies, pillow lava. The dimensioning of organisms for quantitative description and taxonomic studies, and the measurement of burrows, mounds, tracks and trails for biological studies are also subject to this technique.

## Types of cameras and modes of operation

Different photographic techniques can be used for different objectives and studies.

### (a) Types of cameras

#### (i) Still cameras

These cameras are capable of taking still photographs on standard 35 mm films. The camera lenses are corrected for water and enclosed in pressure casings. Most of these cameras have built in or separate battery packs and flash lights.

#### (ii) TV cameras

These cameras can record a film continuously for a length of time. The recording can be done either in the camera or on the surface by transmitting the image through a cable. These cameras also have their power source and strobe lights.

### (b) Modes of camera operation

#### (i) Trigger mode

A trigger suspended from the camera, triggers the shutter when it touches the seafloor. This operation can be repeated number of times for several photographs.

#### (ii) Towing mode

The cameras can be towed behind a boat and still and TV photography can be carried out by operating the camera with timer or trigger to take a number of pictures.

#### (iii) Time lapse mode

The cameras can be pre-programmed to record still/TV photographs at certain time interval for a period of time.

#### (iv) Hand held mode

The cameras can be operated by divers by holding them during dives and recording the features of their interest.

#### (v) ROV/Submersible mounted

Cameras can be mounted on Remotely Operated Vehicles (ROVs) or submersibles (manned and unmanned) for realtime observation of the objects being surveyed. These could be operated from the deck of a ship or by technicians in the submersible.

## Processing of photo data

Processing of photographic data includes an elaborate procedure, which involves processing of films, interpretation of data, storage and retrieval of data, preparation of maps and charts. One of the basic steps for processing of photo data comprises of calculation of area photographed on the seabed, which is estimated from lens angle and altitude of the camera (Fig. 2). For estimation of the dimension of any feature recorded on a seabed photograph, it is necessary to calculate the scale factor (Sf) or magnification factor on the basis of the Area

photographed on the seabed ( $A_s$ ) and Area of the photograph ( $A_p$ ) (Fig. 3). Finally the photo data, navigation

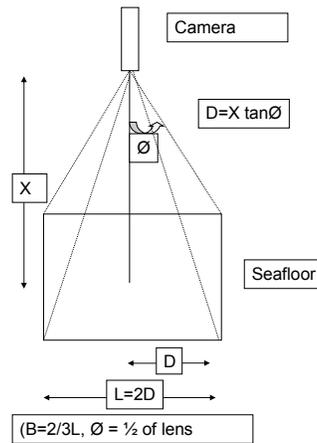


Fig. 2. Calculation of the area photographed on the seafloor ( $X$  = altitude of the camera,  $L$  = length of the photograph,  $B$  = breadth of the photograph,  $L \times B$  = Area of the photograph)

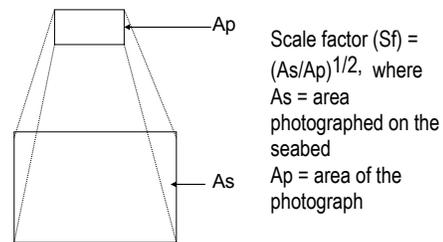


Fig. 3. Calculation of scale factor

data and sounding data, need to be integrated for making meaningful interpretation of the collected data (Fig. 4). After the integration of data, these could be catalogued in standard data base systems, for easy storage and retrieval by users from different subjects.

## Applications of underwater photography

### (i) Geological

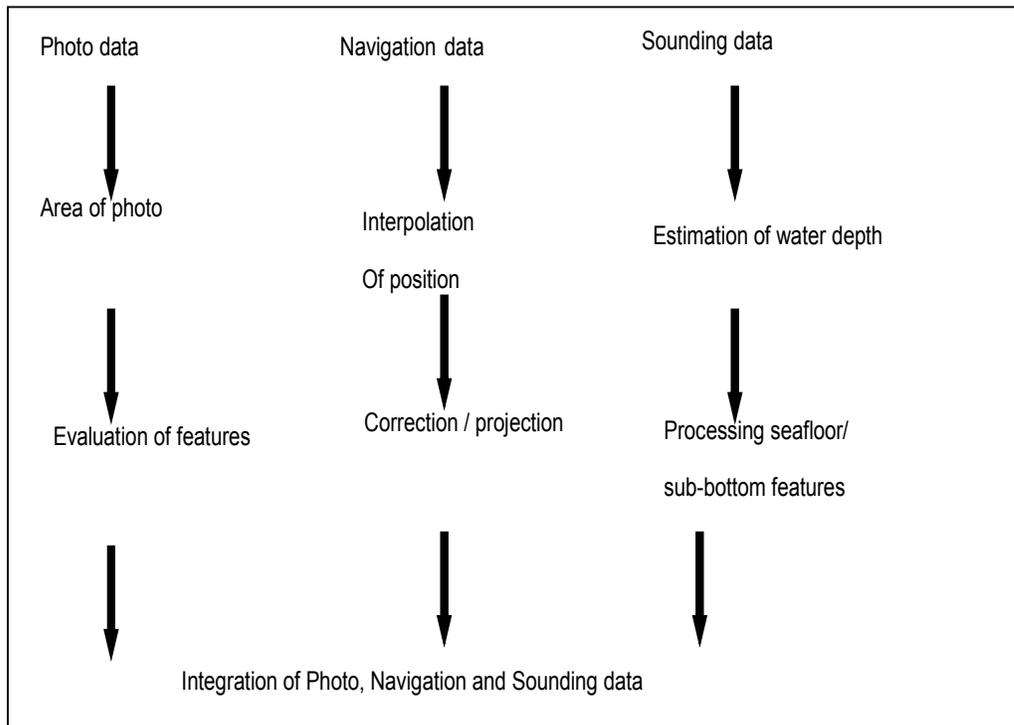
- Occurrence of rock outcrops on the seabed
- Location of minerals on oceanfloor
- Study of microrelief in sediment and crust areas
- Effects of tidal currents on seabed

### (ii) Biological

- Distribution of marine organisms
- Distribution of marine features made by organisms such as tracks, trails, burrows, casts etc.
- Estimating populations of benthic organisms
- Recording habits of marine organisms

### (iii) Environment

- Relation of marine organisms to substrates
- Study of marine environment
- Evaluation of environmental impact



**(iv) Engineering**

- Inspection of underwater structures
- Monitoring of pipelines and cables

**(v) Archaeological**

- Cataloguing of ancient submerged structures and shipwrecks.

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