SUB-AQUEOUS PHOTOGRAPHY.—III.*

PHOTOGRAPHING AQUATIC ANIMALS IN THEIR NATURAL ENVIRONMENT.

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A NEW SUBAQUATIC APPARATUS.

WHEN a camera for subaquatic use is made after the ordinary type the box must be securely closed before submerging it in order to protect the lens and the plates from the action of the water. While the camera is under water it is not possible to remove the plates or plate holder in order to substitute a ground glass for them. It is therefore impossible to focus, and the camera must be adjusted to the desired focus before immersing it. This was the method adopted by Boutan in his third apparatus. It would be possible to construct a camera that might be focused under water by means of a focusing scale such as is provided in those hand cameras arranged to be focused without the use of a ground glass, the operator estimating the distance of the object and then setting the camera for a corresponding division on the focusing scale. This method is of value for more distant objects and with rather slow lenses of great focal depth. When very rapid lenses are focused on near objects only those objects are in focus that lie nearly in one plane. Thus a very accurate adjustment of the camera is necessary in order to bring any near object into sharp focus, and this is not possible when the distance of the object must be estimated and the focusing accomplished by means of a scale. In sub-aquatic photography the objects to be photographed are all near and if instantaneous work is to be done the lens must be very rapid. It is therefore important to be able to focus accurately on the ground glass under water, and this might be accomplished by using two identical cameras (twin camera) united so as to form one instrument. One of these contains the plates and has a lens provided with a shutter. The other camera carries the ground glass. The same focusing mechanism operates both cameras, so that when a sharp image is formed on the ground glass of the one an identical image strikes the sensitive plate in the other when the shutter is operated. One of the cameras serves merely as a focusing finder of full size. A camera of this type properly constructed of metal could undoubtedly be used successfully under water, though it has the disadvantage of being unnecessarily cumbersome and expensive.

The Camera.—All of the advantages of the twin camera are to be had by using a reflecting camera, which is at the same time both lighter and less expensive. The principle of the reflecting camera is shown in Fig. 13, which represents diagrammatically such a camera in longitudinal section. The ground glass (*gl*) is placed, not at the back of the camera, as is usual, but in the top. The operator, holding the camera in front of him, looks in the direction indicated by the upper arrow, at the ground glass through the

Fig. 13.—A Reflecting Camera Shown in Section, with Magazine Plate Holder Attached.

gl, ground glass; *h h'*, hood; *l*, lens; *m*, mirror in position during focusing; *m'*, mirror, showing position during exposure; *p*, sensitive plate; *r* and *r'*, rollers of focal plane shutter; *s*, the shutter; *sl*, slot in shutter; *x*, hinge on which mirror turns; *yy'*, ray of light traversing the lens and reflected from the mirror to the ground glass.

hood (*h h'*), which takes the place of a focusing cloth. The interior of the camera contains a mirror (*m*), which extends from beneath the back edge of the ground glass downward and forward at an angle of 45 deg. The mirror is hinged at *x* to the top of the

camera. When it is in the position shown at *m* in the figure the space between the back of the mirror and the back of the camera is quite dark. Light entering through the lens is reflected by the mirror and

Fig. 15.—Photograph Showing the Method of Using the Reflecting Camera when Inclosed in the Water-tight Box for Subaquatic Work.

The upper part of the box covering the hood rises above the surface, while the lower part, containing the camera proper, is under water. The operator is looking into the hood through the plate glass in the top of the box. With his right hand he focuses; with his left makes the exposure.

strikes the ground glass, as shown by the line *yy'*. The image as seen on the ground glass by the operator looking down through the hood is, on account of the action of the mirror, an erect image, not an inverted image such as one sees on the ground glass in the back of an ordinary camera. It is also an image of the full size permitted by the plate and the lens, not a reduced image such as one sees in a finder. The shutter (*s*) is a focal plane shutter situated at the back of the camera just in front of the plate (*p*). Such a shutter is essentially a roller curtain of black cloth with a slot (*sl*) across it at one point. The width of the slot may be regulated. The shutter is wound upon an upper roller (*r*) until the slot is upon the roller. The exposure is made by causing the curtain to unwind from the upper roller (*r*) and wind upon the lower roller (*r'*) so that the slot passes very rapidly across the face of the plate. The length of the exposure depends on the width of the slot and the rate at which it moves. The rate may be varied by changing the tension of the spring which actuates the lower roller. The operator holds the camera in front of him with both hands while he looks down at the ground glass through the opening in the hood. With one hand he focuses. When the object appears in sharp focus and in the desired position on the ground glass, he presses a button with the other hand. This causes the mirror to swing on its hinge to the position shown by the dotted outline *m'* beneath the ground glass. In this position the mirror excludes light which might otherwise enter the camera through the ground glass. At the same time the change in position of the mirror permits the light, which was before reflected to the ground glass, to fall upon the plate. The adjustment is such that an image which is in sharp focus on the ground glass will be in sharp focus on the plate when the mirror changes

position. The image does not actually strike the plate so long as the shutter is wound upon either roller. Before the instrument is to be used the shutter is wound on the upper roller. When the mirror in swinging upward reaches the position *m'* the shutter is released from the upper roller and taken up on the lower roller. As the slot passes across the plate from above downward, the image falls through the slot onto the plate in successive strips corresponding to the width of the slot.

The advantages of this form of camera are the following:

1. The operator sees a full-sized, erect image on the ground glass, while at the same time the sensitive plate is in position for exposure.
2. He is able to focus and to regulate the position of the image on the ground glass up to the instant of exposure.
3. Much more rapid exposures may be made with the focal plane shutter than with the ordinary diaphragm shutter. The diaphragm shutter occupies a considerable time in opening and closing, and during the period of operation prevents the light from passing through the full opening of the lens. If the time from the instant a diaphragm shutter begins to open until it is closed again is one one-hundredth of a second, then a considerable part of this time (usually about 40 per cent) is occupied by the opening and closing. The shutter is then wide open and the lens working at its full opening during only a fraction of the one one-hundredth of a second. With the focal plane shutter, on the other hand, if the slot requires a hundredth of a second to pass a given point on the plate, the lens may be wide open during the whole of that time, so that all the light that the lens is capable of passing reaches the plate during the whole of the exposure. For this reason much more rapid exposures may be made with the focal plane shutter than with the diaphragm shutter.

Various forms of reflecting camera are in the market, and it is possible to obtain a magazine plate holder, which carries 12 plates, arranged to be changed without removing the plate holder from the camera or inserting the dark slide. Such a camera, with the magazine holder, is shown diagrammatically in section in Fig. 13. It is surprising that Boutan, when he was seeking some means of focusing his camera under water, did not make use of the idea of the reflecting camera; for by merely inclosing such a camera in a water-tight metal box and arranging it to be operated from outside the box, he would have a portable apparatus capable of being manipulated under water almost as readily as on land. A reflecting camera was

Fig. 14.—Galvanized Iron Box with Plate Glass Front. Designed by the writer to contain a 5 by 7 reflecting camera when used under water.

manufactured in New York as early as 1886, and was advertised at that time and represented by a Paris agent.

The Water-tight Box.—A 5 by 7 camera of the type just described, with a magazine holder for twelve plates, was used by the writer to obtain submarine photographs at Tortugas, Fla., during the season of 1907. The box (Fig. 14) to contain the camera was made of galvanized iron by a tinsmith. It measures about 17 inches long, 9 inches high, and 10 inches wide. The front is closed by a square of plate glass

* A reprint of a Bulletin published by the Bureau of Fisheries.

cemented with aquarium cement into a groove formed in the metal. At the top is an opening large enough to permit the camera to pass, bottom first, into the box. To the outside of the rim of this opening is soldered half-inch square brass tubing jointed at the

Using the Apparatus.—The apparatus was used in the following manner: The magazine plate holder containing twelve plates was attached to the camera, the mirror depressed, the shutter set at the desired speed and width of slot, and wound. The dark slide

possible. The apparatus thus made ready was, when in air, as heavy a load as one man could conveniently carry. It was carried to a boat or, if it was to be operated near shore, to the shore. In working with the help of a boat the operator wades on or near the coral reef with his head and shoulders above the water. The boat, with an attendant on board, is anchored near. The operator, with the help of a water glass, now seeks a favorable place for operations. As he moves about the reef, the fish at first seek shelter in the dark recesses of the coral rock, but if he selects a favorable place and remains quiet they soon reappear. They are at first wary, but soon grow bolder and after half an hour or so pay but little attention to him. There is a great difference in wariness among different species of fish. At first only one or two species appear, demoiselles and slippery-dicks usually, then the number of species gradually increase until the shyest butterfly-fish and parrots come within 6 or 8 feet of the operator. He then has the camera passed to him from the boat. It floats with the upper part of the hood protruding and (Fig. 15) may be easily turned toward any point on the horizon or even tilted so as to be pointed at a considerable angle upward or downward. The operator has now merely to direct the camera at the fish, while he focuses with his right hand. He must often wait some time before the fish come to the point selected or assume the desired attitude. Often they may be enticed by throwing in a bait of crushed sea urchins or pieces of crawfish. They are in constant motion so that he must as constantly focus. He often misses a long-awaited opportunity because the fish moves on or takes a wrong attitude before he has had time to focus sharply; but when the favorable time comes he presses the release stem and the exposure is made.

The apparatus must then be lifted into the boat, the cover removed from the box, and the camera taken out in order to reset the shutter and change the plate. It is best that all this be done by the attendant who remains in the boat, as the operator is thus left free to watch the fish, while at the same time the fish are not unduly frightened by the sudden movements that he would make in lifting the camera. With care, however, one person may do all the work necessary. He may anchor the boat near, pull it to him by means of a line, lift in the camera, and make all the necessary adjustments while he himself remains in the water. If the work is done near shore, the camera may be carried to shore after each exposure. In that case an assistant is very desirable, since the return of the operator after each absence disturbs the fish. Moreover, when near shore he is moving over the rock or sand bottom, not over the clean upper surface of the reef, and every considerable movement stirs up the bottom sediment so that some time must pass before the water is again clear enough to permit an exposure to be made. If an assistant is available, he may stand at a considerable distance from the operator, who

Fig. 16.—Photograph Taken with Camera Submerged.

This photograph is reproduced without retouching from original made on orthochromatic plate with a color screen by the use of a reflecting camera inclosed in the water-tight box described in this paper. The exposure was made in sunlight in about 4 feet of water at 11 A. M. at Tortugas, Fla., and lasted 1/33 second.

corners into a rectangular frame. The upper surface of this frame is made as smooth and as nearly plane as possible. Eight brass screw-bolts are soldered into holes drilled through the frame. They occupy the positions shown in the figure and the threaded end of each projects about three-quarters of an inch above the frame. The cover consists of a flat sheet of metal bordered by a frame of brass identical with that on the box. This frame is perforated by eight openings through which the screw-bolts pass. From the cover there arises an irregular truncated pyramid of galvanized iron, which incloses the hood of the camera. At the top this is closed by a piece of plate glass. By means of wing nuts on the screw-bolts the cover may be tightly clamped to the box, against an intervening gasket of rubber.

On the right-hand side of the box is a large milled head of brass from which a brass stem passes to the interior through a stuffing box, which prevents the entrance of the water along the stem. At its inner end the stem terminates in a two-pronged fork. The stem may be pulled in and out in the stuffing box through a distance of about three-quarters of an inch. When the stem is pushed in, the prongs of the fork engage in two holes drilled in the focusing head of the camera. By turning the milled head on the outside of the box the camera may then be focused. On the opposite side of the box is a second but smaller brass head from which a stem passes through a stuffing box to the interior of the box, and terminates in a flat disk. The disk lies opposite the release pin of the camera by which the mirror and shutter are set in motion. A light spiral spring wound about the stem between the outer head and the stuffing box keeps the stem thrust outward to its full extent. Pressure on the outer head causes the metal disk to strike the release pin so as to make the exposure.

In order to use the box, it is necessary to attach to it a weight heavy enough to submerge all but about the upper 6 inches of the hood. In the experimental apparatus used this weight was made by folding sheet lead to form a flat mass of the dimensions of the bottom of the box. The weight (not shown in the figure) was made slightly wedge shaped lengthwise and was attached to the bottom of the camera by wires passing beneath it and soldered at their ends to the sides of the box. As the camera would, in use, usually be pointed slightly downward, the thicker end of the weight was placed in front, so that the box floated with its front end somewhat lower than its back end.

was then drawn from the magazine holder, and the camera, thus made ready for an exposure in air, was placed in the box. Metal cleats soldered to the bottom of the box brought it always to the same position. The head on the right of the box was then pushed in until the fork engaged in the holes in the focusing head of the camera. The top was then put on the box and clamped down by the wing nuts as firmly as

Fig. 17.—Photograph Taken with Camera Submerged.

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sends the camera box to him through the water by a quick shove. The assistant, after he has carried it ashore and readjusted it, returns it in the same way.

The opening of the box after each exposure occupies some little time, and during this time favorable opportunities to make exposures are often lost. It would be better if a mechanism were provided by which the plates might be changed without opening the box, which would then remain in the water until twelve exposures had been made. Nevertheless it is possible with the apparatus described to make twelve exposures on coral-reef fish in about two hours including the lifting of the box from the water between exposures and opening it to change plates. Any form of reflecting camera may be used and any form of plate holder. Films may also be used in rolls or packs. In addition to the reflecting camera the operator needs only a metal box of the structure described and of a form suited to his camera. This may be made by any good tinsmith at a cost of a few dollars.

A camera of this type inclosed in a suitable box may be held in the hand while in use, or it may be set upon a tripod of heavy iron, such as is shown in Fig. 8. Such a tripod would best have a top of the form shown in Fig. 2, but made of heavy iron instead of wood. The operator may descend in a diving suit, as Boutan did, and use the camera at the bottom in deep water either while holding it in the hand or while it is supported on a tripod. There should be no difficulty in focusing while looking through the plate-glass window of a diver's casque. For work on the coral reefs of the Tortugas, however, the writer has found that everything may be done from the surface, so that a diver's suit is quite unnecessary. He is told that similar conditions exist at the Bermudas. From his own experience in fresh water he is inclined to believe that probably all the photographic work that it is desirable to do there may be done without the use of a diver's suit. The occasions on which such a suit is really necessary for work in either fresh or salt water are probably extremely rare.

If the objects to be photographed are motionless, or nearly so, time exposures may be made with this apparatus by suitably adjusting the camera before placing it in the box. For this use it is desirable to add to the box a third rod working through a stuffing box and so placed that by means of it the shutter may be released independently of the mirror.

Two photographs made by the method here described are reproduced in Figs. 16 and 17. In Fig. 16 a butterfly-fish (*Chaetodon capistratus*) with a stripe through the eye and an eye-like spot on the tail is seen over a flat expanse of coral (*Meandrina*) and at the base of a large, branching gorgonian. The photograph was taken while the fish was in rapid movement. The expanded polyps may be seen on the gorgonian just above the fish and elsewhere. Fig. 17 shows a group of parrot-fishes, of at least three species, and several surgeons against a background of branching gorgonians on a ledge of rock. Near the center is a blue and yellow striped grunt, *Hemulon flavolineatum*. At the left of this is a blue parrot-fish, *Callyodon caeruleus*. At the right of the grunt is a green parrot-fish, *Callyodon vetula*, about 18 inches long. Beneath the green parrot is a mottled parrot-fish (*Sparisoma*?). Above the green grunt is a second mottled parrot and to the left of this a third. At the extreme left are two surgeons, *Hepatus hepatus*; a third is seen below the green parrot. Above the green parrot, in the background, is a purple sea fan, *Rhipidoglossa*. In most of the fish the details of the markings and the outlines of the scales are clearly seen.

These photographs were taken in water about 4 feet deep with a Goerz II. B lens at a speed of f5. The exposure was 1/33 second with Sees P. orthochromatic plate and a No. 3 graphic color screen. The plates were fully timed and were developed rapidly with a strong pyro developer.

The apparatus used by the writer was experimental only and was meant for temporary use. It is easy to suggest improvements, the greatest of which would be a magazine plate holder for at least twelve plates and capable of being operated from outside the box which incloses the camera. There appears to be no such holder on the market. Magazine holders provided with a bag cannot be used even though the leather bag of the plate holder be covered with a rubber bag so attached to the box inclosing the camera that the water cannot enter, for the pressure of the water is such that even when the box is but partly immersed the rubber bag is forced into the box through the opening to which it is attached and the holder cannot then be manipulated. This difficulty would be increased if an attempt were made to use the apparatus at a greater depth. What is needed is a magazine plate holder that presents a rigid exterior everywhere and that may be operated from the outside of the box by means of rods passing to the inside through stuffing boxes.

The box can be improved by reducing to its lowest limit the number of screws used to fasten the cover,

for if but one or two screws had to be loosened to open the box much time would be saved in changing plates.

A part of the weight attached to the bottom of the box should be movable, so that it could be fastened either toward the front or toward the back. In this way the box could be made to float with the lens pointed at a considerable angle toward the bottom or toward the surface of the water. The operator would then be spared the very considerable effort necessary to hold the box in position when the lens is directed much above or below the plane in which the box floats.

The purpose of the writer has been to utilize an ordinary reflecting camera for subaquatic work by inclosing it in a suitable water-tight box without in any way lessening its availability for use in air when removed from the box. For use exclusively in water it would be best to design a reflecting camera that could be immersed directly in water without first inclosing it in a box. Such a camera would have to be of metal, water-tight, and would need to have the lens covered by a plate of glass. It would need to have only a small opening at the back on one side for inserting and removing the plates. Such an opening could probably be readily closed by a cover held in place by one or two screws. A camera of this sort, if made rigid enough to withstand the pressure of the water at even moderate depths, would be too heavy for convenient use in air. It would have the advantage of simplicity and increased ease of manipulation.

SOME LIMITATIONS OF SUBAQUATIC PHOTOGRAPHY.

Turbidity of the water sets a limit to subaquatic photography very much as fog or rain or partial darkness restricts photography in air. The water must be clear—that is, apparently free from particles in suspension. If instantaneous work is to be attempted the water must be free from the reddish color that often tinges fresh-water lakes and streams, for the tinge of red or yellow acts as a color screen and greatly lengthens the time necessary for the exposure.

When one looks from the air into the ocean water at the Tortugas or Bermudas, or into the fresh water of some of our northern lakes, it appears to be as clear as the air itself. When the surface is undisturbed, objects on the bottom at depths of 10 to 20 feet appear with as much clearness as though seen through air alone. The impression is created that such water is actually as clear as air, and that the water would offer no more obstruction to the vision of one beneath it than air itself. To test this impression the writer constructed a reflecting water glass somewhat like a reflecting camera without the lens. It was a metal tube 2 feet long, and contained two parallel mirrors, set at an angle of 45 deg. with its long axis, and placed one at each end. By putting one end of this with its mirror beneath the surface and looking into the mirror at the other end, he obtained a view of the subaquatic landscape such as a diver obtains when he looks about him through the glass window in his casque. It is surprising to find how limited is the range of one's vision under these circumstances. Even in the clear sea water about tropical islands objects at a distance of 20 feet begin to appear indistinct, and beyond that distance they fade into a bluish haze which constitutes the background. This haze has not the effect of fog or smoke or twilight. It is as though the near distance were limited on all sides by walls of bluish translucent quartz which merged into the near water. From these walls the fish emerge and grow rapidly more distinct as they approach. Into them they vanish suddenly as they recede.

Subaquatic photographs show the same lack of distance that so impresses the eye. Thus in the photographs Figs. 16 and 17 the distance appears indistinct, partly because the objects are out of focus, but chiefly because they are enveloped in the bluish translucence mentioned above. It is therefore impossible under water to photograph objects at any considerable distance. To the photographer who is unfamiliar with the aspect of the subaquatic landscape this lack of distance in photographs of it seems a defect. But to the artist or naturalist who has seen things as they look to one beneath the water it is really a merit, since it shows these things as they are.

The source of this lack of distance is probably double. It is due in part to the fact that even the clearest water contains very many bodies in suspension, living organisms, and inorganic and organic particles. These, like dust in the atmosphere, interfere with distance vision. It is due also in part to the reflection of the light from the surface of the water. Light which has entered the water from above strikes upon and illuminates various bodies beneath the surface. From these a part of it is reflected to the surface of the water again. If it strikes the surface at an angle of more than 48 deg. 35 min. with the vertical it is totally reflected and passes again into the water. Here it again strikes some submerged body and is again in part reflected to the surface and here again in part

re-reflected. Thus shallow water is traversed in every direction by beams of light which intercross at every angle. These illuminate the opaque particles floating in the water, and are deflected by reflection. They are also deflected by refraction through the more transparent organisms. In this way probably is produced the background of bluish-white opalescence which characterizes the subaquatic landscape. To one who knows that landscape, the background, hiding many mysteries, adds to it character and beauty. A photograph that failed to show it would be lacking in character. Boutan (1893), who discusses this subject, made use of a blue color screen and believed that he obtained greater distance in his subaquatic pictures by this means. In his more recent work (1900, p. 283) he abandoned the use of the color screen. He obtained clear pictures of near objects by using a shade above the lens, as already described. Boutan appears never to have obtained clear pictures of more distant objects. The writer has made use of an ordinary yellow color screen (graphic No. 3), but is unable to say with certainty that it adds anything to the distance in his pictures. The subject needs further study.

A second characteristic of the subaquatic photographs that strikes the photographer unpleasantly is their flatness. Objects of all sorts appear lacking in thickness or rotundity and do not cast abrupt or heavy shadows. This peculiarity the writer believes to be due to the reflection of light from submerged objects into the water at the water's surface. Light thus reflected on the subaquatic object from the bottom beneath and from the surface above and at all angles takes out of it much of its roundness. It takes out the shadows very much as a photographer in his studio may take them out by a suitable adjustment of reflecting screens. Along with this flatness of the individual objects in the subaquatic photograph there is abundance of contrast between different parts.

This lack of distance and this flatness combined with contrast, so characteristic of the subaquatic photograph, are not real defects. They are rather truthful representations of the conditions that actually obtain. To the photographer accustomed only to photographs made on land they appear to be defects. To one who knows the subaquatic landscape they are, from the artistic standpoint, sources of beauty. From the scientific point of view they undoubtedly place limitations on subaquatic photography.

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Experiments with artificial fertilizers in German vineyards have shown that vines treated exclusively with commercial fertilizers are very much less affected by fungous diseases than vines to which stable manure is applied. There are also other arguments in favor of the exclusive employment of artificial fertilizers.