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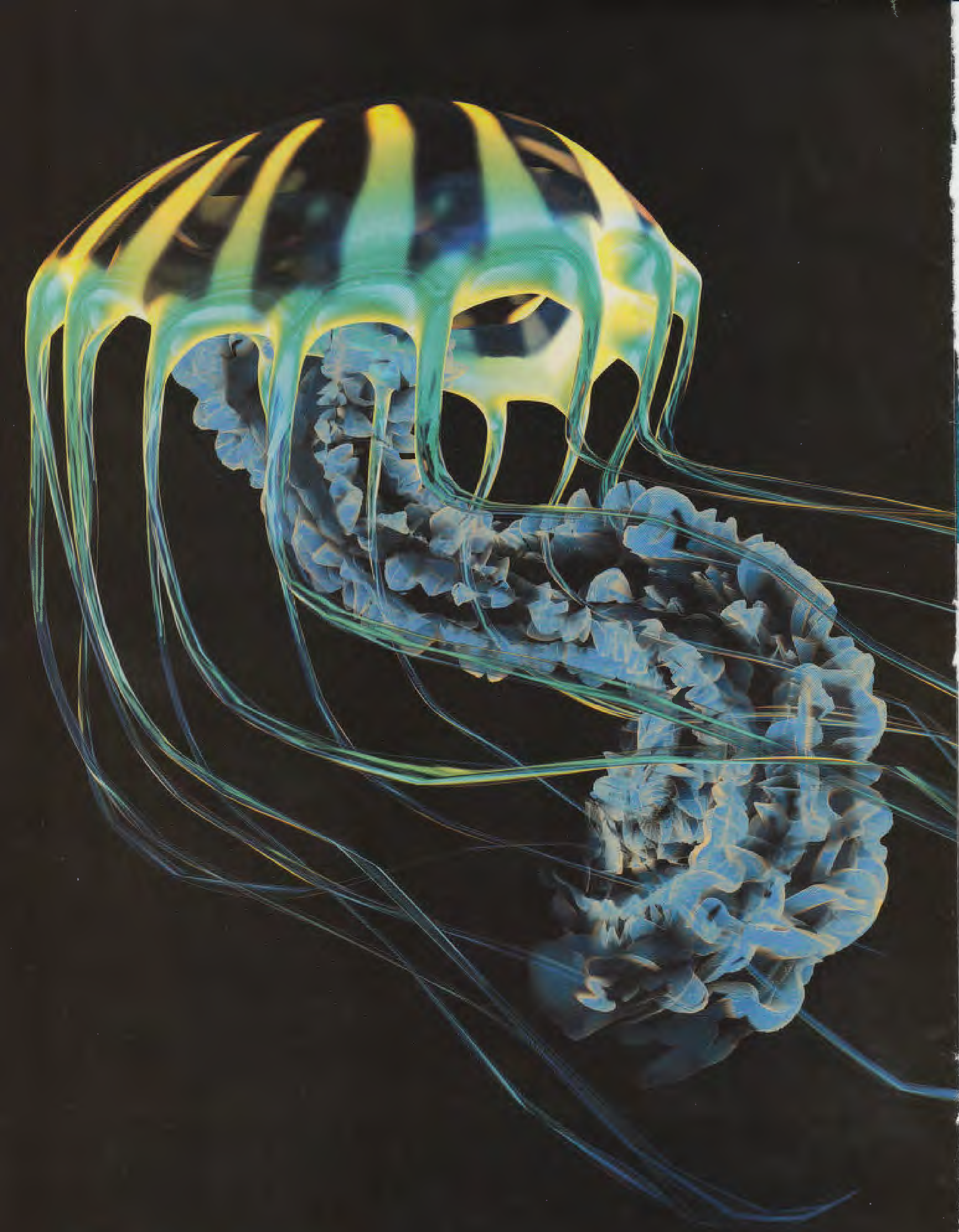


# NEON NIGHTS

## The Magical World of Fluorescence Underwater

NEW LIGHTS, BLUE AND ULTRAVIOLET LIGHTS, are shining on the underwater world, and the results are extraordinary. In this article, we will explore the "glow in the dark" phenomenon, including what biofluorescence is and how and why it happens. We'll also examine the various sources of ultraviolet light as well as certain techniques underwater shooters are using, and the results they're achieving, using these specialized lights while night diving.

Keep in mind that there are a number of ways to experience biofluorescence. One thing for sure, the more I researched this fascinating topic, the more opinions I encountered regarding the best lights, filters and even reasons for biofluorescence. However, most agree that diving with ultraviolet lights is fun and brings a whole new sense of awe and adventure when night diving.

By Barry Guimbellot

Stony corals like the one pictured here show quite a lot of biofluorescence.

BARRY GUIMBELLOT PHOTO

## SHINING A LIGHT ON LIGHT

Let's start with an overview of different types of light. As we understand it, light is a combination of energy particles known as photons. The particles have no mass, just energy. Luminescent light occurs from a chemical change in an object, such as a diver's Cyalume™ glow stick, or a biochemical change within an organism. Bioluminescence is often seen on the ocean at night; water movement, from a spinning boat prop or maybe from quickly waving your hands back and forth, agitates tiny microplankton, causing it to emit greenish light.

Phosphorescence results from shining light on an organism, stimulating it to radiate light. When the light source is removed, the material continues to radiate light photons. This type of light is frequently referred to as glowing in the dark.

The type of light I will be addressing is fluorescence, specifically biofluorescence. The process of fluorescence involves a substance absorbing light at one wavelength and releasing light at a longer wavelength.

## FLUORESCENCE

The first fluorescent protein discovered was green (GFP). It was found in a bioluminescent marine hydroid known as the crystal jellyfish (*aequorea victoria*). Dr. Osamu Shimomura and his team of researchers won the 2008 Nobel Prize in chemistry for their discovery and work on GFP. There are different colors of GFP, but green was the first protein identified and described by the researchers, thus the name GFP. Other colors are caused by mutations of GFP. Dr. Charles Mazel says that different colors are now being synthesized in the lab by injecting different colors of GFPs into other objects and organisms, causing them to fluoresce.

Fluorescence is created when light photons come in contact with an electron in the outer regions of an atom, creating an "excited" state. The term "excited" is a personification used by scientists to describe when an electron is energized and moves to another energy state. When the electron's path decays back to a neutral state, the electron gives off energy in the form of light.

The solar system is a good analogy for understanding what happens during fluorescence. By using the sun as the nucleus of an atom, the planets as electrons, and the orbit of planets and dwarf planets as different energy states, we can understand in simple terms the process of fluorescence and biofluorescence. To initiate the process, lightwaves of a color, thus a certain frequency, hit an atom that contains an electron named Pluto. Prior to lightwaves hitting Pluto, the planet maintains an orbit, which is its neutral or stable state. When these new photons of energy hit the electron/Pluto, it becomes energized or excited and jumps to a higher orbit farther from the nucleus/sun. This jump to a higher orbit creates a state of instability for the electron/Pluto. Because atoms prefer a stable state of existence, the electron/Pluto's orbit immediately decays and reverts back to its normal orbit. When this decay happens, energy in the form of photons, the energy that allowed Pluto to change orbit in the first place, is released. Some of the original energy was used up by Pluto's attempt to stay in its new orbit so the lightwaves given off in the decay have less energy. As a result, the lightwaves have a longer wavelength. The light energy produced by the decay is known as fluorescence. The fluorescent color depends on how far the electron/Pluto had to fall to get back to its lowest or neutral level. This entire process happens almost instantly.

Many objects and colors react to light as described in the preceding paragraph, but the reaction is not always visible. Often light photons are given off at a wavelength we cannot see or are diminished by the effects of ambient sun or white light. Sunlight is only made up of 0.5 percent UV (ultraviolet) light so any sunlight hitting an object makes the fluorescence difficult to see. Sometimes the atom absorbs the light and does not give off photons. Instead, it gives off energy in the form of heat. For example, heat absorption can easily be felt when wearing a black shirt on a sunny day. In contrast, a white or light-colored shirt reflects heat. Various objects react to short-wave light better and others react to long-wave light more readily. Still other colors and objects have a very low reactivity to UV light and fluoresce very little or not at all.

When diving with UV lights, the goal is to reduce the amount of ambient light, restrict the light source to a desired wavelength and filter out any undesired reflective light given off by the light source. Researchers have varied opinions as to which wavelength of light is best to get the most fluorescence and what filters are best to reduce the reflected light.

Now let's turn our attention to biofluorescence, the response of a biologi-

## THE WAVELENGTH INTERVAL OF LIGHT AS MEASURED IN NANOMETERS

**Red 635-700 nm**
**Orange 592-635 nm**
**Yellow 562-590 nm**
**Green 492-560 nm**
**Blue 452-490 nm**
**Violet 400-450 nm**
**UVA 320-400 nm (not absorbed by the atmosphere)**
**UVB 315-280 nm (somewhat absorbed by the atmosphere)**
**UVC 280-100 nm (absorbed by the atmosphere)**

## THE LATEST ON LIGHTS

**Dive lights, including UV lights and filter kits, are one of the fastest-growing accessory categories in the diving industry. Stop by your local dive center to see what's new.**

cal organism in reaction to light in the ultraviolet part of the color spectrum.

All light forms are forms of electromagnetic energy. In addition to visible light, there are radio waves, microwaves, X-rays and gamma rays. Visible light is almost in the center wavelength of the different types of rays listed. Our eyes are sensitive to light waves measuring from 400 nanometers (blue light) to 700 nanometers (red light). A nanometer (nm) is a measurement of one-billionth of a meter. In simple terms, all of the aforementioned forms of light have a high peak and a low peak and are measured on devices where the high peaks appear as waves of equal height and low peaks are all the same depth. The distances between the peaks are measured in billionths of a meter, or a nanometer. When we talk about ultraviolet lights, we are talking about the lower levels or long-wave ultraviolet light in the 315-500 nm range. The lower the nanometer numbers, the longer the wavelength, making this light virtually invisible to the human eye. This type of light is often referred to as black light.

As divers, we are taught that the depth of the water affects light. At depth, color is lost due to the lengthening of energy waves of light caused by the water. We use the acronym ROYGBIV to indicate the colors lost as the dive descends deeper; the first color lost is red, followed by orange, yellow, green, blue, indigo and violet. This is why the "deep blue sea" is blue.

Colors near the red end of the color spectrum are referred to as warm colors. Picture a warm fire filled with red, yellow and orange flames. As colors shift toward blue and violet, the colors are said to be cooler.

There are actually shorter wavelengths than ultraviolet, known as shortwave UV. This type of light can be dangerous and can even cause blindness if one looks directly into the light. In fact, shortwave UV or UVC in the 100-280 nm range is used in many industries to kill bacteria. The sun produces all wavelengths of light, including UVC. Fortunately, the upper atmosphere absorbs the shortwave UV, making life on Earth possible.

Researchers have documented that long-term exposure to any blue lights, even those emitted from cellphones, computer tablets and monitors, can be harmful to the eyes. Avoid looking directly into UV lights.

## FLUORESCENCE ON THE REEF

Biofluorescence is caused by the excitation of proteins within a living organism. The dominant fluorescence emissions observed are in the green (482-520 nm) and red (582-600 nm) ranges. Researchers have found that the stony corals, in the class of Anthozoa and order Scleractinia, show quite a bit of biofluorescence.

Fluorescent proteins are found in three different patterns. The first pattern, called "highlighted," is where certain structural features fluoresce. "Uniform" is the second pattern, referring to when an entire animal fluoresces indiscriminately. When two or more different fluorescent proteins are found in different structural parts, the pattern is called "complementary." Not all corals exhibit the same colors, nor do they exhibit color on the same part of structures. Red is rarely found by itself and is typically found in combination with blue or green fluorescence.

It is not within the scope of this article to consider why some objects fluoresce and others do not fluoresce. Nor do we discuss the objective of fluorescence, whether for safety, sexual reproduction or protection from the sun. One researcher, Dr. Mazel, proposes that fluorescence may simply be a byproduct of the green fluorescent protein (GFP) and may not have any use to the organism. He uses the analogy of fluorescence in human teeth. Do teeth fluoresce for a reason or is it just because we subject them to UV light? For the purposes of this article, it is enough to know that some objects fluoresce and some do not. Part of the joy of diving with a UV or blue wavelength light is the process of experimentation and the fun of discovering what will fluoresce and what color(s) will be given off at different wavelengths of light.

Manufacturers have various ways to produce wavelengths of light to stimulate fluorescence. Some use electronics to allow special light-emitting diodes, or LEDs, to emit light at certain wavelengths. Others use a blue filter in front of the LEDs or electronic flash to create a desired blue light. Still other manufacturers use a filter, known as a woods glass filter, over a white light source to excite the process of fluorescence. This particular filter is actually a dichroic filter with a silver mirrored appearance. A dichroic filter only allows a precise wavelength of light to pass while reflecting other wavelengths, giving the filter a mirrorlike effect. Of note is the fact that any blue filter in front of a light will not make a good blue light source for our desired effect. There are many blue hues and blue filters; one must have the blue filter that only allows the correct wavelength of light to pass.

One of the downsides of using a light in the 455-nm and higher wavelength range is that some type of yellow barrier filter must be placed over the camera lens and the diver's mask so that both the diver and camera can filter reflected blue light. Author Lynn Miner, who has written an instruction manual on night diving and fluorescence, reports that this type of over-the-mask filtration may cause divers to be unable to see as well if moving around the reef at night. As a result, the diver may need to be relatively stationary when using a yellow filter covering a mask. The purpose of a yellow filter is to block blue light. Blue

When two or more different fluorescent proteins are found in different structural part of coral, the pattern is called "complementary."

BARRY GUIMBELLOT PHOTO



and yellow are on the opposite sides of a color wheel, making the colors complementary, and complementary colors block opposing complementary colors. Dr. Fred Fischer of Underwater Kinetics says that using a light in the 395-nm range is beneficial because a yellow filter is not required on either the camera or the diver's mask. Notice I said a yellow filter is not required. The filter can be used to remove some of the blue cast from warmer colors, giving them a warmer hue. Another benefit of using a light in the 395-nm range is that it allows the diver to move cautiously around the reef to see the biofluorescence on the reef.

Using a blue or UV light is not recommended when diving in a cave or wreck without a backup dive light that emits white light. To do so can open up the possibility of injuring yourself, your buddy or the environment. Or you could lose your way in the darkness.

Choosing a particular light and wavelength of light is a personal preference. Before making a choice, I recommend that potential buyers try different lights in a store setting. Discuss with a knowledgeable staff member what results can be expected with each light, and what filters and mounting options may be necessary.

## UV DIVING

Now for the fun part — diving with a UV light and experiencing the underwater world in a fascinating new way. To make your "neon night" adventure most enjoyable, it is recommended that your first UV night dives be done under the supervision of an experienced guide. Keep in mind that you will likely be moving very slowly; the idea isn't to cover a lot of area, but rather to concentrate on viewing small patches of coral reef.

When equipping for night diving, a full wet suit or skin suit is always recommended as protection against the stings of "sea wasps" that are often encountered at the surface at night. I also recommend a lightweight hood that covers the neck. In addition to your UV light, equip with a primary and backup dive light and a personal locator beacon attached to your scuba tank.

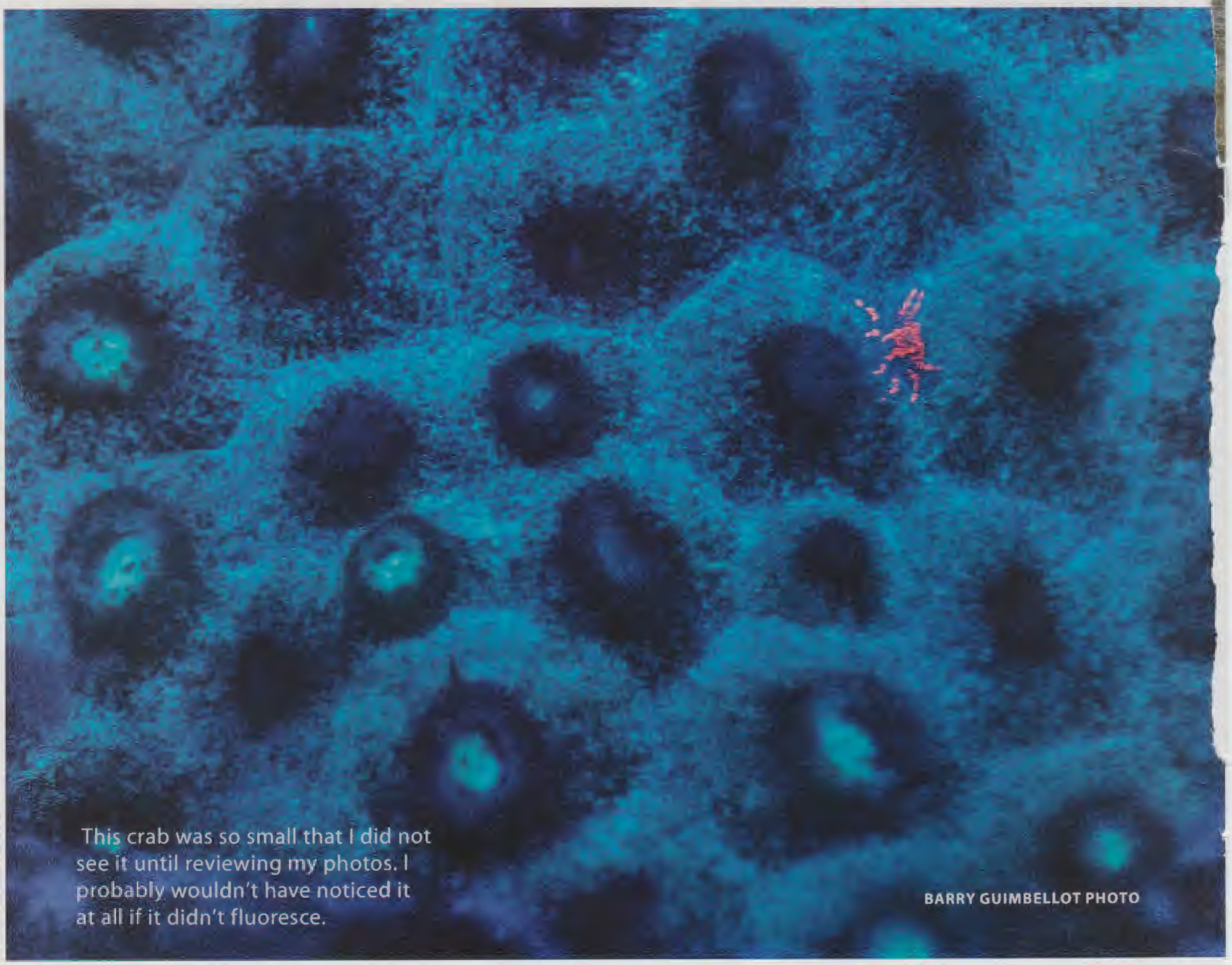
Divers often place a red filter over the dive light to maintain night vision. The red filter may continue to be of use after the dive light is turned off to begin the fluorescent dive.

As soon as the UV light is turned on and the dive light is off, a whole new neon-colored world opens up. It is fascinating to discover how proteins in some organisms such as anemones can emit so much colorful light. Several anemones can look alike and be close in proximity, yet fluoresce very differently. One may be fluorescent green from top to bottom while another will fluoresce only on the tips. Still another one will have green spots fluorescing up the arms to a completely green tip.

Along with anemones, many other organisms show bright colors as soon as the UV light is introduced. Sharp-tailed eels, goatfish, stonefish and some catsharks fluoresce, as do the spines of some pufferfish and fireworms. Many crustaceans, cnidarians, corals, hydroids and corallimorpharians also fluoresce. Small plankton swimming in the water column can also contribute to the light show.

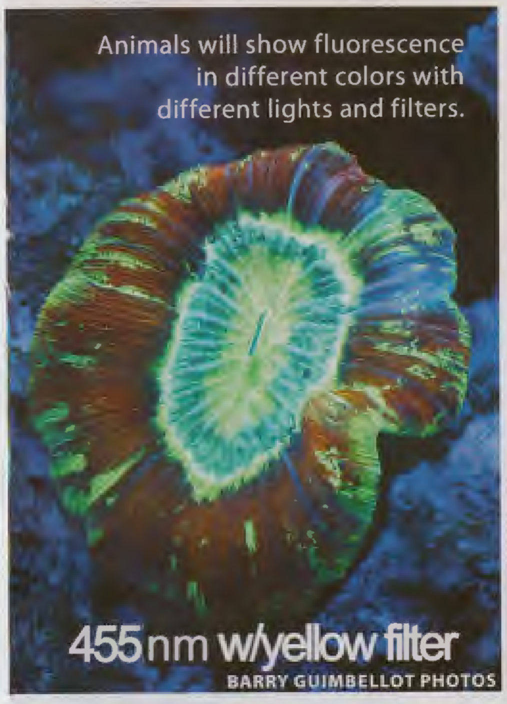
## UV PHOTOGRAPHY

Now that photography is firmly in the digital age, rarely is an image directly from the camera the same as what a diver sees underwater. In other words, post-production work is typically necessary to achieve the best image results. The Internet is one good source of information on how to produce lifelike pictures. Another method is to take a white-balance sample with an image test shot. For the best results, the diver will need to dive with a com-

This crab was so small that I did not see it until reviewing my photos. I probably wouldn't have noticed it at all if it didn't fluoresce.

BARRY GUIMBELLOT PHOTO



Animals will show fluorescence in different colors with different lights and filters.

BARRY GUIMBELLOT PHOTOS

mercial gray card. For reference purposes, take a picture of the gray card to use when adjusting the images topside. Since images taken on a dive are created with the same lighting setup, one gray card image is all that is needed. It is best to use a commercial gray card because there are many shades of gray. Some have more blue, others have more green or red, but they may appear as a midtone gray when viewed without the gray card. For example, if a gray card has a blue cast, adjusted images may also have a yellow tint.

Seasoned divers as well as new divers who have made numerous night dives will feel a new sense of excitement when diving with a UV light. Experiencing the beauty of ocean creatures glowing neon green, red, gold and yellow produces happy divers with stories to share. Whether we dive for beauty, exploration or scientific reasons, diving with a UV light will introduce you to a world relatively few have seen. The experience is catching on quickly, so now is the time to get out there and have fun diving with that magical UV light. The experience is catching on quickly, so stop by your local dive center to learn about the latest UV lights, and then have some fun with "neon" night diving.

*The author wishes to thank Dallas North Aquarium for their assistance with this article.*

## For More Information

**Why Are Reef Fish So Colorful? The Science Behind the Beauty**
dtmag.com/thelibrary/reef-fish-colorful-science-behind-beauty/

**More Than Darkness: Human Factors and the Night Diver**
dtmag.com/thelibrary/more-than-darkness-human-factors-and-the-night-diver/