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THREE EXCITING UNDERWATER ENVIRONMENTS —

Coral Reefs, Submarine Canyons, and Kelp Beds

by Wheeler J. North

Though I have the title of environmental health engineer at Caltech, I am actually only an engineer second-hand, because first I'm an oceanographer. I received my training at the Scripps Institution of Oceanography in La Jolla, and I did a great deal of study in the ocean before I came here. I have become very interested in what man is doing to the sea in the way of discharging wastes into it; in what he does to the various populations of fishes, seaweeds, shellfish, and all the other things he takes out of it; and in the radioactive materials he puts into it. With the sea becoming more and more a part of our environment, I am truly an environmental health engineer in the study of what we are doing to the sea.

Perhaps I have lured you into this discussion under false pretenses with my title, "Three Exciting Underwater Environments . . ." The loaded word here is "exciting," because what the general public considers exciting and what I consider exciting don't always coincide – particularly that element of the general public which avidly watches underwater pictures on TV. When a shark starts nibbling on my swim fins, for example, I don't feel the urge to draw out my dagger and go to work on him. I'm a wet blanket. I go up and get out and climb into the boat. And if I'm diving, and killer whales enter the area, I go back to the beach. I get in my car and lock all the doors and roll up the windows.

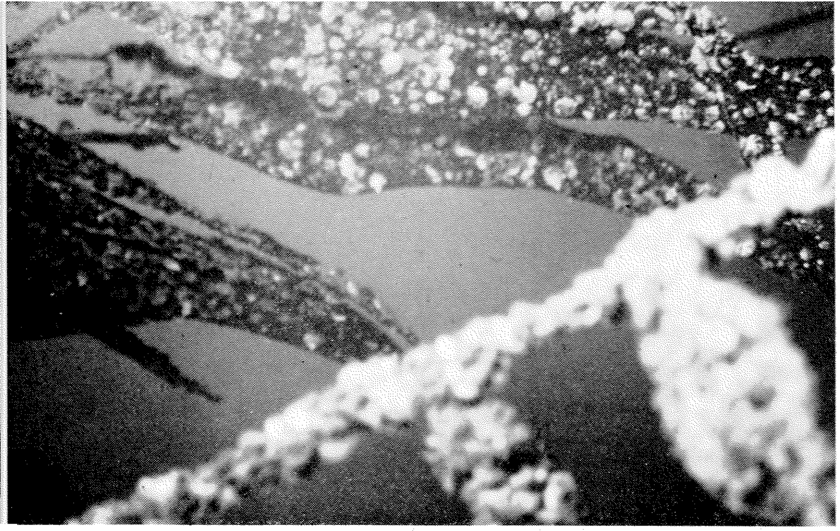
You may say that I lack a little bit of the spirit of adventure but I'm getting to be an old man and I doubt that I could change my ways. The question is, what do I mean by exciting? Well, I like a nice calm dive on a day when the ocean is nice and flat. I like to get down and see a beautiful underwater scene and enjoy it, examine it, and try to understand it. One of the things I am curious about is what makes the difference in some of these underwater environments. For instance, in certain parts of the sea it's just like landing on a desert as far as life is concerned; it's comparable to a barren pavement at 2 a.m., when there is absolutely no life at all. Other areas are teeming with creatures. Why is the ocean so rich in some areas and so impoverished in others?

I might say that this problem has great significance to man; roughly three-quarters of the population of the world is undernourished in one way or another, and if we are ever going to solve the problem of getting all the people of the world properly fed, we are going to have to turn to the sea sooner or later. This is because the area of the oceans – the land that's covered by the sea – is equivalent to 15 continents. By far the greater portion of our world lies underwater, so we must gain some kind of a comprehension of what goes on under the sea.

It has been said that in order for us to exploit the sea successfully we should stop being hunters and become farmers. But before you can farm a place you have to know what makes the soil rich, why plants grow, what plants are best to grow, and what are the most useful animals which can be handled by man in agricultural endeavors.

We know so little about the ocean that we can't hope to answer these questions all at once but we *can* begin by finding out what makes some areas rich and some areas underwater deserts. One can commence by studying the rich areas and I

"Three Exciting Underwater Environments" is a transcript of a Friday Evening Demonstration Lecture given by Dr. North, associate professor of environmental health engineering on Jan. 31.



Myriads of animals use the blades (leaves) and stipes (stems) of a giant kelp plant as a home. Sometimes the encrustations become so thick that the underlying plant is hidden. Occasionally the combined weight is so great that it causes the plant to sink to the bottom and deteriorate.

will limit myself here to three types — which could conveniently be called the swamp thicket, the garbage can, and the jagged wasteland, if we were to choose terrestrial counterparts. Under water these become the kelp beds, submarine canyons, and coral reefs and they are much more beautiful and exciting than their terrestrial stand-ins. The ocean transforms the uninteresting situations of dry land into fascinating environments through processes which we are just beginning to understand. Let's look first at the swamp thicket or kelp bed. Both are areas characterized by very dense vegetation.

KELP BEDS

Underwater vegetation is a good deal like terrestrial vegetation. If you watch a given piece of ocean bottom for a period of time, it may start out as a barren rock. Soon the rock is covered with a beginning vegetation. It is usually very short, comparable to grass on land. After this has grown a while it will gradually be replaced by larger plants, such as the long-bladed laminarians, which are comparable to small shrubs. These tend to shade the plants of shorter stature. Also, a different group of animals feeds on these larger plants. (Just as rabbits feed on grass and deer feed on shrubs, so the character of the vegetation in the ocean tends to determine what animals are present.)

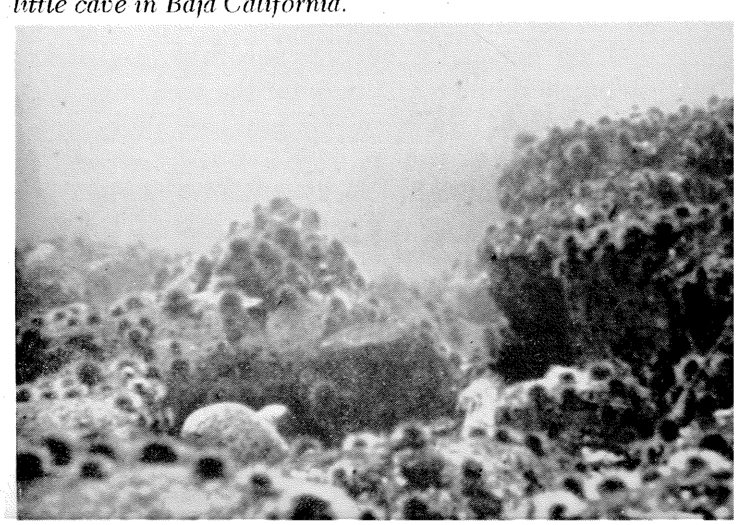
Then other plants tend to come in which are still larger — comparable to large shrubs or small trees — such as the palm kelp. When you start getting plants of this size they become quite attractive to fishes, just as the smaller size trees and the larger shrubs attract birds. Once again the character of the vegetation determines what animals are present.

Finally we get to the largest trees of the sea, which are the giant kelp plants. They grow all the way up to the surface. When they get to the surface they spread out and form a canopy which becomes so thick that sometimes light scarcely penetrates.

One of the important features of kelp is that it provides a surface for animals to roost on. Scallops and other creatures can encrust the blades of these plants to such an extent that sometimes you can't even see the kelp underneath. The ocean is very crowded with respect to available surface where animals can attach, and a kelp bed is like Manhattan Island, where you crowd a lot of people into a small space by building skyscrapers. There is roughly 10 to 20 square feet of surface provided by a kelp tree for every square foot of ocean bottom in a dense kelp bed. Certain animals love the shade provided by the kelp. Various anemones, crustaceans, molluscs, and echinoderms are shade-loving animals, as are some mid-water animals, and these creatures tend to gather in the kelp. The fishes love kelp too, and they come in and feed on all the little animals hiding in the cracks and crevasses, and roosting on the surfaces, so that the whole kelp complex forms a very rich area depending on this one plant, the giant kelp.

The kelp has enemies — particularly a destructive beast called the sea urchin. (It is eaten by Italians and Frenchmen and Portuguese, but Americans don't seem to like it, unfortunately — maybe because it looks like a pin cushion.) An army of urchins moving slowly along the ocean bottom is like a hoard of locusts. They clean everything in their path and remove all vegetation completely. These animals have little, flexible extensions called tube feet, with suckers on the end of them; if a kelp frond, waving back and forth in the currents, touches an urchin, the animal grasps it and slowly consumes it.

Swarms of sea urchins remove virtually all kelp and other vegetation from the rocks at the bottom of a little cave in Baja California.



The urchins never leave the bottom. In a few bites they can cut through the main stem of the kelp and sever the whole top of the plant so that maybe two or three hundred pounds of plant is lost to the kelp bed while only an ounce or so of plant tissue goes to feed the urchins.

After an army of urchins has finished removing all the vegetation, the grazers will move on or else they starve and die. Then the vegetation begins to come back. Fortunately, the vegetation often is restored rapidly because kelp is the fastest growing plant that has been found. Just within the last two years we have measured the growth rates and found that, at the maximum, plants grow 18 inches to 2 feet a day. The lifetime of a kelp "branch," or frond, is rather short – about six months. The base of the plant remains, however, after an old frond deteriorates and this lower part generates new young fronds from the growing tips located near the bottom of the sea. The plant thus may live for years, although the individual parts age rapidly.

The giant kelp may also be the longest plant in the world. Specimens of at least 200 feet in length have been seen locally, and kelp has been reported at tremendous lengths of 700 to 1200 feet, but these may be erroneous estimates made on drifting plants which appear to be anchored in deep water.

In no time at all a young plant can grow to the surface and, once it starts producing spores (which are the equivalent of a higher plant seed), it can seed an enormous area with new kelp. In fact, one adult plant can produce about 70 trillion spores a year.

Many of you know that kelp has been harvested off our coast for many years, but I doubt if you realize how useful are the products derived from this huge seaweed. You may have eaten kelp several times today already – in salad dressing, ice cream, beer, or other foods. You may have used it in toothpaste, pills, paint, ink, cardboard, or other forms. From man's point of view, it is a highly desirable plant.

So here, we think, is an excellent plant which man could use to cultivate the sea. It grows rapidly. It has a tremendous reproductive potential. It has been harvested as a wild crop for many years and proven useful. And many of the fishes and shellfish of the kelp beds are of economic importance. But now it is necessary for us to gain complete control of this aquatic plant, as the terrestrial farmer controls his crops. We must learn to grow it in quantity and transplant it to the sea.

Culturing and raising the tiny juveniles is quite easy, and several transplant experiments have been conducted successfully. In working with kelp transplants, we have anchored buoys to the bottom and then tied plants to them. In one instance I flew a plant 400 miles from where it was originally located in Baja California – a lovely little inlet called Turtle Bay – up to La Jolla, where I transplanted it.

Wheeler North works with a kelp transplant.

It turned out that, for some reason, this species was much more attractive to grazing animals than the La Jolla species, and these creatures would come in and very quickly eat up the transplanted kelp. So we took a La Jolla plant and tied it on the same buoy with the Turtle Bay plant to get the two to mix in with each other. But the grazers were too smart for us; the fishes and crustaceans would come in and pick out the Turtle Bay plants and eat them down to nothing, while the La Jolla plant would be left quite intact and healthy – leaving also some frustrated oceanographers looking at it.

We were particularly interested in the Turtle Bay plant because, coming from so far south, it has somewhat different physiological characteristics. It can withstand warm water much better than our northern plants. In the summer we lose a great deal of our kelp beds because the water gets too warm, so we were trying to transplant the southern strain here to see if it would interbreed and produce plants that had a little better hardiness to temperature.

Another of our experiments consisted in clearing up an area near the entrance to San Diego Bay that was covered with sea urchins until, within a few weeks, we had a nice stand of young kelp plants developing. If all these plants grow to be adults they will be so big and so thick that no diver could possibly make his way through them. There are about 20 plants per square meter. (A good thick bed ordinarily has maybe one plant every 10 square meters, so this semi-artificial bed we created is roughly 200 times as thick as an ordinary bed.) We feel that this is very encouraging and that perhaps in the near future we will be taking our first real steps at culturing kelp in the open sea off La Jolla and Point Loma.

SUBMARINE CANYONS

In most parts of the world, as the dry land comes down to the ocean, usually at a gentle beach, there is a long, broad, rather shallow stretch of bottom that goes out about one or two miles (though sometimes as far out as a hundred miles) and then starts dropping off rather sharply down to the floor of the deep sea (which averages about 12,000 feet deep). The shallow, gently sloping portion is called the continental shelf. The outer edge of this shelf is from 300 to 600 feet deep. It extends all around the margins of most continents. Periodically in the shelves there are steep gorges, many of which come right up to the land. These submarine canyons are very rich areas indeed. When you dive in them you find great flocks of fishes. The rocks are swarming with animals so that sometimes the life encrusting these rocks is up to a foot thick, with animals just piled on animals. It is hard to see how any place can sustain so much life.

A rockfish glares from his crevice home in the wall of a submarine canyon, at the insolent human taking his picture. Note heavy growths of organisms attached to cliffs. These are all sedentary animals; the depth (170 feet) is too great to allow plant development because of the dim illumination at this level.

Why are these submarine canyons so rich? As yet, we can only speculate on this. My own theory is that they are the "garbage cans" of our coast. It may seem odd that such beautiful fish should congregate around "refuse" and "garbage," but very often the garbage they eat has been converted two or three times by smaller animals and more desirable worms and other things that fishes like. Where does all this garbage come from? Here, we will have to understand how the submarine canyons are created.

There is a broad river of sand that moves continuously along the continental shelves. This is the sand that is brought into the sea by the rivers and streams of the continent. Once in the ocean, it is continually being stirred up by the waves and gently moved along the coast by the currents, like a slow-moving river. On our southern California coast the prevailing current tends to go south, so this vast movement of sand – maybe two or three miles wide and greater than the Mississippi River in its volume – slowly and majestically moves along parallel to the shore until it hits one of the submarine canyons. As it moves along it carries with it all the seaweed and the dead animal bodies and everything else that settles on the bottom. When it arrives at a submarine canyon it goes over the edge and down the axis of the canyon, so that all this organic material is concentrated in the canyon and organisms which feed on dead material come in and live there. This is undoubtedly an important source of food that provides for the rich communities that dwell in submarine canyons. I should add that the material arriving from the shelf tends to accumulate in the upper portions of a submarine canyon for perhaps months until it suddenly becomes unstable and sweeps out down the canyon like a tremendous avalanche. Such processes are called turbidity currents and are considered important factors in eroding the canyons.

So, another way in which we could create our own rich areas would be to trap the sand, trapping the organic substances that flow in it, to provide our own "garbage dumps." Here the material could accumulate under controlled conditions and provide enrichment for forms like the larger fishes which man can use.

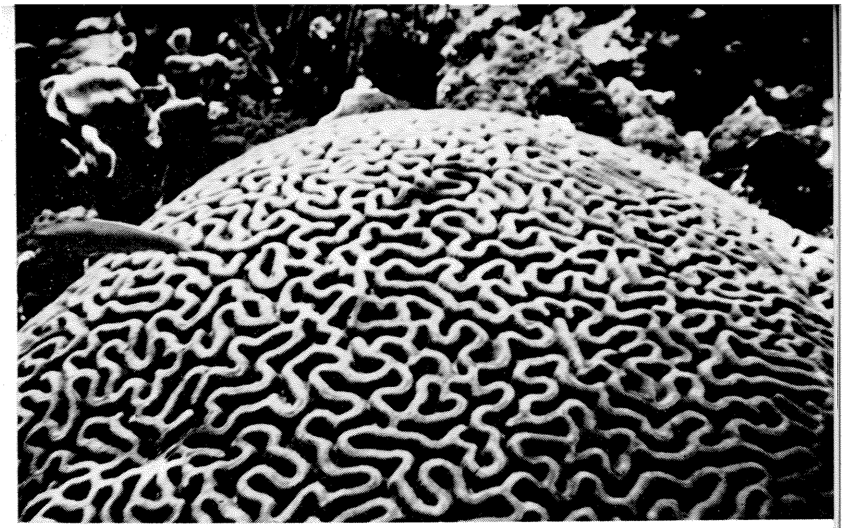
CORAL REEFS

Coral reefs, like submarine canyons, are some of the most fascinating places on earth. Sea fans, sponges, soft corals, hard corals, and molluscs form the base for a very complex community. The rich abundance of life here is reminiscent of the submarine canyons; animals live all piled up and encrusted on each other. Nonetheless, it is a jagged wasteland if you hunt for the plants which presumably are necessary to support this complex community. When you watch schools of fishes to see what they are eating you find they are feeding on little animals that live in the cracks and crevasses in the coral reefs. Some fishes actually bite the coral itself and chew off hunks of it. The coral reefs are filled with noises and crackling. For example, certain fishes are called grunts because they grunt, I guess, if you disturb them. (They are very common in the Florida Keys, and it is said that the early settlers there used to live on grits and grunts.)

All these smaller fishes are the intermediates in the food chains in the coral reefs. Some larger animals – such as the groupers, octopus, and sharks – are often very abundant in coral reefs. They feed on the smaller size fishes.

So we have these very elaborate communities. But there are very few plants in the area. This has caused people to puzzle for years about what was nourishing all this animal life. Animals depend basically on plants. The herbivores, or plant-eating animals, get their nourishment on the land, as in the sea, from plants. Plants get their nourishment from sunlight, of course. The carnivores eat the herbivores and the top carnivores, such as the shark, eat the lesser carnivores. But the puzzle remains: Where are the plants or other basic nourishment for this rich "jagged wasteland"?

Two brothers, Howard and Eugene Odum, started taking coral apart on a windward reef in Eniwetok Atoll recently and found that deep down inside the coral there were a variety of plants. They estimated the photosynthesis by this vegetation and concluded that it was an important source of the nutrition for the entire reef. Some of these little plants actually live right in the tissues of the coral, and it has been shown that these plants photosynthesize; they make chemicals that are extruded into the bodies of the corals and actu-



Large hemisphere formed by brain coral is one of the most massive components of the coral reef. This specimen, at Alligator Light in the Florida Keys, was about six feet in diameter.

ally support the growth of the corals. The coral, in turn, provides protection for the plants.

Other plants live even deeper down in the skeleton of the coral and these account for a good deal of the basic nutrition of the coral reef, but they could not account for all of it. The answer comes when you examine the water itself. Scientists have found out that the ocean is like a dilute soup; the water contains much nutritious material, and forms of microscopic life are suspended in the water. Many coral reefs exist where swift currents flow by. These currents are constantly washing the reef with fresh nutrient soup and the tiny coral animals extrude their tentacles and filter the water as it flows by, thus deriving additional nourishment. This type of feeding is called filter feeding. We are not clever enough to be filter feeders ourselves yet – which perhaps is fortunate, because the microscopic life suspended in seawater tastes terrible.

These microscopic forms are called plankton and in coral reefs there exists this food chain of the tiny, floating, microscopic plants; then the somewhat larger corals which are feeding on the plants; then the small fishes which are feeding on the corals; and then the larger carnivores feeding on the small fishes. So we have three stages in our food chain.

There is one animal which telescopes the food chain – the whale. The whale is a huge animal which has learned how to feed on plankton; it carries a fine sieve in its mouth. If we could learn to telescope this food chain like the whale does, we could get out away from the continental shelves and the kelp beds and the submarine canyons and really get at the most abundant plants of the sea, the tiny plankton. These constitute the true pastures of the great and wide oceans.