THE ENDLESS VOYAGE

"Living Together" Episode 123

In the 20th century, looking at the field of Marine Biology in particular, one of the big discoveries was the discovery of hydrothermal vents in the late 1970's. This was an enormous revolution.

From the top of the ecosystem, which are the large sharks, all the way down to the bottom, which are bacteria, there's millions of bacteria on the reef. There are just so many things out there that in fact, we don't know exactly how many there are.

Because estuaries are the border between land and the ocean, there's a lot of organic material and nutrients available in estuaries. So estuaries are very productive regions in terms of plant life and plankton and the animals that live there

NARRATOR:
FOR THOSE WHO DIVE IN THE VICINITY OF CORAL REEFS, THE EXPERIENCE IS SAID TO BE AWE-INSPIRING, EVEN MYSTICAL. THE BEAUTY OF THE REEF IS UNPARALLELED IN THE MARINE ENVIRONMENT AND PERHAPS ANYWHERE ON PLANET EARTH. SOMETIMES REFERRED TO AS THE RAIN FOREST OF THE SEA, THESE MAGNIFICENT STRUCTURES ARE HOME TO A DIVERSE ARRAY OF PRODUCERS, CONSUMERS AND SCAVENGERS. COLLECTIVELY, THESE COMPRISE A DYNAMIC ECOSYSTEM THAT IS IN EVERY SENSE OF THE WORD A COMMUNITY.

RICK GRIGG, Ph.D., University of Hawaii at Manoa:
Well, you see birth, life, death, just like in any community, organisms living together interacting. There's predation, there's competition. There's disease. There's physical disturbance. There's storms that come along and kill off a reef, and set it back in such a way where it has to begin growing all over again. It's a very dynamic place. Most people think a reef is like the Garden of Eden. It's a very stable, benign place where everything stays the same. That's very completely wrong. Coral reefs are constantly changing.

CHIP FLETCHER, Ph.D., University of Hawaii at Manoa:
Many coral reefs actually are not dominated by coral, as much as they are dominated by coralline algae. Now coral is an animal. It grows in the form of a polyp that secretes a solid coating composed of calcium carbonate that it gets out of the dissolved components—chemical components of sea water. Coral likes to grow as a community member, and so it will grow sort of an apartment building or a community structure, composed of hundreds of coral polyps, each secreting their own exoskeleton. Coralline Algae, however is—it's a plant. It is photosynthetic, and there are two types of algae that are important in coral reefs or in reefs. Both of these types of algae secrete the same sort of calcium carbonate—hard mineralogic material—that the coral will secrete. There is coralline algae, which is the plant that looks similar in growth form and in color to many

types of coral. And there's calcareous algae, which is something that looks much more like a plant. It has leaves and a stalk and it's green. It's photosynthetic. But when it dies, it calcifies. It turns into a white, hard mineral material of calcium carbonate.

NARRATOR:
THE RELATIONSHIP BETWEEN SOME OF THE ALGAE AND ANIMALS THAT LIVE IN CORAL REEFS IS SYMBIOTIC, MEANING THE TWO SPECIES LIVE TOGETHER.

WILLIAM HAMNER, Ph.D., University of California, Los Angeles:
The plant cells get protection from their potential herbivores by being inside the animal. And the animal benefits because the plants photosynthesize and construct more short-chain sugar compounds than they need themselves. And the animal actively digests those short-chain sugars. So the plants are feeding the animal.

NARRATOR:
TWO OTHER CORAL REEF RESIDENTS, ANEMONES AND ANEMONE FISH, ALSO PROVIDE SOMETHING OF VALUE TO ONE ANOTHER.

LISA A. LEVIN, Ph.D., Scripps Institution of Oceanography, UCSD:
The anemone helps defend the fish through its stinging tentacles—nematocysts. The fish lives in right in amongst those tentacles, and receives refuge from predators. The fish itself also helps defend the anemone, darting out and attacking intruders, and also may provide the anemone with food.

NARRATOR:
THE MUTUALLY BENEFICIAL, SYMBIOTIC RELATIONSHIP BETWEEN MEMBERS OF CORAL REEF OR OTHER COMMUNITIES IS KNOWN APPROPRIATELY ENOUGH, AS MUTUALISM. BUT SYMBIOSIS CAN TAKE OTHER FORMS AS WELL. PERHAPS THE LEAST COMPLEX OF THESE IS COMMENSALISMS, IN WHICH TWO SPECIES LIVE TOGETHER, BUT HAVE LITTLE OR NO IMPACT OR ONE ANOTHER. AND THEN THERE'S PARASITISM—ALSO A KIND OF SYMBIOSIS, BUT WITH A DECIDEDLY ONE-SIDED OUTCOME.

LEVIN:
This is a case where one species is living off a host, gaining nutrition from a host. Usually it is harmful to the host, so it's a plus-minus relationship. Typically, parasites will not kill their hosts. It's not beneficial to do that, but they may harm their hosts. There are parasites on crabs that will inhibit reproductive activity. There are parasites on plants that sometimes will cover the photosynthetic surfaces and inhibit photosynthesis.

JAMES NYBAKKEN, Ph.D., Moss Landing Marine Laboratories, CSU:
If it's an obligate parasite, that is, in other words, the parasite doesn't exist unless it is in the host, it doesn't do the parasite any good to have such a deleterious effect on the host that the host dies or is preyed upon by something else, because that kills the parasite at

the same time. So that's why you need this, sort of, adjustment between the parasite—how much damage can the parasite do and still maintain itself and maintain the host?

The relationship between a host and its parasites is very fine-tuned. If the parasite becomes too numerous and becomes too harmful to the host, the host populations will decline, and the parasites will face a shortage of hosts and then themselves go into decline.

NARRATOR:
WHILE SYMBIOTIC RELATIONSHIPS ARE IMPORTANT IN MANY MARINE COMMUNITIES, THEY PLAY AN ESPECIALLY CRITICAL ROLE IN CORAL REEFS. BUT SYMBIOSIS WITHIN A REEF COMMUNITY CAN BE THREATENED BY ANY NUMBER OF FACTORS INCLUDING SEVERE STORMS AND A PROCESS KNOWN AS BLEACHING.

MICHAEL FOSTER, Ph.D., Moss Landing Marine Laboratories, CSU:
People are seriously worried about the impacts of global warming on coral reefs. The corals are not really just animals. They also have symbiotic algae in them that live in their tissues, and are very actively involved in their metabolism. So it really is a mutualistic relationship. When corals bleach, they expel those algae, and they are at a severe disadvantage then in gaining nutrients. And so, if that bleaching occurs over a long enough period, the coral-animal part of the relationship dies. And there's good evidence now that that is to some extent related to temperature.

NARRATOR:
CORAL REEFS ARE ALSO EXPOSED TO A NUMBER OF OTHER THREATS INCLUDING NUTRIENTS USED IN FARMING AND AGRICULTURE.

FOSTER:
…And as you add nutrients, commonly what happens is that the nutrients stimulate the growth of seaweeds, which grow over the coral and kill it. And they're now at sort of an increasing recognition that some places in the tropics, the coral reefs are being degraded by nutrient discharges from the land, either sewers or runoff from agricultural fields. So, all those things sort of combined actually sort of…paint a fairly bleak picture for the future of coral reefs.

NARRATOR:
CORAL REEFS ARE NOT THE ONLY MARINE COMMUNITIES THAT ARE VULNERABLE TO HUMAN ACTIVITY. ESTUARIES AND SALT MARSHES, WHICH ARE FOUND AT THE INTERSECTION OF FRESH WATER SOURCES AND THE OCEAN, FACE SOME OF THE SAME PROBLEMS. THE CONSEQUENCES OF THIS CAN BE QUITE SEVERE, BECAUSE LIKE CORAL REEFS, THESE COASTAL AREAS WHEN HEALTHY CONTRIBUTE A GREAT DEAL OF PRODUCTIVITY TO THE MARINE ENVIRONMENT.

ANTONY ORME, Ph.D., University of California, Los Angeles:
Estuaries represent a wide variety of habitats, in part because they represent the mixing of fresh and salt water, and therefore we have a range of salinities from purely fresh through brackish to salt, and this favors different types of organisms. And these kind of small organisms often favor different types of fish, birds, and different types of plants, and so on. And therefore you have a great variety of ecosystems within an estuarine environment.

Those are very productive systems. That is, the plants grow very well. There's usually lots of nutrients and lots of light—very shallow water. When those plants degrade or die, they provide a detritus—organic matter—which is used by a whole variety of organisms. The systems that are reasonably intact, or portions of systems intact, it's been well-documented that these detrital food chains are extremely important.

LEVIN:
Estuaries host a full range of species, from bacteria to fish and sometimes even marine mammals. Typically among the larger invertebrates we'll find many crustaceans, decapods, such as shrimp or crabs, and we'll find quite a few annelids. Polychaetes are common in the sediments. Mollusks, such as clams and mussels, and oysters also can be common in estuaries. Among the fish we have a wide range of species, many of which use estuaries as nursery grounds, and spend their adult life offshore, in a major current system like the Gulf Stream.

NARRATOR:
LIKE MANY CORAL REEFS, ESTUARIES CAN BE ADVERSELY AFFECTED BY THE NUTRIENTS USED IN FARMING AND AGRICULTURE.

RICHARD ZIMMERMAN, Ph.D., Moss Landing Marine Laboratories, CSU:
Eventually those nutrients make their way downstream into the watershed, and cause problems in coastal waters, where they can eutrify the waters, and this results in blooms of nuisance algae, both phytoplankton and macro algae, that change the structure and functioning of these coastal ecosystems. They can lead to fish kills. They can lead to anoxic waters. They can lead to die-offs of other organisms.

NARRATOR:
IN SOME CASES, ESTUARIES AND WETLANDS HAVE BEEN THREATENED SIMPLY BECAUSE OF THEIR PRIME COASTAL LOCATION IN A CROWDED WORLD THAT IS STARVED FOR SPACE.

FLETCHER:
The need for space, simply the footprint needed to put buildings and houses has led to the filling of wetlands, and filling wetlands occurs where you bulldoze in sand or soil so that you can build a house on a wetland. And this has decreased the surface area of wetlands.

For instance, I think something like 80 to 90% of the salt marshes in San Francisco Bay, for example, have been eliminated and filled, to make salt ponds or to graze cattle, or

whatever. The consequences of that is that whatever functions those habitats had are gone.

FLETCHER:
The food chain is impacted. The food chain starts with the smallest organism, leads to the largest organism and so impacting the food chain like this can have repercussions all the way out into the open ocean, where the large pelagic fish no longer have a robust, smaller-scale food chain to rely on.

NARRATOR:
WHILE MARINE COMMUNITIES ARE CLEARLY THREATENED IN SOME CASES BY HUMAN ACTIVITY, NATURAL PROCESSES CAN ALSO POSE SIGNIFICANT DANGERS. THIS IS ESPECIALLY TRUE IN THE ROCKY INTERTIDAL ZONE.

JUDITH McDOWELL, Ph.D., Woods Hold Oceanographic Institution:
The intertidal zone is that are of the shoreline that is exposed during the tides. Area along this beach will be submerged by water part of the day and exposed to the air part of the day. The actual features of the intertidal zones will change as the tides change daily within the lunar cycle.

NARRATOR:
AS WITH CORAL REEFS AND ESTUARIES, THE INTER TIDAL ZONE CONTAINS A RICH ABUNDANCE OF DIVERSE ORGANISMS. THERE ARE A NUMBER OF REASONS FOR THIS.

MICHAEL LATZ:
One is that there's a lot of habitat available. In other words, there's a lot of surfaces that can be colonized by organisms. There are many cracks and crevices. And so there's open, exposed regions, there are more protected regions. So there's a lot of area available for animals to live and plants to live on. Another reason that intertidal zones are so productive is that they are obviously associated with land, and so they receive nutrient runoff from land. And so there's usually high amounts of nutrients, which promotes growth of the primary producers. And a third reason is that there is mixing by the waves, and this promotes access of nutrients to the organisms and also gas exchange. So, it really is in one way a very good environment for organisms to live in.

NARRATOR:
A GOOD ENVIRONMENT BUT ONE THAT PRESENTS SOME MAJOR CHALLENGES.

STACY KIM, Ph.D., Moss Landing Marine Laboratories, CSU:
The rocky intertidal is a pretty tough habitat to live in. The animals there undergo not only a lot of wave stress from the waves pounding on them, but there's also a desiccation stress.

McDOWELL:
You have the complications of being exposed to air—in the summertime extreme heat, in the wintertime extreme cold. You have the challenges of not acquiring enough oxygen, not being able to acquire enough food during periods of low tide. So organisms that live within the intertidal zone must adapt to both aerial exposure as well as aquatic exposure.

NARRATOR:
THANKS TO A VARIETY OF ADAPTATIONS, MANY ORGANISMS MANAGE TO NOT ONLY SURVIVE, BUT TO THRIVE IN THE INTERTIDAL ZONE.

McDOWELL:
Some of the interesting adaptations of organisms in the intertidal can be represented by just a couple of examples. Periwinkles, small snails, there are many different species of periwinkles that live along the shoreline. Some that dominate the splash zone or very upper reaches of the intertidal zone would actually drown if they were submerged in water for too long. They have so adapted their respiratory system to this combination of aerial exposure oxygen diffusing into their respiratory surfaces from just moist air, to those snails which live in the lower intertidal, which are found very abundantly on large beds of rockweed and other types of seaweed.

NARRATOR:
AS IF THE RIGORS OF WAVE ACTION AND FLUCTUATING TEMPERATURE WEREN'T ENOUGH, ROCKY INTERTIDAL ORGANISMS MUST ALSO FACE ANOTHER MAJOR CHALLENGE: COMPETITION.

Organisms compete with each other for any kind of a limiting resource, so that can be food, that can be space. That can be mates if they're of the same species.

LISA A. LEVIN, Ph.D., Scripps Institution of Oceanography, UCSD:
There are two forms of competition among marine organisms referred to as exploitative and interference competition. Interference competition involves direct contact or chemical contact between organisms. One species might overgrow another, or secrete some allelochemicals, nasty chemicals that inhibit the activities of another. In contrast, exploitative competition refers to a situation where one species uses a resource and therefore makes it unavailable to another species. For example, a species that grows up and spreads out to intercept light—a plant species—and shades the area below is exploiting the light resource and anything that tries to live underneath it, that's a plant, might not make it.

JAMES NYBAKKEN, Ph.D., Moss Landing Marine Laboratories, CSU:
So, the competition is for the resource which is in the least supply or the smallest supply, that happens to be space. And so, now, if something has the ability to dominate the space, in other words, it will out-compete everything else and get rid of them, then it will own the space. It will be the dominant organism. The marine environment is full of little stories like that—of the example of competition actually determining what happens. And we've done a lot of the intertidal because, of course, the intertidal is so accessible. A lot

of marine ecology, paradigms and so on have all been established by working in the intertidal because it's easy to get to.

NARRATOR:
CLEARLY, CORAL REEFS, ESTUARIES AND THE ROCKY INTERTIDAL ZONE ARE HOME TO AN IMPRESSIVE ASSORTMENT OF DIVERSE ORGANISMS. BUT THERE IS ANOTHER MARINE COMMUNITY THAT IS TRULY UNLIKE ANY OTHER IN THE WORLD OCEAN. IT'S FOUND IN PLACES THAT WEREN'T EVEN KNOWN TO EXIST UNTIL THE MID 1970'S, WHEN THE SUBMERSIBLE ALVIN MADE THE STUNNING DISCOVERY OF HYDROTHERMAL VENTS.

DONAL MANAHAN, Ph.D., University of Southern California:
Hydrothermal vents in the oceans exist at the interface of big tectonic plates. As these plates move they change the physical characteristics of the plates and they create small cracks through which hydrothermal vent fluids from deep in the center of the Earth diffuse up. When these fluids come up, they superheat seawater, and that seawater comes out as black. And people refer to it as black smokers. You get super hot sea water at temperatures as high as 400° often coming out thick black smoke, it looks like, but actually it's full of sulfur. And this sulfur compounds form the bases of a chemosynthetic life food chain of hydrothermal vents.

NARRATOR:
BECAUSE HYDROTHERMAL VENTS ARE LOCATED AT A DEPTH OF ANYWHERE BETWEEN 2,000 AND 4,000 METERS, PHOTOSYNTHESIS IS IMPOSSIBLE. BUT THE ORGANISMS IN THAT REGION HAVE FOUND A WAY AROUND THAT SEEMINGLY VEXING PROBLEM.

KIM:
Plants on the surface of the earth use sunlight as an energy source to create compounds. And the microbes in bacteria that live at hydrothermal vents use hydrogen sulfide as an energy source to build carbohydrates. And these bacteria at hydrothermal vents are the base of the food web there.

NARRATOR:
MOST OF THE DEEP-SEA IS CHARACTERIZED BY ITS RELATIVE STABILITY, AND BY THE SMALL AMOUNT OF FOOD THAT DRIFTS DOWN FROM THE SURFACE. THE HYDROTHERMAL VENT ENVIRONMENT, HOWEVER, IS ENTIRELY DIFFERENT.

JAMES CHILDRESS, Ph.D., University of California, Santa Barbara:
In the hydrothermal vents we have environments that may last for two, three, four, five years, very short-lived environments. Food is very abundant. They have tremendous biomasses. You can have, you know, 40 or 50 kilograms of animals in a square meter. Where, if you're looking at the rest of the deep-sea, you'd be looking at a few grams at the most in that space.

By some estimates in hydrothermal vents there are hundreds of species that are unique to vents, not found anywhere else on planet Earth.

The primary producers—the ones with the chemosynthetic symbiants are the tubeworms, the mussels, the clams, and some large snails are the main ones. There are also some shrimp in the Atlantic that culture bacteria on their surfaces, and they eat those. And then, besides that, there are a variety of other animals that feed on those animals or feed on bacteria that just coat the surface of the animals. So, there are a variety of snails. There are fish, there are crabs, shrimp, some octopus. Pretty wide variety of stuff.

NARRATOR:
OF ALL THE ANIMALS WHO RESIDE IN THE HYDROTHERMAL VENT ENVIRONMENT, THE TUBEWORMS ARE PERHAPS THE ONES MOST CLOSELY IDENTIFIED WITH THIS REGION.

MANAHAN:
These worm tubes can be six feet long although the worms in size are a good deal smaller than that, but they set up in big clumps of organisms called tubeworm colonies that live not right at a hydrothermal vent in the super heat because they would be barbequed by that, but just away from it. They comfortably like to live, in temperatures of maybe 10° centigrade. It's a comfortable temperature in the sense that it doesn't damage the tissues, but most importantly there's enough sulfur around for the bacteria to be able to go through the symbiotic relationships with them.

KIM:
The tubeworms have—their blood is circulating near the microbes, and the microbes are excreting compounds that the tubeworms can then feed upon. So, it's still a blood circulation, just like the blood circulates by your intestines and picks up compounds that you need to live and to grow. The same thing happens with the blood circulating in the tubeworms. It's just they don't have a stomach to circulate by. Instead it circulates by all of these symbiotic bacteria.

NARRATOR:
AS WITH COMMUNITIES ON LAND, THOSE IN THE MARINE ENVIRONMENT ALL HAVE THEIR OWN UNIQUE TRADEMARKS. AND YET, THEY SHARE A NUMBER OF CHARACTERISTICS AS WELL. SYMBIOSIS IS CERTAINLY ONE. A TENDENCY TO COMPETE IS ANOTHER. BUT PERHAPS THE MOST FUNDAMENTAL ELEMENT THAT NEARLY ALL COMMUNITIES HAVE IN COMMON, IS THAT THEY DON'T REMAIN STATIC VERY LONG.

As with anything in ecology, nothing is really static. Communities are dynamic systems. They change—they change all the time.

Communities are pretty much always dynamic because there's always births and deaths and immigration and emigration going on. So the animals are moving around, plants are living and dying. There's always change that's occurring.

But the time scales over which they change may vary from daily or diurnally, to extremely long time scales thousands or even millions or years. So if we look at a place-based community such as a tidal flat, we'll find a different group of organisms living there when the tide is in than when the tide is out. So, in that sense, the community can change every 6 to 12 hours.

MYBAKKEN:
You can have communities change because of natural disasters, for example, hurricanes in the tropics. One of the biggest devastators of coral reefs are hurricanes—they're natural disasters. And when a hurricane hits, for example, you break up the coral. You may create new areas for some other organisms to come in, or different corals to come in.

NARRATOR:
AND YET, EVEN AS INDIVIDUAL MEMBERS COME AND GO AND THE NUMBER OF SPECIES CHANGES, OFTEN ALONG WITH THE ENVIRONMENT IN WHICH THEY LIVE, MARINE COMMUNITIES WAGE A DETERMINED BATTLE TO ENDURE. THOSE WITH THE BEST CHANCE FOR SURVIVAL USUALLY BOAST IMPRESSIVE BIODIVERSITY.

Biodiversity refers to the numbers of species and the relative abundance of different species within a community.

STACY KIM, Ph.D., Moss Landing Marine Laboratories, CSU:
So when you have a disturbance that comes in and for example a disease that knocks out one species in a community, if it's a very diverse community, that knocking out one species won't really change the entire community structure.

One example of where it might be important could be resistance to invasion. It's thought that invasion by alien species might be more likely to occur in a low than a high diversity community.

MICHAEL LATZ, Ph.D., Scripps Institution of Oceanography, UCSD:
In the ocean environment, there are many types of organisms. So the bio diversity is very high compared to other communities, say, on land. So, inherently, there is high biodiversity in the ocean. This is threatened by processes such as global warming. There is very intense pressure on coastal communities by human activity, and so we're very concerned about changes in biodiversity. This is an index of environmental change, and perhaps a signal that we are having effects that are global for the entire planet.

NARRATOR:
THE QUESTION, OF COURSE, IS HOW EXTREME THOSE EFFECTS ARE LIKELY TO BE. COMMUNITIES IN THE MARINE ENVIRONMENT

GENERALLY MANAGE TO SURVIVE MOST THREATS, AT LEAST THOSE POSED BY OTHER RESIDENTS OF THE WORLD OCEAN, AND NATURAL PROCESSES LIKE SEVERE STORMS. AS TO WHETHER THEY'RE EQUIPPED TO OVERCOME THE RIGORS OF TERRESTRIAL ACTIVITY, THAT IS A VERY DIFFERENT QUESTION—ONE THAT PROBABLY WON'T BE ANSWERED, FOR QUITE SOME TIME.

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