THE ENDLESS VOYAGE

"Going to Extremes" Episode 109

Most people think a reef is like a Garden of Eden. It's a very stable, benign place where everything stays the same, where it's stable all the time. That's completely wrong.

The controversies about gasses in our atmosphere—chlorofluorocarbons, ozone depletion, CO2, global warming—Antarctica plays an enormous role in this.

The challenge of working in an environment where it's dark 24 hours a day, very cold because there's very little sunlight to warm things up, and the challenges of enduring crunching through what's often times 100% ice cover in an icebreaker is a loud, uncomfortable experience.

NARRATOR:
THE SOLAR SYSTEM—A SMALL CORNER OF THE MILKY WAY GALAXY MARKED BY EXTREME CONTRASTS, FROM THE SEARING HEAT OF MERCURY AND VENUS TO THE NUMBING COLD OF THE GAS GIANTS AND BEYOND. EVEN HERE ON THE MORE MODERATE PLANET EARTH, THERE ARE EXTREMES, FROM THE FROZEN TERRAIN OF THE POLAR REGIONS TO THE TEMPERATE, BLUE WATERS OF THE TROPICS.

CHIP FLETCHER, Ph.D., University of Hawaii at Manoa:
The tropics are officially designated as the area between the Tropic of Cancer and the Tropic of Capricorn, which are about 23 degrees North and South latitude. The tropics are typically characterized by higher sunlight, radiance and the seas are warmer. So you get a different type of marine fauna and flora that will form ecosystems in these warmer tropical seas.

NARRATOR:
DESPITE THE MODERATE CONDITIONS IN THE TROPICAL OCEAN, PRODUCTIVITY, THE PRODUCTION OF FOOD MOLECULES BY PHOTOSYNTHETIC ORGANISMS, IS RELATIVELY LOW, BECAUSE NUTRIENTS ARE NOT ABUNDANT AT THE OCEAN SURFACE.

PETER RHINES, Ph.D., University of Washington:
If you look at one of these beautiful color images of the ocean biology, you'll see beautiful demarcation of the living ocean and the almost dead ocean, or the not-so-productive ocean. Blue—the deep, powder blue of the subtropical oceans is the color of the ocean desert. It's not entirely lifeless, but it's certainly lower in productivity than the higher latitude oceans or the strip along the equator.

NARRATOR:
DESPITE FREEZING OR NEAR-FREEZING CONDITIONS, THE POLAR REGIONS BOAST SOME OF THE WORLD'S MOST PRODUCTIVE WATERS.

RICK GRIGG, Ph.D., University of Hawaii at Manoa:
During the summer, the sun is 24 hours in duration, so you get tremendous production in the water column. Phytoplankton blooms and the seas are just teeming with life. They're just rich. Whereas, in tropical seas, it's pretty much barren, almost devoid, sterile sea.

DONAL MANAHAN, Ph.D., University of Southern California:
In the Polar Regions, the light is such a dominant factor, in the availability of light that the season is fairly narrow in terms of when this productivity occurs. And we have very large phytoplankton blooms in and around the large, receding ice edge as the ice is melting in the summer. Those are very active biological zones. You see lots of seals there, lots of whales, lots of zooplankton, and all of the food chain that lives on the bloom of phytoplankton when this occurs in the spring early summer time-frame in the Polar Regions.

NARRATOR:
WHILE THE ELEVATED PRODUCTIVITY IN THE POLAR REGIONS CAN BE EXPLAINED IN PART BY THE NEARLY FULL-TIME PRESENCE OF LIGHT DURING SIX MONTHS OUT OF EVERY YEAR, THERE ARE ALSO OTHER FACTORS AT WORK.

ERICH HORGAN, Woods Hole Oceanographic Institution:
In terms of the productivity in comparing equatorial regions and the Polar Regions, we are not seeing as much of the nutrient-rich dense water being brought to the surface in equatorial regions as we are in Polar Regions. It's difficult because of circulation patterns to get as much of this nutrient rich, fertilized water, if you will, into the sunlit shallow areas of the world's oceans where the phytoplankton can benefit and bloom. In the world's Polar Regions, particularly in the southern ocean, upwelling is the standard of the day. And it is why the Antarctic region is so rich productivity-wise—why there's so much krill, why there can be so many salps, why so many whales swim down there to spawn. There's just so much food available for the entire food web to take advantage of, due to the upwelling and due to the incredible amount of mixing of cold, fertilized deep water being brought to the surface through the process of upwelling and some other processes.

NARRATOR:
ALTHOUGH THE TROPICAL SEAS LACK THE AVAILABLE NUTRIENTS AND RICH PRODUCTIVITY OF THE POLAR OCEANS, THEY CONTAIN SOME OF THE MOST UNIQUE COMMUNITIES FOUND ANYWHERE ON EARTH—THE MAGNIFICENT STRUCTURES KNOWN AS CORAL REEFS.

GRIGG:
Just the beauty of a reef—if you've ever dived on it, it's overwhelming. You're awe inspired. Reefs are one of the most, I think, significant communities on Earth.

NARRATOR:
CORAL REEFS ARE COMPOSED OF A FASCINATING AND DYNAMIC COMBINATION OF LIVING ORGANISMS, PLANTS, AND OTHER MATERIALS.

CHIP FLETCHER, Ph.D., University of Hawaii at Manoa:
Many coral reefs, actually are not dominated by coral as much as they're 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 seawater.

Corals are very similar to sea anemones. They're in the same phylum as sea anemones. They're very primitive animals.

FLETCHER:
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:
IN ADDITION TO THE CORAL AND THE ALGAE, CORAL REEFS ALSO CONSIST OF SEDIMENTS—SAND AND SILT PRODUCED WHEN THE ORGANISMS THAT LIVE ON THE REEF DIE.

FLETCHER:
The sands and silts that are associated with reefs are largely a product of Halimeda, coralline algae, and then, secondarily, bits of coral and other organisms on the reef—echinoderms, mollusks or seashells and things like that. Those sands are an important part of the reef system. And not only the geologic system of the reef, but the ecosystem of the reef.

NARRATOR:
PERHAPS THE MOST STRIKING ASPECT OF CORAL REEFS IS THEIR EXTRAORDINARY DIVERSITY.

GRIGG:
Coral communities are sometimes called the rainforest of the sea. And this is because they're so diverse. In Hawaii we have maybe 5,000 different kinds of species living on a reef—any given reef. But in Indo-West Pacific, where we have the richest diversity in

the world, the reefs might contain 50,000 species—different kinds of organisms, from plants to invertebrates to fish.

NARRATOR:
ALONG WITH THEIR BIOLOGICAL DIVERSITY, CORAL REEFS ALSO BOAST IMPRESSIVE STRUCTURAL DIVERSITY.

FLETCHER:
You can have branching coral, which can be rather delicate and easily broken and hence, won't be growing in shallow water influenced by waves. You can have platy coral, which grows in deeper water. These are great solar panels of coral that accumulate the lesser amount of sunlight that you find in deeper water. You also have more robust forms of coral growth, such as encrusting coral, which is just a thin layer of coral that's laid down, and can resist the abrasion of sands in high energy waters and the pounding associated with waves breaking. And you have doming coral or coral patches or coral heads that can grow. These tend to be fairly robust and can withstand moderate wave energy, but they can be broken off at the base under extremely high wave energy. So coral reefs, like beaches and all coastal environments, are a reflection of the energy that's incident to them, and the materials that are available to them, and, in the case of coral reefs, the chemistry of the waters.

NARRATOR:
THE POLAR REGIONS CAN'T COMPETE WITH TROPICAL REEFS IN TERMS OF SPECIES DIVERSITY. BUT THEY DO PROVIDE A HOME TO A BROAD RANGE OF ANIMALS, WHICH HAVE MANAGED TO NOT ONLY SURVIVE, BUT FLOURISH IN CONDITIONS THAT ARE FREQUENTLY HARSH AND UNYIELDING.

If you swim in tropical regions, you have coral reefs. You have an enormous biological diversity of plant life and fish life. When you go to the Polar Regions it's—the diversity is there, but it's a lot more subtle.

GEORGE MATSUMOTO, Ph.D., Monterey Bay Aquarium Research Institute:
When you think about fish, a lot of people think about coral reefs and the beautiful colored fish out there, but fish live everywhere. For instance, there are fish that live in the Antarctic and in the Arctic waters. And they've adapted for their cold environments, and the way they do that is they actually put a form of ethylene glycol into their blood—antifreeze—the same as we put into our cars, they've got in their bloodstreams—and that keeps their blood from freezing up in these extremely cold environments.

NARRATOR:
BUT EXTREME TEMPERATURE IS NOT THE ONLY CHALLENGE CONFRONTING POLAR ORGANISMS.

MANAHAN:
A very interesting question about the seasonality of the Polar Regions is, if light is not there for say six months of the year, what happens to life? Well, obviously photosynthesis can't proceed without light. And then all the organisms that would live on these plant forms would be faced with potentially starvation conditions.

STACY KIM, Ph.D., Moss Landing Marine Laboratories, CSU:
The animals have different strategies for dealing with the lack of food during the winter months. Some animals simply migrate away. So, a lot of the larger animals that can swim fairly fast—the marine mammals, some of the larger birds—just swim up to another area and they make a living. There's not as much food in that area, but there's enough for them to keep going through the winter months. Other organisms just tough it out. They're adapted to deal with a very seasonal—high seasonal variability in the amount of food that's available. And so they either go into hibernation, or some parallel of hibernation where they just simply do not feed during the winter months and they have very low metabolic rates, and they're just sticking it out until the summer comes again, and all that food comes in and they eat like crazy and they reproduce like crazy and then they basically just go back to sleep.

DONAL MANAHAN, Ph.D., University of Southern California:
Let's take a famous example of Antarctic krill. It is felt that they are able to winter over by taking in large amounts of food when food is available, and storing it as lipids and so forth. And then, there's some debate as to how they actually regulate their metabolism and where they actually live under ice floes during this period. But the sense is that they can just basically go through a winter over almost starvation conditions for many months pending the next bloom.

NARRATOR:
THE TROPICAL SEAS AND POLAR REGIONS ARE SUBJECTS OF ENDLESS FASCINATION, IN PART BECAUSE THEY REPRESENT UNIQUELY DIFFERENT EXTREMES IN TERMS OF PHYSICAL CONDITIONS. BUT THEY ARE UNIQUE IN MANY OTHER WAYS AS WELL.

FLETCHER:
The geology of coral reefs is a subject of active research around the world. Reefs are dipsticks, in a sense, of past positions of sea level. And past movements of sea level is a reflection of past climate because, as glaciers grow and retreat around the world in association with ice ages and warm periods coming and going, sea level will rise and fall.

ELLEN DRUFFEL, Ph.D., University of California, Irvine:
They're like diaries. They lay down about a centimeter a year of calcium carbonate. It's like a tree ring. It's a change in density. And we can go in and, with monthly resolution, reconstruct temperature, climate changes over long time periods, nutrients that it was surrounded by.

CHIP FLETCHER, Ph.D., University of Hawaii at Manoa:
One of the things we do to look at the geology of coral reefs is we drill into them, and you can actually take a drill system underwater on SCUBA, and extract cores of the reef and look at the internal structure and you can date the fossil coral within the reef and put together a paleo or old ecosystem model. The paleoecology will tell you something about the growth of the coral under past positions of sea level. It will also tell you something about the influence of waves and also the influence of the watershed on the adjacent shoreline, because heavy loading of silts and heavy loading of freshwater off a watershed will tend to decrease the amount of coral growth in an area. So, they are reflections of their environment. They are extremely important to us because, just like all natural environments, they are sources of biodiversity. And the biodiversity of the oceans is important for maintaining the food chain and maintaining the constant evolutionary process that goes into promoting life on Earth.

RICK GRIGG, Ph.D., University of Hawaii at Manoa:
But it's also important from an implied aspect. It provides—well, first of all, food in the form of fisheries, other natural products, building materials, sand. The reefs protect the land from erosion caused by waves. They are a buffer between the ocean and the land. There's shells, there's precious corals, jewelry, pharmaceuticals that are used for medicine.

NARRATOR:
WHILE THE TROPICAL SEAS, AND ESPECIALLY CORAL REEFS, PROVIDE A VARIETY OF USEFUL INFORMATION AND RESOURCES, SCIENTIFIC INTEREST IN THE POLAR REGIONS FREQUENTLY FOCUSES ON OCEAN CIRCULATION AND GLOBAL CLIMATE.

KIM:
As you have ice that's freezing and melting, you change the salinity of the surface waters in polar seas. The surface waters then become colder and much more dense during the winter months as you start to form sea ice. And those dense waters then start to sink to the seafloor, and it's in the Polar Regions that we form all of the deep water that circulates around our planet. So, in that way, polar surface waters are a source for all of the deep-water circulation around the Earth.

MANAHAN:
This whole blanket of cooling and freezing and re-thawing and re-melting of those ice sheets drives a lot of issues about ocean circulation, because it makes cold water that in many models predict that become deep ocean water, 'cause cold water sinks, so when it sinks at the poles, it takes thousands of years to find its way across the deep plains of the Pacific and the Atlantic Ocean. And there are models out there suggesting that these changes in the way the poles handle this freezing and cooling have an enormous impact on the oceans and climate change. People refer to it as the conveyor belt theory, that the oceans are all interlinked through this movement of water driven a lot by the cooling at the poles.

ERICH HORGAN, Woods Hole Oceanographic Institution:
For instance, in the Antarctic, that water that's formed, that cold water that's formed in the surface adjacent to much of Antarctica that sinks and is allowed to flow readily—northerly direction into the South Atlantic, the South Pacific and the South Indian Oceans. The effects are not necessarily felt immediately, but it you've got a year where there's more cold water made in the Antarctic, it may take decades to have its effect in more distal areas of, let's say, the North Atlantic Ocean.

NARRATOR:
WHILE TROPICAL AND POLAR OCEANS ARE VERY DIFFERENT IN MOST WAYS, THEY SHARE AT LEAST ONE SIGNIFICANT ELEMENT IN COMMON. BOTH ARE SUBJECT TO A HOST OF THREATENING FACTORS. SOME OF THESE CAN BE TRACED TO HUMAN ACTIVITY, WHILE OTHERS ARE THE RESULT OF NATURAL CAUSES.

JAMES NYBAKKEN, Ph.D., Moss Landing Marine Laboratories, CSU:
One of the biggest devastators of coral reefs are hurricanes. And when a hurricane hits, if you break up the coral, you may create new areas for some other organisms to come in or different corals to come in. And then that will stay that way for some time, until the interaction of various organisms changes it again, or until you get another hurricane, or some other thing that changes it. So, we tend to think, for example, of coral reefs as being sort of immutable, that is, they last forever. We have one going back 60 million years or more. We've seen reefs go back that far. We seem to think that this is an example of a stable system that doesn't change. But in fact it does change.

Hurricanes, typhoons, enormous storms in the North and South Pacific that create waves that range across the entire ocean basin, waves produced off New Zealand will end up breaking on the shores of Alaska. The reefs in between get hammered by these events, sometimes six, eight, 10 huge wave events every year.

NARRATOR:
AS SERIOUS AS THESE EVENTS MAY BE, THEY ARE HARDLY THE ONLY THREAT TO CORAL REEFS.

FLETCHER:
Over-fishing is probably the most important source of stress to Hawaiian reefs and reefs in populated areas. Even reefs that are carefully managed, such as the reefs in Hawaii, have been subject to hundreds of years of fishing pressure. The fish themselves in coral ecosystems are often herbivores, and so they are important in cropping back or eating the fleshy algae, which tends to accumulate in areas where there's a lot of nutrient loading to the water column. And, of course, when you remove any component of the food chain, through overfishing in this case, the food chain is going to suffer, and you'll see ramifications in all aspects of the ocean waters, which rely on coral reef ecosystems.

Bleaching is another impact that is seriously affecting coral reefs around the world. It's not new, it's been going on probably for millions of years. However, we're seeing now a slight increase in the ocean temperature around the world, and it's the increase in temperature, which triggers the bleaching reaction in corals. What bleaching actually is is the coral expels the symbiotic algae in their tissues when they're stressed. And stress can be caused by either increases in temperature, or by sedimentation covering the coral. Or even low temperature can cause a coral to undergo stress and expel the algae, to bleach.

FLETCHER:
The widespread bleaching that's been observed over the last decade or so is currently being attributed to warming of shallow waters in areas where there is not good circulation. And we need to get a better understanding of how atmospheric warming is leading to warming of surface ocean waters, which in turn is leading to bleaching of coral reefs. How can we manage this process? And how can we rejuvenate or recover or restore reefs that have been bleached or damaged in the past?

NARRATOR:
IN THE POLAR REGIONS, THE IMPACT OF ENVIRONMENTAL FACTORS CAN BE FELT IN SOME CASES NOT ONLY LOCALLY, BUT ON A GLOBAL SCALE.

STACY KIM, Ph.D., Moss Landing Marine Laboratories, CSU:
An example of a global human impact would be the ozone hole. Someone far away is putting CFC's—chlorofluorocarbons, into the atmosphere, and that eats up the ozone and that ozone hole forms over the Antarctic, which increases the U.V. radiation. So that's a global impact, a direct impact, a local impact, is from humans who are actually in the Antarctic. One of the specific projects that I've worked on is at McMurdo Station, and this is the largest base in the Antarctic, and it has over 1,000 people during the summer months. There's, of course, sewage from these people and the sewage is masticated, or ground up, before it's discharged into the marine environment. But there's no other treatment until this year. They're putting in a sewage treatment plant, and so there's going to be a big change in the amount of organic material that's going out and how that's impacting the environment. We're going to go back this year and start to record the recovery of the community after they turn that sewage outfall off—or start treating the sewage. So that we hope to see what the recovery dynamics are, and do some experiments to elucidate how those recovery processes happen, and perhaps be able to apply some of the things that we learn to enhance recovery rates, not only in polar regions, but in other areas as well.

NARRATOR:
ANOTHER LOCAL ISSUE OF CONCERN INVOLVES TRAWLING FISHERIES IN THE PENINSULA REGION OF ANTARCTICA. AS TRAWLERS GO ABOUT THE BUSINESS OF CAPTURING FISH, THEY DRAG NETS ACROSS THE SEAFLOOR, IN THE PROCESS BRINGING UP INVERTEBRATES THAT LIVE THERE. SOME OF THE SPONGES THAT ARE DISLODGED CAN BE HUNDREDS OF YEARS OLD.

KIM:
And you might ask, why we would care about a sponge in the Antarctic? You can't really eat it. It' not directly impacting you. But the sponges provide habitat for the fishes. And once you remove all the sponges in an area, the fish have no place to lay their eggs, they have nowhere to hide from seal predators. So it does have an impact on the fishery itself. In addition, a lot of the species are undescribed in the Antarctic, and this is a hot area of research for people who are doing natural products chemistry. Sponges are one of the groups of organisms that have a lot of defensive chemical compounds, and these are the types of chemical compounds that often have biomedical applications. So it could be that by prospecting for these types of chemicals that we may find some new drug that can help us with medical problems.

NARRATOR:
WHETHER ATTEMPTING TO MITIGATE ENVIRONMENTAL PROBLEMS OR CONDUCT OTHER FORMS OF RESEARCH, SCIENTISTS WORKING IN THE POLAR REGIONS FACE A HOST OF CHALLENGES.

HORGAN:
Typically, it's easier for us to work in Polar Regions during the summer months, because there's more light, because you can see more things. Physiologically, we do better when we get more sunlight. When we're deprived of that sunlight, depression can happen to certain people. Some people are more prone to that sort of a thing than others. We work in Polar Regions year round. We're involved with projects right now where we're trying to understand more about how krill survive the winter in Antarctica in a region called Marguerite Bay, regions of which are below the Antarctic Circle. So, this time of the year or in the summer, what we're seeing is 24 hours of darkness. We're seeing a lot of ice cover. You're working hard when you're at sea, whenever you're at sea. But when you're in the Polar Regions and you're in the ice, the crunching, the cold, the dark, all contributes to a greater challenge than we normally experience in other parts of the world's oceans.

NARRATOR:
THE CHALLENGES, WHILE FORMIDABLE IN ALL POLAR REGIONS, ARE MORE DAUNTING IN SOME THAN IN OTHERS.

DONAL MANAHAN, Ph.D., University of Southern California:
Antarctica is a continent surrounded by ocean. The Arctic is an ocean surrounded by continents. And so the Arctic is in some ways harder to penetrate. You're on open ice fields. You can't fly in and land with helicopters and planes. You need ice breakers to penetrate up to the North Pole. And we can skip some of these problems in the Antarctic because we can fly over the ice pack and land on glaciers.

NARRATOR:
ALONG WITH DIFFERENCES IN GEOGRAPHY, THERE ARE A NUMBER OF OTHER FACTORS THAT DISTINGUISH THE ARCTIC REGION FROM ANTARCTICA. FOR EXAMPLE, EXTENSIVE NUTRIENT UPWELLING IN THE

SOUTHERN OCEAN DRIVES PRODUCTIVITY TO MUCH HIGHER LEVELS THAN IN THE ARCTIC. AND THERE ARE VERY DISTINCT ANIMAL SPECIES PRESENT AS WELL AS ABSENT IN EACH REGION. BUT AS REAL AS THEY ARE, THESE DIFFERENCES DON'T COMPARE IN SCOPE TO THE EXTREME CONTRAST BETWEEN THE TROPICAL SEAS AND THE POLES…IN NEARLY EVERY WAY IMAGINABLE—FROM AVAILABILITY OF LIGHT TO TEMPERATURE, FROM PRODUCTIVITY AND CIRCULATION PATTERNS TO BIOLOGY. THESE ARE VASTLY DIFFERENT REGIONS. SO MUCH SO THAT IT SCARCELY SEEMS POSSIBLE THAT THEY COULD OCCUPY THE SAME PLANET. AND WHILE THE DISTINCTIONS BETWEEN THEM MAY NOT BE QUITE AS SEVERE AS, FOR EXAMPLE, THE DIFFERENCES BETWEEN MERCURY AND JUPITER, THEY REPRESENT EXTREMES THAT, AT LEAST HERE ON PLANET EARTH, ARE UNPARALLELED.

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