Ecosystem Ecology: Links in the Chain - Crash Course Ecology #7

Crash Course: Ecology
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===== Introduction (0:00) =====

There's a lot of ideas that we just assume that we know a lot about because we hear about them all the time. For instance, I know what pop music is, but if you were to corner me at a party and say, "Hank, what is pop music?", I'd be like, "It's, uh...it's like, uh...the music that plays on the pop station?" Just because we're familiar with a concept does not mean that we actually understand it.

Ecology's kind of the same way, even though it's a common, everyday concept and "ecosystem" is a word that we hear a lot, I think most of us would be a little stumped if somebody actually asked us what an ecosystem is or how one works or why they're important, *et cetera*.

I find it helps to think of an ecosystem--a collection of living and nonliving things interacting in a specific place--as one of those Magic Eye posters, for those of you who were sentient back in 1994. An ecosystem is just a jumble of organisms and weather patterns and geology and other stuff that don't make a lot of sense together until you stare at them long enough, from far enough away; then suddenly a picture emerges. And just like with Magic Eye posters, it helps if you're listening to Jamiroquai while you're doing it.

===== Ecosystem Ecology (0:53) =====

So the discipline of ecosystem ecology, just like other types of ecology we've been exploring lately, looks at a particular level of biological interaction on Earth. But unlike population ecology, which looks at interactions between individuals of one species, or community ecology, which looks at how bunches of living things interact with each other, ecosystem ecology looks at how energy and materials come into an ecosystem, move around in it, and then get spat back out.

In the end, ecosystem ecology is mostly about eating--who's eating whom and how energy, nutrients, and other materials are getting shuffled around within the system. So today, we're setting the record straight: no more not understanding how an ecosystem works, starting now!

[Title Sequence]

===== A Mountain Stream Ecosystem (1:41) =====

So ecosystems may be a lot like Magic Eye posters, but the way that they're not like a Magic Eye poster is in the way that posters have edges. Ecosystems, I'll just come out and say it: NO EDGE, only fuzzy, ill-defined gradients that bleed into the ecosystems next-door. So actually defining an ecosystem can be kind of hard; mostly it depends on what you want to study.

Say you're looking at a stream in the mountains. The stream gets very little sunlight because it's so small that the trees on its banks totally cover it with shade. As a result, very few plants or algae live in it, and if there's one thing that we know about Planet Earth, it's that plants are king--without plants, there are no animals. But somehow, there's a whole community of animals living in and around this mountain stream, even though there are few plants in it. So what are the animals doing there, and how are they making their living?

From the land, of course--from the ecosystems around it. Because no stream is an island, it isn't there all by itself. All kinds of food and nutrients drop into the stream from the trees or are washed into it when it rains. Leaves and bugs, you name it, flow down from neighboring terrestrial ecosystems, and that stuff gets eaten by bigger bugs, which get eaten by fish, which in turn are eaten by raccoons and birds and bears.

===== Defining Ecosystems (2:47) =====

So even though this stream's got its own thing going on, without the rest of the watershed, the animals there wouldn't survive. And without the stream, plants would be thirsty and terrestrial animals wouldn't have as many fish to eat. So, where does the ecosystem of the stream start and where does it end?

This is a perennial problem for ecologists because the way it works: energy and nutrients are imported in from some place, they're absorbed by the residents of an ecosystem and then passed around within it for a little while, and then finally passed out, sometimes into another ecosystem. This is most obvious in aquatic systems where little streams eventually join bigger and bigger waterways until they finally reach the ocean. This flow is a fundamental property of ecosystems.

So at the end of the day, how you define an ecosystem just depends on what you want to know. If you want to know how energy and materials come in, move through, and are pooped out of a knot in a tree that has a very specific community of insects and protists living in it, you can call that an ecosystem. If you want to know how energy and materials are introduced to, used, and expelled by the North Pacific Gyre, you can call that an ecosystem. And if you want to know how energy and materials move around a cardboard box that has a rabbit and a piece of lettuce in it, you can call that an ecosystem; I might tell you that your ecosystem is stupid, but go ahead, do whatever you want.

===== Measuring Ecosystems (3:53) =====

The picture you see in an ecosystem's Magic Eye is actually dictated by the organisms that live there, and how they use what comes into it. An ecosystem can be measured through figuring out things like its biomass, that is, the total weight of living things within the ecosystem, and its productivity--how much stuff is produced and how quickly stuff grows back, how good the ecosystem is at retaining stuff. And of course, all these parameters matter to neighboring ecosystems as well because if one ecosystem is really productive, the ones next-door are going to benefit.

===== Trophic Structure (4:18) =====

So, first things first, where do the energy and materials come from? And to be clear, when I talk about materials, I'm talking about water or nutrients like phosphorus or nitrogen, or even toxins like mercury or DDT. Let's start out by talking about energy because nothing lives without energy and where organisms get their energy tells the story of an ecosystem.

You remember physics, right? The laws of conservation state that energy and matter can neither be destroyed or created; they can only get transferred from place to place to place. The same is true of an ecosystem--organisms in an ecosystem organize themselves into a trophic structure, with each organism situating itself in a certain place in the food chain.

All the energy in an ecosystem moves around within this structure, because when I say energy, of course I mean food. For most ecosystems, the primary source of energy is the sun, and the organisms that do most of the conversion of solar energy into chemical energy--you know this one. Who rules the world? The plants rule the world.

===== Primary Producers (5:12) =====

Autotrophs like plants are able to gather up the sun's energy, and through photosynthesis, make something awesome out of it: little stored packets of chemical energy. So whether it's plants, bacteria, or protists that use photosynthesis, autotrophs are always the lynchpin of every ecosystem--the foundation upon which all other organisms in the system get their energy and nutrients. For this reason, ecologists refer to plants as primary producers.

===== Primary, Secondary, & Tertiary Consumers (5:36) =====
Now obviously, the way that energy gets transferred from plant to animals is by the animal eating the plant. For this reason, herbivores are known as primary consumers, the first heterotrophs to get their grubby paws on that sweet, sweet energy. After this stage of the trophic structure, the only way to wrestle the solar energy that was in the plants that the herbivore ate is to--you guessed it--eat the herbivore, which carnivores, known as secondary consumers, are very happy to do.

And assuming that the ecosystem is big enough and productive enough, there might even be a higher level of carnivore that only eats other carnivores, like an owl that eats hawks, and these guys are called tertiary consumers.

And then there are the -vores that decompose all the dead animal and plant matter, as well as the animal poop: detritivores. These include earthworms and sea stars and fiddler crabs and dung beetles and fungi and anything else that eats the stuff that none of the rest of us would touch with a three-meter pole.

===== Food Webs (6:22) =====

So that's a nice hierarchical look at who's getting energy from what or whom within an ecosystem, but of course organisms within an ecosystem don't usually abide by these rules very closely, which is why these days we usually talk about food webs rather than food chains.

A food web takes into consideration that sometimes a fungus is going to be eating nutrients from a dead squirrel, and other times squirrels are going to be eating the fungi. Sometimes a bear likes to munch on primary producers, blueberry bushes, and other times it's going to be snacking on secondary consumers, like a salmon *(sic)*. And even at the tippy-tippy top, predators get eaten by stuff like bacteria in the end, which might or might not be the same bacteria that eat the top predator's poopies. Circle of life!

===== Sonoran Desert vs. Amazon Rainforest (7:00) =====
It's also worth noting that the size and scope of the food web in an ecosystem has a lot to do with things like water and temperature, because water and temperature are what plants like, right? And without plants, there isn't going to be a whole lot of trophic action going on.

Take for example the Sonoran desert, which we've talked about before. There aren't many plants there, compared to say, the Amazon rainforest, so the primary producers are limited by the lack of water, which means that primary consumers are limited by lack of primary producers. And that leaves precious few secondary consumers: a few snakes and coyotes and hawks. All this adds up to the Sonoran not being a terribly productive place, compared to the Amazon at least, so you might only get to the level of tertiary consumer occasionally.

===== Ecosystem Efficiency (7:36) =====

Now all this conversation about productivity leads me to another point, about ecosystem efficiency. When I talk about energy getting passed along from one place to another within an ecosystem, I mean that in a general sense organisms are sustaining each other, but not in a particularly efficient way. In fact, when energy transfers from one place to another, from a plant to a bunny or from a bunny or a snake, the vast majority of that energy is lost along the way.

So let's take a cricket. That cricket has about one calorie of energy in it. And in order to get that one calorie of energy, it had to eat about 10 calories of lettuce. Where did the other nine calories go? It is not turned into cricket flesh; most of it is used just to live, like to power its muscles or run the sodium-potassium pumps in its neurons. It's just used up.

So only the one calorie of the original 10 calories of food is left over as actual cricket stuff. And then right after his last meal, the cricket jumps into a spider web and is eaten by a spider, who converts only 10% of the cricket's energy into actual spider stuff. And don't get me started on the bird that eats the spider; this is not an efficient world that we live in.

===== Bioaccumulation (8:33) =====

But do you want to know what's scary efficient?: the accumulation of toxins in an ecosystem. Elements like mercury, which are puffed out of the smokestacks of coal-fired power plants, end up getting absorbed in the ocean by green algae and marine plants. While the tiny animal that eats the algae only stores 10% of the energy it got, it keeps 100% of the mercury. So as we move up the chain, each trophic level consumes ten times more mercury than the last. And that's what we call bioaccumulation--concentrations get much higher at each trophic level until a human gets ahold of that giant tuna that's at the top of the marine food chain, and none of that mercury has been lost. It's all right there in that delicious tuna flesh.

Because organisms only hold on to 10% of the energy they ingest, each trophic level has to eat about ten times its biomass to sustain itself. And because 100% of that mercury moves up the food chain, that means that it becomes ten times more concentrated with each trophic level it enters. That's why we need to take the seafood advisory seriously. As somebody who could eat anything you wanted, it's probably safest to eat lower on the food chain: primary producers or primary consumers. The older, bigger, higher-in-the-food-chain, the more toxic it's going to be.

And that's not just my opinion, that's ecosystem ecology.

===== Credits (9:39) =====

Thank you for watching this episode of *Crash Course: Ecology* and thank you, everyone who helped us put this episode together. If you want to review any of the topics we went over today, there's a table of contents over there that you can click on, and if you have any questions or comments for us, we're on Facebook or Twitter or, of course, down in the comments below. We'll see you next time.