Population Ecology: The Texas Mosquito Mystery - Crash Course Ecology #2

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

In our series on biology, we spent many weeks together talking about the physiology of animals and plants and how cells work together to make tissues to make organs to make organ systems to make us the hunks of meat and vegetables that we are. In understanding the whole organism, it's important to know what's going on at all those levels, and the same is true for ecology, only instead of zooming in and out on different levels within a living thing, we can zoom in and out on the Earth.

Depending on the power of the magnification, we can understand a whole range of things about our planet. For instance, we can look at groups within a species and how they live together in one geographic area--that's population ecology. There's also community ecology, where you look at groups of different organisms living together and figure out how they influence each other. And then the most zoomed out we get is ecosystem ecology, the study of how all living and non-living things interact within an entire ecosystem.

===== Case Study: Dallas & the 2012 West Nile Virus Outbreak (0:48) =====
So let's start by zooming in with population ecology, the study of groups within a species that interact mostly with each other, to understand why these populations are different in one time and place than they are in another. "How?" you may be asking yourself, "is that in any way useful to anyone ever?" Well, it's actually super useful to everybody always.

Let's look, for instance, at the outbreak of West Nile virus that struck Dallas, Texas in the summer of 2012. In Dallas County, 12 people died from the virus as of the filming of this, and nearly 300 people have been infected. But in 2011, the whole state of Texas reported only 27 cases of West Nile, and only two deaths. That seems kind of significant, so what's up?

Turns out, this is a population ecology problem. West Nile is mosquito-borne illness, and the population of mosquitoes in Dallas in 2012 busted through brick walls like the Kool-Aid man, spreading West Nile like crazy. So why did this outbreak happen in 2012 and not the year before? And why did it happen in Texas and not in New Jersey? The answer, is population ecology.

[Title Sequence]

===== Fundamentals of Population Ecology (1:57) =====

Before we start solving any disease outbreak mysteries, we've got to understand the fundamentals of population ecology. For starters, a population is just a group of individuals of one species who interact regularly. How often organisms interact has a lot to do with geography; you're going to have a lot more facetime with the folks you live near than those who live farther away. As a result, individuals who are closer to you will be the ones that you compete with for food and living space, mates, all that stuff.

But in order to understand why populations are different from time to time and place to place, a population ecologist needs to know a few things about a population, like its density--in this case, how many mosquitoes there are in the greater Dallas area that might come into contact with each other. A population's density changes due to a number of factors, all of which are pretty intuitive. It increases when new individuals are either born or immigrate, that is move in, and it decreases because of deaths or emigration, or individuals moving out.

Simple enough, but as a population ecologist you also need to know about the geographic arrangement of the individuals within the population. This is their dispersion. Like, are the mosquitoes all clumped together, are they evenly spaced across the county, is there some kind of random spacing? The answer to these questions gives scientists a snapshot of a population at any given moment, and to figure out a puzzle like the West Nile outbreak, which involves studying how a population is changed over time, you have to investigate one of population ecology's central principles, population growth.

There are all kinds of factors that drive population growth, and they can vary radically from one organism to the next. Things like fecundity, how many offspring an individual can have in a lifetime, make a huge difference in the size of a population. So for instance, why do mosquito populations seem to grow so quickly while the endangered black rhino may never recover from a single act of poaching? For starters, mosquitoes can have 2,000 offspring in their two-week lifetime, while the rhino can have, like, five in forty years. Still, a population doesn't usually, or even ever, grow to its full potential and it can't keep growing indefinitely.

===== Limiting Factors (3:50) =====

To understand how fast or slow and high or low a population actually grows, you need to focus on what's keeping growth in check. These factors are appropriately called limiting factors. Say you're a mosquito in Dallas in 2011, the year before the outbreak. Back then, the growth rate wasn't what it was in 2012, so something was keeping you down. To figure out what your limiting factors were, your first have to narrow down what you need as a mosquito to live and reproduce successfully.

First, you've got to find your food. Now, you mosquitoes, you eat all kinds of things, but in order to reproduce, assuming you're a female, you need a blood meal--so you have to find a vertebrate and suck some of its blood out. Presumably there's no shortage of vertebrates walking around Dallas for you to suck blood out of; I have good friends who are vertebrates in Dallas, you might even be able to suck some of their blood.

Next, temperature--because you mosquitoes are ectothermic, it has to be warm in order for you to be active and now Texas is pretty warm, and the winter of 2011-2012 was especially balmy. In fact, the summer of 2012 was exceptionally hot, which helps speed up the mosquito life cycle, so that's one limiting factor that's been removed for Dallas-area mosquitoes.

Moving on to mates. If you're a female mosquito, you need to find a nice male mosquito, with a job and preferably his own car, because you know Dallas is a pretty big city, to mate with. This isn't actually all that hard because of the way mosquitoes do it; males just gather into a mosquito cloud at dusk every night during mating season and all the female has to do is find her local dude-cloud and fly into it in order to get mated with. Easy cheese!

Finally, space, and aha! Because here we have another important clue. Mosquitoes need to lay their eggs in stagnant water, and if there's anything mosquito larvae hate, it's a rainstorm flushing out the little puddle of water they've been living in. And since Dallas saw a pretty severe drought in the summer of 2012, there were lots of pockets of stagnant, nasty, mosquito water sitting around, acting as nurseries for many, many West Nile-infected mosquitoes.

So, when we look at this evidence, we find at least two limiting factors for Dallas's mosquito population growth that were removed in 2011: the constraints of temperature and space. It was plenty hot, and there were lots of egg-laying locations, so the bugs were free to go nuts.

===== Density Dependence (5:53) =====

Population ecologists group limiting factors like these into two different categories, density-dependent and density-independent. They do it this way because we need to know whether a population's growth rate is being controlled by how many individuals are in it, or whether it's being controlled by something else. And the reason these limitations matter is because they affect what's known as the carrying capacity of the mosquitoes' habitat. That's the number of individuals that a habitat can sustain with the resources that it has available.

===== Density-Dependent Factors (6:16) =====
So, density-dependent limitations are factors that inhibit growth because of the environmental stress caused by a population size; for example, there may simply not be enough food, water, and space to accommodate everyone. Or maybe because there are so many individuals, a nearby predator population explodes, which helps keep the population in check. Things like disease can also be a density-dependent limitation; lots of individuals living in close quarters can make infections spread like crazy.

Now, I don't think that the Dallas mosquitoes are going to run out of vertebrates to dine on any time soon, but let's say hypothetically that the explosion of local mosquito populations caused a similar explosion in the number of Mexican free-tailed bats, the official flying mammal of the state of Texas. And they eat mosquitoes--that would be a limiting factor that was density-dependent. More mosquitoes leads to more bats, which leads to fewer mosquitoes.

It's pretty simple. When density-dependent limitations start to kick in, and start to limit the population's growth, that means that the habitat's carrying capacity has been reached.

===== Density-Independent Factors (7:11) =====
But the other type of limiting factor, the density-independent ones, have nothing to do with how many individuals there are or how dense the population is. A lot of times these limitations are described in terms of some catastrophe: a volcanic eruption, a monsoon, a Chernobyl. In any case, some crucial aspect of the population's lifestyle changes enough that it makes it harder to get by.

But these factors don't have to be super dramatic. Going back to mosquitoes, say in 2013 there's a huge thunderstorm, a real gully-washer, in Dallas every day for three months. That's going to disturb the clutches of mosquito eggs hanging out in the stagnant waters, so the number born that year would be substantially smaller. By the same token, if the temperature swung the other way, and it was unseasonably cold all summer, the bugs' growth rate would drop.

Now the truth is, there are a billion and a half situations, both big and small, that could lead to a population either reaching its carrying capacity or collapsing because of external factors. It's a population ecologist's job to figure out what those factors are. And that is what math is for.

===== Exponential & Logistic Growth (8:05) =====
Our friend math says that any population of anything--ANYTHING--will grow exponentially unless there's some reason that it can't. Exponential growth means that the population grows at a rate proportional to the size of the population. So here at the beginning of 2012, we might have only had a thousand mosquitoes in Dallas, but then, after say one month, we got 3,000. Now with three times as many reproducing mosquitoes, the population grew three times as fast as when there were 1,000, so then there are 9,000, at which point it's growing three times as fast as when there were 3,000, and on and on into infinity.

And in this scenario, the mosquitoes are all "Carrying capacity my chitin-covered butt! There's no stoppin' us!" But you know what doesn't really happen? I mean, it can happen for a while--humans have been on an exponential growth curve since the Industrial Revolution, for example. But eventually, something always knocks the population size back down. That thing might be a density-dependent factor like food scarcity or an epidemic, or a density-independent one like an asteroid that takes out the whole continent. Regardless, this exponential growth curve can't go up forever.

And when those factors come into play, a population experiences only logistic growth. This means that the population is limited to the carrying capacity of its habitat, which, when you think about it, ain't too much to ask. See how this graph flattens up at the top? The factor that creates that plateau is almost always a density-dependent limitation. As you add mosquitoes, eventually the rate of population growth is going to slow down because they run out of food or space, and when we get to where that number levels off, that number is the carrying capacity of the mosquito population in that particular habitat.

===== Sample Calculation of Population Growth (9:34) =====

Now, let's apply all of these ideas using a simple equation that will allow us to calculate the population growth of anything we feel like. I know, it's math, but wake up because this is important--the city of Dallas is depending on you!

So, let's calculate the growth of Dallas's mosquito population over a span of two weeks. All we have to do to get the rate of growth, that's r, is take the number of births minus the number of deaths, and then divide that all by the initial population size (which we generally just call N).

So let's say with start with an initial population of a hundred mosquitoes, and each of those mosquitoes lives and average of two weeks so our deaths, over a span of two weeks, will be 100. Half of these mosquitoes are going to be female, so 50 of them, and they can produce about 2,000 babies in their lifetime, so that's times 2,000. So 50 mommy mosquitoes times 2,000 babies per mommy and you get births equalling 100,000 little baby mosquitoes.

===== Significance of Population Growth (10:39) =====

Once we plug in all the numbers into this equation, even though this is totally a hypothetical, we will see the true scope of Dallas's mosquito problem. So blink!, in two weeks the population had 100,000 babies and only 100 of them died, so this is a population growth rate of, if you do the math, 999. This means that for every mosquito out there at the beginning of two weeks, there will be 999 more at the end of two weeks. That is a 99,800% increase, by THOR'S HAMMER!

Again, these are hypothetical numbers, but it gives you a sense of how a population can just go out of control when all the factors that we talk about go in its favor. And you guys haven't even seen trouble until you've seen what the graph of human population looks like over the last couple millennia. But to find out more about that, you going to have to join us next week.

===== Credits (11:24) =====

Until then, thank you for watching this episode of *Crash Course: Ecology*, and thanks to everyone who helped put it together. The table of contents is over there if you want to go rewatch anything, and if you have any questions for us we're on Facebook, and Twitter, and of course, in the comments below. See you next time.