[crickets]

[footsteps]

[cymbal plays]

[chime]

[music plays]

[TONY SINCLAIR:] I arrived as an undergraduate. This was the beginning of July of 1965. I got a lift down from Nairobi with the chief park warden. Next day, one of the drivers picked me up and took me out on a 3-day trip around the Serengeti to measure the rain gauges. And in that 3 days, I got to see the whole park, and I was blown away.

[music plays]

I of course grew up in East Africa, so I'd seen various parks, but there was nothing that came anywhere close to this place. Serengeti, I think, epitomizes Africa because it has everything, but grander, but louder, but smellier.

[music plays]

It's just more of everything.

[music plays]

What struck me most was not just the huge numbers of antelopes, and the wildebeest in particular, but the diversity of habitats, from plains to mountains, forests and the hills, the rivers, and all the other species.

The booming of the lions in the distance, the moaning of the hyenas. Why was the Serengeti the way it was? I realized I was going to spend the rest of my life looking at that.

[NARRATOR:] Little did he know, but Tony had arrived in the Serengeti during a period of dramatic change. The transformation it would soon undergo would make this wilderness a living laboratory for understanding not only the Serengeti, but how ecosystems operate across the planet.

This is the story of how the Serengeti showed us how nature works.

[music plays]

[film projector starts]

[TONY:] When I first arrived, there were a few other scientists there. And they had established some form of ballpark figure for the number of animals.

[airplane engine noise]

[NARRATOR:] The first aerial survey of the park tallied an incredible total of almost 400,000 large mammals. And curiously, the numbers of certain species were increasing dramatically.

[TONY:] The very first surveys of the buffalo in 1961 counted about 15,000 animals in the park. The next time they did that, in 1965, they counted 35,000. For a large mammal, they just don't do that sort of thing!

[TONY (from footage):] The idea is to follow the herd around …

[TONY:] And so I became involved in counting the buffalo from that moment on, year after year, which required doing a lot of flying. Once a year, we had to fly across the whole of the Serengeti and count every single animal that we saw.

[music plays]

Of course these herds are quite big, so we had to take photographs, and then I counted the animals off the photographs.

[music plays]

[NARRATOR:] Tony's counts revealed that buffalo weren't the only ones increasing. Wildebeest populations were skyrocketing too. Tony's PhD project was to figure out why.

[music plays]

He learned that a virus called rinderpest had killed 95% of East Africa's cattle when it first arrived in 1890, and it had periodically decimated Africa's cattle populations ever since.

[TONY:] It turns out that wild animals that were closely related to cattle, like buffalo and wildebeest, they also suffer from this disease.

[NARRATOR:] Tony discovered that a new vaccine to eradicate rinderpest from cattle had also eliminated the virus from the Serengeti's wildlife. The disappearance of rinderpest precisely matched the time when buffalo and wildebeest populations began to explode. This boom was an opportunity for Tony to learn what regulates these animals' numbers, and the entire Serengeti ecosystem.

[TONY:] We found in the mid-1970s that the buffalo population was finally stabilizing at around 75,000 animals. Meanwhile, the wildebeest population was continuing to climb, and climb at a very fast rate.

[NARRATOR:] Between 1961 and 1973, the wildebeest populations had tripled, reaching 770,000 individuals. Park officials began to worry they were growing out of control.

[TONY:] Some people thought that we needed to do something about it, that we needed to reduce the population because they may have caused damage to the environment. There was a lot of opinion. We decided that we'd let biology follow its natural course and see what happened.

[NARRATOR:] The population continued to grow until 1977 when it peaked at 1.4 million — the largest herd of large herbivores in the world. The big question was, why had they stopped increasing? Answering that question would take a long time and the efforts of a dedicated collaborator.

[music plays]

[SIMON MDUMA:] It was in September-October 1988, that was my first experience arriving in Serengeti.

[SIMON:] I was going to meet Tony Sinclair. He was going to be my advisor. So we were going to talk about possible projects.

And at this time I was driving and I was all by myself. It was the first time to see the migration. They were all there in front of me, in thousands. I could see as far as I can, and it was all wildebeest. And I was saying, "I can't believe this. Is this real?"

I got myself interested in what's really happening with the wildebeest population. Why has it stabilized? What is limiting the wildebeest population growth?

[NARRATOR:] To consider the factors that might regulate the wildebeest, imagine an ecosystem as a pyramid. At the base of the pyramid are primary producers like plants that get their energy from the sun. Those plants are eaten by herbivores like wildebeest, which are in turn eaten by predators like lions at the top.

[SIMON:] Wildebeest being at the middle of the pyramid, you can think of two things which could be limiting the wildebeest population growth. One would be food because herbivores have to feed on plants, which is at the bottom of the pyramid. On the other hand, it could be from above, which are predators feeding on the herbivores.

[NARRATOR:] When a population is limited by its food supply, we say that it's regulated from the bottom up. If, however, the population is limited by predators, we say that it's regulated from the top down.

To figure out how the wildebeest population was regulated, Simon and Tony needed, of all things, dead animals. They began examining hundreds of dead wildebeest to determine the most common cause of death: predators or lack of food.

[SIMON:] Okay, definitely here I see a wildebeest carcass. And if it were hyenas, all the limbs would have been scattered around. So this is predation. Lions, most likely.

Age, you have to look at the tooth wear. Well, there we go. This is adult. And looking at the horn shape, this is a male, an old male.

So some of them will be dying from predation, but also some individuals could be dying out of starvation. For an animal which died from starvation, because of lack of food the animal starts using its body reserves, stored fat in the body. When conditions are good, most of the fat reserves are stored around the stomach of the animal. But we cannot use that because they are eaten by predators. Scavengers also go for the fat around the belly; everything will be gone.

Because of that, we have to look at what is left behind. Luckily, the very last fat reserves that are used are bone marrow from the long bones. Very few scavengers will go into it. So this is what you'll find most of the time. And I'll crack it open. Yeah, so there we go, and there is the bone marrow. The bone marrow will tell you the condition of the animal at the time of death.

For three years, I recorded not less than 300 carcasses.

In the early years, I would see this type of kill, and normally I would think, "Well, for sure, predators, given their numbers, they would be regulating the wildebeest population." So that was my first thought.

But after three years of studying, you look at the data and to my surprise, that was not the case.

During the wet season, when there's lots of food to eat, there were very few deaths which were recorded. And when you look at the bone marrow, it was solid, fatty, and whitish, indicating that the animals died in good health.

But then, during the dry season, we recorded more deaths, and animals were in poor condition, with their bone marrow being translucent and gelatinous.

This research tells us that wildebeest are regulated by availability of food. During the dry season, there's much less food resource for the animals to feed on, and that regulates the wildebeest population.

[NARRATOR:] How does food regulate the population? It depends on the density of wildebeest: the number of animals in the ecosystem.

[SIMON:] After rinderpest was removed, there were very few wildebeest, and food was in superabundance. So, the population responded by increasing. It grew exponentially, and as the population was increasing, the amount of food available per individual was becoming less and less and less, until they reached a peak in the year 1977.

[NARRATOR:] The population stopped growing when the food available in the dry season couldn't sustain any more animals. The maximum population that can be supported in an ecosystem is called the carrying capacity. For wildebeest in the Serengeti, the carrying capacity is roughly 1.3 million animals.

[SIMON:] Well, after this detailed study on wildebeest population, we were all excited to talk about other species.

[NARRATOR:] To understand how other species were regulated, Tony, Simon and their colleagues used decades of data on the cause of death of many of the Serengeti's mammals.

[TONY:] Well, amazingly, these are the ledgers that I recorded the natural deaths — what caused the deaths, what ages they were.

In February '72, an old adult here killed by seven hyenas. December of '71... 1972... May of 1972... a male, died in the dry season, November 1971, undernutrition... nine hyenas... killed by lion... drowned... hyena... lion, lion... now, here's an interesting one, leopard. We know that because it was found up a tree.

We collected many hundreds of them over the period of time. From 1967 to 2000. That's 33 years of data.

[SIMON:] After we collected the data, it was plotted, and here a clear pattern emerged.

Looking at body weight versus proportion of animals being killed, for the smaller herbivores — oribi, impala, topi, and zebra — they mostly died by predation, while larger species — buffalo, giraffe, rhino, hippo, and elephant — most of them were not even touched by predators.

[NARRATOR:] Tony, Simon, and their colleagues figured out that small animals are regulated from the top down by predators, while large animals are regulated from the bottom up by food. But a mystery remained. Why are there so many wildebeest, more than any other mammal of any size in the Serengeti?

[music plays]

[GRANT HOPCRAFT:] I remember the first time I came to Serengeti. And it's the view that you get as you cross over the crater highlands. You see this enormous plain. I mean, it's 5,000 square kilometers. And that's the

Serengeti plain. And off in the distance, you see hills in the haze. Forests and woodlands heading up to the north.

And if you have a keen eye, you'll see animals.

[music plays]

[NARRATOR:] Grant Hopcraft has studied wildebeest with Tony Sinclair since 2003.

[GRANT:] There's two big things about wildebeest that are really unique. One is that they're superabundant, right? In the Serengeti, the wildebeest are about 1.3 million animals, give or take 100,000. That's more than all the other herbivores in the system combined.

The other thing is that they migrate, that they move.

[NARRATOR:] The annual wildebeest migration around the Serengeti is one of the world's best-known wildlife spectacles. Yet for decades, the causes of this epic migration remained a mystery. Knowing that food regulates the wildebeest's population size, Grant and other researchers wondered if food also drove their migration.

[GRANT:] So there's two predictions that come out of this hypothesis. First of all, that the availability of food varies across the system. Secondly, that the animals are able to track that food supply.

[NARRATOR:] Wildebeest are short grass specialists. But the short grasses that wildebeest prefer only grow in certain parts of the Serengeti, and their growth depends on the rains.

[GRANT:] In the tropics, the seasons are defined by rainfall. And here in the Serengeti, the rainfall comes in from the monsoons off the Indian Ocean.

[NARRATOR:] Rain can fall at any time of year, but most of the rain comes during a wet season that lasts just a few months.

[GRANT:] This system, which is usually quite dry, ends up with a deluge of rain.

So what we're seeing here is we're seeing some satellite imagery. And what we're measuring here is actually the grass greenness. What we see is this whole area in the south down here, this huge pulse of green-up as those monsoon rains arrive.

So the rainfall comes, these really nutritious grasses start growing, and if wildebeest really are migrating because they're looking for food, then what we should see is a massive congregation of wildebeest on those areas.

[NARRATOR:] To test this prediction, Grant has been tracking wildebeest with GPS collars for several years. Each collar transmits its location every day, so Grant can track the collared animals as they move throughout the park.

[GRANT:] So basically what we've done is this morning we got up early, we had a look online to see where those collars were, got some GPS coordinates which we recorded in our notebook here. We've come to within a few kilometers of where she was at 2:00 am.

And as you can see, we're completely surrounded by wildebeest here. And at this point, it's a bit of a needle in the haystack, right? I mean, she could be anywhere. So what we're going to do is we're going to put together the VHF antenna and then we're going to start listening to see if we can hear a signal.

[music plays]

[meter clicks]

[GRANT:] Oh yeah, there she is.

There's this group walking by here and then there's two standing next to each other in the background. She's the one on the right.

Yeah, it's good to see her. She's doing well. I mean, yeah, I've probably got a few more gray hairs as well, but I think she's doing better than I am. [laughs]

[NARRATOR:] By downloading the coordinates of all the GPS-collared wildebeest, Grant can determine the location of the migrating herd.

[GRANT:] So we put on these GPS radio collars, and I'll show you the layer right here. What we see is a large congregation of animals all coming down onto those short grass plains to coincide with that pulse of green-up.

[NARRATOR:] Here in the southern plains, many of the female wildebeest are accompanied by their young calves.

[GRANT:] The wildebeest drop all their calves to coincide with the big rain. The calves are standing within 15 minutes. They're able to run within half an hour, 45 minutes, or at least sort of wobble along with their mothers. And they'll move several kilometers within their first day.

So these calves are growing up on this ideal landscape, right? Perfect wildebeest habitat. And so why would you ever leave?

And the reason you have to leave is because the Serengeti doesn't have its own irrigation system. It starts drying out and it dries out really rapidly. Wildebeest need to have water every couple of days. There's no permanent water on the plains. The nutritional quality of the grasses declines very rapidly as it dries out. And suddenly you're faced with no food and no water.

Okay, so everything is drying up, where do you go? If we're thinking that wildebeest are tracking food, then our prediction should be that wildebeest will go to where there's the next available food source.

So what do the GPS collars tell us? If we put on the dry season locations of animals, what we see is this huge congregation up in the north. And the north is where there's the highest amount of rainfall in the dry season.

[NARRATOR:] Once again, the GPS collars reveal that the wildebeest herds seem to be following the rainfall. But as they move north to reach the best grazing grounds, the Mara River stands in their way.

[music plays]

When rain falls on the opposite side of the Mara, the wildebeest have a choice to make.

[dramatic music plays]

The lure of new rain and fresh grass is powerful, but every crossing carries the risk of drowning, or an encounter with one of the Mara's infamous crocodiles.

[dramatic music plays]

But even in the north, the rains and green grass don't last forever.

[GRANT:] You can imagine this whole system is drying out slowly. Imagine a grape becoming a raisin. And everybody's keeping an eye out for the new rain.

[NARRATOR:] When the monsoon rains return, the wildebeest herds once more move south toward the short grass plains, where the cycle begins again.

[GRANT:] So we had two predictions from our hypothesis. One is that there is variation in space in the availability of food. And the second prediction is that our radio-collared animals are able to track the availability of that food very precisely. And what we see from this imagery is actually both are actually true.

[NARRATOR:] Migration gives wildebeest access to fresh food year-round. Could it be that migration is the key to explaining their enormous numbers? To answer this question, Grant took advantage of the fact that not all wildebeest migrate.

[GRANT:] There are actually four small populations of wildebeest that don't migrate at all. The largest herd does. The 1.3 million, those are the big migrants. The resident populations are far less abundant. By orders of magnitude, 5000 animals, as opposed to 1.3 million.

[NARRATOR:] The migratory herds follow a 650-kilometer circuit each year, taking advantage of a massive, temporary food source in the south, then retreating to the north when the southern plains dry out.

Migration gives them access to more food, and since their population is regulated by food, they have become far more numerous than the resident populations.

But the food supply isn't the whole story. Resident and migratory wildebeest also experience dramatically different rates of predation.

[TONY:] For resident wildebeest, 87% of the deaths was caused by predators, as we would expect from the relationship between body size and the cause of death. In contrast, only 25% of the deaths of migratory wildebeest is accounted for by predators, even though they are of the same size.

[NARRATOR:] Compared to the residents, migratory wildebeest are somehow better at avoiding being eaten by predators. But why?

[TONY:] Predators cannot follow migrants. And this is because of their basic biology. A baby lion takes six weeks before it can basically follow the mother. The mother carries it. A baby wildebeest can run as fast as the mother within 24 hours. So the wildebeest can keep moving and the lions cannot keep moving.

[lion growls]

[NARRATOR:] Migration gives wildebeest a double advantage: finding more food without being eaten.

The migratory wildebeest aren't just more abundant than the residents. They also exist at densities up to 64 animals per square kilometer — more than four times greater than the density of resident populations. The reason is that migration helps them reduce top-down regulation by predators and bottom-up regulation by the food supply.

Most of the Serengeti's herbivores don't migrate. But in addition to wildebeest, the ecosystem's second- and third-most numerous grazers — zebra and Thompson's gazelle — also migrate each year.

[music plays]

[NARRATOR:] Migration is a widespread strategy that allows animals to access more food and reduce their exposure to predators, allowing their populations to grow very large. Around the world, animals that migrate — like caribou in the Arctic, or sandhill cranes in the American Midwest — often attain larger numbers than animals that don't migrate.

[music plays]

[NARRATOR:] By the late 1970s, with more than a million hungry wildebeest eating their way across hundreds of kilometers of grassland each year, the Serengeti was in uncharted territory. No one really knew how so many wildebeest would impact the ecosystem. Some wildlife managers even worried that the Serengeti couldn't sustain such massive herds for long. But they, and Tony, were in for a big surprise.

[music plays]

[TONY:] We're on top of Wogakuria Kopje, which is the highest point in northern Serengeti. It overlooks Kenya and the Mara River, some 10 miles or so north of us there. And we can see either way east and west, to the park boundaries, each way about 40 miles.

[NARRATOR:] These hills in the northern Serengeti overlook wooded savannas, defined by their distinctive mix of grasses and trees. But in the 1960s, when Tony first arrived in the Serengeti, trees were disappearing all over the park and had been for decades. Older trees were dying, and no seedlings were growing to replace them.

[TONY:] And I thought it would be valuable if I could set up a series of photo points that would record, if you like, the last of the trees. So that we could say, "There were trees here once."

[NARRATOR:] Tony established a photographic monitoring program in 1980 to document the park's tree cover. From high vantage points, he could photograph broad expanses of savanna and count the trees in each image.

[TONY:] So on the photograph, I look to see what is at the very left-hand edge of this photograph, which is that big tree over there. And the very right-hand edge there's a pair of bushes and then another bush here to the right. And so I just zoom in so that I've got that on the left and that on the right to take the photograph.

[camera beeps]

Ok. So in that way I get more or less a precise repeat of what I took before.

I set them up in 1980 entirely with the view that somebody else would come back in 50 years' time and take them again. In 1986, I came back and had a shock. Everywhere I looked, baby trees were coming up. And that has continued for the last 30 years now. When I first saw it, I was gobsmacked. I hadn't the faintest idea what was going on. It was exactly the opposite to what we were expecting.

[NARRATOR:] What had caused this unexpected turnaround in the Serengeti's woodlands?

[music plays]

In the early 1960s, fires were everywhere in the dry season. Up to 80% of the Serengeti savanna burned each year, killing young trees and preventing the woodlands from regenerating. But by the late 1970s, that figure had dropped dramatically.

So why was there less fire?

Over that very same period, Tony had watched the wildebeest population grow fivefold. Could wildebeest have something to do with the decline in fires?

[TONY:] The test for this was to compare the area burned with the size of the wildebeest population. And surprise, surprise, we found that there was an exact correlation. As the wildebeest population went up, so also the area burned went down.

[NARRATOR:] What was the connection between wildebeest and fire? Fire needs dry grass to burn and spread.

[TONY:] You can think of wildebeest as glorified lawn mowers. Imagine hundreds of thousands of them all lined up together marching across the landscape.

[NARRATOR:] Once the wildebeest reached their carrying capacity of around 1.3 million animals, there simply wasn't enough dry grass left to sustain large fires in the dry season.

[TONY:] Now, when there is less fire, less burning, then baby trees can start to regrow. Now, 40 years ago, in the 1970s, none of these trees were here. It was an open grassland. With all of these trees here, we then see indirect consequences on the rest of the community.

We've got huge numbers of bird species that have come in. We've got other species of mammals that have taken advantage of having the trees there.

Elephants are one of those because elephants feed on trees. So the elephant population has increased as a consequence of the wildebeest population, even though wildebeest have nothing to do with elephants directly.

Giraffes have taken advantage of this. So, it has been a magnificent comeback in the ecosystem.

[music plays]

Before we put the story together in the late '70s, people were working on individual projects: on predators, on trees, on burning, on rainfall, and on the various ungulates, the herbivores. But it was only when we all started talking to each other that we understood that all of these different things were in fact connected. We realized that all of the things that they had been studying actually could be explained, almost entirely, by the changes in the wildebeest population.

[NARRATOR:] Tony and his colleagues had found the engine that drove the Serengeti: a migrating herd of a million living lawn mowers.

[TONY:] This species, the wildebeest, was a keystone in the ecosystem.

[NARRATOR:] When the wildebeest population rebounded, a cascade of unexpected effects rippled through the entire community. Through a web of connections to other species, it was this "keystone species" that made the Serengeti, the Serengeti.

From the very beginning, Tony had an inkling that it would take a lifetime to unravel the Serengeti's secrets.

[TONY:] Given how long I've been around, it's obvious that my time out here is going to come to an end fairly soon. And of course I'll miss it. The Serengeti is a special place. It is just as magical, just as mystical, as when I very first came.

[NARRATOR:] In a quest to learn what makes the Serengeti special, Tony and his colleagues had actually uncovered some of the shared principles that operate in ecosystems around the world.

The species may be different, but the underlying rules are the same. Populations grow quickly at low density and slow down as they reach their carrying capacity. Some populations are regulated from the top down, and others from the bottom up. Migration allows some animals to escape regulation and reach greater numbers. And a keystone species can influence nearly every part of an ecosystem.

Yes, the Serengeti is special. But the unexpected lesson from Africa's greatest wilderness has been that ecosystems everywhere follow the same set of ecological principles. And in that sense, every place is a Serengeti.

[music plays]