"EXPEDITION PANAMA -- SPECIAL FROM PANAMA"
SHOW 801

TEASER

ALAN ALDA On this edition of Scientific American Frontiers, we're on our way to the wild rainforests of Panama.

ALAN ALDA (Narration) We'll find out how bees talk, and ants run forest farms. We'll try to save the Panama Canal -- in the kitchen.

ALAN ALDA Rat soup!

ALAN ALDA (Narration) We'll enter the forest at night.

ELISABETH KALKO It's a whole symphony of bat calls that's around us right now.

ALAN ALDA (Narration) And we'll see how the world changed -- when Panama formed just a few million years ago.

ALAN ALDA I'm Alan Alda, join me now -- exploring Panama.

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EPISODE OPEN

ALAN ALDA For this episode of Scientific American Frontiers, we're in Panama. And here's Panama's most famous feature, the Panama Canal. But it was the building of the canal that led to the creation of something else here, that for scientists may be even more famous -- and that's Barro Colorado Island. The island's a mecca for scientists from all over the world, who come here to study

the wonderful intricacies of tropical forests. How thousands of different plants and animals, insects, birds, bats, trees, get along together. And how they're connected. Actually this whole show is about connections. Like how the canal created the island, but also brought in a terrible alien grass that only now is beginning to be beaten back. And how millions of years ago the formation of the Isthmus of Panama itself intensified the Gulf Stream, changed the climate of Europe and Africa, and maybe even caused human beings to evolve. Quite a record for a small country. So now let's plunge into the forest.

ALAN ALDA (Narration) To get to Barro Colorado Island, there's no better way than along the canal...Although that can be a bit of a squeeze. The canal opens out into Lake Gatun. It's a twenty-three mile long fresh water lake, designed to form the canal's middle section, and created just eighty years ago.

ALAN ALDA What happened to all the trees and everything that were flooded?

ANTHONY COATES Well, they would just drown, and then they died, and now their, their ghostly sort of stumps are left throughout the lake. In fact for our scientists and our park rangers, we have a constant problem with boaters being wrecked by running over the stump of a tree.

ALAN ALDA (Narration) Without mishap, here we are at Barro Colorado Island. And here, nestled in the trees, is the Smithsonian Tropical Research Institute, known to everyone as "STRI".

ANTHONY COATES Hello, David.

ALAN ALDA (Narration) David Roubik is STRI's resident bee expert. We'll be looking at his wonderful discoveries later.

ALAN ALDA How unusual is this place in the whole world?

ANTHONY COATES It's pretty much unique because of the sophistication of its facilities, and the primary protected nature of the forest.

ALAN ALDA (Narration) And here's STRI's forest laboratory. Protected as a national park, uninhabited, and unexploited -- except by scientists. It's just three miles by two, covered with a riot of tropical growth, spilling down to the edge of the lake. What fascinates scientists about all the world's tropical forests is their amazing diversity. Take trees, for instance, the basic building blocks of the forest.

ALAN ALDA If you walk around in a square mile here, how many different kinds of species are you liable to come across?

ANTHONY COATES You could probably describe the entire Appalachian Forest from Maine to Alabama with thirty different species. We have what we call a fifty hectare plot, that's five football fields by ten football fields. It contains 330 species of tree.

ALAN ALDA (Narration) Lots of different kinds of tree, and, lots of everything else, too. Well there are only twenty-one kinds of large animal on the island -- these are howler monkeys -- because it's too small an area for more. But how about the little things? There are a few hundred kinds of ant, for example. Or take bees -- there are dozens of kinds, just on Barro Colorado. We're a long way from understanding, or even identifying, everything that's small in tropical forests. The talk in the STRI cafeteria is not about the food, it's all about what's going on out there in the forest. And lately, thanks to this talented young Rearcher, Elisabeth Kalko, it's the forest at night that's come alive. She's an expert on Barro Colorado's bats...

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ECHOES IN THE NIGHT

ALAN ALDA (Narration) Night falls on Barro Colorado Island -- but the forest doesn't sleep. It's time for the island's bats to swing -- quietly -- into action. But a few bats will have their hunting briefly interrupted by Elisabeth Kalko's mist nets. One of the world's leading bat experts, she's identified over seventy different bat species, just on the island.

ELISABETH KALKO This is a round-eared bat and it has very large ears here, and it's actually a pregnant female, when I touch her belly I can feel the embryo. And it also belongs to the leaf-nose bats and has this little funny leaf-nose on its snout, and rather large eyes. It's also a little carnivore. It eats insects and has been reported also to catch birds.

ALAN ALDA (Narration) Here's another kind of leaf-nose bat. This one's also a carnivore, but eats fruit and nectar, too. It's one of the forest's best flyers.

ELISABETH KALKO Bats fly with their hands, here this is the thumb, with the little claw on it, and then here you see the elongated fingers, and between the fingers there's this rubber-like membrane. This bat has enormous wings, a large wing span, and it's a very fast flyer. It flies huge distances every night, and you may sometimes see it above the canopy, hunting for insects in the air.

ALAN ALDA (Narration) This is the round-eared bat Elisabeth caught tonight. She and her graduate student will use a tiny transmitter that broadcasts

differently when it's upside down -- so they'll be able to tell when the bat's resting. There's a delicate procedure to glue the transmitter in place.

ELISABETH KALKO That looks great.

ALAN ALDA (Narration) How long it'll stay depends on this particular guy's personal habits.

ELISABETH KALKO We have a lot of bats that are really grooming a lot and sometimes we loose the transmitter after one night, but occasionally we find bats that carry the transmitter several weeks. We have right now a bat that carries the transmitter now for three weeks already, and that's, well, one of the longest times. Bye bye... echolocating... stretching the wing... whew!

ALAN ALDA (Narration) On most nights, two or three of Elizabeth's students are prowling through the forest, tracking bats. Here's our round-eared bat. The slow beeps means it's resting -- probably recovering from the stress of being handled. Night after night, year after year, painstaking work like this has built up a unique record of the bats on Barro Colorado. But what are the bats actually doing out there, in the pitch black of the forest? Here's one way to find out.

ALAN ALDA Is this good?

ALAN ALDA (Narration) Elisabeth calls this her bat detector -- a high-tech box that transforms bat sounds, which are normally too high for humans to hear.

ELISABETH KALKO Oh! And we have a bat already flying above us.

ALAN ALDA I didn't hear anything.

ALAN ALDA (Narration) The box instantly lowers the pitch of the bat sound, so we can listen in.

ELISABETH KALKO These are the bats that live under the roofs of the houses here.

ALAN ALDA Can you tell from that sound what it's doing?

ELISABETH KALKO Yeah, right now -- beautiful, beautiful -- we hear a lot of different things but it's very fast, unfortunately. What you hear now, these are search calls. They are searching for insects, and when you hear ddd... brrrrr, the brrrr is a terminal phase. This is when they home in on insects.

ALAN ALDA That brrrr?

ELISABETH KALKO Right, that was a terminal phase again. And what I find so fascinating about it is when you walk out here usually or normally you wouldn't get any of the life above us, and we wouldn't even know that bats are here, and now the forest comes alive, the acoustic world comes alive, and there's a lot of action going on!

ALAN ALDA What? What? You're hearing something great - what?

ELISABETH KALKO Well, they're just feeding like crazy right now. Hear all these weird buzzes?

ALAN ALDA Well you went into ecstasy with these sounds happening, and I can't - that's my question - how many years did it take before you could interpret these sounds so acutely? I mean, you can tell everything they're doing! How long did it take you?

ELISABETH KALKO Well, I'm working with this system here, with echolocation I think, well, let's see - it was almost ten years.

ALAN ALDA (Narration) We brought a special night vision system out to the island, to help us see what Elisabeth already sees in her mind. The night sky in the forest is filled with action. The bats are hunting. All those clicks and squeaks are different kinds of echolocating sounds, used to bounce off, and find, the prey. It's mainly insect eaters that are out right now.

ELISABETH KALKO Wha!

ALAN ALDA (Narration) The zipping noise is the final burst of sound as the bat swoops in for the kill.

ELISABETH KALKO That must have been an excellent sound recording.

ALAN ALDA (Narration) Elizabeth's latest work is figuring out exactly how bats use all these different sounds.

ELISABETH KALKO The white-lined bats, they're called Saccopteryx bilineata, catching the insect about three meters above the ground.

ALAN ALDA (Narration) So her nights are spent out in the forest, making recordings for analysis later.

ELISABETH KALKO Searching for the insect...

ALAN ALDA (Narration) Here's a typical hunting sequence.

ELISABETH KALKO Now... Speeding up the calls... Right...

ALAN ALDA (Narration) And then in for the kill.

ELISABETH KALKO A gorgeous terminal phase.

ALAN ALDA (Narration) For Elisabeth, it's like some kind of air show up there.

ELISABETH KALKO I hear the naked-backed bat, then I hear Saccopteryx bilineata, the white-lined bat, in the background I hear a free-tailed bat. So it's a whole symphony of bat calls that surrounds us right now.

ALAN ALDA (Narration) The edge of the lake is a favorite hunting ground for bats. Every night, insect eaters and the big fish eaters swoop out of the forest in a spectacular aerial display.

ALAN ALDA Are the bigger ones one species, and the smaller ones another?

ELISABETH KALKO Yes, yes. The big one is the fishing bat, Noctilio leporinus, and that's a bat that is specialized in catching small fish and occasionally also insects from the water surface, and the smaller one is Noctilio albiventris and that's a purely insect eating bat and taking prey from the water surface too. We are now connecting the synchronization unit with my sound recording equipment, so that we can actually later on release this whole system.

ALAN ALDA (Narration) To understand exactly how different bats hunt, Elisabeth invented this multi-flash picture system.

ELISABETH KALKO So let's see whether the flashes are working. Uh huh. Ready, go.

ALAN ALDA (Narration) The bats' echolocation sounds are recorded at the same time. Watch this bat delicately plucking fish from the water surface.

ALAN ALDA Are they zeroing in on the water and the prey at the same time, and each other, all those things?

ELISABETH KALKO Actually what they do is since they echolocate individual targets, they know exactly which spot they want to go to. For example, for the fishing bat when a little fish breaks the water surface, the echolocation call to the bat gives an echo back that indicate very clearly there's a fish breaking the water surface, so the bat goes specifically for this spot. There were almost 300 nights

that I was out there, listening to bats, making multi-flash recordings, and trying to decipher a little bit of their mysterious lives.

ALAN ALDA (Narration) Elisabeth keeps an exhausting schedule -- nights in the forest, then days in her lab.

ELISABETH KALKO Yes, I have a print here from one of the pictures that we took last night, and it shows the bat approaching a little fish that broke the water surface, and the bat approaches this water disturbance and hits the water with its claws, tries to get the fish out of the water, takes the fish out, and then carries it away.

ALAN ALDA When the bat senses the fish coming out of the water, by the time the bat gets there the fish is back in the water.

ELISABETH KALKO Exactly.

ALAN ALDA So the bat has to know where it would be at the right time.

ELISABETH KALKO Right, and this is visible here, because we see the disturbance here in the water, but when the bat hits the water surface it's different.

ALAN ALDA (Narration) In the split second the fish breaks the surface, the bat measures its speed and direction, using a rapid burst of calls. Here they're slowed down fifty times.

ALAN ALDA So how many of these little beeps is the bat making in a second?

ELISABETH KALKO In the terminal phase, and this is when they make the most calls, they may make about 150 to 170 calls per second. So that's a lot.

ALAN ALDA It is! What kind of a mechanism does the bat have to make such rapid sounds? How does it do it?

ELISABETH KALKO It does it, like we talk. Bats produce their calls, with their vocal cords, and so it's like talking. But of course they have special muscles that allow them to get the tension up and to produce these calls at such a fast rate.

ALAN ALDA (Narration) Now look at insect eaters. First they use a special call which actually tells them what kind of insect is out there. Then they track the insect -- it's the lower set of dots in the picture -- with a different call, until the moment they snatch it out of the air. So here's the first call, used to identify the

prey. It's a series of steady notes that bounce off the insect's wings, and come back wobbly.

ELISABETH KALKO It gets modulations back that tell the bat there is an insect. And not only that, it can also determine the wing beat rate. It knows, this a beetle, this a moth--it knows the direction the insect is flying.

ALAN ALDA It's a real sound picture of these wings beating.

ELISABETH KALKO That's a real sound picture. But the bat has great difficulties with its call type to determine how far away is the insect.

ALAN ALDA (Narration) Now the bat changes to rapid calls, like the fish eater. Elisabeth discovered that each of these is a falling call, like a series of piano notes. They're a super-accurate way to measure the distance.

ALAN ALDA It's going "ddddddddd", and from the other end of the room it's coming back, "ddddddd", but it's measuring the time of each of those notes as it comes back.

ELISABETH KALKO Right.

ALAN ALDA (Narration) Elizabeth's work is sorting out, for the first time, just what it takes to be a bat. Sometimes she'll keep some from the nets for a day or two, for detailed study. Tonight she's looking at fruit bats, so she sets out an irresistible bunch of wild forest figs. Figs are not known as fast movers, so fruit bats don't need fancy calling systems -- only a simple call to avoid obstacles in the forest. First it flies a series of passes by the fruit.

ELISABETH KALKO Very good, very good, it's coming... very soon. Yes it's going to do it...

ALAN ALDA (Narration) And then...

ELISABETH KALKO Yeah!

ALAN ALDA (Narration) Elisabeth has figured out how it actually finds the fruit -- it's by smell. Elisabeth Kalko has to be one of the world's most enthusiastic bat people. Here on the island, she must be in paradise.

ALAN ALDA What is there about this place that gave you the chance to learn so much more about bats?

ELISABETH KALKO Just imagine in all of the United States you may find about 44 species of bats. Here, BCI, this little island, 15 square kilometers, we are up to 71 species already, and all of Panama may hold 120 species of bats. And that's even a lot when you look at the world where there's about a thousand species, including flying foxes. So Panama has basically more than a tenth of all bat species, and that's quite astounding.

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RAT SOUP

ALAN ALDA (Narration) So here are the ingredients for this story... Willi, the Swiss chef...Antonio, the committed environmentalist...A table full of rainforest produce, none of which I can identify... And finally, a large forest rodent which Willi seems to want to eat...And I don't think I really do.

ALAN ALDA Can I ask you a personal question? Do you eat this?

WILLI DIEGELMAN Yes. It's fantastic! I like it. Smells good?

ALAN ALDA Smells very good. Yeah.

ALAN ALDA (Narration) While the soup simmers, we'll put our story's ingredients together. The story begins in the first decade of this century. The Panama Canal was being built, the world's largest construction project at the time. Even though it involved earth moving on an unprecedented scale, the clever design of the canal reduced excavation to a minimum. Ships were to be lifted up through locks to a new artificial lake, forming the central twenty five miles of the canal. That way, massive excavation at sea level, from ocean to ocean, was avoided. Gatun Lake was created by damming a river which flowed out of Panama's interior. Here's Barro Colorado Island becoming isolated as the surrounding valleys flood. Here's one end of the lake today, and here's the dam which caused it. It was a smart design for the canal, but it has to have lots of fresh water to keep it going. This is how it works:

ALAN ALDA These are in place in kind of a v-shaped position. Is that for a reason?

EDGAR PAULK Yes, that's actually a concept originated by Leonardo da Vinci. Centuries ago, he designed this type of gate. Water pressure keeps them tightly closed.

ALAN ALDA The water pushing this way keeps it closed?

EDGAR PAULK Exactly. With just a small difference -- right now there's 54 feet here -- but with just a couple of inches, it would be impossible to open them.

ALAN ALDA (Narration) Watch as this ship enters the first lock from the Pacific Ocean. Fresh water has to be released from the lock above, to raise the ship below.

ALAN ALDA That water's beginning to bubble down there. What's happening?

EDGAR PAULK Right now they're transferring water from the upper chamber. It's about 26 million gallons that enter into this chamber by gravity, and it's all divided up through 100 holes in the bottom, so it comes out very quickly, but very smoothly.

ALAN ALDA How quickly does 26 million gallons...

EDGAR PAULK Eight minutes.

ALAN ALDA Eight minutes?

EDGAR PAULK Yes. The tunnels are 18 feet in diameter.

ALAN ALDA Because I'm thinking how long it takes to fill a bathtub.

EDGAR PAULK A bathtub takes 9.

ALAN ALDA (Narration) So it takes an awful lot of water for a ship to pass through the Panama Canal.

ALAN ALDA Like how much does Panama City use every day? GUIDE Panama uses probably for a whole day what they use here for one ship.

ALAN ALDA (Narration) With the water levels equalized, Leonardo da Vinci's lock gates are free to swing open. These are the largest lock gates ever built, by the way. Then our ship can be guided into the next lock, for another step up. So feel like a quick cruise through the canal? Let's go. Here we are in the Miraflores locks, coming in from the Pacific. Up we go, 28 feet. Next lock -- another 28 feet. Then out across a small intermediate lake to Pedro Miguel locks, the last step up. Into Pedro Miguel... up 28 feet... and now we're in the six-mile Gaillard Cut. This was where the bulk of the excavation had to take place. At 85 feet above sea level, we're sailing across the continental divide. Now we're crossing Gatun Lake... And at the end of the lake, we're into Gatun Locks for our three steps back down to sea level. And of course, flushed out into the Atlantic Ocean with us are 26 million gallons of fresh water. No problem, right? Well, actually there is a

problem. In Panama, as in many countries, poor farmers burn the forest vegetation to clear fields. It's called slash-and-burn agriculture. Every few years, when the soil's exhausted, they have to move on to clear fresh areas, to grow crops, or graze cattle. Slash-and-burn by a growing population is a big threat to the canal. A forest stores rainfall like a sponge, but without forest the land erodes rapidly. The canal and the lake could just clog up with forest soil washing off the land. So far routine dredging has kept things clear, but in the hills bordering the canal, there's a radical alternative to slash-and-burn taking shape. The process does start with some slashing -- attacking these tall, tough stands of grass.

ALAN ALDA Where did this grass come from? Why do you say it's invading, I mean, wasn't it always here?

ANTONIO TELESCA Yeah - this is not native. This comes from Asia, and when the grass comes into Panama, we begin to have a problem. Because the grass is more aggressive like any kind of grass we have in Panama, and it's growing more fast than any kind of tree we have.

ALAN ALDA How fast does this grass grow?

ANTONIO TELESCA Well, some of the investigation... talking about 5 inches a day.

ALAN ALDA 5 inches a day?

ANTONIO TELESCA 5 inches a day.

ALAN ALDA In one day this grass grows 5 inches?

ANTONIO TELESCA Yes. In the beginning when you're cutting the grass, if you let the grass keep growing again -- 5 inch a day it's beginning to grow.

ALAN ALDA (Narration) The fast-growing grass was brought in to control erosion while the canal was under construction, but now it has spread all over the canal zone. It's wasted, unproductive land.

ANTONIO TELESCA Buenos dias.

ALAN ALDA Buenos dias.

ALAN ALDA (Narration) The goal is to restore forest on the grassland -- and this is the second step. They're harvesting a kind of bean, planted here a few months ago, after the alien grass was cut. The beans grow even faster than the grass, and once there's shade on the ground, the grass can't grow back.

ANTONIO TELESCA Take a piece.

ALAN ALDA (Narration) The beans are a good crop for a poor farmer, too.

ANTONIO TELESCA Open one, open one. You can put this in rice and you can eat it. The taste is good.

ALAN ALDA (Narration) Now here's the best part. At the same time they plant the beans, they also put in young trees -- native, forest species that can handle some shade, and including plenty of valuable fruit and nut trees for the farmers to harvest later. With the grass held back by the beans, the young forest gets its start in life.

ALAN ALDA So this plant gets this tall in eight months. In eight months, how tall would the grass get if there were no beans here?

ANTONIO TELESCA If no beans? Maybe in eight months the grass is like 2 or 3 meters.

ALAN ALDA Like 6 feet maybe.

ANTONIO TELESCA Like 6 feet.

ALAN ALDA 6 to 9 feet!

ANTONIO TELESCA Like 6 to 9 feet.

ALAN ALDA So this plant would have no chance whatsoever!

ANTONIO TELESCA It's impossible because the grass is growing like this, and there's no sun.

ALAN ALDA (Narration) Seven years later the restored areas look like this. From useless grassland to valuable new forest.

ALAN ALDA Was this all grass before?

ANTONIO TELESCA Yeah. Seven years ago, all this area was grass.

ALAN ALDA (Narration) And there's one more remarkable aspect to the project. One of its biggest successes -- pacas.

ALAN ALDA Paca?

ANTONIO TELESCA Yup. Have you ever feed paca?

ALAN ALDA Have I ever what?

ANTONIO TELESCA You ever eat paca?

ALAN ALDA Eat? I've never seen it!

ANTONIO TELESCA You've never seen it?

ALAN ALDA What a strange looking animal!

ANTONIO TELESCA You want to give him one of these?

ALAN ALDA Well, let me see you feed him first. I want to see how...Yeah that's what I thought. There's a great sense of sharing among the pacas.

ALAN ALDA (Narration) Pacas are nocturnal rainforest animals, prized for their meat and hunted almost to extinction in Panama. But Antonio's project is now giving them to farmers to breed. Pacas eat rainforest produce, so they're another part of a system which encourages poor farmers to use the forest, not cut it down. Many of these ideas -- like domesticating pacas -- were first developed at STRI to help prevent rainforest destruction throughout the Americas. This is just a small sampling of the hidden wealth of the rainforest. For example, "picsbai". It's a kind of palm nut, that you roast.

ALAN ALDA Mmm....it's good.

ANTONIO TELESCA It's really good. And they grow it in a pod...

ALAN ALDA It tastes so much like something I know, but I don't-

WILLI DIEGELMAN A little bit like.....chestnuts.

ALAN ALDA Chestnuts - yeah!

ALAN ALDA What is that made of? What are these things? This is in the pie?

WILLI DIEGELMAN Nispero.

ALAN ALDA Mispero?

WILLI DIEGELMAN Nnn... nispero

ALAN ALDA Nispero. What's that?

ANTONIO TELESCA It's a wild fruit.

ALAN ALDA A wild fruit. So this is a fruit pie.

ALAN ALDA (Narration) Cashews are a rainforest crop, but they can yield more than nuts.

ANTONIO TELESCA This is the nut.

ALAN ALDA Oh! this the nut - okay, look! look! How many times we've eaten cashews and we never knew how it looked on the tree!

ALAN ALDA Cashew juice. I have never had cashew juice before. This is going to be great - let's see... It doesn't taste like a cashew at all.... It's very good tasting juice. I mean, I have to tell you, I have to get over the way some of it looks. Like that fruit looks like it needs a shave over there! This doesn't look too good, and then when you open it up, it looks even worse! It's very interesting. It's got...The flavor has twists and turns that I'm not used to in anything else I've ever tasted. It looks like it comes from another planet, and it tastes like it comes from another planet!

ALAN ALDA (Narration) And now the chef's specialty. Yes, it's paca.

ALAN ALDA Rat soup... mmm. Well, whenever I'm in the jungle this is what I have. Mmm... whoa! You've got to try this! This is great!

ALAN ALDA (Narration) Then, over the nispero pie, it came to me -- a new business. Good for the forest, too.

ALAN ALDA You've got to go to New York, or Paris or Geneva and open up a restaurant that just serves jungle foods. It would be interesting for people to try all these tastes.

WILLI DIEGELMAN A jungle restaurant in New York. With a Swiss chef!

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BEE LINES

ALAN ALDA Now these are stingless bees, huh?

DAVID ROUBIK Yeah these are the user friendly bees.

ALAN ALDA (Narration) David Roubik, STRI's resident bee expert, works with Panama's stingless bees.

ALAN ALDA How do they keep from getting eaten?

DAVID ROUBIK They have all the same problems that any other bee that makes honey and has a big luscious nest to eat would have, but they're very selective about where they build a nest. It's usually only in a standing tree, and they do have defenses. Some of them bite very well.

ALAN ALDA Oh, oh, oh.

DAVID ROUBIK So it's a combination. They're not fools, you understand.

ALAN ALDA But we're surrounded by them here, so we don't have to worry?

DAVID ROUBIK Yeah, well they're just coming and going here. It's an active colony.

ALAN ALDA (Narration) Actually inside his lab, David keeps an entire colony of one of the many stingless bee species.

ALAN ALDA They make honey, so what do they make it out of?

DAVID ROUBIK Well, out in this forest there are about a thousand species of different flowering plants they can go to, they might use two or three hundred kinds during the course of a year. So constantly, every day of the year, all during the daylight hours they're foraging . Bees are going out, maybe as far as two or three kilometers and bringing back food.

ALAN ALDA (Narration) The bees have to make hundreds of trips each day, back and forth between forest and hive. What the researchers have found is that the bees can tell each other exactly where to go in the forest.

ALAN ALDA How accurately can the bee communicate to the others where this good source of food is?

DAVID ROUBIK Finding how well they could communicate was really what shocked us, because they're not just kind of giving a general cue of "there's some good food out here, fly around and maybe you'll find it". They're saying how far away, how high up and in what direction, so three dimensions.

ALAN ALDA (Narration) The story of this remarkable discovery begins with David's specially arranged bee colony.

ALAN ALDA Where are they, here?

ALAN ALDA (Narration) A pipe running through the wall channels the bees into an observation hive, where you can watch and listen to the bees in action.

ALAN ALDA So this is what it looks like inside a normal hive.

ALAN ALDA (Narration) These are foragers entering and leaving the hive. Here on the left is where other workers store honey. This is the queen, mother of all worker bees, who lays her eggs in rows of cells. There's also one other thing about these bees.

ALAN ALDA They have little numbers on them.

DAVID ROUBIK This is a sign we've been here before.

ALAN ALDA Just let me make a guess -- you put them there, right?

DAVID ROUBIK You're exactly right.

ALAN ALDA (Narration) How on earth do you put a number on a bee?

JAMES NIEH How we do it is we just grab a bee. They're quite docile when they're feeding, and also they're stingless so that helps. Here I'll let you try and label it....

ALAN ALDA (Narration) Biologist

JAMES NIEH works with David on bee communication research.

ALAN ALDA Now what do we do?

JAMES NIEH And then you smear a little bit on to her thorax.

ALAN ALDA Her thorax is right after her head, right?

JAMES NIEH Right. Exactly, that little furry spot.

ALAN ALDA (Narration) Being able to tell one bee from another is crucial for doing communication experiments.

ALAN ALDA Seventy-eight. Now we've numbered a bee! Number seventy-eight is my bee! When this bee makes a great scientific discovery, and we all go to Sweden to get the prize, number seventy-eight is mine!

ALAN ALDA (Narration) After the bees are numbered, they're trained. Sugar water is injected into the hive to excite the bees interest. Next, a feeder with the same sugar water is placed at the hive entrance. In just a few seconds the bees discover the feeder, and there's no doubt they like what's there. Once a few bees have had a good drink, the feeder is moved away from the hive. As long as it stays within smelling distance of where it was before, the bees can easily find it again after making deliveries to the hive. James steadily leads the bees into the forest, advancing twenty feet at a time -- about the maximum distance the bees can smell. So they can train bees to forage anywhere in the forest... Even at the top of a hundred-and-twenty-foot tower, which simulates a tall flowering tree. You really have to love bees to make this climb. The question they're asking here is whether bees can communicate the height of a food source to their fellow workers back in the hive. Of course some bees already know where the food is, because they've been trained. That's why you have to know their numbers, so they can be discounted. Here's 3... 34... 5... 26. They're all trained bees. Wait a minute -- here's one without a number. Well, that's a complication. New workers are born every day, so there are always a few like this. They have to be marked as they show up. Now as the bees fly between the tower and the hive, James looks for new recruits -- ones he hasn't trained to come here. Meanwhile, down at the base of the tower David watches a second, identical feeder. Maybe new recruits will find this one.

DAVID ROUBIK OK James, there you have it set up here now.

JAMES NIEH Let me know if you get any new recruits, over.

DAVID ROUBIK No recruits here yet, James, haven't seen a bee.

ALAN ALDA (Narration) If the bees can communicate how high the food is, then no new recruits should show up at the ground level feeder. They should all head out of the hive, straight to the top of the tower. And that, in fact, is what happens. These are all new recruits.

JAMES NIEH Looks like I just got my ninth recruit, and that means about nine to zero, is that correct? Do you have any new recruits down there? Over.

DAVID ROUBIK They're making a bee line to you it seems to me. It's been pretty dull down here.

ALAN ALDA (Narration) When the experiment is reversed, and the bees are trained to the base of the tower, all new recruits show up there. So the bees do somehow communicate height. Next, bees are trained to a feeder north of the hive, and the new recruits show up there -- not at a feeder to the south. So the bees can also communicate direction. And it's the same for distance. Even when two feeders are set up only about thirty feet apart, new recruits always went to the feeder where their hive mates were trained. So how do the bees do it? Maybe the new recruits simply follow the trained bees. So James repeated the experiments, this time capturing all bees leaving the hive, and keeping those which had been to the feeder. But new recruits still found the correct place, so simple following can't be the explanation. Is it possible the recruits follow some kind of scent trail in the forest? After all, biologists know that bees often deposit a mysterious liquid on leaves. To rule out this possibility, feeders were taken across a lagoon where no scent trail could be left -- and the recruits still went to the right feeder. So looking for some form of communication, James began videotaping bees as they returned from feeders... And he found the secret world of bee talk. This red marked bee has just returned from a feeder. As it hands over food to other workers, it makes a series of pulsing buzzes. Then it does a brief dance, accompanied by another series of buzzes. By comparing bees that came in from different feeders, James managed to decipher the buzzing code.

JAMES NIEH This is a bee that's foraging at the base of the canopy tower. We also have another group of bees that's foraging at the top of the canopy. And what you should notice here, is that...

ALAN ALDA The pulses are shorter.

JAMES NIEH Exactly. Right. So from here to here the bee's unloading food, and if you compare the pulses, they're definitely shorter.

ALAN ALDA (Narration) Short buzzes made while unloading food mean that the food comes from near the ground. And the longer the pulses, the higher the food source. For sound made during the dance, the longer the buzz, the farther away the food.

ALAN ALDA It's like the bee book! It's like if they weren't at home you could leave this around, they could walk across it and read it and see how far to go.

JAMES NIEH Exactly. It's a bee sentence.

ALAN ALDA It's a bee sentence.

ALAN ALDA (Narration) As for how the bees communicate direction, that's still a mystery. Maybe number seventy eight will show them how it's done.

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CHAMPION CHOMPERS

ALAN ALDA (Narration) This is STRI's solution to one of the biggest obstacles that forest researcher's face.

RESEARCHER Arriba. Rapido.

ALAN ALDA (Narration) It's one of those simple ideas that seems so obvious once someone has thought of it. It's a construction crane that gently flies researchers around the normally inaccessible tree tops. Until they built the crane, nobody had really had a good look around up here. In tropical forests the sun-drenched canopy is where the action is. It's where well-known big guys like monkeys or iguanas live. But it has also turned out to be home to an astonishing variety of small things -- to a degree that has just stunned the biological world. Hector Barrios and his team return to the same trees week after week to collect insects. From its fixed base, the crane can reach about 200 trees. There are specialized traps for flying insects. Here's a sampling of the results -- literally thousands of kinds of beetle, found on just two tree types. After these revelations, scientists are now convinced there may be thirty million species of life on the planet, most of them tropical insects. Nobody quite knows why tropical forests have so many insects, or for that matter why these particular insects can manage to consume so much of the forest without damaging it. They're leaf cutter ants. Everywhere you look in the forest you'll find their trails. The ants haul enormous leaf chunks along trails up to a quarter mile long. The leaves usually come from way up in the canopy, from trees that have just sprouted a fresh crop of foliage. The new foliage is tender -- easier to chomp into pieces. Then comes the long march home. The most amazing thing about these ants is they don't actually eat the leaves, once they're back in their underground nests. This is what a leaf cutter nest looks like. It's not a pile of leaves, but a mass of spongy fungus which grows on the leaves, consuming them in the process.

ALAN ALDA Can I just feel that? It' s sort of moist, and soft, mushy.

ULRICH MUELLER And that's all like plant parts that have been invaded by the fungus.

ALAN ALDA Now, do they eat that fungus? That's their food?

ULRICH MUELLER The fungus produces particular structures which are rich in portion and sugars.

ALAN ALDA (Narration) The ants only eat the nutritious products of the fungus -- and that's all they eat. They have to grow their fungus to survive.

ALAN ALDA This is a really a farm, isn't it? This is real farming.

ULRICH MUELLER Yeah, that is the closest in the animal kingdom of what humans would be calling agriculture. It's not true agriculture, it's fungiculture. But it has the same kind of features of our agricultural systems.

ALAN ALDA So humans developed farming, about when?

ULRICH MUELLER As far as we know the first signs of agriculture date back about ten thousand years ago.

ALAN ALDA And ants figured it out, about when?

ULRICH MUELLER About fifty to sixty million years ago.

ALAN ALDA Ten thousand years verses fifty or sixty million.

ALAN ALDA (Narration) Not only were leaf cutters way ahead of us as farmers, they also invented the world's first professional classes... Like garbage collectors. Here they're throwing out dead fungus, that no longer produces ant food. Within a mature ant colony of maybe twenty million members, perhaps a million will be specialized garbage handlers. And the garbage dumps can get enormous. Then there are the security forces. This little fly, on the right, attacks worker ants. So all along the trails you'll see special guard ants riding shotgun on the leaf cargo. And there are always openings in the highway maintenance department. If a leaf blocks the trail, special road crews quickly maneuver it aside, so traffic can get moving again. STRI biologists have been figuring out how much foliage the highly-organized leaf cutters consume each year. First they count ants on the trail... Then they collect sample cargoes to work out the average ant leaf load. It seems that ants cut down as much as twenty percent of the forest's foliage each year. This result really has people puzzled -- how does the forest handle that kind of impact? As for the ants -- well, they must keep pretty busy.

ULRICH MUELLER I don't think there's any time for them to develop anything like watching TV or playing golf.

ALAN ALDA Well you don't see any little... most of the antennas are attached to the ants themselves. Very few on the TV sets.

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BRIDGE THAT CHANGED THE WORLD

ALAN ALDA (Narration) This is the Isthmus of Panama, as seen today by a satellite's camera. It's a delicate land bridge, connecting North and South America. But for most of the earth's history, if satellites had been around they would have seen something like this -- open ocean between the two continents. A direct connection between the Atlantic and Pacific. Panama's sleepy Caribbean coast, on the Atlantic side, bears traces of the Isthmus' violent origins. Our guide is Tony Coates, STRI's deputy director. He's a geologist by trade, who has spent the last five years searching the coast for rocks that tell the story.

TONY COATES Let's talk a little bit about what we're going to do today. You've got the Cusapin map? ASSISTANT Yes.

TONY COATES We'll go down to Tabobe, here, and then if we've got enough time we'll come on down to Nancy Point.

ALAN ALDA (Narration) For Tony, what's special about this remote coast is that its rocks were formed deep in the ocean. Forces in the earth's crust have since pushed them up to the surface, where geologists can get at them. Here's our first stop. The rock here was formed by layers of mud which piled up on the ocean floor about twenty million years ago. As you'd expect, the mud layers trapped within them traces of ocean life from that time. And for Tony, the life forms carry a simple, dramatic message.

TONY COATES These rocks tell you that 20 million years ago, there was no Isthmus of Panama. There was only an ocean -- a deep ocean, more than six thousand feet deep -- and we know that because these rocks are filled with trillions of microscopic organisms that only live in the mud at the bottom of such an ocean.

ALAN ALDA (Narration) When you wash off the ancient ocean mud, and sort through the remains, you find countless tiny fossil shells. Today we only find these creatures living at ocean depths of a mile or more. So twenty million years ago -- no Isthmus. Tony reads in rocks like this what happened next.

TONY COATES The Isthmus began when the volcanoes erupted on the floor of the ocean, and this is a perfect example of the lavas that would have come out of those volcanoes. The moment is perfectly demonstrated in this little section over here. Here we have the deep ocean sediments that we saw before, and you can see along this line they are overlain by the jagged boulders of lava that you were just looking at. This is the moment in time when the Isthmus began to form.

ALAN ALDA (Narration) About eighteen million years ago, the ocean between North and South America was a very violent place. Lava spewing out from the underwater volcanoes steadily built up from the ocean floor. A chain of volcanic islands began to form, linking the continents. And after a few million years, a solid land bridge was established. Just up the coast, Tony finds evidence of the final, placid stage of the creation of the land bridge -- the remains of an ancient beach, that formed on the slopes of an extinct volcano. It's complete with fossilized seashells. Tony has figured out that the land bridge was continuous by about four million years ago, setting the stage for violent upheavals, in turn, in the animal world

ALAN ALDA What did that do to the evolution of the animals in the water, and the plants and so on?

TONY COATES Obviously there's the dramatic connection of the two continents in this incredible ecological confrontation that took place -- predatory birds 12 feet high, that could have ripped your and my head off, came north as far as Florida and Texas. 18 foot high sloths could browse these forests...

ALAN ALDA They still have them in Hollywood.

TONY COATES They didn't fair well when they went north. Today we only have three species in America that derive from South America -- the hedgehog, the opossum, and the armadillo. By contrast, vast numbers of species have evolved from the animals that went south. So that South America today is about 60 percent made up of animals derived from the north in that great ecological confrontation.

ALAN ALDA (Narration) The isthmus joined two continents, but it separated two oceans. In the process the warm, sheltered Caribbean Sea came into being. Coral reefs now grow here -- but not on the colder and rougher Pacific side.

NANCY KNOWLTON Xavier, did you find anything?

XAVIER Si, venga a ver.

ALAN ALDA (Narration) On this beach on the Pacific side, STRI's

NANCY KNOWLTON is looking for snapping shrimp. They've been around here for a while -- in fact, since before the oceans were separated. So now there are shrimp cousins on each side of the Isthmus who haven't seen each other for a few million years. What happens when there's a family reunion? As you might expect, things don't go so well. A fight breaks out almost immediately between this Pacific-side male and an Atlantic-side female. Here's a pair from one side

only. This friendly behavior is how things ought to go. In fact, Atlantic-Pacific pairs don't get along, and could never reproduce. They've evolved into separate species. Dozens of species are now split between the two sides, evolving separately. So the Isthmus had an impact on life in the ocean... It transformed life on land, in North and South America...And it even made itself felt half a world away. What happened is this. Before the Isthmus formed, the tropical waters of the Caribbean flowed into the Pacific Ocean. But once the way was blocked, this flow was diverted north -- forming the Gulf Stream. This immense conveyor belt of water warmed up Europe... And at the same time transformed Africa. Lush, tropical forest turned to drier, savanna grassland. Many scientists think it was this change that prompted our ancestors to begin to walk upright -- on their way to becoming human.

ALAN ALDA If you look at a map of the globe, the Isthmus of Panama is a relatively small part of it. It's a pretty minor dot on the globe.

TONY COATES A sliver, a tiny sliver.

ALAN ALDA And yet once that formed, there were these vast changes in life on the planet that you're describing, all over the planet.

TONY COATES It triggered what I think is probably the most dramatic event that's happened on earth since the extinction of the dinosaurs.

ALAN ALDA (Narration) So from its ancient effects on climate and nature, to today's priceless knowledge that scientists are extracting from the forest, Panama continues to profoundly affect our world. As we said at the beginning -- quite a record for a small country.

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