Science Magazine Podcast
Transcript, 22 July 2011
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Music

Host – Stewart Wills
Greetings, and welcome to the *Science* Podcast for July 22nd, 2011. I'm Stewart Wills. This week: how to preserve coral reefs amid an uncertain future; deciphering the causes of a mass extinction 200 million years ago; and exploring parrot communication in a unique long-term experiment. All this, plus a wrap-up of some of the latest science news from our online daily news site, *Science*NOW.

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Music ends

Host – Stewart Wills
Global warming and its effects in the sea have especially sobering implications for coral reefs. Some forecasters have suggested that a worldwide collapse of reef ecosystems may be in the offing in only a matter of decades. A review article published this week in *Science* notes that the current danger for coral reefs is indeed very great -- but that the actual response of reefs to climate change is likely to vary a great deal, in space, in time, and among different coral species. That variability, the authors suggest, opens up a window of opportunity for better management to delay and reduce the effects on reef environments of both climate change and local stressors. I spoke with the review's lead author, John Pandolfi, from his office in Brisbane, Australia. He pointed out that human insults on coral reefs are not a new thing.

Interviewee – John Pandolfi
I think one of the most important things that we've found out over the last 10 years or so is that there's really few places that we can go, if any, that remain untouched from human impact. So really, any reef you might like to visit has suffered from human degradation. And this degradation started from the first interactions with humans, long before the effects of climate change were being felt. And this degradation has really increased in rate and intensity over the past 50 years. So again, many reefs are in a highly degraded state even without considering any future effects from climate change.

Interviewer – Stewart Wills
So what are the main environmental threats facing reefs right now?

Interviewee - John Pandolfi

Well, we like to – in the coral reef community – to talk about the big three, and those are, firstly, overexploitation – our incredible ability to overfish, to extract resources from the sea to a point where they no longer become sustainable. The second major threat, of course, is pollution, and this involves coastal development, changing land use practices that result in terrestrial runoff and high nutrients; in effect, we're reducing the water quality that the coral reefs are able to exist in. And of course, thirdly is climate change, and the two double whammies are global warming, of course, and ocean acidification.

Interviewer – Stewart Wills
One of the points that you make in your review was that corals are living creatures, and so, perhaps to some extent, they can evolve their way out of some of this, but I guess there are limits to that?

Interviewee – John Pandolfi
Well, in some sense, evolution is the real wildcard in all of this. On the one hand, I think it's wrong-headed to think that Darwin has taken a vacation just because the rate of climate change is so rapid. Similarly, though many corals do have long generation times, the large majority of them don't; they're able to reproduce after only four or five years, and often sooner. And they have symbionts – the photosynthetic dinoflagellates that are the engine of the coral growth – they have exceedingly short generation times. So there's a great potential for adaptation and acclimation that really hasn't entered the equation yet. Now, on the other hand, just because coral reef organisms respond to natural selection and potentially evolve doesn't mean that will save them, either. For example, positive selection on one trait, say, thermal tolerance, might be deleterious for a correlated trait, say, calcification response to ocean acidification, but because we know next to nothing about these processes on coral reefs, it really is very difficult to speculate on what the effects of evolution will have. And I think this is a real glaring hole in coral reef science right now.

Interviewer – Stewart Wills
Well, I wonder if the geological record can tell us anything? There have been climate and environmental changes in the geologic past. What does the rock record tell us?

Interviewee – John Pandolfi
Well, we do know that corals and reefs have had tremendous resilience to climate change over the geological past. No matter how hard and how many times they've been knocked down, they seem to generally be able to return. Now, that return is undoubtedly at far slower rates than the ecological and management time scales that most people are concerned with today. In addition, evidence from the geological past tells us that global warming and ocean acidification acting together have been responsible for a number of past reef crises – they've even played roles in mass extinction events – so we know that these threats, these climate change effects, are very important in the past demise of coral reefs. Now what's different today is the rate of climate change. We're unable to identify any periods in Earth history where rates of CO_2 rise are comparable to that of today. Now this could, in part, stem from our inability to measure CO_2 rise with the fine-scale temporal resolution that's available for us to measure it today, but so far, there's no real

known mechanism where we could get such huge rises in the rate of CO_2 in the geological past – we just don't know any mechanisms that would give us this comparable rate that we're seeing today. Now, again, on the other hand, there does seem to be some evidence that coral reefs can vary in their ability to cope with dramatic changes in climate. So, for example, about 55 million years ago, we had a major warming event in the Earth. It was called the Paleocene-Eocene thermal maximum. We got a dramatic spike in CO_2, we had a dramatic warming event, so those two things were acting together, and what happened was in coastal reefs, we had reefs that were dominated by corals that switched over to foram-dominated reefs. Now, forams are little, almost microscopic one-celled organisms with a calcareous skeleton that can be quite prolific and build reefs in and of themselves, but there was this big switch from a structuring, coral-dominated ecosystem to a more flattened, foraminifera-dominated ecosystem. But, if we go offshore, there are other places where an oceanic reef continued, with coral-dominated reef growth, and seemingly unaffected by this spike in CO_2 and warming. So, the message here is that there really is spatial and temporal variability in reef response to climate change.

Interviewer – Stewart Wills
Looking at the whole picture that you lay out in your review, there seems to be an awful lot of contingency and complexity, a lot of if this, then that scenarios. Is there any way to get a general handle on what the future holds for coral reefs given the trends that we're seeing today?

Interviewee – John Pandolfi
Well, Stewart, one of the issues we tried to stress in the review is that our ability to project what the future holds is really impaired by our lack of knowledge in certain key areas, and as I've already mentioned, one of the most important of these is the evolutionary potential of coral reef organisms. A lot of the current projections that we're hearing today tend to emphasize the worst-case data coming out of experimental and modeling studies, but we think that the response to coral reefs to climate change is going to be quite subtle and quite nuanced. There's going to be a lot of spatial variability, a lot of temporal variability, a lot of taxonomic variability in the way that different corals respond to climate change. So let me give you a couple examples. Within coral communities, there's a lot of variation among species about how susceptible they are to bleaching. Now, coral bleaching is when the coral symbionts are lost from the coral host, and the name comes from the fact that when that occurs, the coral turns white, and it often leads to mortality. But, if we look at mass bleaching events, we find that in certain places bleach, and certain other places don't; certain species bleach, and then certain species don't; certain populations from one species might bleach in one area, and might not bleach in another area. So there's a lot of variability there. Moreover, corals may flip from a less resistant symbiont strain to a more resistant symbiont strain in the aftermath of a bleaching event, and they might also switch back again, and it's these sort of dynamics – these symbiont dynamics – that may impart some measure of protection against vulnerability to climate change that we really need to investigate. Let me give you another example, and this gets back to the coral's ability to calcify under conditions of ocean acidification. The problem for corals, or for any organism that precipitates

calcium carbonate as a skeleton, is that when CO_2 rises in the present day, aragonite saturation state falls, and aragonite saturation state is essentially a measure of the potential for organisms to secrete their skeletons. Now, it's been commonly assumed that corals will have a hard time secreting their skeletons when this aragonite saturation state falls below three, but in our review, we've uncovered literature where coral reefs are thriving where saturation states fall well below three. Even more astonishingly, there is an ability for corals to make their skeletons in seawater where aragonite saturation states fall below one; that's the point at which abiotic carbonate begins to dissolve in the sea – we go from a saturation state to a dissolution state. So, it's very clear that the corals are able to mediate the seawater in which they precipitate calcium carbonate. We simply can't project that aragonite saturation states less than X caused by CO_2 levels higher than Y will result in the demise of coral reefs by decade Z – we just can't do that. It's far more complex and variable than that, and I think our task is to try to understand this subtlety, and then evaluate reefs on a more regional scale to understand how this demise of coral reefs is going to unfold. And it surely will – that demise, or that degradation, will surely be a feature of the coming seascape, there's no doubt about that, but I think the important point is that we need to identify the mechanisms at work to see if we can understand the variations spatially, temporally, and taxonomically.

Interviewer – Stewart Wills
Well, given all of that complexity, I guess I'd be interested in your views on what this means on a policy level, in terms of actually managing and conserving reef resources.

Interviewee – John Pandolfi
Well, I think basically, there's three things that we can do. Basically, we need to do anything that's going to slow the rate of climate change. Slowing the rate of climate change will diminish its impacts and maximize the potential for the reefs to recover and even adapt. So I think at the level of policy, the first thing we must really do is to act to slow that rate of climate change; that means aggressive CO_2 emissions reductions. The second thing we can do is to reduce local stressors. Larger, well-connected populations generally have greater capacity to evolve, for example, than smaller, poorly-connected populations. So when we look at human impacts, like fishing, pollution, habitat destructions, these processes all fragment population, and they decrease population sizes, so they reduce the potential of coral reefs to adapt to warmer, more acidic conditions. And the last thing is we just need the immediate expansion of sensible management strategies. You know, we're at a point where right now that we've developed some very sophisticated management strategies – marine spatial planning, marine protected areas, controls over exploitation, increases in water quality – these are all very, very effective management strategies that can reduce the degradation in living coral reefs, and we feel that the very best we can do is to reduce those stressors, manage the reefs well, so that when climate change does act in a more aggressive way, that the reefs are in as good a shape as they can to handle that.

Interviewer – Stewart Wills
John Pandolfi, thanks very much.

Interviewee – John Pandolfi
Thank you, Stewart.

Host – Stewart Wills
John Pandolif is lead author of "Projecting Coral Reef Futures Under Global Warming and Ocean Acidification," a review article in this week's *Science*.

Music

Host – Stewart Wills
From the tribulations of corals amid modern climate change, we next wind the clock back 200 million years, to another major climate event -- a huge release of atmospheric carbon, and subsequent rapid climate change, that may have triggered the mass extinction that marked the end of the Triassic period. Previous research has linked this extinction to long-term volcanic outflows related to the breakup of the supercontinent Pangaea and the subsequent opening of the Atlantic Ocean. But a new study in *Science*, which zeroed in on the carbon isotope signature of land plants, has identified a massive, and much more abrupt, methane burp at the end of the Triassic, possibly intensified by positive climate feedback loops. The authors of the study believe that its results may be instructive as a deep-time analogue of contemporary climate change. I spoke with the lead author, Micha Ruhl, from his office in the Netherlands.

Interviewee – Micha Ruhl
Well, the aim of this study was mainly to better understand the relations between the massive release of carbon to the atmosphere, and especially causal relations tochanges in climate, and especially temperature, and extinctions of plant and animal species.

Interviewer – Stewart Wills
Okay, well let's try to set the stage for this. This work, in particular, was about the mass extinction that took place at the end of the Triassic period, about 201 million years ago. Could you tell me a little bit about that event generally?

Interviewee – Micha Ruhl
At the Triassic-Jurassic time interval? Well, we have to remember that that Earth looked very, very different there than today. So, all the continents were still connected in one big continent called Pangaea. In the end-Triassic, this continent started to break up, and it started to form the Atlantic Ocean, and this is a very, very long process that continues for hundreds of millions of years, and still continues today. And, somewhere in the end-Triassic, we also have a major volcanic event, and it's believed that this volcanic event is related to the onset of the breaking up of this major continent, Pangaea. And, at the same time, at the onset of this volcanic event that we know of, there was a major extinction event in the oceans, so we know that about 50% of all species, animal species, that lived in the oceans went extinct, but also on the continents there were big changes in the vegetation.

Interviewer – Stewart Wills

And I guess that extinction has previously been ascribed to this massive volcanic outflow that you touched on?

Interviewee – Micha Ruhl
Yes, that's right, yes. So, we know from previous studies that the onset of the volcanic event coincides with the mass extinction events. So the extinction event is only very briefly, it takes about 40,000 years, but then the volcanic event takes much longer.

Interviewer – Stewart Wills
So, was that difference in timing – the difference between the very brief, geologically sudden mass extinction and this much longer volcanic outflow – was that sort of the puzzle to be solved here?

Interviewee – Micha Ruhl
That's right. So, there were two major questions, actually. So, one is, is the volcanism the main trigger for the change in climate that were going on, and the extinctions that we observed in the oceans? And the second question was what is causing the extinctions, basically, so is it only the volcanism, or have there been other processes involved?

Interviewer – Stewart Wills
And, I guess, from looking at your paper, you used carbon isotopes to study this, as people have done before, but you took a very much more sort of refined look at them. Could you tell me something about the approach you used?

Interviewee – Micha Ruhl
So, normally people study changes in the carbon cycle to study the release of carbon to the atmosphere, and what people normally do, they measure the changes in the ratio between two different types of carbon. So, people collect rocks and they study the ratio between these different types of carbon isotopes in those rocks. The problem is, however, that there are many processes influencing this ratio between these two isotopes, and now what we did is we looked much more in detail. What we studied is the change between these isotopes in plant leaves. So we extracted molecules from the rocks, and these molecules are produced by these plants, and these plants take up the carbon from the atmosphere. So if we look only at the molecules and not at all kinds of forces, but only at the change of the isotope ratio in these molecules, then we could potentially see how the ratio in these isotopes – between these isotopes – changes in the atmosphere.

Interviewer – Stewart Wills
So, in some sense, by focusing on one type of carbon and one type of molecule, this could kind of screen out a lot of the sort of extraneous factors that might contribute to the carbon signal?

Interviewee – Micha Ruhl
That's right.

Interviewer – Stewart Wills

Okay. Well, what did this approach tell you, that you didn't know before about this event?

Interviewee – Micha Ruhl
Yes, so one of the things that we found, that people previously thought that the amount of carbon being released was relatively small, and also, so the changes between these different isotopes was also relatively small. We now see that the change in the ratio between these isotopes in the atmosphere is much, much bigger. So that suggests that there was much more carbon released than people previously thought. And I guess that's one of the major findings. Then the second finding is that it's likely that it's not only the volcanism where the carbon is coming from, but that there's another process which releases much more carbon than only the volcanism.

Interviewer – Stewart Wills
So, yes, that was very interesting to me, because, as you noted, people have kind of tied this mass extinction to this huge eruption event associated with the break-up of Pangaea. But your work seems to suggest that either this wasn't the triggering event, or the story was a lot more complicated. What sort of models are you thinking about?

Interviewee – Micha Ruhl
Yes, that's right. So, people previously thought that this whole event was only related to the volcanism, but what we now know is that the volcanism took about 600,000 to maybe a million years, and we know that this mass extinction event was only maybe 40,000 years, so that was much shorter, so that made us think that maybe the volcanism couldn't be the only trigger for this event. What we now observe, what the data suggests, is that the volcanism triggered carbon dioxide release from volcanism, and that triggered an initial increase of temperature, and this initial increase of temperature then triggered the massive release of methane from the sea floor – and methane also consists of carbon – so this caused that a lot of carbon was released to the atmosphere. So likely, the volcanism triggered the release of methane, and then the methane was the major contributor of carbon into the atmosphere.

Interviewer – Stewart Wills
So, in a sense, what you think you might have been seeing here is one of these positive feedbacks that people talk about in thinking about today's greenhouse warming – essentially a small increase in temperature hits a part of the system that is sensitive to that, and then there's a positive feedback effect.

Interviewee – Micha Ruhl
Yes, that's right.

Interviewer – Stewart Wills
I'm interested, because at the end of the work, you do sort of suggest that this situation is an analog to today's greenhouse warming, and I guess I was wondering if you could just touch a bit more on that, because, clearly, we're talking about very different sorts of

processes here. Could you just talk a little bit more about how you see a parallel between those two situations?

Interviewee – Micha Ruhl
Yes. Of course, we have to be very careful in comparing the current-day situation with time intervals which are hundreds of millions of years ago, especially as I already told, that the earth looks very differently, and there were possibly also different processes working in those time intervals. But the interesting thing to learn from these kind of studies, I think, is that just a small release of carbon seems to set in motion these positive feedbacks that you already talked about, and then release a lot of carbon. So, this positive feedback that may now not have started yet, but could potentially start and massively influence the current release of carbon to the atmosphere.

Interviewer – Stewart Wills
Micha Ruhl, thanks very much for joining us today.

Interviewee – Micha Ruhl
You're welcome.

Host – Stewart Wills
Micha Ruhl is the lead author of a new study on the end-Triassic mass extinction and its causes.

Music

Host - Stewart Wills
In a News Focus article this week, Virginia Morell reports on a unique long-term study in Venezuela that's plumbing the mysteries of parrot talk in the wild. Here's Virginia Morell.

Interviewee - Virginia Morell
A couple of years ago, I was at Cornell University to meet with elephant researchers who are studying elephant vocalizations. And Cornell, you know, they collect natural sounds around the world from various species of all sorts, and especially birds – that's what they're famous for. And, at the time, Jack Bradbury, behavioral ecologist there, was in charge of the lab, and someone introduced me to him and we began talking. I told him what I was working on, which is a book about how animals think, and Jack said, "Oh, well, you really must include parrots." I said, "Well, I had Alex," – the famous African grey parrot – and he said, "Well, more than Alex, you really must look at what parrots are doing in the wild," because Alex was raised with humans, and so that's different. And he said he had a student who was working at this wonderful study site in Venezuela, where they'd been studying parrots in the wild for 24 years. And that immediately got my attention, because I had never heard of it. And I said, "Why isn't this known?" and he said, "Well, people in ornithological circles and ecology circles know about it," because it's a very famous study site, Hato Masaguaral – it's a cattle ranch. And so, the project was started by Steve Beissinger, an ecologist at Berkeley.

Interviewer – Stewart Wills
I gather from your article that this study, which, as you say, is the longest-running study of wild parrots, that it got started almost by accident.

Interviewee - Virginia Morell
Yes. Steve Beissinger had gone there actually to study raptors; he was working on snail kites, and from an ecological perspective, he had some particular questions that he wanted to ask about them. And while he was there, I went to the site – I was invited by Karl Berg to go there a couple of years ago – and so I saw all of these things, and the ranch is just full of birdlife. It's just fabulous. And one of the things that Steve Beissinger noticed was that these little parrotlets – these small green parrots – were nesting in some of the fence posts on the ranch where there was a hollow in the fence post. And he said it was amazing, because rather than being high overhead in the canopy where usually parrots nest, you could just walk right up to this fence post, right at, basically, three or four feet off the ground, and there were the little birds, nesting and doing all the things parrots do. So it occurred to him, "What if I put up artificial nesting boxes, as we do with bluebirds? Would they nest in them?" And it took him a couple of seasons to figure out exactly what the birds would like, and he eventually came up with this design and put out a nesting box in 1987. A few weeks later, a pair of parrotlets moved in. Then, over the next two seasons, he added more. So he had 40 initially, and then over the years, they have now a whole array of them: 106. They're spaced a few meters apart along the fence line, and the parrotlets just flock to them. They have them, actually, in two different ecological settings, because his initial questions are all about what are the birds doing and living in this particular habitat? So some are out more in pastures, and some are more forested area covered with a lot of vegetation, and those particular boxes are not popular because, inevitably, either the mother is killed by a snake, or the eggs are eaten by snakes, so those are not sought after.

Interviewer – Stewart Wills
So, what are some of the other things that make this a particularly special study?

Interviewee - Virginia Morell
To begin with, parrots in the wild just have not been studied, and the reason for that is, first, that they live high in the canopy, and so the access to them is really difficult. And then, once you find a nest, you're not going to have a number of nests – Jack Bradbury actually said he had sort of one nest of these larger parrots he was studying in Costa Rica to look at – so you don't have the sample size to really understand what the birds are doing. Then, usually, with new-world parrots, it's rather difficult to tell the sexes apart, but these little parrotlets, they have markings that are slightly different between the male and the female. You can actually see the males have a little bit more yellow on their foreheads, and they have these blue patches that they use to advertise that they're the best guy to be a mate. So you have that easy accessibility as probably the key thing. They overcome all of these practical, logistical problems that you usually have when you're trying to do a study of parrots.

Interviewer – Stewart Wills
So in a sense, they've got sort of both a wild study and a captivity study rolled into one.

Interviewee - Virginia Morell
Yes, essentially, but it is all wild; these birds are absolutely wild. They do move into the nesting boxes; and the nesting boxes, Beissinger designed them in such a way so that you can take off the top and the bottom, and the birds do not leave when this is done, so you have absolute access. They can go in, and once they start laying eggs, they just take the eggs out and they mark each one, so they know individuals from the moment that they are laid as eggs, and then they can follow all the events that take place to those marked individuals. Once they hatch, then they get a little plastic band at a particular age, and everything's known about those as individuals, and they have records going back, I think, now for over 8,000 known individual birds.

Interviewer – Stewart Wills
Wow!

Interviewee - Virginia Morell
So, yes, it's a remarkable amount of data.

Interviewer – Stewart Wills
Well, a lot of the focus, at least in your article, is how researchers are using this site to study parrot communication, and, I guess everyone knows that parrots can mimic human speech, but what do they say to each other in the wild?

Interviewee - Virginia Morell
This has always been the big question, because why do they imitate us? And, obviously, they're not doing that in the wild. One study had suggested that maybe parrots were imitating ambient sounds, and it had to do with developing a larger repertoire for the males to impress females, but that doesn't seem to really hold up. What they really do – and Jack Bradbury and other people have shown this – is that they imitate each other's calls. And it's very much like me saying your name, "Stewart". You have a name and I can imitate it, no problem at all. And it's a way that we have of getting one another's attention, and it's so hard to imagine how our society would function if you couldn't call someone by their name. And, so in parrot society, it seems to be very much the same kind of thing, where each individual bird has a unique, what they call a contact call, or signature contact call, and they are saying each other's names. They can say their name, and then they can say someone else's name, and, perhaps they can even add additional information to it; that's an open question. But, at this point, what they wanted to know is how do they get these contact calls? And there was one captive study that suggested that some of the family members might be giving those to the little nestlings, but why would they do that, why would this sort of system evolve? And, so, that's what Karl Berg set out to look at in his study was, was it true that the parrotlets are getting some sort of a name, more or less, from their parents, and were they learning the calls in the wild? And, at what age, and what would be the reason for that?

Interviewer – Stewart Wills
It's one thing to listen to the bird calls, but I imagine there must be a lot of subtlety here. How are they actually analyzing them?

Interviewee - Virginia Morell
The big difference between a parrot call and a bird song is that these are not songs; these are little sounds that they make, and it sounds to our ear like a peep – just a real short little peep. We can't hear the information that is in that peep because our ears just don't hear fast enough. And so, they make recordings and they take them back to the lab and they convert it into a spectrogram, which is like a visual picture of the sound. A little peep actually looks kind of like a Japanese calligraphy mark; it kind of has a little tail to it and then rises up. And within that peep, if you stretch it out, play it slowly, one can't even begin to imitate it, but the sound's something like [sound]. And it has this inflection at the end [sound], you know, it's a very odd thing…

Interviewer – Stewart Wills
They're probably different from bird to bird, I would imagine.

Interviewee - Virginia Morell
Well, it is different from bird to bird, but they all have a little bit of an inflection at the end, and it's just like, you know, my name, Virginia Morell. So in my family, people have the last name Morell; the first name changes. Well, something like that is going on within little parrotlet families, because all of their signature calls have something similar to them, but they vary. And what Karl's studies showed was that the parents are providing, if not the actual name, at least they're providing them with some template, as he called it, some kind of a model that they learn at about age 3 to 4 weeks, and then they modify it somehow and make it their own name. And a clutch may have anywhere from, oh, just a couple individuals up to 14, and they're hatching asynchronously – that's over the space of several days – so as the chicks grow, some of them fledge earlier than those who are still in the nest, and the parents have to find the little guys who fly out and are living in a roost with other fledglings from other nests. They have to find those chicks because they still need to be fed for another three weeks. So, how are you going to find your little chicks, your own babies, who are out there in the wild world, unless you have some way to identify them? And that's what the contact call served. The parents can come in and say, "I'm mom, you know, and where are you, baby Joe?" and baby Joe can call back and say, "I'm over here, Mom, feed me."

Interviewer – Stewart Wills
Well, going from chicks to another species, I gather from your story that some of these scientists think that this might be able to tell us something about how human infants acquire speech?

Interviewee - Virginia Morell
Well, that's another area that people really debate, which is what are the first things that infants start learning? And one thing is their name. And how this is actually done is the source of a lot of debate. So, if you had a species which is doing it in a way similar to the

way that our human infants do it, it provides you with a model to perhaps look at and analyze and see, well what exactly takes place in the parrots? Is it similar to what takes place in humans? And if you have models like that from two widely divergent species, it just gives you a better way to look at the question and to ask, well, what are the pressures, and why, and how does this develop, and what are the genes involved, you know, is there an overlay here? We know there's some similarities already between bird song, for instance, and human speech. So then if you have a species that perhaps is even more similar, such as parrots – because in parrots, both the males and females are doing this, and also these little parrotlets, like many parrots, are what we call lifelong vocal learners, as we are – maybe the parallels are more similar than even with song birds.

Interviewer – Stewart Wills
Virginia Morell, thanks very much.

Interviewee - Virginia Morell
Thank you, Stewart. It was very fun.

Host - Stewart Wills
Virginia Morell writes about Hato Masaguaral Ranch, and what it's teaching us about parrot communication, in a News Focus this week.

Music

Interviewer – Stewart Wills
Finally, today, David Grimm, the online news editor of *Science*, is here to bring us up-to-date on some recent stories from our daily news site. First, Dave, something about the very slow cooling of the earth over the last 4-1/2 billion years.

Interviewee – David Grimm
That's right, Stewart. You might be hard to imagine, or think about it, but despite the fact that earth is about 4-1/2 billion years old, it is still cooling off. And, as you may know, Stewart, the earth formed in a very hot event. It coalesced from this hot ball of gas, dust, and other materials. Very early in Earth's history, it was very much a molten, hot world. But despite the fact that it's been cooling off for so long, for billions and billions of years, it still has about half of its original heat, according to this new study.

Interviewer – Stewart Wills
And how did they figure that out?

Interviewee – David Grimm
Well, the study was conducted deep inside a Japanese mountain, and apparently you have to go way down deep to measure what's called the radiogenic heat produced by Earth. So there's two main types of heat that earth produces; first, that original primordial heat from its formation, but there's also this radiogenic heat, which is basically a heat produced when isotopes decay. And this is a lot of heat, too, but it's not heat directly linked to the formation of the planet. And this natural radioactivity produces neutrinos as

a byproduct, and by going deep into the Earth, the researchers were able to try to eliminate a lot of the background sources of neutrinos, like nuclear power plants and other emitters of neutrinos. Basically, by doing all this, they found that about 111 of the neutrinos they measured were associated with natural radioactivity within Earth. And, by doing a bunch of other calculations, they basically came to the conclusion that all the natural radioactivity on Earth generates about 20 terawatts of heat. And what that adds up to is about 54% of the heat that's flowing through Earth's surface comes from this radioactive decay, which means 46% – the leftover – is this original heat. So that means that just about half, a little under half, of the heat that earth produces is still left over from all of these formation events that happened billions and billions of years ago.

Interviewer – Stewart Wills
Isn't this something that was already known, though? This is sounding awfully familiar.

Interviewee – David Grimm
It actually was known before, but the studies that had been done before were really based on inferences, researchers had done analysis of meteorites, and other sort of more secondary sources to get at this figure. This is really the first direct measurement of this background radiation. And what's really interesting about it, just besides knowing that hey, Earth still has a lot of heat left in it, is a lot of this internal heat is actually what guides the plate tectonics, the volcanic activity of our planet; so by studying how fast earth loses heat, scientists can study a lot of the geological processes in the past, and even extrapolate into the future. And, finally, if you're wondering when earth may eventually totally become cold…

Interviewer – Stewart Wills
I was – it was at the top of my mind.

Interviewee – David Grimm
The researchers say that, according to their calculations, the planet is cooling about 100-degrees every one billion years. Now, that may not sound like a lot, but if you calculate forward a bit, it means that in a few billion years from now, earth will essentially be a cold, dead planet, so…

Interviewer – Stewart Wills
Something to look forward to.

Interviewee – David Grimm
Something to look forward to.

Interviewer – Stewart Wills
And next, a tale of intrigue in the elephant seal harem.

Interviewee – David Grimm
Right, Stewart. This next story is all about the beachmaster system in elephant seals. And basically what this system is, is elephant seal males, especially the dominant males,

they're these really big, hulking guys, and they are very territorial, very aggressive, very defensive, and they have these giant harems of females on a beach – sometimes hundreds of females, that they look over. And they jealously guard these females, so if any other male comes on the beach, they fight them. The battles can be very bloody. And biologists have often pointed to this as a classic example of what's called polygyny in the animal kingdom – and that basically means one male mating with lots and lots of other females, and all those females only mate with that one male. Well, according to this new study, this system may not be as polygynous as researchers had suspected.

Interviewer – Stewart Wills
Not as polygynous, meaning that the females are indulging in a little hanky-panky here?

Interviewee – David Grimm
Exactly. The females are indulging in a little extracurricular hanky-panky. The way the researchers found out about this is they actually tagged a group of females, and what they found was that, although the females tend to spend a lot of their lives at the beach, they're actually spending a lot of time, also, in the open water. They usually come back to the beach about once a year, ostensibly to give birth, and also to mate with this dominant male. But a lot of times when they show up, they show up pregnant, which means that they've been…

Interviewer – Stewart Wills
Which surprises the beachmaster.

Interviewee – David Grimm
Exactly. And it means that the females are having sex with the non-dominant males that are out in the open ocean, or out elsewhere, and it really sort of challenges this idea that these females are sort of loyal to this one male. The reason some scientists thought this originally is they sort of went into this with a very male-biased approach to the research – the idea that, well, of course, a man is going to have total control over females, and is going to be able to sort of dictate their every moves. And they would have said, "Well, the females get something out of it too, because even though they only get to mate with one male, that male is sort of providing them protection, and it's sort of a system that works out for everybody." But, in this new idea, the fact that a lot of these females are going out and having these "extramarital affairs" means that the females actually have a lot more choice than the scientists have been giving them credit for. And, yes, they may get some protection from this male, and that may be why they come back to this beach year after year to be with him, but by going out into the open ocean, they can exert a lot more choice, in terms of who they mate with. And, so, they're sort of getting the best of both worlds – they're getting the protection, but they're also getting a lot more mate choice than scientists had previously believed.

Interviewer – Stewart Wills
And, finally, this one really seems wild. A cloaking device, not for hiding an object in space, but for hiding an event in time?

Interviewee – David Grimm
Right. Well imagine this scenario, Stewart. A robber breaks into a bank, steals all the money from the safe, then returns home and activates a device that basically masks his entire foray into the bank, so as far as the people in the bank know, the money just magically disappeared. The robber was never there, but all of a sudden, the money is gone.

Interviewer – Stewart Wills
It sounds like it would help the elephant seals.

Interviewee – David Grimm
It very much could. This idea is called a time cloak, the idea that you could, as you said, Stewart, take a moment in time, rather than an object, and make it disappear. Now, the scenario I just described is a long way from reality, but researchers have actually made an important first step into turning such a time cloak into reality. And the experiment they set up involves a laser beam, and the basic idea of what they were trying to do with this laser beam is to create a gap in the beam so they would see that gap in the beam, but then find a way to retroactively make that gap disappear so that any other observer looking at the beam would just sort of see this continuous laser beam, as if there had been no gap.

Interviewer – Stewart Wills
Well, how do you open a gap in a beam of light like that?

Interviewee – David Grimm
Well, the researchers created what they call a time lens, which is basically a device that can shift the frequency of the light. And, basically, at the particular moment, they shift the frequency of the light higher, and then suddenly lower – this is the frequency of the light in the laser beam. Then they send this "frequency modulated light" through an optical fiber that's designed so that some of the wavelengths of light are sped up and travel faster than other wavelengths. And as one of these sets of wavelengths races ahead of the other set, a gap opens up between the beam. So that's how you get your gap. Now, here's how you get your cloaking. After the light is passed through the spot where the hidden event will occur, where they want to sort of mask this gap in the beam, the experimenters reverse the process. They run the light through a fiber in which the wavelengths have been sped up and slowed down, and those that have been slowed down are sped up, so the gap essentially closes. This all sounds very complicated, but the essential effect is to retroactively erase that gap in the beam. So again, an observer that was looking at that beam would just see a continuous beam, whereas the researchers know that they had created a gap, and then made it disappear.

Interviewer – Stewart Wills
So, how long of a gap are we actually talking about here?

Interviewee – David Grimm
Well, we're not talking about a very long gap here. In fact, they hid an event that lasted 15 trillionths of a second, not nearly long enough to rob a bank. So we're a long way

from the next *Ocean's Eleven* movie where a bank robber employs this type of technology. But again, it is an important proof of concept, it's an important first step. The researchers think that as they keep on working on this, they may be able to eventually hide an event that lasts up to 110 billionths of a second, so not…

Interviewer – Stewart Wills
That's progress.

Interviewee – David Grimm
Still very much the blink of an eye, but definitely getting farther along. And, of course, as this is developed down the line, perhaps you could eventually get a device that could mask an event that takes place over a much longer span of time – robbing a bank or, perhaps, erasing an embarrassing faux pas earlier in the day. You're going to have to wait a while for that to happen, but researchers are well on their way.

Interviewer – Stewart Wills
They're on the trail. Nice to know they're working on the important things. Okay, Dave, what else are you looking into for the news site this week?

Interviewee – David Grimm
Well Stewart, for *Science*NOW, we've got a story about what it may have been like for medieval knights to do battle with armor. Researchers actually put a man in a suit of armor and made him run on a treadmill to see how much energy it actually takes to walk around with a suit of armor, so that's a fun story we're doing. Also, another fun story about rock, paper, scissors, and the psychology behind this child's game. On *Science*Insider, *Science's* policy blog, we've got a story about the new Indian science minister and the impact that person may have on science in the country. Also, a story about plutonium production, what's going on with that in the U.S., and what the impact of that is on various scientific experiments. And finally, for *Science*Live, our weekly chat on the hottest topics in science this week, *Science*Live is about the science of mummies; what are mummies telling us about diseases in the past, and how those diseases are affecting us right now, and also in the future. So be sure to check out all these stories on the site.

Interviewer – Stewart Wills
David Grimm is the online news editor of *Science*. You can check out the latest *Science* news and the policy blog, *Science*Insider, at news.sciencemag.org, where you can also join a live chat, *Science*Live, on the hottest science topics every Thursday at 3 p.m. U.S. Eastern time.

Music

Host – Stewart Wills
And that wraps up the July 22nd, 2011, edition of the *Science* Podcast. Thanks to Kerry Klein for her help with this week's show. If you have any comments or suggestions for the show, please write us at sciencepodcast@aaas.org. The show is a production of

Science Magazine. Jeffrey Cook composed the music, and I'm Stewart Wills. On behalf of *Science* Magazine and its publisher, AAAS, thanks for joining us.

Music ends