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00:40 SC: Welcome to the Science Podcast for September 7th 2018. I'm Sarah Crespi.

00:46 Meagan Cantwell: And I'm Meagan Cantwell, on this week's show we talk to science writer Warren Cornwall, about triaging species rescue. Do we need to start weighing the cost of saving caribou against the cost of saving Orcas?

00:57 SC: And we talk to Hope Michelsen about her research on soot formation, soot is in our fire-places in our atmosphere and in interstellar space? And yet, until now, we didn't know how, it formed.

01:13 MC: I'm Meagan Cantwell, and I'm here with science journalist Warren Cornwall based out of Washington State. Hey Warren.

01:19 Warren Cornwall: Hi Meagan.

01:20 MC: The approach of conservation that you discuss in your piece is called Species triage, and Triage is a pretty intense word, and it's typically associated with battle field like conditions. How did this term emerged specifically in Conservation Science and what does it mean in this context?

01:37 WC: Its a term that's been used in conservation science since the late 80s or early 90s? So it's been around for a while, and I guess you could argue that in some ways trying to conserve species these days, is a battle field. We're in the middle of what's in term the sixth grade extinction. I've heard estimates that the extinction rate today is 100 times what it would be under more normal conditions. Triage originally in the battlefield, was a tool for deciding how you were gonna use the limited resources that you had, and they would basically decide who they could save, and who they couldn't and if you had people that seemed so badly injured that they couldn't be saved, they sort of went to the bottom of the list.

02:21 WC: When you look at that for species conservation, the question is: Who winds up at the top of the list and who winds up at the bottom of the list. As far as how you're gonna spend your money. The folks who are proponents of triage, one of the things they say is Look, right now, there's a ton of species that are going extinct, that nobody is paying any attention to at all. And triage or prioritization at least forces you to confront. Like, "Okay here is how we are spending our money and that means we are not spending our money on this thing." That there's this whole other list of species that are on the edge of blanking out that nobody is even acknowledging.

03:02 MC: Your piece centers on the struggle to preserve what is left of Canada's woodland caribou. How do attempt to preserve this species exemplify what the current issues in conservation are?

03:12 WC: The big challenge with the Caribou, is that they're really sensitive to human intrusion on their habitat. And their habitat happens to overlap with a lot of natural resources that have a lot of economic value. They prefer to live in old-growth forests, and then a lot of the terrain that they pass over also has a lot of oil sands and natural gas underneath it. So you have a lot of temptation to encroach on their habitat, so it makes conservation hard to do and also really costly.

03:44 MC: What are they doing that requires so much money?

03:47 WC: Probably the most cost-intensive is actually setting aside habitat, this habitat that's worth a lot of money if you can cut down the trees and sell them as lumber, or if you can extract the oil sands and the natural gas. But the hands-on management efforts to get more attention are these efforts to protect herds from predation, from wolves or bears or Mountain lions. One of the things that they've begun doing, in a few herds is capturing a number of the females in the winter when they're pregnant. And then rearing them in these enclosed pens where they are sheltered from predators. And then the calves that are born grow to a certain size before they're released, and the hopes are that they'll better be able to outrun predators. There's even discussion about trying to create a much bigger predator-free penned enclosure, where a certain part of one of the herds would just basically live.

04:47 MC: Wow.

04:48 WC: Year round. And the estimate for that is that it could cost as much as $15 million over a decade.

04:54 MC: Yeah. And unfortunately that doesn't really address the root problem of the habitat destruction. Does it seem like a sustainable solution to them?

05:00 WC: The people who are proponents of penning efforts. None of them will say The penning alone is gonna solve the problem, but it's essentially a way to keep these herds that are really in bad condition going while the habitat protections that are necessary in the long run, are able to start to take effect. It takes a long time for a logged forest to grow back.

05:24 MC: So there are a lot of moving pieces in the caribou problem in Canada, and I'm sure that's the case for a lot of endangered species, all around the world. So how is conservation spending currently prioritized in most countries? If we can't save them all, then what type of species usually gets the top spot on the list?

05:42 WC: It's often species that are charismatic in some way, that have captured the public attention, it can also be species that are in the most dire situations. So the ones that are down to just a tiny fragment of their earlier numbers, you can have a species that have gotten a lot of attention, due to lawsuits or due to political pressure. So a classic example would be the northern spotted owl an endangered species in the United States, and really became an icon of environmentalists in the 1980s and 1990s, as a tool for stopping logging of old growth on federally owned land in the Pacific Northwest. The owl became this kind of celebrity partly because of legal leverage it provided to stop logging.

06:34 MC: So who are the other players in this debate besides conservationists, also policy-makers and who's kind of leading the charge on this?

06:42 WC: This approach is something that has started to be embraced by some policy makers, and most notably in New Zealand, but it's really in its infancy, in moving from scientific conferences and scientific journals, into the world of policy.

07:00 MC: So those who are in opposition to this species triage approach, what do they say are some of the unintended consequences of approaching conservation in this way?

07:08 WC: I think that people who are critics of this kind of triage approach, might argue that, if you embraced it, that it would make it easier for policy makers to sort of give up on a species where it's politically hard or technically hard to try to save it. It's not that one side in this debate doesn't have the interest of species at heart, it's just that they see different strategies.

07:34 MC: In some countries, they actually do have enough resources to preserve whatever endangered species are within their area, whereas in others there may be little to no funding for conservation. So in these kind of countries with very little access to funding, do you think that species triage is something that they know about as an approach, is it discussed there as well?

07:53 WC: Yeah. That's a good question. It was interesting when I was talking to... When I Was talking to Hugh Possingham, who is one of the leaders of the scientific effort to develop this prioritization or triage, depending on what you wanna call it. He really thinks that the places where this kind of approach is most desperately needed is in parts of the world where there's not a lot of money for species conservation. So parts of the developing world, it's not happening in those places, at this point, I think partly because they don't really have the regulatory infrastructure.

08:31 MC: Right. So it's definitely something to think about in the future.

08:33 WC: Yeah.

08:34 MC: Alright. Well thank you so much for speaking to me.

08:37 WC: Yeah, Meagan, thanks. I hope some of it is helpful. [chuckle]

08:39 MC: Warren Cornwall, is a freelance journalist based out of Washington State. You can read his piece on species triage in this week's issue of Science. Stay tuned for an interview with Hope Michelsen on the chemistry of soot inception. How do these complex molecules form inside of flame?

[music]

09:02 SC: Soot is a common thing in our lives, I'm talking about that black powdery residue from fire that collects inside our chimneys and on our marshmallows. And like most common place things, it holds a mystery. Usually when you heat things up, set them on fire, solids become gases but not soot, it forms, it comes together under these extreme conditions. How is this happening?

09:26 SC: Hope Michelsen is here to talk about her group's work. Looking into this question. Hi hope.

09:32 Hope Michelsen: Hi Sarah.

09:33 SC: So, Soot is kind of an odd thing. What exactly is it made of?

09:37 HM: Well, it's really interesting. Soot is made out of carbon. And carbon is a very important element in our life. It is the basis for life and really interesting chemistry. Soot itself starts out as a hydrocarbon. And you've probably heard about hydrocarbons. Fuels are very often hydrocarbons. And what we wanna do when we try to understand soot, is how it goes from a hydrocarbon, which is Hydrogen and carbon combining with oxygen to make just the carbon particle.

10:08 SC: Right.

10:09 HM: The particle itself is like graphite. Kind of like a pencil. So if you take soot and you smoosh it you'll get a black line. So you can see that is very similar to a lot of the things that you're really comfortable with and understand, but it turns out that soot in the atmosphere is really dangerous for our health, it causes millions of deaths a year globally. It causes air pollution, reduces air quality, it contributes to climate change. So there are a lot of reasons why we want to understand soot, so that we can understand how to control it.

10:42 SC: Soot is actually used in some processes, right? It's like a pigment. What kind of things does industry make with this kind of pigment?

10:48 HM: You're absolutely right, it's very, very important in industry. There are entire companies that all they do is make different kinds of soot, for pigments, for addition to tires. So when you see a black tire that blackness is caused by soot. Its important in making glass, so people try to generate... So in glass furnaces, because when soot... When it gets hot, it radiates light. And then it can distribute the energy more evenly in a furnace, so it's important in boilers. It's important for a lot of different reasons.

11:21 SC: I'm looking at a fire where's the soot, what's happening with the soot? When I look at a flame.

11:26 HM: When you have a flame and you take the fuel, say methane, which is one carbon and four hydrogens, that molecule when it reacts with oxygen and you'll get a lot of radicals formed. As those elements start to come together, they'll make a particle, is actually a liquid, we think it's a liquid, because it has a lot of these hydrocarbons in it, so it's not graphitic yet when it's first formed. And then it evolves during its life in the flame. So when you look at a candle think of soot as starting out as almost invisible when its first formed and then starts to become darker and blacker. So the stuff that you see coming out is the black stuff that's more graphitic. And when you see that yellow part of a candle, then you know that you have soot there because that's hot soot radiating, [chuckle] that's the heat that's coming out of the particle.

12:18 SC: Wow. So you're telling us what flames are made of. That's pretty amazing.

[laughter]

12:25 SC: That's really what caught my ear when I heard someone talking about this paper in a meeting once. They were talking about chemistry inside a flame. What was the thinking before your work, about how soot forms in a flame?

12:37 HM: There are a couple of main theories that people had been working on. You were talking earlier about maybe Particles in the atmosphere. Well, most particles in the atmosphere are made out of water vapor. We have rain droplets, and if you think about it, you start out with a gas molecule, that's water. And then when you make the rain droplet, usually that happens when it gets a little bit colder and it condenses. Everyone has seen water condense on a cold glass, and then if you drop the temperature even lower, you get ice. So now you've taken a gas into a solid form by lowering the temperature. And for a long time, people were trying to understand how do we get these hydrocarbons that are in the flame to condense, like you would have a water droplet condense. How do we get that to happen, how do we make them sticky enough to wanna be together?

13:27 SC: Right.

13:27 HM: But that doesn't work, because you formed soot when you get hotter and then if you cool it down, it still stays a solid and you can pull it out, you can heat it up and its a solid. So what's happening is very different, it's a chemical process. Then for a long time we've been trying to understand if we can't get it to condense, how can we get a chemical process to go and make the soot. So it's more like baking a cake, more like taking a liquid and turning it into a solid, you know when you heat a cake up it gets solid and it stays that way. So how would you get these gas molecules to do that? And we couldn't figure it out because they just wouldn't go fast enough. The chemistry just wasn't fast enough to make a particle go as quickly as we see it in a flame. We actually figured out how you can get that reaction go fast enough. That's what our whole paper is about.

14:17 SC: Did it start out as a new theory and then you tested that theory? Or did you make some observations that it made you think, "Oh, well this is what's happening."?

[chuckle]

14:25 HM: That's a really good question. I guess we were kind of triggered by some observations initially. When we do an experiment in our flame. We do a lot of different types of techniques. And one of the techniques we do is; we put a probe into a flame and we suck the particles out. And then we put them into a mass spectrometer, we vaporize what's in the soot or on the soot, and we look at the molecules that are there. And what we saw were these really interesting molecules called radicals. So most molecules want to have their electrons paired up. In a radical, it has one electron that's not paired, so that's a radical. And it's really reactive because it really wants to share that electron with another molecule. So you can have a paired up electron.

15:10 SC: People are probably familiar with free radicals in the body, they're...

15:13 HM: That's Right, that's right.

15:14 SC: They're running around, looking for friends.

[chuckle]

15:17 HM: That's right.

15:18 SC: Doing things that we don't want them to do. So this is also happening in a flame in those conditions.

15:22 HM: That's right, that's right. And these are very special radicals, in that, they really want to be radical but they also wanna react.

[chuckle]

15:31 HM: So they wanna cause trouble, so they go out and they react with another molecule. But then they still wanna be be out there doing some mischiefs, so when they react with another molecule they become paired up electrons, but then they pop off a hydrogen atom and they become a radical again.

15:48 SC: So it's a bigger radical.

15:49 HM: So this is a bigger radical, now they've made a bigger radical, and now that can go out and bond with something else and then it wants to become a radical again. So you basically have a chain.

15:58 SC: So you get this snowball.

16:00 HM: Its like a snowball reaction, so we call it a chain reaction.

16:04 SC: And you saw some of these intermediates when you looked at the contents of the soot from the flame.

16:09 HM: That's right. So what happened was, we saw the sequence of these radicals, and we're just fascinated by them, because we had been doing what everyone else had been trying to do. Look at the stable species and trying to understand how they can react and how we can get them to wanna stick together. And we had been kind of ignoring these, but they're bothering us, 'cause they were always there, every flame we look that they were there, so we finally start to looking at them and thinking about them more carefully. And one of our colleagues at Berkeley, professor Head-Gordon gave us a paper and said, "You know, I've been interested in these molecules too." And so we started to look at what he had done. We start to collaborate with him, and we ended up coming up with this chain reaction mechanism.

16:53 SC: And there's a really nice illustration of this in the commentary piece here, and it shows you some of the players and kinda where they are in the flame, I think it really helps understand the paper. [chuckle] It help me anyway.

[chuckle]

17:07 SC: I think I'm gonna try to put that in the podcast notes so people can take a look at that, I think it really helps. What does this mean for everybody else who's studying soot? Are they gonna have to start looking at these radicals, so they could understand how different kinds of soot forms and how this process works, maybe in other places where soot is happening, like interstellar space.

17:25 HM: Well, so now this starts us thinking about a lot of different things, because if you know how its formed, then you can control it.

17:33 SC: Yeah.

17:33 HM: If you know what is it that actually initiates the reactions that starts at formation. Maybe you can try to stop those, or maybe if you actually want to generate these different materials, maybe you can take advantage of that information to control the processes that generate these materials. When I've talked to different people about it, they've been very excited about the possibilities, because now it opens up a wide range of possibilities of different types of mechanisms and processes we can study under different conditions.

18:04 SC: But this isn't gonna help us understand nucleation in the atmosphere, that condensation process you were talking about.

18:10 HM: No, it's very different.

18:11 SC: But interstellar space, this was amazing to me. Has something that's like soot in it. Is this Something that we can look for there now.

18:20 HM: Yes, absolutely, because the processes in interstellar space that make interstellar dust, and there's lots of carbon in space, and it's amazing to think about. But a lot of the processes are very similar. In fact, interstellar dust in the outflow of these very carbon-rich stars is made under very similar conditions very similar temperature conditions, with very similar, what we call precursors, the species that make up the particles, and we think this is a mechanism that could work in space. That's not an area we normally work in, so I don't...

[laughter]

18:57 SC: You're just throwing it out there for other people to pursue. I see, I see.

19:00 HM: Yes, exactly. [chuckle]

19:01 SC: Well, that's really amazing. I really appreciate you coming on the show, thank you so much Hope.

19:05 HM: Thank you Sarah, it's a pleasure.

19:07 SC: Hope Michelsen is a Staff Scientist at Sandia National Labs. You can find a link to her research and a related commentary piece at Sciencemag.org/podcasts.

19:17 SC: And that concludes this edition of the Science Podcast. If you have any comments or suggestions for the show, write to us at @Sciencepodcast@aaas.org. You can subscribe to the show anywhere you get your podcasts.

19:31 MC: Or you can listen on the Science website, there you will find links to the research and news discussed in the episode. That's sciencemag.org/podcasts. To place an ad on the science podcast, contact midroll.com. M-I-D-R-O-L-L.com. This show was produced by Sarah Crespi and Meagan Cantwell, and edited by Podigy. Jeffrey Cook composed the music.

19:53 SC: On behalf of Science and its publisher, AAAS. Thanks for joining us.