S3 E3 Sara Lewis

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SPEAKERS
Sara Lewis, Cheyenne McKinley, Matthew Zipple

Matthew Zipple 00:07

Hello, and welcome to another episode of the Animal Behavior Podcast, I Matthew Zipple. There are certain everyday ordinary events that no matter how many times we experience them remain beautiful. And every time they happen, we just can't help but smile. And for those of us who have been lucky enough to live in the same places that they live, fireflies nightly performances on warm summer nights are just one of those things. Today, I'm very pleased to be speaking with Dr. Sara Lewis, Professor Emeritus of Biology at Tufts University, who is deeply enamored with fireflies, and has studied them for decades. She's the author of the book "Silent Sparks", which is simultaneously extremely accessible and scientifically rigorous. And in addition to her behavioral research, she serves as co-chair of the Firefly Specialist Group of the International Union for the Conservation of Nature. So we'll talk about both her behavioral research and hear about her experience expanding from basic research to conservation. So Sara Lewis, thanks so much for being here.

Sara Lewis 01:05

Thanks so much for having me, Matthew.

Matthew Zipple 01:07

One of the themes of the season has unintentionally become awe and wonderment. And you start your book by placing awe at the center of your story and your motivation. So let's start there. Talk about the role of wonder in your scientific story, and how fireflies play into it.

Sara Lewis 01:24

Yeah, so I think that wonder and science are very much inextricably linked. And you know, we think about wonder in a couple of ways, so there's wonder like. Hey, I wonder how that works like curiosity, right? So curiosity is really what drives science forward. And so that's one sense of wonder. And the other is, as you've mentioned, a sense of real appreciation for nature beyond just what it can tell us. So that's a sense of awe. And I think that many really great scientists were perfectly upfront, like Einstein,

you know, basically, awe of the universe and of the physical nature of the universe was really what motivated him. But in all of my scientific sort of education as an undergraduate at Harvard, and then as a PhD student at Duke, I felt like you couldn't really tell people that you were really excited about the wondrous side of your study. You know, if you told your best friends, your graduate student buddies, that you had this experience of wonder, when you were out studying your organisms, then that was fine. But you wouldn't want to put it in like your thesis or anything. So for many years, in my scientific training, I felt like there was an unspoken policy that, you know, keep any sense of wonder that you might have about the science that you were doing, the organisms that you were studying the processes that you were revealing, keep that under wraps. So yes, it was really exciting to me to be able to express that sense of wonder that I had felt for all of those years when I was writing about fireflies for a general audience. And that's really I felt like it was kind of a confessional. I was a little embarrassed about, you know, showing my colleagues even at this point in my career, like, Hey, I actually am really into wonder.

Matthew Zipple 03:23

Before your research career focused on fireflies, you were a community ecologist. How did fireflies catch your intellectual attention

Sara Lewis 03:31

It was really accidental that I studied fireflies. So as a graduate student, I studied community ecology of coral reefs. And in particular, I was looking at the foraging behavior of herbivorous fish on coral reefs. There was a point I was waiting around for the funding to come through, and I was sitting in my backyard with my dog outside of Durham in North Carolina. And I guess it was probably June, July, something like that. And it was maybe five o'clock in the afternoon, and a thunderstorm was rolling through, and it suddenly got really, really dark. And we're looking around at the sky thinking, wow, you know, this just looks like it's gonna be a really, really big storm. And then in the back yard, all of a sudden, we had, it wasn't exactly a yard, it was more like a meadow because we never mowed the grass. So in the back meadow, suddenly these lights appeared. And these fireflies just rose up out of the grass, and they were all around us. And I had actually, you know, I grew up in Connecticut, so I should have seen fireflies a lot. I have no memory of fireflies from my childhood. But that afternoon that evening in North Carolina, I was just blown away by all of these fireflies that were out there and so. The funding came through for me to continue my work. And it wasn't until I started to think about what I wanted to work on as a postdoc that fireflies really jumped out at me and said, you know, wow, interested in sexual selection. This is an organism that has a very, very visible, easy to eavesdrop on courtship signal. They have incredibly intense sexual selection because they have a very biased sex ratio. For example, in my backyard, there were hundreds of males and very, very few females. And they also they have a courtship signal that can be easily mimic. So they're tractable for studying sexual selection. So it took me a while to go from tropical reefs and community ecology, and fish foraging behavior, to seeking about sexual selection mostly. And in my lab. Before we worked on fireflies, we actually worked on courtship behavior in seahorses, we worked on pre and post copulatory sexual selection in flower beetles, Tribolium. They're still one of my favorite beetles. And we also worked on

sexual selection in butterflies. So for many, many years, fireflies were kind of a side interest, and then became more and more of a focus of work in my lab.

Matthew Zipple 06:19

Okay, well, so introduce us to what we colloquially called fireflies. Where do they live? How many species and how much diversity are we talking about?

Sara Lewis 06:26

Yeah, so fireflies, you know, people are really surprised that there's more than 2200 different species of firefly all over the world. And they're pretty much found on every continent, except for Antarctica. And they are incredibly diverse, they have really, really different lifestyles. So the unifying feature of all fireflies is that all of the larvae light up. And so we know that they are a family with a shared evolutionary heritage. But they've diversified a lot in their courtship signals. So there are some fireflies that use pheromones to attract mates. There's some fireflies that use light signals to attract mates, there's some fireflies where both sexes use light. So it's a courtship dialog between males and females. And there's some fireflies where only the females light up and they glow. They're called glow worms and the male's don't light up at all. So a lot of diversity of lifestyles in those 2200 different species, and we're still finding out about them.

Matthew Zipple 07:28

So I want to turn to that lifecycle a little bit. You mentioned the larval stage, and everyone probably is going to be familiar with what adults, what those look like. But I found your description of the larval and pupal stages to be kind of just as interesting but much less familiar. So talk a little bit about that growth cycle in their carnivorous practices.

Sara Lewis 07:47

As you say, you know, the undercover part of the firefly lifecycle is very rarely seen. And that's the larval stage. In the US, all of North America, all fireflies have a terrestrial larval stage. And it lasts a really long time compared to the duration of the adult stage. So the larval stage can last anywhere from a few months in tropical areas to a couple of years in the northern temperate zone. And during that larval stage, they are voracious carnivores. So they live underground. We hardly ever see them. And they hunt for soft body prey.

Matthew Zipple 08:29

And then what do they eat as adults?

Sara Lewis 08:31

Most fireflies don't eat anything once they turn into an adult. So they only live for a couple of weeks. And they're really, really focused on reproduction.

Matthew Zipple 08:41

So it's really interesting to hear about kind of the diversity of, of the glowing today, as you mentioned, the fact that larvae of all species glow, but not all pupa or adults glow, tells us something about the evolution of glowing and suggests something about its original function.

Sara Lewis 08:56

Yeah, so you know, we think that firefly bioluminescent first evolved in the larval stage, and that it functioned there as an aposematic signal. So a warning signal, warning predators that these larvae are toxic. Most vertebrates find most fireflies to be extremely distasteful. They have a set of compounds called lucibufagins. And those are related to bufotoxins and cardenolides. And so they are a steroid that's extremely bitter, extremely distasteful and extremely cardiotoxic. So the Photinus fireflies, larvae and adults, are really good and full of these lucibufagins. And so larval bioluminescence certainly has a different function than the adults that have coopted that light producing ability into a courtship signal that they use to attract mates.

Matthew Zipple 09:59

Yeah, so I want to spend some time talking about the visual display that, of course, fireflies are most famous for these kinds of flashing in particular patterns, step us through what that courtship interaction looks like for males, and also for females.

Sara Lewis 10:13

I'm going to give you a cartoon of this because there is a lot of diversity. And the more we learn about different firefly species around the world, these behavior patterns that were first discovered in North America don't always apply. But the sort of classic American courtship dialogue for fireflies goes like this. So it's early in the evening, and it's getting dark, and you're out in the field, and there's pretty much nothing happening. And then one species of firefly will start to sit up and pay attention, you can actually watch them if you're out in the field sit in the grass, who would do that? Not me! You can watch them crawl up the grass blades to the very, very tip, and they're waiting to take off and when the light reaches a certain level, maybe it's cloudy, or you know, just going to be earlier in the evening, then they will start to first make a couple of tentative flashes, then open up the rain covers in the lift off into the air. These are males that are advertising their availability with a particular flash pattern. And so it might be a single flash that's repeated at a specific time intervals like bleep, bleep, bleep, bleep. Or for another species, it might be a double flash, bleep-bleep, bleep-bleep, bleep-bleep, bleep-bleep. Or it might be a twinkling flash. That kind of thing. So they're giving their species specific advertising call, let us call it even though it's a light signal. And if you ever seen a display of fireflies, there can be hundreds

or 1000s of male fireflies in the air at any one time. And so they're all looking for a female. The females, meanwhile, are usually not flying, they can fly they have wings, they could fly, but they don't, they have better things to do, like investing their energy into producing eggs to lay. So the females are down below, usually, they've climbed up into the vegetation to be a little bit visible. And in many North American fireflies, the males are the primary signalers the females don't say anything at all, until they see a male that they like, and then they respond with a particular flash of their own. That is given at a species specific time delay from the male advertisement flash. So females are pretty particular, when the female responds to a male, it attracts a lot of attention, not only from the male whose signal she's responded to, but also from a lot of other males. And so that male female flash dialogue that begins with the female response attracts lots of other males. And so you can often watch a female firefly in dialogue with up to 10 males that are surrounding her, sometimes they're hanging around, hovering around her in flight, sometimes they're down on the ground, sometimes they're frantically running up and down blades of grass, trying to find that perched female, if you were just to go out into a field, almost everything you see is going to be a male, you have to look pretty hard, and in a specific spot to find female fireflies. So that flash dialogue and the species differences are really really important way of distinguishing among what are morphologically very, very hard to distinguish species.

Matthew Zipple 14:04

So these flashing patterns are important signals of species identity. Do females show a preference for particular flashing patterns within a species?

Sara Lewis 14:13

So we knew for a long time that the timing, the duration and the interval between pulses, which by the way, are temperature dependent also, but these were really, really important signals of species identity, and sex identity. So in my lab, when we first started working on fireflies, we didn't really know what other information was encoded in these flash signals. And so we started looking at variation within a species and the great things about fireflies is that you can measure the signal very easily. The fireflies that communicate using pulse light signals don't seem to have other channels of communication and so by recording the flash signals and then playing back the flash signals, we were able to look at how this intraspecific flash variation affected female response rates, it was a really fun thing to be able to go out into the field. And to do playback experiments using LEDs that mimic the range of flash signals and to find out what females liked and what they didn't like, because females would vote with their flash, if they didn't like it, they weren't going to respond at all. If they liked it, they would give a flash response. So we callrf these firefly opinion polls. And in many firefly species, different for different species, but females prefer male flash signals that are slightly longer in flash duration, so still within the species specific parameters, but if they're a little bit longer, females are more likely to respond. In other species where males are giving a double pulsed flash signal, bleep-bleep, females actually prefer males that have a slightly shorter inter pulse interval. So the two signals are a little bit closer together.

Matthew Zipple 15:58

So males flash these signals, their identity signals, and females prefer particular patterns. And early investigations into firefly courtship usually ended after the animals made it. But much of your work really begins with the mating event.

Sara Lewis 16:13

Yeah, so there was this big sort of gap in our knowledge about what happens after the male and the female find each other, we had no idea. And so one of the first things that we did was to look to see whether males and females mated multiple times. Or maybe they were, you know, monogamous, and that was it. So we were able to individually mark our fireflies with little tiny dots of paint, and to follow them night after night after night after night. And what we found early on was that yeah, females would mate with multiple males. And so because we were interested in what happens not just mating success, but what determines a male's paternity success, we started dissecting fireflies. And after months of looking inside, we finally realized that males were using all of these fancy accessory glands to produce a very, very elaborate nuptial gift that they were transferring to the female during mating. And that females were receiving this nuptial gift inside their reproductive tract in a very special structure. The sperm was shunted in one direction to a sperm storage organ, the rest of the spermatophore was shunted in a different place where it was slowly digested over the course of several days. And by radio labeling males, so labeling their sperm matter for us, we were able to trace the radiological proteins that were in the spermatophore showed up in the female ovaries first, and then later in the eggs that the female was ovipositing. And so females are taking some of the protein and other nutrients from the spermatophore, and incorporating them into their eggs. So this was kind of big news. For us, it was very exciting, because it meant that these nuptial gifts were really, really important economically, to the female. So this was the only income that they have during their adult lives. And so everything that they're doing all of their egg production, walking around flying, if they fly, that's all based on larval resources, except if they get these nuptial gifts from males. So that was an explanation for females mating with several males. And it was also an explanation for males being limited in their reproductive capacity. We did an experiment where we gave males a new female to mate with every night, and we discovered that males were capable of mating up to 10 times and every single time they gave an actual gift, that natural gift though, gets smaller and smaller and smaller across all of those matings, because males also don't have any income coming in. So by the time the male has mated, like 10 times, he's transferring. Tiny, tiny, perfectly formed really beautiful, but tiny, nuptial gifts, And the size of the natural gift matters for females in terms of reproductive success? Yeah, so females that get larger spermatophores and females that get more sspermatophore lay more eggs.

Matthew Zipple 19:26

So within a species, females as adults are getting resources from males that are voluntarily given in the form of nuptial gifts. But between species some females extract resources from males through much more violent means.

Sara Lewis 19:39

Ah, yeah, so there are however some fireflies and this is restricted to North America where the females are predatory. The Photuris, "femme fatales", is a really remarkable evolutionary story of how a firefly not only uses that bioluminescence to attract mate but also to attract prey. Because the females are able to mimic the flash signals of their prey species, which makes these male prey think that they're a female that they might meet with the males are attracted to the predator, and then the predator can reach out grab the male and these predatory females in the Photuris fireflies are able to consume like six or seven Photinus males in an evening. So they live longer because they're eating and the reason that Photuris fireflies seem to have evolved this predatory behavior which is very, very unique is that they are born without any lucibufagins, they have a couple of other defensive compounds but those compounds are not nearly as effective against vertebrate predators like birds or mice, as the lucibufagins are, so what Tom Eisner did was to rear Photuris fireflies in the lab, and then to give some of them access to for Photinus firefly prey, and then he tested the lucibufagins concentration in their blood. And it turned out that when they were had access to Photinus prey their lucibufagin concentrations went way up and by sequestering the Photinus firefly toxins, these Photuris, "femme fatales", are able to protect themselves against their own predators, and then also to pass some of those toxins to the eggs and reduce predation by certain egg predators.

Matthew Zipple 21:45

So let's take a quick break now. And when we come back, we'll talk about your recent work focused on firefly conservation and science communication.

Cheyenne McKinley 21:55

The Caribbean Sea is full of beautiful sights. White sandy beaches, clear blue waters and sunny skies. However, you have to wait until the sunsets to see something truly magical. If you go out into the shallow seagrass beds in the periods of total darkness in the days following the full moon, you will see bright displays of blue light shimmering throughout the water, reminiscent of fireflies on a hot summer night. These lights are produced by bioluminescent ostracods conveniently also called sea fireflies. These crustaceans are only the size of a sesame seed, yet they produce large bright displays of light. My name is Cheyenne McKinley, and I am a PhD student at the University of California Santa Barbara. I use these sea fireflies as a study system to investigate the evolution of lunar rhythm and bioluminescent courtship behavior. Because these displays peak in activity after the full moon, I'm looking to find out how these animals know it's the right time to make their displays. I'm conducting field experiments and lab experiments to determine if ostracods use an internal clock, similar to our circadian clock, which tells us when to go to sleep and when to wake up. Or if they use an external stimulus such as moonlight to time their behaviors. Ostracods use these bioluminescent displays to attract mates. So if ostracods use moonlight to time these displays, increasing light pollution could disrupt these cycles and have major consequences for ostracod populations. I'm hoping that my results will show if protection should be developed for at risk populations of ostracods. In addition to understanding how lunar rhythm works, I'm also interested in how lunar rhythm evolved. Right now, we only know a lunar rhythmic behaviors in the ostracods that use these displays to find mates. However

there are a wide diversity of ostracods from those that use bioluminescence only to scare off predators, and many that aren't bioluminescent at all. I'm working to identify the presence or absence of lunar rhythm and other groups of ostracods, which I will use to construct an evolutionary history of linear rhythmic behavior. If you want to find out more or see what I find, you can find me on Twitter @Sci_Chey

Matthew Zipple 24:09

Welcome back. I'm speaking today with Sara Lewis, Professor Emeritus of Biology at Tufts University. I'm going to talk now about some of your work in the conservation realm. There's substantial evidence that firefly populations are declining around the world. What do we stand to lose if fireflies disappear?

Sara Lewis 24:27

Fireflies are one of those creatures that just is revered everywhere around the world and cultures around the world in Asia, in Mexico, in the US, it's an insect that people love. And that's not a very surprising thing for most of Asia, where people like insects in general, but for Europe and for the Americas, for the US. You know, we are mostly, I'm sorry to say entomophobes, and so for people to have an insect that they love. That's what really, really big deal. So, you know, here's something that inspires wander in people of all ages. And so I think we would lose a lot if we lost all the fireflies around the world.

Matthew Zipple 25:13

And in recent years, conservation of fireflies has become a focus of your work, both from an academic research perspective, and also in a sort of very official way through co-chairing the Firefly Specialist Group at the IUCN. How did that transition come about for you?

Sara Lewis 25:27

You know, I think that like most academic biologists, I was really focused for a very long time on basic research, questions about behavior, questions about evolution, questions about ecology, that was really, you know, curiosity driven research. And it was great. But when I talk to people that I would meet, like on an airplane, people would say, oh, fireflies, I love fireflies. But hey, why aren't there as many fireflies as there used to be? I would say, I have no idea. You know, is that true? I don't know. But here's what I know about fireflies. And I explained about nuptial gifts and all that stuff. But you know, by the time that like, you know, 100 people had said to me, hmm, you know, why aren't there as many fireplaces there used to be? And everyone who works on fireflies in the US was hearing this. And then in Asia, and Europe, everybody was saying, you know, why aren't there as many fireflies? So a group of international experts in firefly behavior and ecology, called Fireflyers International, we meet every three years in different parts of the world. And this got to be a bigger and bigger component of our meetings where, I guess all of us kind of backed into thinking about firefly conservation from this overwhelming tide of anecdotal evidence. There were some firefly experts like Jim Lloyd, who had been studying particular firefly populations for many decades and traveling around the country in his pickup

truck, and he would go back to places where he had known there was an established population of a particular species of firefly and, oh, there's a golf course here and there aren't any fireflies. So in some cases, we had, you know, expert, anecdotal evidence, let us call it that population has been extirpated.

Matthew Zipple 27:19

I want to talk about some of your work in this area, maybe starting with your work to assess how many firefly species are threatened with extinction or endangered.

Sara Lewis 27:27

This is pretty recent, that we have basically tried to do a science based assessment of the extinction risk of fireflies in the US and elsewhere, using the International Union for the Conservation of Nature's criteria for extinction risk. The IUCN Red List estimates the extinction risk of species according to certain criteria that are applied across all animals, all plants, all fungi. So we decided in 2018 to form a firefly specialist group, and we're now about 35 firefly experts, conservationists, photographers, videographers from all over the world. And we are trying to identify the most endangered firefly species in different geographic regions. And so we started with the US and Canada fireflies. And we did this work in collaboration with the Xerces Society and the New Mexico BioPark Society. And we gathered all of the existing information on about 130 firefly species in North America about the area occupied their habitat specificity. Their known threats to their populations, unfortunately, what we still don't have our population size of any particular firefly species. So population surveys and monitoring hasn't been done for any firefly species yet, the Xerces Society is just beginning to work on that for some of the firefly species with the smallest geographic ranges, and apparently the smallest estimated population sizes. So we finished this work in 2021 and published a paper on it and what we discovered is out of 130 Firefly species in the US about a third of them are doing fine. They are what IUCN calls least concern. They have robust population sizes, extensive geographic ranges, they're abundant wherever they are found, about half of the species that we looked at our data deficient, we don't know enough about them to be able to even place them along this continuum of extinction risk. But about 14 of the species that we looked at turned out to have various levels of extinction risks that classify them as threatened, according to the IUCN. And so since we were able to identify these high priority species, the Xerces Society started last year to survey for additional occurrences of these species and to begin to keep track of the population of the species in the places where they remain. So the goal here is to collect long term population trends for these threatened species.

Matthew Zipple 30:30

For listeners, we're going to put that report in the show notes in case people would like to see that kind of distribution and the species that are at risk.

Sara Lewis 30:37

Yeah, they're two things. One is a PloS ONE paper and the other is the state of the fireflies, Xerxes publication.

Matthew Zipple 30:43

And what are the particular risks that fireflies face in terms of what's causing their populations to decline?

Sara Lewis 30:49

As you know, populations of lots and lots of different insects are declining, fireflies are suffering from habitat loss is the main thing. There are many fireflies that have to complete their lifecycle within a very specific habitat type. And when they lose their habitat, they have very low dispersal distances. And so that population is gone. One of the big threats to fireflies that we've worked on is light pollution. So the bioluminescent signals that fireflies used to find their mates, just based on the detectability of those signals, which is reduced in a environment where there's a lot of background ambient light, and so artificial light at night is a major threat to especially nocturnal fireflies that use bioluminescent signals. My former graduate student, now Dr. Avalon Owens did her PhD work looking at how different intensities and different colors different wavelengths of artificial light affect various North American firefly species. And it turns out, males are much less likely to give a signal when the ambient light is high, and females are very unlikely to respond if males do signal and then of course, the overuse of pesticides. So that's rather a no brainer for insect declines is that the increased use of broad spectrum insecticides, including more recently neonicotinoids, both in agricultural settings and then also in residential settings is one of the big threats for fireflies and other insect populations and also firefly prey.

Matthew Zipple 32:29

Okay, so those are kind of the current risks that fireflies face. And then historically, one of the risks that I thought was really fascinating in your book was actually harvesting of fireflies by people. So tell us the story of the firefly scientists club.

Sara Lewis 32:43

Yeah, so fireflies, not only are they beautiful, and wonder inspiring, but they've also been really, really useful for people in the 1940s or so it was discovered that firefly luciferase, that is the enzyme that allows fireflies to produce light is ATP dependent. This isn't true for all of the luciferases that's like a common one word for many, many different enzymes with completely different structures and completely different mechanisms. But firefly luciferase depends on the presence of ATP in order to produce light. And so monitoring ATP was a way that for many, many years, the food industry detected bacterial contamination of soft drinks and meat and cheese and milk and all other things using an assay for living things bacteria, which contain ATP, and they use firefly luciferase as part of this assay. And so there got to be a pretty big market. And the way that luciferase was manufactured, it was harvested from fireflies. So what was at the time called Sigma Chemical Company, based in St. Louis, Missouri, now is Sigma-Aldrich and is a multinational corporation. But Sigma Chemical Company got their start extracting and purifying luciferase enzyme out of what had previously been live fireflies, which were collected from the wild by an army of citizens who thought that they were like really contributing a lot to

scientific research. Maybe they were maybe they weren't, but they were collecting back millions of fireflies from wild populations around the country. So there were people who got like whole communities together and they would go out every summer evening with their nets and they would grab as many fireflies probably mostly males, which is a good thing. And then they'd get together, pool their fireflies, and then they ship them off and they would get paid something like a penny a firefly with a bonus for every 20,000 or something like that. So really, millions of fireflies were collected over from about 1960 to about 1990. They were still collecting fireflies. Fortunately for us, and for the fireflies, the luciferase gene was cloned, so synthetic luciferase is now available. And people stopped collecting fireflies and extracting luciferase. But for the US, that was a really big deal. And fireflies were also harvested in other countries. In the late 1800s and early 1900s. A particular species of firefly in Japan was harvested in order to sell them to hotels and restaurants so that they could be released into the courtyards. And patrons in the cities where there weren't any fireflies anymore, could still enjoy firefly viewing, or their chemistry or their beauty, completely different reasons that fireflies were harvested.

Matthew Zipple 35:51

Okay, so in terms of science communication, I wanted to hear about how your writing approach and your communication approach changes when you're talking about conservation and who your audience is, which is presumably different from the academic audience that you wrote for, for most of your career.

Sara Lewis 36:05

Science communication is a really interesting thing, again, sort of like wonder, scientists aren't really encouraged to talk to people who are beyond their specialty, except for NSF having broader impacts. You know, many of us aren't really trained, and many of us have no time, and perhaps no interest in talking to the general public. But to me, it has always seemed like for scientists whose work is funded by federal grants, we have a responsibility to at least try to tell the people who are paying taxes and supporting our research, what it is we do, why we do it, and what we have found out. And so that responsibility is maybe something that always falls off the table. Because you know, as a scientist, you're busy, you're wearing a lot of hats, you're doing a lot of things. But I don't think that's a good thing at all. And so, I have always worked with students in my department at Tufts to encourage them to do as much science communication in as many different ways as they possibly can. And over the last couple of years, I have been lucky enough to be able to teach a course in science communication for graduate students, where we talk about all the different ways the different channels that you can use to get your research results out there. So you know, you can write articles for the conversation. You can write articles for Scientific American blogs online, you can do interviews, you can do podcasts, for example. And there are many, many different skills that we don't usually teach to our graduate students that can help them to do this. The American Geophysical Union, AGU, has a fantastic program called sharing science that trains not just geologists and geophysicists. But scientists of all stripes to get better at getting the word out about what we do as scientists and why it's important. Then, you know, I think that there's an obvious benefit to doing that beyond just educating the public. And so from a conservation standpoint, certainly the more people know about insects in general, and about fireflies in particular, the more likely they are to get behind any conservation efforts and to be interested and to

participate in those conservation efforts. With iNaturalist and other kinds of citizen science platforms. There's an increased interest among folks who are just out there, helping to document biodiversity and then to conserve biodiversity. And I think this is true worldwide, not just in the US.

Matthew Zipple 38:51

Sure. Do you find that the benefits of science communication are a two way street? Do you feel like your understanding and thinking about your science changes by describing it to a non academic audience?

Sara Lewis 39:02

Yeah, that's a really interesting point. And I would say that when I had an opportunity to write about fireflies, and I was writing Silent Sparks for Princeton University Press, and so I could have actually written a much more academic book with a different audience. But I decided that because I had fielded, like so many questions from like, my neighbors at the bus stop and people who just ran into it, but they didn't know anything about fireflies, and they were curious to know more. And so it was a great opportunity. And I'm really grateful to be able to put the science into a more approachable format. So that was a big challenge for me and to be able to go from writing in scientific format to writing in plain English using exclamation points. That was cool. Question marks, punctuation. It was very exciting to be able to do that. And I even have a very short little play in there about what it's like to be a firefly larva. And that was kind of out there. But I think that made it more approachable and more understandable to people even though it's something that you would obviously never ever do as an animal behaviorist.

Matthew Zipple 40:19

I thought it was extremely effective if you're willing. My favorite part of it is act two, scene one if you'd be willing to read it to us.

Sara Lewis 40:28

Okay, yeah, let's. Let's do this. This is a section of the book. It's in "Lifestyles of the Stars", that's chapter two, and it's called "A Portrait of the Firefly as a Young Beetle". Act two, scene one. mid summer, the longest day approaches, this larva has taken its job seriously. Over the past 18 months, it has consumed 70 snails shed its skin several times and increased its body weight 300 fold. Yet, for the last few weeks, the larva has been on walkabout. It"s been wandering restlessly seeking shelter suitable for a life changing transformation. This vagabond, now crawls beneath a fallen log were other wandering larvae have gathered, curling up, each lies motionless for a few days, then sheds its final larval skin. Now it is a pupa. For two weeks, all the pupa huddled together hidden under their log, they hardly move, though when they're disturbed, they wriggle and glow brightly on the inside. They're hard at work, completely dismantling their old bodies, and painstakingly assembling new ones.

Matthew Zipple 41:42

I think does such a good job of capturing such an interesting thing because like 70 of those snails. Are you kidding me? It's 300 times as big as before. I mean, it's just the kind of transformation. I think that if you write it down in a academic journal, it's like okay, but I think that presenting it in this way really captures the… the awe of it, the wonder of it.

Sara Lewis 42:06

Yeah, thank you. You know, when I was trying to describe insect metamorphosis, which as you say is a dry subject for many of us with I really kept coming back to the idea of the curious magic of metamorphosis. It really is magic that everything with a complex lifecycle not just insects undergoes. And in a way that mammals we don't really have that. Right. So I was trying to convey the magic of metamorphosis. I still think of it that way.

Matthew Zipple 42:33

Okay, so one of the things in your book, in terms of communicating to a broader audience, thinking about conservation are a few tips for promoting firefly success in our backyards.

Sara Lewis 42:43

I think there's something that all of us can do easy things, and one of them is to recognize that we need to provide resources and habitat that is conducive for all of the life stages of fireflies, many people think of okay, I want to make it dark for the adults. But also you need to think about an inviting habitat for the larvae. And so fireflies in all of their different life stages need a certain amount of moisture. And so having shady environments with high soil moisture, letting your grass grow longer, not having a lawn is a good thing for fireflies, leaving some leaf litter and some places where rotting wood is accumulated. These are places where the prey of fireflies can thrive. And then for the adult fireflies, making sure that they have a dark environment, rethinking your outdoor lighting, not having bright security lights that are on all night or putting them on timers or on motion detectors so that the lights are only on when and where you absolutely need it. Especially if you live near firefly habitat or if you're trying to promote fireflies in your yard. And then something that's obviously really important for all insect conservation is being really thoughtful about what you put on your garden. So not using broad spectrum insecticides, pesticides, and using organic or least toxic practices in your garden. And, you know, also getting involved telling your neighbors about dark skies and about light pollution and the effect that it has on fireflies.

Matthew Zipple 44:18

Great, thanks so much for those. I think we'll leave things there. Sara Lewis, thanks so much for joining us today.

Sara Lewis 44:23

Thank you so much for having me. It's been a pleasure.

Matthew Zipple 44:28

The Animal Behavior Podcast is created by talented team of animal behavior researchers. We have three excellent content editors, Niko Hensley an NSF, postdoctoral fellow studying the evolution of neuro sensory systems and their impact on animal communication and speciation at Cornell University. Camilla Cenni, who studies tool use, object play, and animal innovation in non human primates. And Logan James, a postdoctoral fellow at the Smithsonian Tropical Research Institute, studying acoustic communication in frogs and birds. Our communications director is Casey Patmore, a PhD student at the University of Edinburgh studying the behavior of burying beetles. You can follow us on Twitter @AnimalBehavPod, or check out our website at animalbehaviorpod.com. Our education team makes lesson plans and classroom materials that you can incorporate into your undergraduate classes. You can find those materials on our website. The Education Team is Emily McLean, an assistant professor of biology at Oxford college at Emory University, Georgia Lambert, a PhD candidate studying parental cooperation in burying beetles at the University of Edinburgh, and Smile Choudhary, a recent Master of Research graduate in Biological Sciences from the University of Exeter, who works on camouflage and escape responses and green shore crabs. Our sound director is Brian Leavell, a PhD candidate studying the evolution of acoustic signals in Ximena Burnal's lab at Purdue University. This season, I'll be recording my side of most conversations in the Cornell Broadcast Studios with engineering support from Bert Odom-Reed. Our art is all produced by animal behavior researchers. Our logo was designed by Adeline Durand-Monteil. Our theme music is by Sally Street, and transitions are by André Gonçalves. I direct and host the show along with my co host, Amy Strauss, we received financial support from the Animal Behavior Society. Finally, if you liked the show, then please help us by telling someone else about the show. And leave us a rating or review on Spotify or Apple podcasts. Thanks for listening. See you next time.