

Erin Welsh	"My name is Dr. Jack Abrams. I'm a physician at the Atlantic Hospital in Maryland. I'm making this video in the hope that I will be able to watch it at some point in the future and I'm gonna show the world what happened here. I locked myself in the ICU. The CDC stopped taking my phone calls. Called FEMA, help hasn't arrived. I think I now know what is killing people. We were looking for some kind of virus, some kind of viral outbreak. I now know this is not a virus, this is an organism. It is an organism that has somehow infiltrated people's bodies. The blistering, that's a symptom. That is what threw us off. It is the isopod. It's eating their organs. It's literally eating them from the inside. It is eating their intestines, it is eating their liver. It goes for the kidneys, lungs, tissue. This is a rapidly growing, accelerating organism. How it's growing this fast, I have no idea. I noticed this rash about 45 minutes ago and I'm going to continue to take the camera and I'm going to document everything that I see here. If you find this tape, just please get it out."
TPWKY	(This Podcast Will Kill You intro theme)
Erin Allmann Updyke	Erin, it was so hard not to laugh out loud. I loved your rendition of it.
Erin Welsh	Clearly I am not an actor but I did the best I could.
Erin Allmann Updyke	I disagree. I disagree based on that beautiful...
Erin Welsh	And that is my audition tape for The Bay 2.
Erin Allmann Updyke	You're hired.
Erin Welsh	Yes. That magnificent piece of fiction I pulled from this incredible movie from 2012 called The Bay, which really the creature at the heart of this episode is also the creature at the heart of this creature feature film.
Erin Allmann Updyke	Oh my goodness.
Erin Welsh	It's amazing. Hi, I'm Erin Welsh.
Erin Allmann Updyke	And I'm Erin Allmann Updyke.
Erin Welsh	And this is This Podcast Will Kill You.
Erin Allmann Updyke	It's a little different of an episode perhaps today.
Erin Welsh	It really is. I think this is one of the first episodes where we were just like let's do this weird looking thing that we don't know anything about.
Erin Allmann Updyke	Yep.
Erin Welsh	There's got to be a story there.
Erin Allmann Updyke	Yeah.
Erin Welsh	And there is. And a movie.

Erin Allmann Updyke A whole movie about it.

Erin Welsh Yeah. We are covering what is commonly known as the fish tongue parasite.

Erin Allmann Updyke Right. Or the fish-eating louse.

Erin Welsh Yeah.

Erin Allmann Updyke Or tongue-eating louse, not fish-eating louse.

Erin Welsh Yeah. I mean there are lice or well isopods-

Erin Allmann Updyke Yes.

Erin Welsh Marine isopods that eat fish.

Erin Allmann Updyke Yeah, this is what they do. So it's an isopod that we're talking about today. Have you seen the pictures? If you haven't, well you will by the end of this episode.

Erin Welsh Yeah. It is an adorable little isopod sticking out of the mouth of a fish or it's like in there right where its tongue should be. And that's because it has eaten the fish's tongue and replaced it.

Erin Allmann Updyke We'll get into it, a lot of it.

Erin Welsh Organ-replacing parasites. I mean beautiful.

Erin Allmann Updyke Amazing.

Erin Welsh Yeah. There is a lot of fun stuff to cover today. But first-

Erin Allmann Updyke It's quarantini time.

Erin Welsh It is. Erin, what are we drinking this week?

Erin Allmann Updyke Well we're drinking Louse Got Your Tongue.

Erin Welsh Yeah.

Erin Allmann Updyke Because we just said it.

Erin Welsh We just said it. That's the name of it. Yes, Louse Got Your Tongue. It's your standard mai tai which I'm shocked that we haven't actually done before.

Erin Allmann Updyke I know.

Erin Welsh But we haven't. So in your standard mai tai is rum, Curaçao, orgeat, and lime juice.

Erin Allmann Updyke It's fantastic.

Erin Welsh: Yeah.

Erin Allmann Updyke: So delish.

Erin Welsh: So delish.

Erin Allmann Updyke: We'll post the full recipe for that quarantini and the non-alcoholic placeborita on our website thispodcastwillkillyou.com and on all of our social media channels. So make sure that you're following us and you can see all the pics and also videos of this recording, we do that now.

Erin Welsh: Yeah, we do do that.

Erin Allmann Updyke: You can see Erin's fish shirt, by the way.

Erin Welsh: Yes, yes, Minnow Madness. He's got sunglasses.

Erin Allmann Updyke: It's a very cute fish. It's not infected.

Erin Welsh: Yeah.

Erin Allmann Updyke: I can tell.

Erin Welsh: He's drinking what appears to be a mai tai.

Erin Allmann Updyke: It could be a mai tai.

Erin Welsh: It's pretty thrilling. Yes.

Erin Allmann Updyke: Oh yeah.

Erin Welsh: But also on our website you can find all sorts of things from transcripts, you can find the resources that we use to put together all of these episodes. You can find links to bookshop.org affiliate account, our Goodreads list, music by Bloodmobile, merch. Some pretty sweet merch. Patreon, a contact us form if you want to reach out, suggest an episode, you can invite us to give a talk. We'd love that.

Erin Allmann Updyke: We'd love that.

Erin Welsh: You can ask us to do a workshop or you can say hey, here's my firsthand account, there's a firsthand account form for that. And other stuff on the website.

Erin Allmann Updyke: There's so much stuff there.

Erin Welsh: Yeah.

Erin Allmann Updyke: Well shall we take a quick break and then get into the creature feature of this week?

Erin Welsh: Let's do it.

TPWKY

(transition theme)

Erin Allmann Updyke

So the creatures that we're discussing today are isopods. And I thought we should start by what the heck is an isopod?

Erin Welsh

That's a good starting point.

Erin Allmann Updyke

Yeah. Isopods are crustaceans which means that they're arthropods, so they have exoskeletons that they shed between life stages in order to grow. And these are more closely related to like crabs and lobsters which are also crustaceans, they are decapods, than they are to like bugs or insects which are other terrestrial arthropods. So the isopods that everyone listening is probably most familiar with, whether you realized it or not, are like roly-polies, right. Or also known as woodlice, also known as armadillo bugs, pill bugs. There's so many colloquial names for these.

Erin Welsh

Yeah. What did you grow up calling them?

Erin Allmann Updyke

Roly-polies. What about you?

Erin Welsh

Me too. Yeah, roly-polies.

Erin Allmann Updyke

Okay. I'm always curious where the different names are.

Erin Welsh

I'm sure there's a map for that, yeah.

Erin Allmann Updyke

There probably is. But what did you call them, listeners?

Erin Welsh

Yeah.

Erin Allmann Updyke

Roly-polys, I love that name.

Erin Welsh

It's very cute.

Erin Allmann Updyke

But so the roly-polies are terrestrial isopods. Most isopods are not terrestrial, most of them are marine or freshwater dwelling. There are probably at least 10,000 species of isopod in the world and they make their home everywhere across the entire globe. And some of these isopods make their homes inside of other creatures, meaning they're parasites. And parasitic isopods come in a lot of different flavors, many of which infect fish hosts. Fish are really phenomenal hosts for so many parasites. And many isopods infect fish in a whole bunch of different ways. Some of them might infect fish externally, like attaching on near their eyeballs. Some of them might attach in the gill chambers, some of them might even burrow their way partway into their flesh, and some live in the mouth holes of fish. And that is the isopods or those are the isopods that we're focusing on today.

Erin Welsh

Mouth hole?

Erin Allmann Updyke

Mouth holes.

Erin Welsh

Like mouth?

Erin Allmann Updyke

Yeah, mouth.

Erin Welsh

Just wondering what the 'hole' part added.

Erin Allmann Updyke

I mean yeah, the whole hole, they're in there. And there is not just one of these so-called tongue-stealing parasites. No, no, no. There are many in fact. They primarily fall in the family Cymothoidae and within that family there's a couple of genera that seem the most common to specifically do this tongue-stealing thing. That is the genus Cymothoa and Ceratothoa but there's several other as well and I think the phylogeny seems to be in flux.

Erin Welsh

Yeah.

Erin Allmann Updyke

The most famous of these, I think the one that has gotten the most popular press is Cymothoa exigua, if that's how you pronounce it correctly.

Erin Welsh

Your guess is as good as mine which is probably not great.

Erin Allmann Updyke

So we can use that species as an example since it's maybe one of the most popular ones but all of these family of isopods share a pretty similar life cycle. And we definitely don't know everything that there is to know about these parasites, so there's a lot more that we could learn. And because there's so many different species which infect such a wide range of host fish, we're going to look really broad strokes at what their general life cycle looks like to understand these parasites. So in general, these baby Cymathoids, when they're born, they're born as like a live birth kind of because isopods have a brood pouch that's called a marsupium, kind of like a kangaroo or a koala.

Erin Welsh

It's adorable.

Erin Allmann Updyke

Isn't it? And so they hold their young, their eggs in this little pouch and then they hatch and then they develop through several little life stages before they're ready to go off on their own. So baby Cymothoids which are also called manca or mancae, that's the like baby form-

Erin Welsh

Oh my god. I had no idea.

Erin Allmann Updyke

I know. So many weird names. Like don't call them larva, they're called manca.

Erin Welsh

Wow. Okay.

Erin Allmann Updyke

And once they leave their mothers, they are free in the water and they will first attach to a host. Sometimes they might attach to a host fish that they didn't mean to, like maybe not the one that they really wanted. So then they might take a few nibbles from somewhere on the fish and then drop off. And eventually the point is to find a suitable host. What species of fish that is will depend on the species of isopod. But the goal is to find a host that it's well adapted to which is going to be some type of bony fish. And once they do, they will attach to that final host. Every single one of these isopods, these Cymothoid isopods, is born a male. So once they attach to their final fish host, they will look around and if they're the first ones there colonizing this host, they will change their sex into a female.

Erin Welsh

That's amazing.

Erin Allmann Updyke I know. It's called protandrous hermaphroditism and it's a form of what's called sequential hermaphroditism. So they're all born with one sex and then some of them will go on to change sexes over time, rather than simultaneous hermaphroditism which is something like snails which have both male and female organs at the same time.

Erin Welsh Right, right.

Erin Allmann Updyke It's fascinating. But what this does is it allows for these isopods to attach, change if needed into a female, and then every other isopod that finds that same host will then be a male that they'll be able to mate with and then make eggs from there. Right?

Erin Welsh That's incredible. Because I kept seeing like the female isopods are the ones that replace and I'm like I wonder why that is. But now I know.

Erin Allmann Updyke It just means that she was the first one to attach.

Erin Welsh Yeah. Wow.

Erin Allmann Updyke And then this isopod will live essentially the rest of its entire life attached to that host, primarily eating their blood.

Erin Welsh Okay. Not eating scraps of whatever the fish is eating.

Erin Allmann Updyke Not eating scraps of whatever the fish is eating. Some species, because again we're talking about a pretty wide range of different Cymothoid isopods here, some of them it's thought maybe feed more like on tissue in the fish's mouth but again, it's feeding on the fish host itself, not on what the fish is eating. But some have different mouth parts that maybe look more like they're sucking pure blood vs eating the fish tissue.

Erin Welsh Yeah.

Erin Allmann Updyke But in any case, they're feeding on the fish.

Erin Welsh And you said the rest of their lives. How long is that?

Erin Allmann Updyke I knew that you were going to ask me that question, Erin.

Erin Welsh I can't resist.

Erin Allmann Updyke I don't know.

Erin Welsh Okay.

Erin Allmann Updyke Again, there's so many different species. For at least one of these, and the paper that I found wasn't actually looking at one of these mouth-dwelling isopods but it was a different Cymothoid isopod that attaches near the eyeball of a fish, those can live for at least one year.

Erin Welsh Okay.

Erin Allmann Updyke Does that mean that they all can live at least one year? Do any live longer? Who knows? I don't.

Erin Welsh

Okay.

Erin Allmann Updyke

So they spend the rest of their lives. At what point then do they... So they are reproducing while replacing the tongue, while acting as the tongue.

Erin Welsh

Right.

Erin Allmann Updyke

While acting as the tongue. Yes.

Erin Welsh

Okay, okay.

Erin Allmann Updyke

So essentially it's like this. One isopod finds a fish, they are the first ones there so they're going to attach in the mouth, for the ones that we're talking about today, they'll attach in the mouth far back in the buccal cavity of the fish, kind of near the gills but not quite near the gills. And then they will transform into their final form and in this case if it's the first one there, they'll transform into a female. That's the one that's going to take up the whole mouth. Where they attach, generally because they're feeding on blood, what it does is it disrupts the blood flow to the fish's tongue to such a degree that that fish tongue essentially begins to die.

And then this isopod is able to grow and fill that entire buccal cavity, the entire mouth hole of that fish, kind of replacing where that tongue used to be. Other isopods will also find this fish and they will attach sometimes closer to the gills, sometimes just farther back in that buccal cavity which again connects to the gills because that's how the fish is breathing. And those will remain as males. The males are much smaller than the females, so they'll be farther back and they won't get as big. And they'll be able to mate and then that female that has that little brood pouch, so it's just holding a bunch of little eggs that are growing and then releasing as they're ready to do so. Ta-da!

TPWKY

(transition theme)

Erin Welsh

Okay, so a couple of questions.

Erin Allmann Updyke

Okay.

Erin Welsh

You said that like finding the right host, I know that a wide variety of fishes are affected or like can be infested I guess with with this parasite-

Erin Allmann Updyke

Yes.

Erin Welsh

And then it will grow. So is its growth limited by the size of the fish's mouth? Or do they find fish that have a big enough mouth? Do they ever grow so big that the fish can't actually feed?

Erin Allmann Updyke

Erin, I love you're such an ecologist.

Erin Welsh

Thank you.

Erin Allmann Updyke

These are all great questions. Where to begin? So there are a lot of different species of Cymothoids and they can infect essentially like any fish that you imagine, there's probably a Cymothoid that could infect that fish. Some of these species of isopod are more host-specific than others and some are less host-specific.

Erin Welsh

Okay.

Erin Allmann Updyke

The question of like how big do they grow? Why do some grow bigger and some don't grow as large? We don't really know. Like does that depend on just who they ended up in? Is that part of why there are strong host associations between some of these isopods and some of their hosts? These are all really great questions. They're like evolutionary questions, they're like ecological questions because then it's also like what is it doing to this fish? So there's a lot to unpack there that we don't fully know the answer to.

Erin Welsh

Okay.

Erin Allmann Updyke

So let's talk a little bit more about like what this ends up looking like and what this ends up doing to the fish.

Erin Welsh

Yeah, yeah.

Erin Allmann Updyke

So first, I want to talk about what this looks like to give everyone like a mental image. We're just seeing like a tongue-replacing... What? What? Google Image search it but then also I'll describe it for you. I also first want to say that a fish tongue is different than our tongue and this is important for the idea that a fish could have their tongue replaced in function by a parasite.

Erin Welsh

Right.

Erin Allmann Updyke

Our tongue is this massive muscle, right. So our tongue is really important in moving food around in our mouth, pushing it from side to side. It's also important in moving food to the back of our throat so that we can actually engage our swallow reflex. And we also use our tongue to speak, to talk. It's important in our breathing because it has to move in certain ways. But a fish tongue is not like that. A fish tongue doesn't have any skeletal muscle of its own, it's just like a little meaty bit. Well it's not a muscle, it's just flesh.

Erin Welsh

What does it do?

Erin Allmann Updyke

It's essentially a mechanical device that just helps hold prey up against the roof of the mouth so that the fish can do whatever it needs to do, eat that prey and then swallow it.

Erin Welsh

But there's no muscle.

Erin Allmann Updyke

But there's no muscle to it. And if you Google Image search a whole bunch of pictures of fish mouths without parasites, some of them don't even have that much of a meaty tongue, some just have like this kind of flat surface, some have what almost look like teeth all along the bottom of their palate. So there's a pretty wide variety of what a fish mouth might look like. But there are none of them as complicated as like a muscle that needs to be able to move around. And so the paper from 1983 by Brusca et al that first kind of proposed this hypothesis that the isopod could functionally replace a fish's tongue kind of really brought this to light. Like it makes sense that this isopod could serve that same function because it's not that hard. It's not.

Erin Welsh

Anyone could do it.

Erin Allmann Updyke

Anyone could do it; an isopod could do it. So what does it then look like when a parasite is replacing a fish's tongue?

Erin Welsh: It's frankly adorable.

Erin Allmann Updyke: It is so adorable.

Erin Welsh: So we might be outliers in this because when I showed John I was like isn't this adorable? And he was like is that the word? Is that right? Is that the correct adjective? And I'm like it certainly is.

Erin Allmann Updyke: I know. When I was describing it to Brett, he was like visibly shook where he just was like...

Erin Welsh: Well I think because we immediately put ourselves in the position of having an isopod, a large isopod in our mouths forever. Which is not what happened in The Bay by the way.

Erin Allmann Updyke: Oh it's not?

Erin Welsh: No, the tongues were gone. And then everyone was eaten from the inside out. It's eating the kidneys, it's eating the livers.

Erin Allmann Updyke: Right. Much more intense than just the tongue.

Erin Welsh: Yeah. I mean it wasn't let's say the most scientifically accurate movie.

Erin Allmann Updyke: Oh I'm really shocked to hear that.

Erin Welsh: I enjoyed it though.

Erin Allmann Updyke: Okay. So if you see a front on view of like an open fish mouth that's infected with one of these parasites, the first thing that you'll notice is a pair of black eyes staring at you.

Erin Welsh: So cute.

Erin Allmann Updyke: And then this little kind of almost triangular-shaped head, it's like a little bit round on top and then a little pointy little... Looks like a chin.

Erin Welsh: Yeah.

Erin Allmann Updyke: And then they have what look like almost little hands curled up under their chin like the way that a raccoon kind of holds their hands across their chest.

Erin Welsh: It's like hi, hello!

Erin Allmann Updyke: Hi there! That's that's how it talks. Oh hi, I'm just making my little home here, it's a cave, don't mind me. And then you can see what almost look like kind of scales that disappear back into the fish's mouth. They're not really scales but isopods are arthropods and so they have segmented body parts like a shrimp or something. And then these guys have seven pairs of these little leggy things, they're called parapods, and they end in these pretty sharp little hooks that they use to attach themselves to the fish. Just like hook in there. If you were to look, so that's what you see if you look straight on in an open fish's mouth.

If you were looking at a fish in cross section, like you sliced off the side of their cheek and then you were looking at what this isopod looked like, you would see something that looks an awful lot like a roly-poly except it's white usually. And then based on most of the pictures that I've seen, and I haven't seen one of these in real life, but they are usually quite a bit bigger depending on the species of fish that they're infecting than most roly-polys in your yard and they're a little bit more flattened dorsoventrally, so like tummy to back they're a little more flat so that they can fit in their fish's little mouth there.

Erin Welsh

Yeah.

Erin Allmann Updyke

And this isopod essentially will take up the entirety of the fish's mouth, the female will at least. And then sometimes if you do that cross section, you might see one, a smaller one further back like almost halfway into the gill cavity. And that is what it looks like to be infected with one of these isopods.

Erin Welsh

There are some amazing pictures out there.

Erin Allmann Updyke

They're really, really incredible. If you're not following us on social media, you'll have to Google search for yourself. You should just follow us. We post the pictures.

Erin Welsh

Now's the time, yeah.

Erin Allmann Updyke

Now's the time. If you're wondering when the time, it's now.

Erin Welsh

Okay, I have a question though about the effects. Because we basically said okay, well a job so easy an isopod could do it, as in replacing the tongue. But it's not just replacing the tongue, it's also taking blood.

Erin Allmann Updyke

It sure is.

Erin Welsh

So are the fish negatively impacted by that aspect?

Erin Allmann Updyke

That is a really important question. A lot of the studies that have looked at what the effects are on the fish that are infected are primarily in aquaculture settings with farmed fish. Which is logical because not only is that a place where you can like really study things like survival and growth and length and all these things but also fish in aquaculture seem to be particularly susceptible to infection with these parasites.

Erin Welsh

Okay.

Erin Allmann Updyke

I don't know exactly why. It is thought that in aquaculture settings it's almost always not a species that typically infects those fish.

Erin Welsh

Okay.

Erin Allmann Updyke

And they're introduced by wild fish that then come in contact and then they're able to infect like the whole entire aquaculture pen or whatever.

Erin Welsh

Right. Opportunity knocks, yeah.

Erin Allmann Updyke

Right. But there are also some really incredible, sound really difficult to do, ecological studies that have looked at these isopods in more natural settings. What are the effects on like population dynamics even but also survival, reproduction? Long story short, overall, and again it varies species to species, caveats, fish that are infected with these tongue-replacing parasites do seem to be negatively affected to one degree or another. We see things like anemia, we see evidence of tissue damage and of the host's response to that tissue damage, so things like inflammation where the parasite was attached. We also can see inhibited growth and a reduction in weight and length of fish that are infected vs not infected. In some cases we have increased mortality of infected fish compared to non-infected fish. And in a lot of studies we see a reduction in egg production or in egg quality in fish that are infected with a parasite compared to not infected.

Erin Welsh

Okay.

Erin Allmann Updyke

So yeah, it's not great for fish to have their tongue replaced by an isopod. But Erin, getting back to some of the questions that you had asked about like why does this isopod infect the mouth? Like what is the strategy there and then like what are the trade-offs between a mouth infection vs an infection of an isopod somewhere else like on the gills or on the external body or whatever? So there was a really interesting paper, I mentioned it already, by Brusca et al from 1983 and that was the first one that really was like hey, this isopod is essentially functionally replacing the tongue.

Erin Welsh

Yeah.

Erin Allmann Updyke

The one that said it's not that hard. And one of the things that they pointed out that's really interesting is that by making a niche in the mouth of this fish, the isopod in a lot of cases can grow to a significantly larger size than it could in say the gills of a fish. Because necessarily the size that that isopod grows to essentially is displacing fish tissue, right. It has to like eat away a hole in the gills which is going to more negatively, theoretically, affect the fish if it can't breathe as good than by replacing a space in its mouth that's already a potential space to inhabit, right.

Erin Welsh

Okay, okay.

Erin Allmann Updyke

And so that is one of the big ideas as to like how this relationship works. It allows for the females to grow to a larger size which theoretically means they can hold more brood, so the isopods can reproduce more readily or have greater fitness. And in the fish it's a relatively less negative impact. And they even said in this paper, which I thought was really interesting, that well we think that sure, maybe there's a negative impact for an isopod to replace your tongue but it's less negative than just having your tongue eaten without anything to replace it.

Erin Welsh

So that in itself is really interesting.

Erin Allmann Updyke

Isn't it? It's so, so interesting.

Erin Welsh

So these isopods essentially were pre-adapted to attach to a fish host and consume tissue. And so there could have been many different areas and it was like oh the tail region, not great, not a whole lot of tissue there, the fish can't swim, it's just going to sink and die.

Erin Allmann Updyke

Right.

Erin Welsh

And then it's like what area is going to promote longevity for both the fish and the isopod?

Erin Allmann Updyke

Right.

Erin Welsh

And that happens to be the mouth.

Erin Allmann Updyke

Yeah.

Erin Welsh

For these species.

Erin Allmann Updyke

For these species. And like we know, biologists, evolution doesn't quite work like that but yes.

Erin Welsh

Right. And is a greater size always a good thing? Not necessarily.

Erin Allmann Updyke

Yeah, exactly.

Erin Welsh

Right.

Erin Allmann Updyke

Isn't that so interesting though, Erin?

Erin Welsh

I just love it. I just think these little guys are fascinating and fun and they've really been a parasite that I have thought of ever since the day I first saw them.

Erin Allmann Updyke

They're one of your, what? Roman Empires?

Erin Welsh

Roman Empire. Yeah, one of my one of my parasite Roman Empires.

Erin Allmann Updyke

Parasite Roman Empires. I mean yeah. Same, honestly. And like every time I re-remember them, I'm like wow, what a thing to exist.

Erin Welsh

I know. I'm glad that we did this deep dive.

Erin Allmann Updyke

Yeah. Well tell me, speaking of deep dives, Erin. I have so many... I don't know where to begin with trying to understand the history of this, the evolution of this, the what?

Erin Welsh

Yeah. Yeah. Yeah. Let's just take a break and then I'll begin.

Erin Allmann Updyke

(transition theme)

Erin Welsh

It probably won't come as a tremendous shock that the history of the fish tongue-replacing isopod, specifically the species that I feel like gets a lot of the press, the *Cymothoa exigua*, that history is a little thin. The history in general is a little thin.

Erin Allmann Updyke

Right. It's like hey, we found this thing in 1979 and well there it is.

Erin Welsh

Yeah. I mean so this genus of parasitic isopods actually goes back farther than 1979. So Cymothoa was described, depending on who you ask, it was either Linnaeus or Fabricius in the late 1700s. And then Cymothoa exigua got its recognition or its name I think in 1884 when two naturalists, Schiødte and Meinert, included them in a big monograph about the subject. I probably said those names wrong. But nearly 100 years would pass after this monograph before anyone would pay significant attention to these bizarre creatures. And in 1981 and 1983, Brusca, like you said, Erin, we've mentioned these papers a couple of times, published first a monograph and then a paper, the second paper, the '83 paper was with Gilligan, describing this isopod in detail including some absolutely incredible pictures with the isopod in the mouth of a fish, the spotted rose snapper specifically. Also side note, in this paper is where I learned that there is a fish species whose species name is Boop boops.

Erin Allmann Updyke

Boop boops? Erin, I almost included that as a fun fact too because I loved it so much.

Erin Welsh

I loved it. I was like this can't... It's some type of sea bream, right?

Erin Allmann Updyke

Boop boops. And I was like what's a sea bream? I don't know but I love it.

Erin Welsh

It's incredible.

Erin Allmann Updyke

Also this episode made me feel really depressed about how much knowledge your brain can just leach out.

Erin Welsh

I know.

Erin Allmann Updyke

Because I used to know so much about fish, Erin.

Erin Welsh

Same. I took an ichthyology class in grad school.

Erin Allmann Updyke

Yep.

Erin Welsh

I couldn't tell you anything.

Erin Allmann Updyke

Same. I'm like what's a... I had to re-look up like teleost, Erin.

Erin Welsh

Oh yeah.

Erin Allmann Updyke

It's embarrassing.

Erin Welsh

I mean I'm married to a fish biologist and I still don't know very much.

Erin Allmann Updyke

Listen, we all have our strengths.

Erin Welsh

Yeah. But anyway, so since this 1983 paper, researchers have mapped the general distribution of this critter and other related critters. We've gained a better but incomplete understanding of its life cycle and we've measured the impact of these isopods on their fish hosts. But perhaps the most exciting development in the history of this tongue-eating isopod is the 2012 movie The Bay which is where our firsthand account came from. I really do think that it like increased awareness of this parasite and pollution in the Chesapeake Bay. I don't know.

Erin Allmann Updyke

Maybe.

Erin Welsh

Maybe. The Bay is a found footage mockumentary. I just feel the need to include this.

Erin Allmann Updyke

I love it.

Erin Welsh

Because I watched it last night so you don't have to, like 'you' meaning general audience. Erin, I still want you to watch it.

Erin Allmann Updyke

I am going to watch it, don't worry. I'm going to watch it tonight. I just felt I didn't have time last night.

Erin Welsh

Oh man, it is ridiculous. And it has a shockingly high rating on Rotten Tomatoes, 76%. And I just want to read you one more little quote from it because how does it have a 76%?

Erin Allmann Updyke

I want also everyone listening to know how many times I've heard Erin say that it has a 76% on Rotten Tomatoes.

Erin Welsh

You could tell me that it has 76%. That's going to be your Roman Empire is that The Bay has a 76% rating on Rotten Tomatoes. Okay, here we go. "I don't think we can rule out a foodborne virus or anything airborne but this looks like a water vector. The blistering looks like a Echinococcus." I don't know if that is spelled correctly or anything but that's how I wrote it down exactly from the subtitles. "The lesions could be mycobacterium marinum or schistosomiasis. I mean, Jesus, there could be cholera in there! If the water is being polluted by anything chemical on top of the bacteria, we could easily see a new form evolve, maybe a fungal bacteria." What? "Maybe a mutated tapeworm, who knows?"

Erin Allmann Updyke

Oh we would be so annoying for most people to watch movies with I think.

Erin Welsh

Oh my gosh. I mean this is why when you and I watch something together, we drive other people away.

Erin Allmann Updyke

Yes.

Erin Welsh

Yes.

Erin Allmann Updyke

I love it. I mean a fungal bacterium mutated tapeworm? What?

Erin Welsh

I know. What does that mean?

Erin Allmann Updyke

A new form evolve!

Erin Welsh

A new form.

Erin Allmann Updyke

If that doesn't make someone want to watch this movie...

Erin Welsh

Yeah, okay. But amazing movie aside, that's pretty much it when it comes to the history of these tongue-eating isopods. They haven't played a major role in world wars, they don't feature in the Hippocratic texts or Ancient Egyptian papyri, they aren't associated with any major developments in medicine. They do have this incredible creature feature about them which is more than you could say for most parasites, I will give it that.

Erin Allmann Updyke

True, true.

Erin Welsh

But most people wouldn't place them high on a list of quote unquote "important" parasites.

Erin Allmann Updyke

True. Even amongst fish parasites, I couldn't find enough papers that gave them the credit I feel like they deserve.

Erin Welsh

Exactly. And to that I would say yeah, most people are wrong. Our human-centric perspective prevents us from grasping the significance of parasites and pathogens that don't directly or even indirectly impact us, like livestock diseases. And even if we do acknowledge the role that these underappreciated parasites might play in an ecosystem, it's largely from a parasites are bad and cause disease perspective. This is especially the case when it comes to conservation where parasites are more often than not seen as a barrier to conservation efforts rather than a focus of conservation itself. So if you think of any wildlife conservation program, what animals come to mind?

Erin Allmann Updyke

Big, like big charismatic mammals.

Erin Welsh

Yeah.

Erin Allmann Updyke

I don't know, big cats.

Erin Welsh

Big cats, giant pandas, elephants, polar bears, sperm whales.

Erin Allmann Updyke

Right.

Erin Welsh

These gorgeous and charismatic megafauna. You probably don't picture the sperm whale roundworm that can grow up to 9 meters long.

Erin Allmann Updyke

9 meters?

Erin Welsh

9 meters.

Erin Allmann Updyke

That's like when you said it, it actually didn't even register because I was like that doesn't, it's not... Wait, wait, wait, hold on.

Erin Welsh

Cannot compute. Yeah.

Erin Allmann Updyke

Yeah. What?

Erin Welsh

Yep. Or you probably don't think of the protozoan parasite that infects black-footed ferrets or the fish tongue-eating louse, parasites that would go extinct if their host went extinct.

Erin Allmann Updyke

Like for example, the California condor's lice which did go extinct.

Erin Welsh: Yes, I have it in here. I have that in here as an example.

Erin Allmann Updyke: Yes!

Erin Welsh: Yes.

Erin Allmann Updyke: Oh my gosh. Such a good example.

Erin Welsh: Several conservation plans include directly ridding a target species population of their parasites. So they choose one species over another.

Erin Allmann Updyke: Yep.

Erin Welsh: They choose the free living organism over the parasitic species, even if that means the extinction of that parasitic species.

Erin Allmann Updyke: Right. Because no one's worried about extinction of parasites.

Erin Welsh: Exactly, exactly. And maybe out there you're thinking okay but like what's the problem with that? Like parasites cause disease, they are bad, they're gross. Like why wouldn't we want a parasite-free world? And that's kind of what I want to spend the rest of this history section talking about, like why we should care about parasites, why they matter in ecosystems, and why conserving parasite biodiversity rather than reducing it should be a goal of conservation programs.

Erin Allmann Updyke: I love this so much. This is like such our roots.

Erin Welsh: I know, I know.

Erin Allmann Updyke: Who knew?

Erin Welsh: Who would have thought we found our roots in the fish tongue-eating louse parasite? And so maybe at the end of this I won't have convinced you to love and adore parasites but at the very least I hope that I leave you with a little bit more appreciation for them. We're going to call this the Parasite Appreciation Hour.

Erin Allmann Updyke: Yes. Yeah.

Erin Welsh: This is a planet of parasites. And I don't mean that in the sense of like humans are parasites because we're exploiting all these natural resources and destroying ecosystems and killing the planet and we are the parasites ourselves. That is true. But I mean that on this planet, parasites dominate. Parasitism is the most common consumer strategy on this planet.

Erin Allmann Updyke: Nobody... Can you say that again? Because nobody appreciates that.

Erin Welsh: Yeah. Parasitism is the most common consumer strategy on this planet. Parasites make up 30% -50% or more of all living species.

Erin Allmann Updyke: That's a lot of species.

Erin Welsh: That's a lot of species. They may be the most abundant and the most diverse group of multicellular animals on Earth.

Erin Allmann Updyke: I mean...

Erin Welsh: And yet. And yet.

Erin Allmann Updyke: And yet.

Erin Welsh: Compared to free living organisms, they get a sliver of the attention and the funding. In a 2020 paper by Colin Carlson et al, one of my favorite authors of scientific papers to read because they're just so-

Erin Allmann Updyke: I have a quote from... Is it from the same paper? It might be.

Erin Welsh: It might be. It might be, yeah. So in this paper, the authors estimate that there are between 100,000-350,000 parasitic helminth species, the vast majority of which, 85%-95%, are still unknown.

Erin Allmann Updyke: Oh my gosh.

Erin Welsh: Hundreds of thousands of species unknown.

Erin Allmann Updyke: Unknown.

Erin Welsh: Researchers who study free living organisms massively outnumber those who study parasites. I mean and we can attest to this being like the minority in our grad program of people who studied disease ecology or parasites at all. And many large scale ecological survey programs like NEON, the National Environmental Observatory Network, barely make an effort to characterize the diversity of parasites in an ecosystem, despite the fact that they have been found in some communities to make up the most biomass.

Erin Allmann Updyke: I mean where's the caring?

Erin Welsh: Where's the caring? The bias against parasites is clear. But what is also clear is their incredible importance in ecosystems. Conservation costs money and the goals of conservation programs sometimes conflict or appear to conflict with the needs of a region or community or the interests of a corporation. And so one big challenge that conservation organizations face is justifying why conservation is important. Like why should we invest time and resources into preserving ecosystems and restoring biodiversity?

Erin Allmann Updyke: Right. What's it going to get us as humans?

Erin Welsh

Exactly. Especially if that comes at the cost of human economic development. It goes without saying that this is a complex issue and that the balance of trade-offs or even whether trade-offs exist at all might be different depending on who you ask and the time scale and landscape scale that you're looking at. But the bottom line is that conservation must be argued for and convincing people that we need to conserve charismatic species like blue whales or snow leopards, that's one thing. But persuading them that wormy parasites or parasites that replace the tongue of a fish that we don't really think that much about, that these are also worthy of conservation, that's a whole other can of worms, pun intended.

Erin Allmann Updyke

Yep.

Erin Welsh

In their 2023 paper 'Conservation of Parasites: A Primer', authors Lymbery and Smit lay out three broad, not mutually exclusive categories that most pro-parasite conservation arguments fall into. So like why should we conserve parasites? Here are the three general categories. Number one, intrinsic values. Parasites are worthy of conservation because they are living things and like all living things should be protected because all of life has value. Number two, their ecological role. Parasites are key species in all ecosystems and their removal could have unforeseen or foreseen and disastrous consequences. And number three, parasites can tell us how healthy or unhealthy an ecosystem is. In other words, parasites are valuable, number one, because they are, number two because they are vital in ecosystems, and number 3, because they are important to humans.

These are not the only reasons why parasites are important. For instance, if we lose parasite diversity, we also lose opportunities to study the incredibly varied ways these creatures have adapted to this lifestyle which could give us insights into the evolution of novel traits, the transition from a parasitic to a free living life cycle, and even the evolutionary history of certain host species which we could assess by looking at parasite genetic diversity. But for today, I want to chat a bit more about just those three I mentioned. And actually just two and three because besides the true parasite enthusiasts out there, I'm not sure a whole lot of people are going to be convinced that parasites have intrinsic value. As we learn in school and as Webster dictionary defines-

Erin Allmann Updyke

Wow.

Erin Welsh

A parasite is quote "an organism living in, on, or with another organism in order to obtain nutrients, grow, or multiply, often in a state that directly or indirectly harms the host". End quote. So why would something that directly or indirectly harms another organism be valuable to keep around? The answer to that question comes down to perspective and scale. To an individual elk infested with tapeworms, that's not going to feel good. You're not going to like that.

Erin Allmann Updyke

You're not like yay, more tapeworms.

Erin Welsh

Wow, this is wonderful.

Erin Allmann Updyke

Love that.

Erin Welsh

But to the wolves who can more easily take down elk infested with tapeworms, that's great. And the fact that not all elk in an ecosystem are infested with tapeworms or have different parasite burdens, that introduces diversity into this dynamic, influencing which elks survive and which don't and potentially driving the evolution of this population. Parasites are well known to mediate predator-prey relationships like this.

Erin Allmann Updyke I love parasites and predator-prey relationships.

Erin Welsh I know!

Erin Allmann Updyke They're just so good.

Erin Welsh There's so much there. It's just like life is trade-offs, all of life is trade-offs and it's all these interconnected trade-offs and relationships. And we don't understand it all and that's what I love about it.

Erin Allmann Updyke Yeah. Also there's just so many beautiful examples, including a fish parasite that like when you're infected with these parasites, you're far more likely to get eaten by a bird and then that parasite is going to infect the bird and then it-

Erin Welsh Exactly.

Erin Allmann Updyke It's just so good.

Erin Welsh It's so good. And then it's not just predator-prey relationships, right. Like there's also competition among members of a species. And so in these ways, parasites can affect how energy and resources flow through an ecosystem. So take camel crickets and grasshoppers, which when infected with a certain parasite, quote, "are 20 times more likely to jump into a stream where their biomass constitutes up to 60% of the energy intake of endangered fish populations."

Erin Allmann Updyke Whoa!

Erin Welsh Isn't that so cool?

Erin Allmann Updyke I love that.

Erin Welsh I know.

Erin Allmann Updyke Wow.

Erin Welsh The cascading effects of parasites in an ecosystem are difficult to measure but it's kind of like as Joni Mitchell says, you don't know what you got til it's gone. Parasite removal from an ecosystem is kind of like what we saw with the removal of apex predators to protect livestock which led to an explosion in some populations, like some herbivore populations, a decimation of others, and an overall vastly changed landscape that regained stability once those apex predators like wolves were reintroduced. Parasites play similar roles in ecosystems, helping to organize, stabilize, and promote genetic diversity. Parasites can also stimulate a host's immune system. So some studies have shown that parasites can protect hosts from a novel pathogen or damages from heavy metals.

Erin Allmann Updyke See our allergies episode for more on that kind of hypotheses.

Erin Welsh

Yeah. Zoomed in to like an individual level, it's very easy to see why the word 'parasite' has such negative connotations. But taking in the big picture of an ecosystem, these are vital and so underappreciated parts of this beautiful, intricate machine, one where we don't fully understand how it runs and what might happen if we fiddle with this knob or adjust that lever. And let me remind you again, this isn't a handful of parasites playing an important role in a few interactions here and there, even though I've only given a few examples. This is everywhere. This is everywhere.

Erin Allmann Updyke

Every free living organism on this planet has parasites.

Erin Welsh

Yeah. Again, yeah, parasites might be the most dominant life form on Earth.

Erin Allmann Updyke

Period.

Erin Welsh

And so maybe you're still not fully convinced that we should conserve parasites. I know you are, Erin. I had you at intrinsic value.

Erin Allmann Updyke

Yeah, you did.

Erin Welsh

But what if I told you that we can use parasites to assess whether an ecosystem is healthy or unhealthy? Certain species of parasites actually accumulate pollutants more readily than their hosts and so they can set off early warning bells about a new pollutant or one that's on the rise in a particular ecosystem. And parasites with complex life cycles involving multiple hosts also tend to be more sensitive to environmental change. So if humans alter a habitat or introduce pollutants, or if the climate gets warmer and drier, these parasites might be the first ones to feel those changes which can be helpful for us to forecast potential downstream effects. Although it might seem like a contradiction, a healthy ecosystem is one with parasites, not one without. But as human-mediated change keeps on trucking, as this extinction crisis keeps on going, we're at risk of losing this key component of ecosystem function. As a group, parasites are among the most if not the most overall threatened with extinction, with estimates ranging from 3%-33% at risk.

Erin Allmann Updyke

Wow.

Erin Welsh

Because when a free-living species goes extinct, it takes with it its species-specific parasites uniquely adapted to that species. And most of these parasites have never been characterized in the first place, which makes it that much harder to track their disappearance. Most conservation aims don't specifically include parasites and very, very few parasites are on any endangered species lists, which doesn't mean that there aren't any endangered parasites because there absolutely are. What we need is a shift in how we perceive parasites. We need to do a better job at recognizing their value, characterizing their diversity, understanding their role in ecosystems, and developing concrete goals for their conservation. And very importantly, let me underline this, these goals are not preserve all parasites no matter what. Because I know some of you out there are like wait a second, I thought we were trying to eradicate dracunculiasis caused by this parasitic worm. Should we save that? No, no, absolutely not. We are trying to eradicate dracunculiasis and we will get there eventually. Shout out to Jimmy Carter and the amazing work of the Carter Foundation.

The research groups that have put together these roadmaps for parasite conservation make it very clear that there are exceptions. No one is a parasite extremist. Parasites that are excluded from these plans include those that present a disease risk to human health, livestock health, or threaten the existence of a wildlife species like the nematode that infects giant pandas and can actually lead to their death. So no, this is not a call to save all the parasites but it is a call to acknowledge their incredible diversity and underappreciated significance and maybe just to reflect on our own bias when it comes to parasites. Save the whales, absolutely, but also save the whale tapeworm. Save the fish tongue louse parasite. So with that, Erin, I'll get off my soapbox and hand it over to you to tell us what's going on in the world of fish tongue-replacing isopods today.

Erin Allmann Updyke

We'll get into it right after this break.

TPWKY

(transition theme)

Erin Allmann Updyke

Oh Erin, that was so much fun to just think about parasites in a much larger context. That's also where I will end.

Erin Welsh

Yay.

Erin Allmann Updyke

But to bring it back for a moment to Cymothoid isopods.

Erin Welsh

Like what are we talking about again?

Erin Allmann Updyke

What's this episode about? One of the things that I wanted to underscore here because I think that these parasites, specifically *Cymothoa exigua*, gets the most attention as like the one. It is not the one. There are so many of them.

Erin Welsh

I mean I fell into that trap too. I was like this is the one that I see the papers about.

Erin Allmann Updyke

Right. It's an understandable trap to fall into. But there are so many of these parasites which are mouth-dwelling parasites and they're literally everywhere across the entire globe. In some studies that I found that were looking at specific species of this particular isopod in specific species of fish, right, so like one paper on this species, another paper on this species. Across the board, in some of these prevalence of these parasites was as high as like 45%.

Erin Welsh

That's so high.

Erin Allmann Updyke

I know. And it does seem to vary depending on the size of the fish. So smaller fish, prevalence seems to be higher in a lot of cases and less prevalence in the larger fish. Why is that? I don't know.

Erin Welsh

Interesting.

Erin Allmann Updyke

Is it that once they get larger, has the isopod already died? I don't have an answer for that. But it also varies geographically. Though these isopods are present across the entire globe, they do seem to be at higher prevalence in warmer tropical waters as well as in places where we have a lot of aquaculture. Because in some studies they have found prevalence of these fish tongue parasites in aquaculture that are as high as like 98% and there have been some cases of like relatively high rates of mortality in aquaculture species of fish. And that's not usually due to like a typical host parasite interaction but maybe like a parasite that doesn't typically infect that species of fish.

Erin Welsh

Right.

Erin Allmann Updyke

So there's not like a general conclusion that I can draw from all of this because there's so many different species of these parasites that infect so many different species of fish.

Erin Welsh

Erin, what about geographic range? Like are these parasite species sort of distributed globally across the world or they increase in prevalence or incidence or diversity as you get closer to the equator?

Erin Allmann Updyke

That's a good question. I didn't look at whether you have like an increase in diversity with latitude and stuff like that. I would assume similar to a lot of other parasite and species in general that you probably see higher diversity in tropical areas that are warmer, etc. A lot of the papers that tried to look at like overall diversity of these parasites were very region-specific. So we have papers that are like here's the diversity in the Indian Ocean, here's the diversity in this region, here's the diversity around Australia and stuff like that. So I didn't find any that were... Well there was a couple actually that was like global diversity but they're just like really, really broad and also don't tend to be specific to just the tongue-replacing Cymothoids but are looking at Cymothoids more broadly because again these can also infect fish in other areas, not just in their tongue. In any case, there's a lot of them. They're everywhere. So where do we go from here, right? There's so many open questions.

Erin Welsh

Yeah.

Erin Allmann Updyke

How many species are there really? Because we don't know. Are they changing in distribution? Like are they moving around? And if so, why? What is it that's driving changes in distribution? Why is it that some species are much more host-specific than others? What are the factors that are driving this host specificity? I don't know. So many questions, Erin.

Erin Welsh

So many questions.

Erin Allmann Updyke

And so I don't have answers to any of those questions. There are so many people doing work to better understand the natural history, the evolution, the ecology of these parasites. But I also wanted to end this episode with some bits from I think the same paper.

Erin Welsh

I have three Colin Carlson papers.

Erin Allmann Updyke

Yeah.

Erin Welsh

Et al. It's not just Carlson.

Erin Allmann Updyke

No. Colin Carlson et al, a longtime friend of the pod. I've decided we're friends, never met. But this was the paper from 2020 that was published in Proceedings of the Royal Society B. And I just really appreciated this paper not only for its thoroughness, it was like a really long detailed paper that essentially makes the case for a real need to get a handle on the existence of parasite diversity across the globe.

Erin Welsh

Yeah.

Erin Allmann Updyke

And this paper uses worms, mostly worms that do infect humans as a case study in this. And it also goes into a lot of detail on like how does one, how do we as a scientific community go about actually accomplishing this and what does it mean for understanding our planet and the health of our planet both now and of course under conditions of climate change in the future? And so I just want to... I don't have like profound things to say as conclusion of this paper but I just do think that this parasite which is charismatic in its own way, right-

Erin Welsh

More than other parasites if we are allowed to be the judge.

Erin Allmann Updyke

Much more.

Erin Welsh

Yeah.

Erin Allmann Updyke

Yes. Much more than other parasites because it is very cute. It is very startling, like it makes you feel things even if those things aren't like the warm and fuzzies. I think that it gives us the opportunity to really think about parasites in a way that most people just don't ever think about parasites or try not to think about parasites. And so I want to end with this one little quote from this paper. Quote: "Though some consider the task of cataloging parasite diversity, a testimony to human inquisitiveness, it is also a critical baseline for understanding biological interactions in a world on the brink of ecological collapse." End quote. And I feel like that's an important thing to keep in mind. Parasites have a lot that they can teach us and we should learn from them.

Erin Welsh

Yeah. Agreed. Case closed.

Erin Allmann Updyke

Case closed. Not taking questions, thank you.

Erin Welsh

Goodbye. Comments only.

Erin Allmann Updyke

But we have lots of places that you can learn more about these parasites, the Cymothoid isopods, so cute.

Erin Welsh

So cute.

Erin Allmann Updyke

And so many other parasites and their roles in our ecosystem. So let's hit you with some sources.

Erin Welsh

So, so many sources, Erin. Okay. So I will shout out once again that Brusca and Gilligan paper from 1983 that has a great description of one of these parasites. And then when it comes to the importance of parasites in ecosystems and why we should conserve parasites, I have a million papers. I really enjoyed one by Lynbery and Smit from 2023 titled 'Conservation of Parasites: A Primer' which I also shouted out in the history section. But there are so many ones out there that are not reviews but like specific papers about this parasite in this ecosystem or in this population. And it's just honestly really enlightening reading. I love it

Erin Allmann Updyke

I have a number of papers, more than I expected for this episode. I also loved that Brusca and Gilligan paper. There was one from 1998 by Bunkley-Williams, and Williams called 'Isopods Associated with Fishes: A Synopsis and Corrections'. And then one I really loved from 2014 by Smit et al, 'Global Diversity of Fish Parasitic Isopod Crustaceans of the family Cymothoidae'. So there's a few other papers that are more broadly about the Cymothoids and then a bunch of like specific ones about this species vs that species, etc. But as always, we'll post the full list of our sources from this episode and every single one of our episodes on our website thispodcastwillkillyou.com. Check it out.

Erin Welsh

Thank you to Bloodmobile for providing the music for this episode and all of our episodes.

Erin Allmann Updyke

Thank you to the film director of The Bay. Just kidding. Thank you to Tom Breyfogle and Lianna Squillace for the audio mixing.

Erin Welsh

Thank you to everyone at Exactly Right.

Erin Allmann Updyke

And thank you to you, listeners. We hope that you enjoyed this episode. We hope you love parasites a little bit more than you did before.

Erin Welsh

Yeah.

Erin Allmann Updyke

And we hope you learn something new.

Erin Welsh

And a special thank you and shout out as always to our fantastic patrons. Your support means the world to us.

Erin Allmann Updyke

It really does. Thank you.

Erin Welsh

Well until next time, wash your hands.

Erin Allmann Updyke

You filthy animals.