[MUSIC PLAYING]

SYDNEY WIDELL: I'm Sydney Widell.

BONNIE WILLISON: And I'm Bonnie Willison.

SYDNEY WIDELL: And you're listening to *Introduced.*

There was this man named Otis. We think that's what his name was. For the purpose of this story, that's what we're going to call him. And Otis lived in Northern Wisconsin. He was a fisherman and he ran this bait shop on a lake near Rhinelander. And at some point, Otis goes south to Indiana, and when he comes back, he brings these rusty crayfish with him. Have you seen rusty crayfish?

BONNIE WILLISON: No. What's a rusty crayfish?

SYDNEY WIDELL: So rusty crayfish look kind of like miniature lobsters. We have this-- why do we-- why do we have this and what is that? Like what is it encased in?

BONNIE WILLISON: We have this little rusty crayfish encased in like a plastic block. It's like a little bit smaller than my hand. Aw.

SYDNEY WIDELL: Yeah. Kind of like a miniature lobster, almost like. These giant pinchers that are--

BONNIE WILLISON: --kind of red.

SYDNEY WIDELL: Yeah. They're supposed be identifiable because they have these little rusty patches on their backs. Because there are crayfish that are native to Wisconsin, but this specific species is from the south predominantly. And you can, but definitely should not-- and maybe I shouldn't even say this because it's illegal-- use these as bait to

catch bass and muskie and perch and like these big game fish.

And the story goes that Otis released the crayfish that he brought up from Indiana with him into this lake where he runs his bait shop, and then the crayfish just take off. His plan was to establish this crayfish fishery on that lake where his bait shop was, and then on other area lakes where he could come back and harvest them and then sell them to other fishermen as bait or other bait shops and basically have this-- what felt like a limitless supply of crayfish.

And supposedly all of that was happening back in the 1960s. But what Otis and other people who are participating in this trade didn't realize at the time was, the success of the bait crayfish that they were introducing into these lakes is happening at pretty much the expense of everything else in the lake, and today, we actually classify rusty crayfish as invasive, which means they are capable of causing economic and ecologic harm.

BONNIE WILLISON: What were these crayfish doing?

SYDNEY WIDELL: I asked Dick Lathrop about that. He is a research scientist with UW Madison's Center for Limnology, but he spent a whole career working for the state's Department of Natural Resources as well. And he explained what happens when you introduce a rusty crayfish into a lake. Like what happens in that lake next.

DISK LATHROP: A lot of our northern lakes had a lot of aquatic plants in them and the crayfish go in there and just eat all the aquatic plants. They eat fish eggs. And they'll denude a lake bottom of all the really nice aquatic plant habitat that was in there. So you're basically screwing up the whole fish community and the ecology of the lake-- Presque Lake.

SYDNEY WIDELL: Which is really, really close to the border between Wisconsin and Michigan's Upper Peninsula.

DISK LATHROP: Presque Lake used to have a lot of aquatic plants, I was told, back in the late '80s. It was loaded with crayfish, and there's hardly any aquatic plants. And so if you don't have aquatic plants as habitat, it's just not good for the whole fish community, the whole ecosystem.

BONNIE WILLISON: I kind of imagine these crayfish as like lumberjacks that are like deforesting the bottom of the lake. Does that seem right to you?

SYDNEY WIDELL: That does seem right. Or out there with like a weed cutter just going for it.

BONNIE WILLISON: Yeah.

SYDNEY WIDELL: Yeah.

BONNIE WILLISON: They're cutting cutting down like all the good stuff--

SYDNEY WIDELL: All the good stuff. All the fish habitat just eating themselves out of house and home seriously.

BONNIE WILLISON: Yeah.

SYDNEY WIDELL: So Dick first heard the story about the crayfish introductions one summer in the '90s. So in theory, three decades after they began. At this point he is working for the DNR. So he's sitting on the Sack and Presque Lake, and this commercial crayfisherman comes floating on past in this boat. He's got all these crayfish traps in it and he's out to hunt some crayfish. And Dick described him as potentially disgruntled.

And so Dick and this crayfisherman start talking, and then Dick asks him a few questions about the history of crayfish in Presque Lake.

DISK LATHROP: And that's when he mentioned to me that he used to work for this guy and now they they're more competitors. So I don't know if you can believe everything he was saying, but he was saying this guy went down to Indiana, brought some crayfish back, and dumped them in this particular lake where his family or he had a bait shop, or his family did.

And then he said he went off to the Vietnam War and he came back and the crayfish

were just exploded in this lake. And everything was looking great, so he took him out of there and he went to other lakes and planted them. Well, that's just one maybe way of them getting around. And this can't be verified. And apparently, he supposedly had a map-- this guy that I was talking with said that the guy who went to Indiana that was running the bait shop, he had a map with pins on where he put the lakes and when.

But nobody's seen the map and maybe doesn't exist. And anybody now wouldn't even want to admit it because it's illegal to be moving invasive species around.

BONNIE WILLISON: Oh my gosh, this is so intense that this map-- has anyone seen the map?

SYDNEY WIDELL: No. And so Dick has not been able to confirm whether or not any of that story is true. But if it was, it could help explain why some of the lakes up north have rusty crayfish in some lakes don't. Because that's a question that's on a lot of people's minds. And finding a map is not going to remove the crayfish from any of these lakes where they already are or prevent them from spreading to new lakes. It's not going to bring back lost fish habitat or boost declining fisheries either.

But Dick has been thinking about that since the first moment he heard about it, and he is not someone who likes loose ends was the impression I got from talking to him. And for him, it exemplifies this fundamentally human point about invasive species, which is that so many of the plants and fish and other creatures that wind up causing problems in Wisconsin's lakes and rivers were introduced to those ecosystems by people.

I'm Sidney Widell.

BONNIE WILLISON: And I'm Bobby Willison.

SYDNEY WIDELL: And you're listening to *Introduced.*

BONNIE WILLISON: We work at Wisconsin Sea Grant, an organization that does research, education, and outreach dedicated to the stewardship and sustainable use of the Great Lakes.

SYDNEY WIDELL: We're based at the University of Wisconsin Madison, and here at Sea Grant, we think a lot about water. Bonnie, do you have a favorite body of water in Wisconsin?

BONNIE WILLISON: Yeah. I guess I'd have to say Lake Koshkonong. It's one of the biggest lakes in Wisconsin, actually. It's south of Madison and I grew up on that lake. And my mom grew up on that lake. We would always go swimming and boating, and I just love the sunsets there. And so I'd have to say that's the body of water that I'm the most tied to. What about you?

SYDNEY WIDELL: I grew up on Lake Michigan. So that lake will always have a really, really special place in my heart, I guess. But I was really lucky that I got to spend a summer hiking up north at this field station on Trout Lake which is in Northern Wisconsin, a little bit north of Minocqua, and that lake has also been like the backdrop, too. Slash is central, a central figure in so many of my best memories. So that lake also is really, really special to me.

And Trout Lake was also where I met Carol Warden. Carol is a DNR aquatic invasive species specialist, and when I asked her what her favorite lake is, she said that I was asking her to pick a favorite child, [CHUCKLES] but then she also said her favorite lake was Trout Lake, so we might run with that one.

But Dick and Carol have been friends for a really long time, and so when Dick heard about the map, he asked Carol if she could do a little investigation for him. Carol remembers Dick asking her about the map at a Christmas party back in 2012. She said she didn't really have a clear picture in her mind of what she was looking for, but she agreed to help out. But that isn't exactly how Dick remembers things.

DICK LATHROP: And I was bugging Carol about it probably for three or four years before she finally said, OK, I'll do it. Stop bugging me. I really like her. She's just a cool person. I thought, she's the right person that could go and do this interview.

BONNIE WILLISON: It sounds like Dick is using Carol as kind of like a private investigator at this point.

SYDNEY WIDELL: [LAUGHS] If anyone is going to have the last name Warden, I just feel like that's their destiny. So in 2013, Carol heads out to the bait shop that the cray fishermen had mentioned to Dick all those years ago. And if you've never been to one of these

bait shops, it's not like you're walking into a Cabela's. It's a little different.

CAROL WARDEN: Well, in terms of bait shops up north, I was picturing exactly what I walked into. People hanging out selling live bait for people to go fishing. And I don't know, I guess I mostly just envisioned a literal map on the wall with the lakes that have crayfish markered or outlined. And maybe-- I don't know-- now that I'm thinking of it, maybe just some records.

SYDNEY WIDELL: But if those records existed, the people who now own the bait shop didn't know about them, or at least they didn't show them to Carol when she came to ask. But they were able-- these people at the bait shop were able to tell Carol from memory where they had trapped rusty crayfish before that was not allowed. And according to the notes Carol took at the time, they had trapped along the Manitowish Chain, Big Bearskin Lake, which is a little bit south of Minoqua, Butternut Lake. Just lakes that, if you were going to go up and fish, you might end up stopping at.

They also told Carol a lot about the history of the bait shop, like who had owned it over the years, and what had happened to those people. I tried to contact the bait shop, but I couldn't get a hold of anyone. Dick said the story Carol heard didn't exactly corroborate the version he'd been told earlier, and without the map or any other records, it's pretty hard to pin down the chronology and the geography of the crayfish introductions, or to grasp how many of those introductions were made intentionally by humans.

But map or no map, the story of the rusty crayfish in the northwoods is inherently also about the people who brought them there, and how they've been impacted since. In many ways, it's also similar to the stories about so many of the invasive species that have found their homes in Wisconsin's waters.

DICK LATHROP: A lot of invasive species get moved around by people. And I think-- so it makes it really hard to understand why one lake has it and why another one doesn't if you don't understand that part of it isn't all just an invasive. It has to move by some river stream or something out of one lake connected to another lake, that they can be put somewhere where you don't expect it just because somebody moved them intentionally or unintentionally.

So every time you bring in a non-native species thinking that you're going to benefit

from it, we end up regretting it. I mean, how many times this has happened? Whether it's insects, birds, rabbits, you name it.

BONNIE WILLISON: So is Carol still looking for the map?

SYDNEY WIDELL: Carol told me that she would love to see the map, but that finding it has never been as big of a goal for her as she thinks it might have been for Dick. And then she made this point that really, really stuck with me. She said that the difference between her and Dick is that Dick can actually remember this time when there weren't crayfish in the majority of the lakes up there. But for Carol, that Wisconsin where there are rusty crayfish in most of the lakes is something that feels pretty normal.

CAROL WARDEN: I'll never really know what Trout Lake looks like without rusty crayfish. And he does.

SYDNEY WIDELL: I think you could zoom all the way out and think about the state. For example, the DNR has-- in addition to rusty crayfish, it has 42 species on their current aquatic invasive species list.

But there are so many factors, like changing global trade networks, tourism patterns, infrastructure, and development, and not to mention climate change, that are creating all these new pathways for species to wind up here, and to be introduced, or to be introduced and be successful here. And depending on how you define it, there are over 15,000 lakes in Wisconsin and 84,000 miles of rivers and streams, also according to the DNR.

The cool and powerful thing about water is how it transcends political boundaries. You have watersheds that extend beyond the state. Like you have the Mississippi River running down the western border of the state, and then there are Great Lakes to our north and to our east. And that makes managing invasive species this really complex challenge.

[MUSIC PLAYING]

BONNIE So yeah, speaking of international waters, here in Wisconsin and in the Midwest, we

WILLISON: have these Great Lakes. How would you describe geographically how the Great Lakes look like on a map?

SYDNEY WIDELL: Well, I always think about Lake Michigan first. It's the only Great Lake that's completely contained within the United States, and it borders Michigan and Wisconsin. But it's essentially the same lake as Lake Huron-- like, they're connected. And Lake Huron shares a border with Michigan and Canada. Lake Superior is the furthest north and the furthest west. And then the two lakes to the East are Lake Erie and Lake Ontario. And all of these lakes are connected either to each other, or connected by rivers. It's wild that these Great Lakes contain 90% of all the freshwater in the United States, and 18% of all the freshwater in the entire world.

BONNIE WILLISON: Yeah, I totally feel like we take these for granted, just growing up here, not really realizing that we have so much freshwater just sitting out there. And the Great Lakes are also important to the economy, if you think about it. People use them for fun, go fishing and boating, and do tourism. Like, there's the Circle Tour of Lake Michigan that people can take a road trip around. And then people rely on them for a lot of jobs, like the shipping industry, other industries that rely on water. I love thinking about how much the Great Lakes really provides this area.

SYDNEY WIDELL: Right. And if you think about it too, they're international waters. The moment for me that I really realized what that meant was I was driving around with my family on Michigan's Upper Peninsula, and the radio was on. And then all of a sudden, we realized that we were picking up French on the radio. And it was this crazy realization that the radio was coming from across Lake Superior, which was actually French-speaking Canada and Ontario. And it's just there. You can't see it, but it's there.

BONNIE WILLISON: That's amazing. So if you go to Lake Michigan today, we'd probably see a really clear giant lake. But it always strikes me that it's hard to tell what's going on below the surface of the water. I was curious what the lake might have looked like before all of our development and our industry-- fishing, and shipping, and all these things we've been talking about. What was going on in the lake then?

TITUS SEILHEIMER: I like to point out that the Lake Michigan of today is a completely different lake than the Lake Michigan of the 1980s, the 1960s, 1880s. Just profound changes to the

ecology of the Great Lakes.

BONNIE WILLISON: Titus Seilheimer is the Fisheries Outreach Specialist here at Wisconsin Sea Grant. I asked if we were to go back to, say, the early 1800s, what would be the tiniest living things in the lake?

TITUS SEILHEIMER: Yeah. So early 1800s, that is very early in the sort of-- at least European settling of the region. There would have been a much different mix of algae out there, the tiny aquatic plants. That's something we can actually-- we can actually go back and look at that. Scientists will take cause of the sediment, and they can actually divide up the sediment into years, and actually look at those progressions. And so we can go back and actually identify these species were abundant before the lake was changed, and these are the species that are abundant now.

BONNIE WILLISON: OK, so we have tiny bits of algae. And then what is eating that?

TITUS SEILHEIMER: Right. So that is the base of the food web. That's biomass-wise-- and "biomass" is a term where we talk about sort of-- we could talk about fish biomass, or algae biomass. If we took it all out of the lake and weighed it, how much would that way? And so if we had 10,000, say, kilotons of algae, the zooplankton-- which are what eat that-- there would be 1,000 kilotons.

BONNIE WILLISON: So you need a lot of algae. You need a lot of the tiny things.

TITUS SEILHEIMER: Right. Lots of the tiny stuff. So the algae is really the main food for the zooplankton, and those are the small grazing invertebrates that are swimming around in the water column, and also the invertebrates that live on the bottom of the lake. So the zooplankton are probably out there grazing. They're actively feeding on--

BONNIE WILLISON: Something around.

TITUS SEILHEIMER: Yeah. They're kind of like the cows of the lake.

BONNIE Oh. OK. So then moving a step bigger, what's at that point?

WILLISON:

TITUS SEILHEIMER: Then we get into the prey fish. So those are the smaller fish that are food for the larger fish. And so they tend to be-- in the Great Lakes especially, if we were back into that early 1800s, there would have been this-- what's called a flock of closely-related species. They all kind of ate different food. And so it's a interesting mix of some of these species not really found anywhere else in the world, just in the Great Lakes.

So on the top would be our predator fish. And really, for most of the northern Great Lakes other than Lake Erie, that would have been lake trout. Lake trout was really sort of "the" top predator. Burbot, as well. Burbot's a freshwater cod.

BONNIE WILLISON: And the food web is not so simple. Like for example, there's lake sturgeon that would be in the middle who aren't prey or predators, and whitefish as well. So thinking about all those the whole system that we just talked about, do you think the Great Lakes was prepared for new species to come in that people brought?

TITUS SEILHEIMER: That's a good ecological question. I would say, in general, of most undisturbed ecosystems aren't really prepared. The Great Lakes have been sort of this unique example. They were separated. It's a pretty defined watershed. There were not a lot of connection between the ocean and the Great Lakes. Lake Erie and up were definitely separated. They had the Niagara Escarpment. That big cliff that Niagara Falls falls over, and that we can go and see into our county here in Wisconsin, that really separated the lakes.

And so it was a pretty untouched system since the last glacial retreat, say, 10,000 years, 12,000 years of this system getting up and running and being pretty well balanced. And then that's when new species started getting added, and some of those had really large impacts.

BONNIE WILLISON: So like Titus said, the Great Lakes are really in the middle of the continent. The only way out to the ocean is the St. Lawrence River, and this river is super long. It has really giant, long rapids, so only one or two species of fish could actually travel that river and maybe get in and out of Lake Ontario. And they could get into Lake Ontario, but they couldn't make their way past that.

SYDNEY WIDELL: Why?

BONNIE WILLISON: Have you ever been to Niagara Falls?

SYDNEY WIDELL: No.

BONNIE WILLISON: Me neither. I would really love to go.

SYDNEY WIDELL: Seen some pics.

BONNIE WILLISON: Yeah. The Niagara Falls is this-- obviously-- giant waterfall. Not too many species of fish can get up that. It would take some real talent. How did these species start coming in the first place? What was that first step?

TITUS SEILHEIMER: Some of the first pathways early on would have been accidental transport. Really, it's back to humans, because it's, how did we move these species? Some of them, we would carry with us by accident-- things like plants, where the seeds might be in some load that we're carrying, or even today, on our boots.

Also, I think early on, really before the impact of these non-native species was that well understood, there were a lot of intentional releases. So things like, hey, we have this species where we came from. Let's add it to the Great Lakes. It'll be great. And in some cases, it wasn't great.

BONNIE WILLISON: Yeah. And then humans, right? We start building canals. We want to get to the Great Lakes, and we want to be able to ship on them, right?

TITUS SEILHEIMER: That's right. It was those canals where we started breaching natural watersheds, connecting waterways. The Erie Canal started at the Hudson and connected through the Finger Lakes, connected the Lake Ontario watershed to the Hudson River watershed.

BONNIE Did you ever sing the Erie Canal song in school? Do you know what I'm referring to?

WILLISON:

SYDNEY WIDELL: Um, no.

BONNIE WILLISON: Oh, no, now I'm going to have to sing it.

SYDNEY WIDELL: [LAUGHS] Wait, yes. But you should still sing.

BONNIE WILLISON: It's like, (SINGING) got a mule and her name is Sal. 15 miles on the Erie Canal.

SYDNEY WIDELL: And there's a part that's like, (SINGING) we've hauled some barges in our day. Yeah.

BONNIE WILLISON: Yes, we definitely-- I've had that song stuck in my head throughout this whole writing of this episode, because in our-- I don't know-- American history music class, we sang this song. And looking back now at the Erie Canal, I'm really shook about how long this canal is. Like, have you recently looked at a map of it?

SYDNEY WIDELL: Like the song does not do justice.

BONNIE WILLISON: I mean, the photo's kind of small here, but as you can see, the Erie Canal literally goes through the whole state of New York.

SYDNEY WIDELL: That's kind of insane. It's so-- wait, can I see it again?

BONNIE WILLISON: And the canal is fairly flat most of the way, but then there's a huge step to get up to the level of Lake Erie that they had to cut through. And then they constructed the Welland Canal, which goes around Niagara Falls. And so that connects Lake Ontario to Lake Erie. And that was completed in the early 20th century. And really, with that canal, it opened up this pathway for species living in Lake Ontario to move to the other lakes if they could get by with the ships. And you remember lake trout, which we talked about earlier?

SYDNEY WIDELL: Yeah.

BONNIE WILLISON: New technologies made it so that people were fishing 8 million pounds of lake trout out of Lake Michigan every year in the early 1900s.

SYDNEY WIDELL: I can't comprehend that number.

BONNIE WILLISON: But in the mid 1940s, numbers began to drastically drop of the lake trout that they were able to catch, so that people who used to catch 6,000 pounds of fish in just one netting were bringing up nets with six fish. Like, six individual fish. Can you imagine going out to your nets where you used to catch 6,000 pounds and getting only six fish?

SYDNEY WIDELL: I don't know what I'd do.

BONNIE WILLISON: Yeah. That's pretty drastic. And we'll learn why after the break.

[MUSIC PLAYING]

OK, so Sydney, how would you describe a sea lamprey?

SYDNEY WIDELL: You know, what we used to do at this job I had we used to do, we saw-- someone had to produce a sea lamprey sample one time, and we thought it was kind of weird-looking, because it's like this long, slimy eel-type fish. But we would start making these sea lamprey faces at each other like all the time.

BONNIE WILLISON: What did a sea lamprey face look like?

SYDNEY WIDELL: Do you want me to teach you how to do it?

BONNIE WILLISON: Yeah.

SYDNEY WIDELL: OK. So close your eyes.

BONNIE WILLISON: Close my eyes?

SYDNEY WIDELL: Yeah. OK. And then, like, move your head backward into your neck. Yeah, like that. And now open up your mouth as wide as you can.

BONNIE WILLISON: And showing my teeth?

SYDNEY WIDELL: Yeah. Kind of. Like, make your mouth as circular as possible. Yeah. And I might be taking a photo.

[LAUGHTER]

BONNIE WILLISON: Did you get it?

SYDNEY WIDELL: No. Do it one more time.

BONNIE WILLISON: I kind want to see what I look like.

SYDNEY WIDELL: OK. Yeah, that's the one.

[LAUGHTER]

This is your visual.

BONNIE WILLISON: Oh. So beautiful. Speaking of preserved sea lamprey specimens--

SYDNEY WIDELL: Oh my God, are you going to-- oh, Bonnie!

[LAUGHTER]

BONNIE WILLISON: Can you smell it already?

SYDNEY WIDELL: Oh, it's so weird.

BONNIE WILLISON: Describe this.

SYDNEY WIDELL: Honestly my worst nightmare. [LAUGHS] My eyes are immediately drawn to its mouth, which is on the underside of its body. But also just, like, it is its body. Like its mouth is just how its body ends. And I can't see any eyes, but that doesn't mean it doesn't have any. Just can't see them. Yeah.

BONNIE WILLISON: What does its mouth look like?

SYDNEY WIDELL: OK. I can see into its throat, maybe. It's just like this round, gaping hole and there are rows of teeth just everywhere.

BONNIE WILLISON: OK. So yeah, sea lamprey are this primitive form of fish. You're right, they have no jaw. They evolutionarily split off from fish and other things-- even our ancestors that developed jaws-- like 400, 500 million years ago. So they've been around for a really long time in pretty much the same form. So commercial fishermen started pulling out lake trout with these sea lamprey attached to them, or seeing fish with these round wounds.

TITUS SEILHEIMER: It was the commercial fishermen that were the first to identify that this was happening, because they were fishing like they always had, and they were pulling up these fish these round-shaped wounds, holes in their side, or with lamprey attached.

BONNIE WILLISON: Yeah. So they're literally-- they're getting all their nutrients from blood? That's so troubling.

TITUS Yeah. Sea lamprey is truly the vampires of the Great Lakes. And they go from being

SEILHEIMER: maybe six inches long, and over that 12- to 18-month period, grow to up to 36 inches long. So just rapid fast growth, and it's because they're attaching, sucking blood and fluids out of those fish. So the number we have, it's a single sea lamprey, to get to spawning size, will kill 40 pounds of fish in about 12 to 18 months.

BONNIE WILLISON: Oh, wow.

TITUS SEILHEIMER: So huge impacts. And before the lamprey control program starts, there's hundreds of thousands of lamprey in pretty much all the Great Lakes. Each one has-- I think Lake Michigan, 700,000 was the peak sea lamprey population estimate. So 700,000 times 40 pounds of fish. That's a huge impact on our lake trout. So by the mid 20th century, lake trout are extirpated or eliminated from Lake Michigan.

BONNIE WILLISON: Just all of them.

TITUS SEILHEIMER: All of them, they're gone. All that combination of factors really hurts the lake trout populations.

BONNIE WILLISON: So I'm assuming over time, we were like, we need to figure out how to get these out of the lake, or how to stop these. How did we figure that out?

TITUS SEILHEIMER: Really, the overall lamprey biology, they all have this juvenile stage where they're burrowed down in the sediment, and they're filter feeders. For some of them, like the sea lamprey, or our native chestnut and silver lamprey, there comes a point where they're like, OK, I'm going to transform. And that's the official name. They're transformers at that point. So they go from being small filter feeders, they turn into their juvenile adult phase, and then they will head out downstream, out into the lake, and that's when they become parasitic.

The US and Canada started working together. All the states started working together. And they started-- they were like, what kind of tools do we have to control sea lamprey? And they started throwing a lot of things at them, building barriers, building things like these electrical barriers in the rivers, which early on, they called them death fences, because basically, we have electrical barriers today that are much safer. And these were basically, if anything went in the water, it would kill

them. And I think things like moose would wander too close and be killed.

BONNIE WILLISON: Oh, no.

TITUS SEILHEIMER: So really high risk tools that maybe weren't as effective. But it was really the chemical control tool. And so people like Vern Applegate-- he's one of the early researchers into the lampricide programs-- through thousands of chemicals, like 6,000 or 7,000 different chemical compounds-- and these companies were sending all their different compounds they might have. They just sent them into the lab.

And they had, at the Hammond Biological Station in Lake Huron and Michigan, just all these jars set up. They would put in a fish and a lamprey, and they would put in different doses of the chemicals, and then just track to see what would kill lamprey but not kill the fish. They identified one compound. TFM is the shorthand for it. And it-- very effective, you can dose it into the streams. At the right concentrations, those sea lamprey-- so we're targeting the juvenile lamprey at this time.

BONNIE WILLISON: Yeah. So while they're babies, they're in the stream for a few years, so that's when we're trying to kill them?

TITUS SEILHEIMER: Yeah. Really most of their life, they're in the stream. It's not until the end they become parasitic and go into the lake. So--

BONNIE WILLISON: So did that work, the poison?

TITUS SEILHEIMER: Yeah. So one of the most successful invasive species control program. So we went from peak population numbers of sea lamprey in the mid 20th century, and now, over 90% reductions in those populations. Which the other side of that is, when it appears that it's not a problem, people kind of forget about it. And the only reason it's been successful is that, every year, teams from US and Canada are going all over the place, they're treating the streams, they're monitoring where the lamprey are. And it's that pressure. If we stop the program, lamprey numbers would increase right away. So--

BONNIE WILLISON: We still are putting in a lot of money, I'm assuming, for the chemicals for the people to go out every spring and do this. And that's the only reason that we're able to

keep them down, right?

TITUS SEILHEIMER: Yeah. It's $20 to $25 million a year spent to maintain those low levels. So it's cost. If lamprey hadn't come into the Great Lakes, that would be $20 to $25 million we could spend on other things.

BONNIE WILLISON: Just to clarify, it was actually poison number 5,209 that ended up being the right combination of chemicals to use now as our lampricide.

SYDNEY WIDELL: So before that they tried 5,208 poisons.

BONNIE WILLISON: Exactly. So at this time, there was substantially less predators in the Great Lakes because of this. And also, it was before the Clean Water Act, and there was also overfishing that was going on. And lamprey weren't the only species to take advantage of the new habitat that was opened up to them. An East Coast fish called the alewife also came in through the canals, and they found basically no predators to eat them.

TITUS SEILHEIMER: If I went out to the ocean and grabbed just any saltwater fish, threw it in Lake Michigan, most of them would die, but some of them have this physiological ability to survive in freshwater.

BONNIE WILLISON: Yeah. I read that by 1965, over the last few years, alewives became 90% of the fish mass of Lake Michigan.

TITUS SEILHEIMER: Yep. Yeah, so 9 out of every 10 pounds of fish in the lake were alewives.

BONNIE WILLISON: As Titus mentioned, alewives grew to an incredible number. And then they all started dying. Millions started dying at once, and they created these floating masses of dead fish that stretched for like 40, 50 miles. And then they would wash up on the shore around Chicago, and they would cover the beaches with literally feet of dead fish goo. And this type of thing was also happening in Lake Huron and Ontario. And so people back then had to bury the fish.

And it was just a huge, smelly problem, using chemicals to control just the amount of fly maggots that would take over them. And Titus was saying that he knows

people in Manitowoc, Wisconsin, who remember when the wind would drift over their city from Lake Michigan, and they would smell all these rotting alewives in the lake.

SYDNEY WIDELL: Do scientists know why that's happening?

BONNIE WILLISON: They actually still don't really know why this happened. Dying off in giant numbers isn't a natural part of their lifecycle. And they're thinking, maybe it had to do with the time of year, and when they spawn. And these die-offs still happen today. But even despite the die-offs, alewives were still somehow thriving. But we did manage to get our numbers down, and I asked Titus, how did we do that?

TITUS SEILHEIMER: Yeah. So that's a complex story with a lot of different players. So one of the first steps that was taken back in the mid-'60s, the state of Michigan said, OK, Howard Tanner, you're the head of fisheries with William Tody, Do something about this. And so what they did was--

SYDNEY WIDELL: No pressure.

TITUS SEILHEIMER: No pressure. Do something amazing. And so they said, well, we've got this lake full of food for fish. Why don't we add some new fish that will eat them? And so what they did is they looked outside of the region and actually went to the Pacific Northwest, and looked at some of the salmon species, and said, well, here's a fish that swims around in the ocean, eats schools of small silvery fish. Maybe they would do well, and also can spawn in freshwater, so physiologically, they might be able to survive.

BONNIE WILLISON: Yeah. OK.

TITUS SEILHEIMER: So starting in the late '60s, coho salmon were stocked first, and then quickly after that, Chinook salmon were stocked.

BONNIE WILLISON: Yeah. I don't know if that would have been a natural choice for me, though, just because we already have seen so many populations that have come in on their own

from the oceans, or something like that, and just kind of wreak havoc. And then Michigan, they actually decide to-- let's import these fish. What do you think about that?

TITUS SEILHEIMER: Yeah. I think it was a different time. It was definitely-- I don't think-- hopefully, today, we wouldn't see one state or one jurisdiction just deciding.

BONNIE WILLISON: One person.

TITUS SEILHEIMER: Right. Because what we know about these fish, if we stock a fish in Michigan, it's going to swim all around Lake Michigan. It's going to go to different states. It might go into Lake Huron. Because salmon especially, they're capable of swimming thousands of miles in the Pacific Ocean.

BONNIE WILLISON: So nevertheless, Howard Tanner decided to start stocking these salmon in Lake Michigan.

SYDNEY WIDELL: So what I'm picturing is, like, live salmon being airdropped into the lake. Is that--

BONNIE WILLISON: That's exactly what I was picturing too. I was picturing somehow shipping crates of fish. What they actually do is they import fertilized eggs from the West Coast, and then they raise them in hatcheries in the Great Lakes region. And so then they're able to put the young salmon into the streams, and they hope that they'll survive enough to get big enough for people to fish for.

And the salmon actually did well. They ate the alewives, and they created a really exciting fishery for anglers who really liked to fish salmon. And all of a sudden, we had a giant, thriving salmon industry in the Great Lakes. It was a huge attraction for bringing people here to fish for them.

TITUS SEILHEIMER: It's still very much-- especially in Lake Michigan, salmon fishing, the charter industry, the recreational fishing industry still really rely on those trout and salmon. And they have a pretty loud voice with the states, because they bring a lot of people out on the water and catch a lot of fish.

BONNIE Mm-hmm. The Erie Canal is just the beginning of the canal-building that we'd be

WILLISON: doing. In the '50s and '60s, people started thinking, we've got all this grain that's growing in the middle of North America, in the Midwest, and wouldn't it be nice if we could ship it from-- using the Great Lakes, ship it all the way out to the ocean so we could start exporting it. And that's when they started looking at the St. Lawrence River.

SYDNEY WIDELL: So that's the one that connects Lake Ontario to the ocean?

BONNIE WILLISON: Exactly, yeah. So they thought, why don't we build a seaway using this river? And they thought it would bring a huge boom to the Great Lakes, basically opening them up to international shipping. But by the time they finished the seaway, the modern ships were too big to really fit through, so it wasn't exactly that huge economic boom that they predicted.

TITUS SEILHEIMER: Yeah. So really, when you look at-- you can look at the history of new species coming in, and really, it was before the St. Lawrence Seaway opened, and then after the seaway opened, it was really a really large increase in the number of species that started rising. The new pathway that was open is these large ships have what are called ballast tanks. So as they load and unload, they can pump in water, pump out water to keep the boat balanced. If they're traveling empty, they can pump full their ballast tanks, and it helps them stay balanced. So it's a safety thing. It's important for those ships. But it also sucks in a lot of water. It can suck in sediment, and it can also pull in lots of different species.

What they found is, it's almost like this little mini ecosystem inside those ballast tanks. They've got a lot of sediment down to the bottom. Places like the Baltic Sea, the Black Sea, where-- these sort of brackish areas, the ports are not super salty, not totally freshwater, so they've got this mix of species that can maybe survive in freshwater. And so that's what really start popping up in the Great Lakes.

BONNIE WILLISON: So once all these ships that came from Europe are starting to make their way into the lakes for the first time, do we see changes right away to the lakes, and what was the first fish or species that we noticed that we'd never noticed before?

TITUS SEILHEIMER: Yeah. So late 1980s, the zebra mussels are first found by a graduate student. They attach to things. They are really good at filtering water and eating algae. And they

also have what's called the veliger stage. So this little zooplankton-like stage where they're free-swimming. So they wouldn't necessarily be picked up in the ballast tanks as adults. They would be picked up as this free-swimming state.

So zebra mussels rapidly colonize the Great Lakes, and within about a decade later, quagga mussels arrive. And so fairly rapidly, the quagga mussels actually replace zebra mussels. I think the most recent mussel survey in Lake Michigan found no zebra mussels, but a ton of quagga mussels. If you look at a map of what quagga mussels are in Lake Michigan, it's the deepest part of the lake, it's the shallowest part of the lake. It's the whole lake. They kind of coat the whole bottom. Trillions of mussels.

We can estimate how many mussels we have in the lake. We can also-- we know how rapidly they filter water. And you can kind of estimate that between 9 and 12 days is all they would need to filter all the water in Lake Michigan.

BONNIE WILLISON: Wow.

TITUS SEILHEIMER: So just try to wrap your head around how much an effect that could have on the lake.

BONNIE WILLISON: Whenever I went to Lake Michigan, I would always be like, this lake is so beautifully clear. Like, it's such a healthy, clean lake. But actually, in this case, it's not a sign of a healthy lake.

SYDNEY WIDELL: I guess I was never really aware of a time when there weren't mussels there, though. But I do remember getting my feet so cut up, like walking barefoot over a bed of mussel shells. And I think anyone who's been on a Lake Michigan beach can relate to this experience of walking, and stepping on one point at the wrong direction, and just totally getting your foot sliced up.

BONNIE WILLISON: That really means that mussels have changed the food web in a huge way. They're filtering out all the plankton, and taking all the nutrients. They'll grow on any surface, any pipe in the water, any pier, any boat. They'll live on that. They decrease property values of property along the lake. And there was one estimate that zebra and quagga mussels cost the US economy $1 billion a year. So I was curious, what

will happen in the future of the lakes?

TITUS SEILHEIMER: I think that the glimmer of hope from 2015 was mussel densities were starting to decline in everywhere except the deepest parts of the lake. And I think what I've been telling people over the years, one of our strategies here is to kind of wait-- because the mussels haven't been here that long. They've been here since maybe-- quagga mussels since the mid '90s, and maybe even later. Maybe around 2000. 20 years in the life of Lake Michigan--

BONNIE WILLISON: Yeah, that's not long.

TITUS SEILHEIMER: --isn't that long. So it seems like we're starting to see maybe that there's going to be a decline. Maybe they've hit their roof for their population potential, and hopefully, we could get a decline where they kind of settle down to lower levels. So I think that's one thing to hope for in the future.

I think the sad inevitable view is that these are totally new lakes. We are probably not going to get to go back to what it was like. No matter how much we invest in restoration, we're not getting back to the species assemblage we had in the 1500s. So in some ways, we can manage some things, we can kind of accept other things, and we can do what we can.

BONNIE WILLISON: We can try to stop new species from coming in.

TITUS SEILHEIMER: That is one of the best-- the most cost-effective ways is to not have to deal with new species.

BONNIE WILLISON: Yeah. During the period from about 1960 to 2000, about 60 new species were introduced to the Great Lakes. If you think about it, that's more than one a year. But since 2006, when stricter ballast regulations were finally passed, the number of new invasive aquatic species discovered in the Great Lakes has virtually stopped. Tim Campbell, the Aquatic Invasive Species Outreach specialist here at Wisconsin Sea Grant, was able to give me a little perspective on this.

TIM CAMPBELL: Truth of that is that we've really done a good job of addressing that through some voluntary standards from the maritime industry, to some regulations from the EPA.

The last established invasive species that we can attribute from ballast water is the bloody red shrimp, which I think was in 2008. And we haven't really seen anything established since then.

I think stopping the spread of invasive species is really hard. And there will probably be more invasions, which bums me out to say. But even though it's hard, it doesn't mean it's not worth doing. And that because all invasive species-- invasions are human-mediated, human behavior can change. Look at recycling. That's not something that happened 50 years ago, or 60 years ago. But over time, people change their behavior, so that's the norm, and most people recycle, and most things get recycled.

And so if you look at invasive species prevention, people can change their behavior. They can take really simple actions at the boat landing, or when they're planting their gardens, to prevent the spread of invasive species. And if enough people take action-- will we get to zero? That'll be really hard. But we might get to such a low invasion rate that it becomes a much smaller problem, which I think we can-- I'll be really happy about.

And then, the idea of, if something invades, it's a failure, that's not great, but every day that you go without an invasion, you're gaining some services that you would have lost had the invasion happened a year earlier, or 10 years earlier. And as we wait longer for new invasions, there might be new technologies that help you manage them, or better infrastructure to help you deal with them. So even if it does happen, the longer we wait until it happens, the more benefit as a society we get out of it.

SYDNEY WIDELL: This progress that Tim is talking about, even 50 to 60 years ago, this was a place where someone could go to Indiana with a bucket, and come back, and plant crayfish in lakes. And even if that's coming from a place of really good intentions, it can still have dramatic consequences years and years and years into the future.

But whether you are coming with a bucket, like this the so-called bucket biologist, or you have a gigantic boat that you've sailed across the Atlantic Ocean, and you bring that into the Great Lakes, either way, it's humans who are acting as these vectors for introducing new species into the lakes and rivers in Wisconsin.

BONNIE WILLISON: Yeah. Since humans have been around, we've been moving around species to help us live, make us more comfortable, make it feel like home. But a lot of times, it's not something that we are intentionally doing to move something, and that's going to hurt the native species that have been living there.

SYDNEY WIDELL: If we're the ones doing it, we're also the ones who can fix it.

[MUSIC PLAYING]

Introduced is produced and hosted by Bonnie Willison and Sydney Widell. Please subscribe, rate, review, and share this podcast with a friend. You can find Wisconsin Sea Grant on Twitter at @uwiscseagrant and on Facebook at University of Wisconsin Sea Grant and Water Resources Institute. We would love to hear from you. Please send in your questions and comments to bonnie@aqua.wisc.edu.

You can listen to our show on Apple Podcasts, Spotify, and Google Play. If you'd like to know more about IDing any of the things we've discussed on the show today, check out our show notes. We'll have more information linked there. Thanks for tuning in. See you next time.