*Cheryl Leonard: So, it had snowed around Thanksgiving, and then that snow melted. And it remained cold up high. Up high in elevation, but the roads opened over the high passes, and the ice… the lakes were not buried in snow. So the ice was bare.*

[Sounds of lake ice expanding]

*Cheryl Leonard: And I had a friend who was working in Yosemite at the time and she called me up. She was like, “You’ve gotta come up and record these lakes.”*

**Sam Evans-Brown: This is Cheryl Leonard, a sound artist from California. You’re hearing a composition she made with recordings of lake ice in Yosemite.**

*Cheryl Leonard: I think I got there around dawn. I have the sounds in the morning of the… it’s like the lakes waking up, really.*

*Sam Evans-Brown: Do you — do you know… what’s the process that’s creating those sounds?*

*Cheryl Leonard: I know in general it has to do with the ice expanding and contracting, if it’s warming or cooling. So more sounds happen in the morning or evening as the temperature is. changing dramatically. And as the ice, it’s literally getting smaller, or getting larger, and it’s stuck in a spot, so it flexes and it buckles and it cracks. And those actions create vibrations or sounds, and those sounds travel across the surface of the lake, it’s like a giant drum membrane. So as the sound travels across that membrane, because of the physics of acoustic dispersion, as the sounds are moving across the ice the high frequencies go faster and the low frequencies are slower so the highs hit your ear first and the low’s hit your ears later, so you hear this sort of glissando from the highs to the lows. Like Deeuuu. Deeuuu. Which most people recognize as the Star Wars blaster sound.*

*Sam Evans-Brown: So, whenever you’re out on a lake that’s making these sounds… does it evoke something for you? I mean, it is still for me something that kind of evokes a bit of dread.*

*Cheryl Leonard: Yeah, it’s not scary to me. I just think it’s really incredible. It’s beautiful, it’s like traveling to another universe or something.*

[Sounds of frozen lake expanding, and high winds]

**Sam Evans-Brown: It is a different world, under the ice of a frozen lake.**

*Ted Ozersky: That used to be the traditional thinking, that there’s just not enough light, no plant growth, all lakes become boring and dark and the same in the Winter, but it turns out that this is really not the case.*

[Muffled Outside/In theme music rises behind sound effects]

**Sam Evans-Brown: This is Outside/In, a show about the natural world and how we use it. Today is one from our occasional series, 10x10, where we look very closely at a specific type of environment: we’re going under the ice. What happens in a lake once it freezes over? What survives, and how do they do it?**

[Outside/In theme music and lake sounds fade]

**Sam Evans-Brown: We’re going to start on top of the ice. Ice fishing.**

[Sound of ice auger drilling a hole]

**Sam Evans-Brown: Now if you are thinking “Sam, fishing? Really? I thought we were going to learn something actually interesting? What are you doing to me here?! Well, get a load of this, straight from the mouth of a real frozen lake scientist. Ted Ozersky.**

*Ted Ozersky: I kind of always say this a bit tongue in cheek but maybe that’s true — is that ice fishermen know more about what happens in lakes in winter than the average aquatic biologist.*

**Sam Evans-Brown: Ergo… fishing.**

*Clay Groves: They got a flag, so when you see a flag you’ve got to yell flag and run towards it… that’s a rule.*

*Taylor Quimby: Everybody?*

*Clay Groves: Everybody!*

[Sound of running across ice and music]

**Sam Evans-Brown: Producer Taylor Quimby recently went ice fishing with his son, Phin.**

*Phin Quimby: I think I’m not good at running on ice!*

**Sam Evans-Brown: Thus… we sent Taylor to go running around between ice-fishing holes on Pequawket Pond in Conway, New Hampshire.**

[Sound of people excited to have caught a fish]

**Sam Evans-Brown: Taylor’s tour guide...**

*Clay Groves: Hey I’m Clay Groves, Chief Executive Fish Nerd of the Fish Nerds Podcast, and I live in New Hampshire.*

**Sam Evans-Brown: Long-time friend of the show, totally... totally untrustworthy.**

*Clay Groves: Our tagline for our show is always interesting, usually funny, and mostly true. So I’m not held to being honest. I am a fisherman.*

**Sam Evans-Brown: But when it comes to what’s active under the lake ice. Clay does know a thing or two.**

*Clay Groves: Yellow perch, white perch, black crappie, burbot, smallmouth bass, largemouth bass, yellow bullhead, brown bullhead, margined madtom, tessellated darter, swamp darter, northern red-bellied dace, finescale dace, creek chub, bluegill, pumpkin seed, uh banded sunfish, uh let’s see Atlantic salmon, uh I’ve lost track did we say burbot already?*

**Sam Evans-Brown: The first thing you need to know about the water under a layer of ice… is it’s actually not that bad.**

*Clay Groves: In the winter it’s warm at the bottom, so that’s why most of the fish are down at the bottom. So it’s usually about 38 degrees at the bottom.*

**Sam Evans-Brown: If 38 degree water doesn’t sound very warm to you, consider that maybe just 20 feet higher up, above the ice, it might be 30 below zero and blowing a gale.**

[Sound of high wintry wind]

**Sam Evans-Brown: So while it’s definitely chilly under a lake in the winter, compared to other extreme winter environments it’s not that bad.**

*Taylor Quimby: So what do you catch in this lake?*

*Clay Groves: So this lake is mostly… they call them warm-water species, so bass, perch, sunfish… that sort of thing… but it’s a strange thing to call a fish a warm-water species when they’re living under the ice, right? It doesn’t make any sense.*

*Taylor Quimby: [laughing] No it doesn’t*

**Sam Evans-Brown: Now let’s ponder this for a second. The whole reason fish can thrive in a frozen winter lake is because the ice forms on top. Effectively capping the lake off, limiting how much the water and winter air interact, making it so the whole lake doesn’t freeze solid. And why is that?**

*Ted Ozersky: Water is really weird.*

**Sam Evans-Brown: Ted Ozersky again, who, by the way, is with the University of Wisconsin-Madison**

*Ted Ozersky: It’s a really weird substance. We take it kind of for granted because it’s everywhere but if you look at other liquids water is really different. And the weird thing with water is its temperature of maximum density — where it’s heaviest — is 3.96 degrees, Celcius.*

**Sam Evans-Brown: Which, in fahrenheit is around 39 degrees. That really cold water that’s right up by the ice — that’s sitting at like 34 degrees and is at risk of freezing soon — is actually lighter than the warmer water, down below. So in the summer, when you dive into a lake and it’s warm at the top but cold a few feet down? In the winter, the lake turns over.**

*Ted Ozersky: In the winter the opposite thing happens, the water at the very surface is getting cooled down to close to freezing temperature and that makes it lighter than the water underneath it.*

**Sam Evans-Brown: This weird quality of water is also what makes ice float. Most substances on earth are more dense as a solid than a liquid, so they sink. But if you’ve ever had a drink with ice cubes in it, you know they bob up to the surface. The same thing happens in a frozen lake: the ice forms on top.**

[Sound of frozen lake expanding, music]

**If frozen water sank to the bottom of lakes, the water at the surface would stay exposed to frigid temperatures all winter long, and more and more water would freeze, maybe eventually freezing the whole lake solid!**

[Sound of water freezing, music]

 **But instead… it floats.**

*Clay Groves: Ice has this unique property of floating… it’s one of the only solids that is less dense as a solid than a liquid. That’s why we have life on the planet. If ice didn’t float we’d have no life…*

*Girl: really?*

*Clay Groves: yep. It’s a true story.*

**Sam Evans-Brown: [Whispered] That’s actually probably not true… or at least… it’s complicated**

[Music]

**Sam Evans-Brown: And what’s more, if you think a frozen lake is a bad place to be a fish, you’ve got to learn to think like a fish.**

*Clay Groves: And also a nice advantage they have in the winter-time. We have eagles around here… you’re under the ice, you’re safe. From eagles not from me.*

**Sam Evans-Brown: Ok, so ice actually keeps fish warmer than they might be otherwise. Fish keeps them safe from predators. What’s not to like?**

*Clay Groves: Hold still right here. He’s coming. Don’t do anything. He’s about to bite. Yeaaaah, pumpkin seed! Look at the size of that thing!*

**Sam Evans-Brown: Well… there are hardships down there. We’ll hear about it, after a break.**

[Ad Break]

**Sam Evans-Brown: Before the break, we learned that the cold and ice really aren’t much of an impediment to most organisms that live in frozen lakes. If you’re looking for threats to life under the ice, one of the biggest is that during the winter… fish can suffocate!**

*Ted Ozersky: So a lot of the oxygen that enters lakes either enters through the atmosphere or through photosynthesis. In the winter you have disruption to both of these processes, right? So the lake is capped by this layer of ice.*

**Sam Evans-Brown: That floating cap of lake ice cuts off oxygen from the atmosphere, and if the ice is covered with snow, that cuts off the sunlight too. The plants can start to die and as they decompose they stop producing and start consuming oxygen. Meanwhile the fish and other creatures keep breathing, so the oxygen gets lower and lower.**

*Ted Ozersky: One of the consequences of that is these winter fish-kills, where in some lakes, the oxygen can get so low in the water column that all of the fish will essentially die, because of suffocation over the winter.*

**Sam Evans-Brown: The whole lake, choked-off… lifeless.**

[Somber Music]

**Sam Evans-Brown: Not every lake does this. Deeper lakes have a bigger store of oxygen and can make it through the winter just fine. But even still, this idea of a choked-off, frozen, silent world is one that have lead people to assume that there’s not much action under the ice in winter. For the scientists who study lake-life, the time to do that in the summer, right?**

*Ted Ozersky: I think it kind of highlights how science sometimes has these blind spots. People haven’t been studying winter very much, which leads to people assuming that nothing is happening, which makes people not interested in studying what’s happening in the winter, which again leads to there being no studies of winter and kind of feeds this circle of in a way ignorance where you don’t find anything interesting because you’re not studying it…*

**Sam Evans-Brown: But hang out with a fisherman, and you’ll get another story.**

[Music shifts to become fun]

*Unidentified Child: Wooooah! Did you just see that?*

*Clay Groves: Wooooah! Yellow perch! Look at the size of that thing! Oh, look at the size of that thing.*

*Taylor Quimby: Holy —*

*Clay Groves: Look at the size of that pumpkin seed.*

*Taylor Quimby: Oh my god. Woah!*

*Clay Groves: That’s a big one. That’s a good one!*

*[Sound of splash as fish is returned to water]*

**Sam Evans-Brown: Sure, there are fish that slow way down during the winter, and survive by just doing way less. Kinda taking the same strategy that bears have above the ice.**

*Clay Groves: So you have your warm water fishes, we’re talking about bass and pickerel and yellow perch, they like to hug the bottom where it’s cozy warm, like 38 degrees, and that’s where they’re going to be.*

**Sam Evans-Brown: But the idea that this is the only way to survive the winter, by hunkering down and conserving calories, that’s only part of the story.**

*Clay Groves: But you have your coldwater fishes, So like, rainbow trout will cruise with their fin touching the top of the ice. And what they’ll do is they’ll chase minnows and shiners and stuff into shallow water and corner them and gorge on them all winter. They love the ice.*

**Sam Evans-Brown: Clay’s favorite coldwater fish is the burbot.**

*Clay Groves: Some people call them eelpouts, lawyers, lingcod, they’re latin name is lota lota… fish so nice they named it twice.*

**Sam Evans-Brown: All summer long, they’re really hard to find because they spend their time down where it’s cold, not doing much.**

*Clay Groves: and then when the lakes freeze, they come to life. They spend all winter, gorging and eating And then in March, they get together in shallow waters, rocky bays under the ice and they have these giant, big, slimy orgies making new fish, and it’s amazing… and they’re delicious.*

*Taylor Quimby: [laughing] The important part [yeah!]*

**Sam Evans-Brown: In other words some fish aren’t like bears, they’re like foxes. Out and about all winter long. Cruising through that weird layer of light, cold water at the top of the lake. In fact, you don’t have to go very deep to find the action in frozen lakes. There is some crazy stuff going on right where the water and ice touch. And that’s all driven by another weird thing about ice.**

*Ted Ozersky: I know if you went to the sea and you licked sea ice, it would taste fresh.*

**Sam Evans-Brown: As ice freezes, all of the stuff dissolved in the water is excluded.**

*Ted Orzeksy: So if you think about the ice freezing at the top of the lake or in the sea, as the ice builds it kind of squeezes all of the stuff, the salt the dissolved organic matter that was in it… and increases the concentration of this stuff right below the ice.*

**Sam Evans-Brown: What that means is that right at this margin, between the ice and the water, things can grow.**

*Ted Ozersky: You can have algae attaching directly to the bottom of the ice. What they describe as these like algae beards hanging down from the ice into the water.*

*Sam Evans-Brown: And I assume, we must be talking microscopic beards.*

*Ted Ozersky: No they can be visible, they can extend like a foot down from the ice.*

*Sam Evans-Brown: Really?!*

**Sam Evans-Brown: Yeah, Sam, really. In fact, if just set your expectation for what constitutes interesting activity a little bit smaller. There’s some wild stuff down there.**

*Ted Ozersky: Algae are really weird, phytoplankton are weird. Some algae are what’s known as mixotrophic, so they can either use light or they can eat bacteria for example or they can even use dissolved organic material to feed themselves. So these mixotrophic algae that can utilize different energy sources become, in some cases, more abundant in the winter.*

**Sam Evans-Brown: Most phytoplankton are autotrophic. Like most plants they use sunlight to make their own food. These little mixotrophic guys can do that, but they also can eat stuff that’s floating in the water. They’re like the venus fly traps of the microscopic plant world. And they actually do better in winter. And even the tiny little things that don’t like the cold, have got some pretty amazing strategies for surviving the winter.**

*Ted Ozersky: What eats the algae are zooplankton. And some species of zooplankton are very avoidant of cold water, winter conditions.*

**Sam Evans-Brown: Remember, phytoplankton: tiny plants. Zooplankton: tiny animals**

*Ted Ozersky: They’re able to produce this resting egg. When they feel the conditions are deteriorating, the summer’s ending, there’s less food, it’s getting darker. They put all their energy into producing this one resting egg that’s really strongly armored, kind of, and when they die it sinks down to the sediment and actually can remain viable in the sediment for hundreds of years. There’s a whole branch of ecology called resurrection ecology where people try to resurrect these hundreds year old eggs of zooplankton.*

[Music]

**Sam Evans-Brown: The idea that its dead down there… that’s a fallacy. Even when things in lakes do die, you can bring them back… like some tiny lake deity.**

*Sanpa Sharma: And the story is that there was a god and goddess that lived together in a shrine on the lake, and what happens when people live together for too long sometimes, they got into a disagreement and the goddess moved out. And she built herself a shrine on the other side of the lake. But every winter the god would walk across the frozen lake with his dragon to make amends with the goddess.*

[Music and sounds of lake ice expanding]

**Sam Evans-Brown: Sanpa Sharma is a professor at York University in Toronto and this story — the god and the goddess, falling in and out of love every year from opposite sides of the frozen lake — is the inspiration for the world’s longest running lake ice data set.**

*Sanpa Sharma: Fifteen generations of the same family of Shinto priests have been recording this information, since 1442.*

**Sam Evans-Brown: They kept records of when the lake would freeze, and when a distinctive ridge of ice connecting the two temples would form. It’s a great story, but also, very useful to the climate scientists who are studying lake ice. And what you see, if you do what Sanpa has done and look not just at this single lake but at lakes all across the Northern Hemisphere, is a trend that will surprise... literally no one.**

*Sanpa Sharma: There is a trend toward earlier ice breakup and later ice freeze. And some lakes that historically froze every winter are beginning to no longer freeze. For example, this lake in Japan, for the first 250 years of this time series it didn’t freeze three times. But if you look at the last decade it only freezes two times out of ten years.*

[Music and sounds of lake ice expanding]

*Sanpa Sharma: But we also looked at the lakes that are still freezing… when might they expect to become ice-free. We were really surprised at how fast these changes are expected and how fast the warming is going to impact lake-ice cover. So if we think about Lake Mendota, is one of the world’s best studied lakes in Madison, Wisconsin, it’s ice record goes back to the 1850s, frozen every year. And our models indicate that by the mid 2020s, that lake is not going to be freezing every winter. That’s really soon!*

[Sounds of ice fishing rise as music fades]

*Clay Groves: So there are people fishing here… and our friends over here have these traps in the water, little flags popped up and they are checking to see if there are any fish on the lines. Hey there any fish on there? [noooooo] Aw, too bad!*

**Sam Evans-Brown: As those lakes stop freezing, everything that has adapted to exist above and below the ice, will find it harder and harder to exist. Tiny venus fly-traps getting crowded out by your standard lake algae. Slimy winter fish-orgies under the ice disappearing in favor of ever more smallmouth bass. No more crossing the lake with your dragon to make up with your goddess. No more pond hockey. And for Clay, well, he’ll only be able to say “Look at the size of that one!” in the summertime.**

*Clay Groves: We’ll ask one question to everybody… you know, “Why do you like to fish?” And no-one can answer the question. It doesn’t make — fishing is the dumbest thing on the planet. Like you think about it, I’m gonna bait a hook with a worm, drop it down through the ice, catch a fish, look at it, put it back in the water and do it again. There’s no outcome! There’s nothing. There’s no goal. It’s just fishing and it’s senseless. It’s dumb. I don’t know why I like it, I can’t explain why I like it…*

*Taylor Quimby: I’m waiting for the turn here.*

*Clay Groves: there’s no turn it’s the dumbest thing ever and I love it and I can’t explain it.*

[Music]

*Clay Groves: But if you think about a lot of things in life that bring you joy… they’re really hard to explain them… it’s when you really get into it… most things we do are dumb… and we just do it because it makes you feel good.*

[Music swells and and fades]

*Clay Groves: You want to hear him go? Alright buddy see you later.*

[Sound of a splash]

[Outside/In theme Music]