Tim Cline:

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Tim Cline:

Joining me today is Dr. Soren Brothers. Soren is a postdoctoral researcher at the University of Guelph, where he has been leading a group of researchers from several universities to address multiple stressors in the Great Lakes. He's the lead author on a study recently published in Global Change Biology titled, "Benthic algae compensate for phytoplankton losses in large aquatic ecosystems." Thanks for joining me, Soren.

Soren B.:

Yeah, yeah, no, thanks for asking me.

Tim Cline:

So I came across this paper recently and it grabbed my attention for a few reasons. First, I myself done quite a bit of research on the Great Lakes, so they are dear to me. And second, because I feel there is an important fundamental ecological question here and as well as some more acute applied Great Lakes questions, that people are very curious to see what will happen going forward.

Tim Cline:

So the Great Lakes are ecosystems that have seen a lot of change over the last half a century, including a recent pretty significant increase in water clarity. So in this study, you and your coauthors estimated the primary productivity and the benthic productivity going back to the 1970s. Then you evaluated the patterns and changes over time in all the Great Lakes and found some interesting results relating to the relative balance of primary production pathways.

Tim Cline:

So what are the major issues you wanted to look at in this study and how did you become interested in these issues?

Soren B.:

In the background for me, going into this paper, is I did my PhD in Berlin, Germany, working with shallow eutrophic lakes. And looking at this specifically, I mean there I guess on the forefront of everything is kind of trying to integrate the benthic zone, primary production and all the benthic processes with what's happening in the pelagic with the water column. And so, I mean, I've been doing these kinds of carbon mass balancing exercises there and looking at algal production being a major part of it, in a lot of these cases more than 50%. And then you look at northern subarctic lakes and it's up to almost 100% of the production is benthic. And when I started this position at the Great Lakes, I mean I wasn't too surprised because it's always sort of, you always hear this caveat, this research is only applicable to really shallow lakes.

Soren B.:

And I think it kind of struck me when I went to, there's the International Association of Great Lakes Research, their conferences, IAGLR, every year. And I went to one and a researcher mentioned that they'd measured Secchi depth readings in Lake Huron of up to 50 meters in one of their campaigns. And that kind of surprised me because I thinking well, if you have 50 meters Secchi depths, that means you have maybe up to 120 meters of... Over 100 meters of actual photic zone.

Soren B.:

And at that point you're reaching sort of mean depth of the actual ecosystem, which means you are occasionally getting light pretty deep down in these lakes, and where you could have some benthic primary production.

Soren B.:

So that was, I think, what sort of keyed me into being maybe an interesting thing to study. And then it seemed like a natural question to ask, A, because no one seemed to be really considering it very seriously outside of just very shallow nearshore zones and as an issue for nuisance Cladophera.

Soren B.:

And then B, just because that's already would have been working on for my PhD. So it was an easy transition to just kind of apply the same sort of theory but to a larger lake and just see whether it was an issue.

Soren B.:

Yeah, so that's why I contacted Yvonne Vadeboncoeur because I'd met her in Berlin as well. She'd given talks there and she's done a lot of work on benthic processes and benthic primary production. And she was also interested in working with the Great Lakes and has now her own PhD student that we're going to follow up and take measurements in Lake Erie and in some of the other lakes to see what the benthic primary productivity is there by scuba.

Soren B.:

But yeah, she had been working on Lake Tanganyika for awhile, so she also had kind of large lake experience with benthic productivity and had seen it there being a pretty large... These high rates of productivity, specific rates.

Soren B.:

And yeah, I mean in terms of the global change biology paper, I feel like it's almost in some ways like a sort of back of the napkin style modeling and just seeing, okay, well what rates are there published? And we could only find four or five or six studies over the last 30 or 40 years that actually measured the benthic productivity rates. And then we took those range of rates and just looked at the changes in the published Secchi depths or light attenuation properties of the waters. And put it together with the dissymmetry just to see what range we'd be looking at and whether it was feasible that benthic primary production would compensate.

Tim Cline:

So you mentioned that you took a modeling approach, which makes sense, as estimating productivity across the Great Lakes as logistically challenging. There are some data available though as there are a lot

of different institutions and agency agencies collecting and publishing data from around the lakes. Could you talk briefly about the approach and where you got any data that you use to inform your models?

Soren B.:

It's a pretty simple approach we used. It's kind of scary using a very simple approach, but then we figured that could be its strength too and not having too many crazy assumptions in there. So we tried to keep that as simple as possible in some ways. And we based it on, there's a Fee model, which has been originally publishing in the 70s and it's been since then tested and used in a lot of different studies. And that's just modeling phytoplankton productivity based on bio-mass and water clarity. And that was developed in Lake Michigan, I believe, originally and now it's kind of the standard for estimating gross primary production in the lakes.

Soren B.:

For the benthic, it was a bit more difficult since there's nothing like that, that's been tested in the Great Lakes. But Yvonne had published a benthic primary production model that just used water clarity basically, and is actually derived from that Fee model. So we figured that would be kind of nice so we could compare them and they're both from the same modeling.

Soren B.:

I mean, one of the main issues we had coming up is that the pelagic or the phytoplankton productivity model uses biomass and it doesn't really make sense to do that for the benthic productivity model, since typically you can assume that the sediments are not nutrient-limited zone and there's not really a good relationship between biomass and benthic primary production. It seems to be in natural systems, just related to the light availability.

Soren B.:

So that was, in the background, we got all the chlorophyll-a data for the pelagic model and all the water clarity data for both models from just as much literature as I could find.

Soren B.:

Yeah. And then we tried to organize by basin as much as possible, too. Because obviously, I mean we were kind of curious about looking, for example, how does it compare that people would typically assume maybe Saginaw Bay would have higher benthic primary production since it's so shallow. But then at the same point, those bays are highly turbid so you're actually not going to have as much light transmission possibly. So it's kind of interesting asking those questions too. So we tried to organize it into basins as well as taking in the weighted mean to the whole lake to see how it kind of balanced out.

Tim Cline:

So you looked at changes in phytoplankton production and benthic production over the last several decades. So what did you find? What were the major changes and the timescale of changes that you observed?

Soren B.:

I guess so for in terms of primary productivity, we saw a decline in the pelagics or in phytoplankton production in all the systems, which I was actually a little bit surprised about. I mean, even with Lake

Superior, there was a slight decline even though they didn't have the zebra mussels and it's not a huge watershed loading. Maybe nutrient loading has reduced in Lake superior too. But that's usually not seen as one of the lakes people focus on.

Soren B.:

But the water clarity had increased and the chlorophyll concentrations had decreased over that same period there. And yeah, I mean with that, the only basin, actually in Lake Erie in general, mostly because of the central basin, there was a decrease in water clarity and a decrease in phytoplankton concentrations or in chlorophyll concentration. And so that seems to be sort of the odd lake out here.

Soren B.:

But in all the other lakes, we see this increase in water clarity and that goes with the decline in phytoplankton production, which makes sense. Because usually that's, especially for large systems, that's basically considered to be the only driver of water clarity, is phytoplankton biomass.

Soren B.:

And it's not necessarily the only driver. You get these whiting events and calcium carbonate precipitation. But usually it's linked to chlorophyll concentrations. And yeah, with the decline in Lake Ontario and Lake Superior, it was a relatively small decline in phytoplankton production. And the increase in water clarity was great enough that it looks as though the benthic primary production would fully compensate, or possibly even overcompensate and increase the total primary production in those lakes. In Lake Huron and Lake Michigan, both increased in water clarity, but it wasn't necessarily great enough to compensate for these massive declines in phytoplankton production that we'd seen.

Soren B.:

So with those ones, I mean it's interesting. So that was one part of the story that didn't seem to compensate. But at the same time, in Lake Huron, for example, because there was such a huge drop in pelagic primary production, by the end, the total primary production of the lake had the highest percentage of any of the Great Lakes that was benthic. So it was at the upper end of our range of your testing for it could be up to about 50% of the total primary productivity of Lake Huron is benthic.

Soren B.:

But you still have this story that from the 70s to 2000s, the total productivity of that system declined and it's still going towards a greater benthic dominance. So you could still have this kind of fish clubs community, but the benthic is there, kind of almost as a safety net that is still an important resource and there's still becoming a more important resource.

Tim Cline:

So there have been these large changes in water clarity and you mentioned nutrient loading as one driver of it. But also I know that the Dreissenid or the Eurasian mussel invasions in the 1980s and 1990s have had impacts on water clarity. So has most of the change occurred since these invasions? Certainly the area of the Lake receiving light all the way to the bottom has increased dramatically since these invasions in the early 1980s.

Soren B.:

Yes, and I mean, but then from a longer time period we're looking at, then it becomes a more interesting question maybe again because there's a question of, for example, Erie was likely before the 1950s or 40s, before the major eutrophication of the 20th century. It was probably clear water, and actually a follow-up paper we're already working on now, which we haven't yet submitted, but that's looking just specifically at sort of Central Basin, Lake Erie. It seems to be that probably the main depth of Lake Erie used to be in the photic zone.

Soren B.:

And so you might be even looking at these kinds of shifts in ecological processes between benthic dominated and water column dominated food webs. And yet definitely the zebra mussels play an important role and I think also watershed nutrient loading played an important role.

Soren B.:

So in terms of this global change biology paper, I mean, we didn't really go into the discussion of the relative role of zebra mussels versus watershed. But we did see we know that there's an increase in water clarity and both of those sort of happened at the same time as the zebra mussels and nutrient load declining.

Soren B.:

And then yeah, I definitely, I think all of the follow-up work I want to do on this is looking more at the sort of ecological repercussions. And I didn't mention it before, but with the work I was doing in Germany, it was also looking a lot at regime shifts. So phytoplankton dominance versus periphyton dominance and trying to see how that affects carbon cycling in shallow lakes. And it's looking to me more and more like that could help explain also what's happening in the Great Lakes right now. And in terms of things Lake Erie problems of recurrent cyanobacteria blooms and these massive fish kills and anoxic events. They could be partially explained by these kind of overall longterm large shifts and actually how the ecosystem is processing its nutrients and carbon, how these cycles are setting up.

Tim Cline:

So I think the food web implications are one of the most interesting aspects of these results. So you observed this compensation from the loss of pelagic production to an increase in benthic production. And this has the potential to majorly shake up the foundations of the food webs in the Great Lakes. So how does the shift from pelagic to benthic production, even though in some cases there is compensation and the total productivity might have increased, how do these changes differentially support consumers? Are there potential shifts in the food web or is this true replacement where we might expect little or no change in the communities?

Soren B.:

Yeah, I guess, it's a theoretical replacement. I mean all it's saying is that the food is not necessarily gone, but it's changing its type and location. In terms of what that means to the food web, I would imagine you could still... I mean I'm not an expert in fish and in macroinvertebrates, but I mean I would suspect or expect that you'd have, for example, maybe a collapse of a pelagic feeding fish population. And then maybe a slow increase in the benthic feeding fish population. Or something like that where you'd see the community change or shift and then if you have an adaptable community that can feed in either habitat, then those are going to be maybe the sort of stronger surviving communities in terms of it.

Soren B.:

And I haven't looked to see whether there's data on the Great Lakes that would support or contravene that. But I mean I do cite in the paper there are a lot of studies that have been showing that fish communities are generally, and from stable isotope analyses, are deriving more and more of their nutrients from the benthos. So that supports this idea that there's a shift from the pelagic to the benthic primary production.

Soren B.:

But I think it's really interesting. I mean, I like the idea that this could be... I mean thinking about what's happening over these kinds of longer timescales and most PhDs or Masters studies just are kind of limited within a two, three or four-year window. But they're actually working on, but kind of taking a larger, broader view and thinking, okay, maybe there's something really slow happening here over the last 40 years. And maybe we're only just seeing a small part of it or just the beginning of it, maybe this is ongoing.

Soren B.:

So it's kind of nice to think about these in terms of those ecological end points, like the restructuring of the actual community. But I think it is interesting. I mean, I like this paper just in the sense that I feel it sort of opens up a lot of other questions. Because in all the work I've been reading on the Great Lakes since I've been here, I mean, I've been working on this since the end of 2013. And even just going to these IAGLR conferences, it feels though people in the Great Lakes science community, there's generally, people are almost scared to kind of consider that anything benthic could be happening at full lake scale.

Soren B.:

And so it's been interesting just kind of seeing that this is coming out now and hoping that this kind of opens up some more questions into how, for me, carbon cycling, but obviously the food web and ecology of these lakes could be linked and could be better understood that way.

Tim Cline:

You've just heard from Soren Brothers, a postdoc at the University of Guelph. He was lead author on a study recently published in Global Change Biology titled, "Benthic algae compensate for phytoplankton losses in large aquatic ecosystems." You can find out more information about Soren and the paper at our website, www.freshwate-science.org.

Tim Cline:

I'm your host, Tim Cline. Thanks for listening.