

Whats the Deal with Wisconsin's Walleye?

Ashley: Good afternoon, or good morning, from the U.S. Fish and Wildlife Service's National Conservation Training Center, in Shepherdstown, West Virginia. My name is Ashley Fortune and I would like to welcome you to our webinar series, that is held in partnership with the U.S. Geological Survey's National Climate Change and Wildlife Science Center in Reston, Virginia.

The NCCWSC's Climate Change Science and Management Webinar Series highlights their sponsored science projects related to climate change impacts, and adaptation, and it aims to increase awareness, and inform participants like you about potential, and predicted climate change impacts on fish and wildlife. I do have the pleasure of announcing our speakers for today's webinar.

We have three folks with us today that worked on the project, and two will be presenting, both Gretchen Hansen, and Dan Isermann, and then Steve Carpenter is also on the line for questions.

I'm going to introduce all three right up here at the front of the webinar, and then we'll get started. Gretchen Hansen is a research scientist with the Wisconsin Department of Natural Resources, where she studies long term changes in lake communities.

She has a Master's degree from Michigan State University, and a PhD from the University of Wisconsin, Madison. Gretchen currently lives in Madison with her husband and her two daughters.

Dan Isermann is the leader of the Wisconsin Cooperative Fisheries Research Unit, and director of the Fisheries Analysis Center at the University of Wisconsin at Stevens Point. Dan's research attempts to address fisheries management issues, with a specific focus on the population dynamics of walleyes and black bass.

Steve Carpenter served as the director of the Center of Mammalogy, and the University...excuse me, at the University of Wisconsin in Madison, where he was the Steven Alfred Forbes Professor of Zoology.

Steve, Gretchen, and Dan have been working together on Wisconsin walleye problems for the past four years. I'd like to welcome all three of our speakers, and turn it over to Gretchen. Thank you.

Gretchen Hansen: Thanks Ashley. I hope my mutes off now. This is Gretchen Hansen. I will be speaking first today, and I'll hand it over to Dan Isermann for a little bit, and then I will wrap it up, and then all three of us will take questions.

Thanks everybody for joining us today. It's exciting for me to be able to talk about the culmination of four years of research that we've been working on here in Wisconsin. Since it's a webinar, and it's a little weird that you can't see us, I thought I would put our pictures up here, so you know who you're dealing with. There we are on your screen. I need to figure out how to work this. I should also, upfront, acknowledge that this project was funded by the USGS Climate Change Science Center.

As well as the Sport Fish Restoration Fund and the Wisconsin DNR. I want to acknowledge that upfront, and also acknowledge that this, what I want to talk about today, is work that has come together from the hard work of a number of people.

We have this bass, walleye group, that we call ourselves, that have been working for the past four years on this research, and we've really taken a collaborative approach, and a multifaceted approach to do a lot of different kinds of research that I'm going to talk about today.

Just want to thank all these people for their involvement in this project over the years. I'm going to start by giving you a little bit of background of how we got started on this project.

In the early to mid 2000s, here in Wisconsin, there were a lot of anecdotal reports coming in to the Wisconsin DNR on a lake by lake basis, mainly, of declines in the walleye population, and largemouth bass population increases.

I should point out right now, I'm going to talk a lot today about bass, and I might just say "bass". For the most part, I'm referring to largemouth bass. We do have smallmouth bass also in Wisconsin, but our data are not as good on smallmouths.

We don't see the same level of trends, so I'm just not really going to talk about smallmouths today. When I say bass, I mean largemouth for the purpose of this talk.

In the early to mid 2000s there were lot of anecdotal reports of declines in walleye and increases of largemouth bass. This is concerning to managers in the state of Wisconsin. Walleye are the most targeted sport fish species in the state, so anything that leads to walleye declines is concerning.

There is some belief among some people in the state that because these two trends are happening concurrently, that possibly they were directly related, that largemouth bass increases were the cause of walleye decline.

So, there was some motivation both within the DNR, and then among people at universities to try to investigate this, to try to understand a little bit more about the magnitude, the extent, and the cause of these changes. I should note that there were similar anecdotes coming in from around the region as well.

It seems like this wasn't necessarily a Wisconsin problem. In Minnesota, Michigan, and Ontario there was some inkling that similar trends might be going on. As these reports were coming in, there have been some management responses in Wisconsin to these declines in walleye, and increases of bass.

One of the major ones has been what's known as the Wisconsin Walleye Initiative. \$12 million were devoted to stocking more walleye, specifically to stocking extended growth fingerling walleye, so larger walleye than are normally stocked. That was one response to declining walleye population.

At the same time, there have been some restrictions on harvest, including closure of a very prominent fishery in Wisconsin to walleye harvests recently, so certainly management is responding to these declines in walleye, even when the causes might be unknown.

At the same time, there has been a liberalization of bass regulations to try to encourage more harvest of bass, including some localized interesting fishing tournament events to promote the idea that harvesting, and cooking and eating bass is something the public should get interested in.

All this management response, while this is going on we still have a lot of questions about what the causes are, what's going on, and causing these trends in these two species. Like I said, there's some idea that possibly the increases in bass and declines in walleye were directly related, but as you can imagine, there are a number of other factors that we could hypothesize might be causing changes in these fish species, and in fact all of these factors may interact in a very complex web of interactions, influencing bass and walleye individually, as well as the way they might interact with each other.

When we started this research project it became clear that no single approach to understanding the system was likely to work, and that we needed to take a collaborative, and multifaceted approach to start to disentangle this web.

That's what we did. I'm going to organize my talk today, talking about three major areas, some broad areas of research that we've done over the past four years. The first thing that we wanted to do, was to really quantify the magnitude, and the extent of these patterns and trends in bass and walleye.

So try to understand how severe is the problem of walleye declines? How widespread is the problem? And the same questions for bass increases, how much has bass increased, and how widespread are those trends?

After we nailed down the magnitude of the problem, we spent a lot of time generating, and evaluating hypotheses about what might be causing them. Something I want to talk a lot about today is water temperature, and how that might be related to these trends.

We also tried to identify other factors we thought might be associated with the trend, and also identify knowledge gaps, and areas where we needed to design some new studies, and new research to get into some of the mechanisms of what might be going on.

At the end of the talk I'm going to touch on some of the ongoing, and future research, and Dan, Dr Isermann will talk about that as well. Finally, these first two areas of research are certainly related to management.

But we also spent some time focusing on research that was really directly management oriented, so really evaluating the role of harvest as a management tool for largemouth bass to try to understand, could increased angler harvest control bass populations in Wisconsin?

We have started an adaptive management study to try to evaluate our management responses in the field. I'll talk a little bit about that, and also develop some models for prediction and prioritization of locations to try to maximize the success of our management actions by targeting them to places where we think they will work. I'll talk briefly about that as well. Let's start at the beginning, identifying patterns and trends. This seemed like an important first step to this project.

Like I said when we started, we had some anecdotal reports on an individual lake basis, of declines in walleye, and when we dug into all the data we had, and we found indeed that state wide walleye recruitment to age zero was declining.

I want to note, I'm going to talk a lot about walleye recruitment today, and in all cases I'm talking about recruitment to age zero, so survival of young walleye to their first fall.

I know that other states might define recruitment differently, and certainly recruitment to age zero is not the same as recruitment to the fishery, but because we're seeing these strong declines in recruitment to age zero, where walleye in many places in Wisconsin are not surviving past their first summer. If they can't make it past their first summer, they certainly can't make it to be a six, or 10, or 20 year old walleye that can be harvested. We're focusing a lot on why aren't they making through that first summer.

What we found when we looked state-wide was an average decline in recruitment of about 6.6 percent per year. This is state-wide average numbers, since 1989. That was pretty concerning. Obviously the state-wide average doesn't tell the whole story.

We have tens of thousands of lakes in Wisconsin, so looking at individual lake trends was also important. We looked at lakes where we had enough data, over the past three decades, to try to identify a trend. We found a similar story, that in fact, in the majority of lakes where we had data, walleye recruitment was declining. This histogram here in the upper left corner shows annual percent change on the X axis. That's this slope of the line on the long scale of walleye recruitment over time, then the percentage of lakes that show that trend.

The red dash line is the zero line. Everything to the left is zero means walleye recruitment in those lakes was declining. Anything up here in the positive range means recruitment was increasing since 1989. There are a substantial number of lakes where we do see increases, but the vast majority, we see decline.

Those trends are plotted here on the map, color coated with the blue color showing declines, and the green showing increases.

What was interesting to note early on was that there was a large degree of spatial heterogeneity, so we could have lakes right next door to each other where you might see strong declines in recruitment in one lake, and then increases in recruitment in another.

That spatial heterogeneity told us that this wasn't just a regional trend that was operating the same in every lake, that there were some complexities that we needed to understand to know why these lakes were responding differently. That's walleye recruitment.

When we looked at adult walleye, we saw also the state-wide average adult walleye densities were also declining since 1989, but the rate of decline was not as large. Average decline of about two percent per year in this case.

That makes sense because adult walleye numbers are really influenced by a large number of things besides recruitment. We do a lot of stalking in Wisconsin, as is the case in many places, and harvest pressure can also influence adult population.

So it makes sense that the declines would not be as strong, but we did see declines in adult density as well. Again, when we look on a lake specific basis, we once again see some heterogeneity, with some lakes showing increases in adult walleye density, but the majority having decreases.

When we looked at largemouth bass we saw, for the most part, increases in largemouth bass throughout the state.

The state-wide average rate of increase was about four percent for year. In this case, in the majority of lakes, bass were increasing, and then in a small number we saw some decreases, and again, some spatial heterogeneity throughout the state.

When we tried to look at concurrent trends between large mouth bass and walleye, we found we had not a huge number of lakes where we had the ability to quantify trends in both species, about 30 lakes where we had data for both species that we could look at the concurrent trends.

What you see here is a biplot. On the X axis is the largemouth bass trend, so anything over zero means largemouth bass are increasing. On the Y axis we have the walleye trend. This is walleye recruitment in this case. Anything below this zero line would mean walleye are decreasing.

Perhaps not surprisingly given the trend in the species individually, we see in most cases where we have data for both, largemouth bass are increasing, and walleye are decreasing in the quadrant here. Because largemouth bass themselves are most of the time increasing, and walleye are most of the time decreasing, we wanted to test whether the co-occurrence of these trends is happening more often than you would expect by chance. The result was somewhat equivocal, a P value of 0.06 when we do Chi-squared test here.

I would say there's some moderate maybe, possibly evidence that these trends are happening at the same time more often than you would expect by chance, but certainly nothing really conclusive came out of this.

It's important to remember the lesson that all of us have heard probably hundreds of times but sometimes it's easy to forget, but correlation doesn't equal causation.

We can see that in a lot of lakes bass are increasing, walleye are decreasing, but this doesn't really tell us much about the mechanism of what might be causing these things. I'd like to show a slide from this great website called Spurious Correlations, where you can find any number of interesting correlations.

This is my personal favorite. In the U.S., per capita cheese consumption correlates quite well with the number of people who died by becoming tangled in their bed sheets. This has an R squared of 0.9. Most of us would be pretty excited to get R squares of 0.9 in our analysis.

Maybe you can come up with some post hoc explanation of why these two things might be related, but I think all of us can agree that this is a spurious correlation. I like to put this up as a reminder that because you see these trends happening at the same time, it doesn't mean that they're directly related. A big part of our job as researchers here is to dig a little deeper, and understand what might be the mechanism.

That was the next step in our research approach, was to, as I said, dig a little deeper and look into what else might be changing at the same time in these lakes that we know could potentially be associated with these two species, and then to design some new project together, some new data, to try to understand more about mechanisms.

A lot of what I have been working on is focused on water temperature, and the potential role of water temperature in driving trends in fish species in lakes in Wisconsin. Temperature can be thought of as a “master factor” in ecology.

It controls the rates of pretty much every process that we might care about, from nutrient cycling to oxygen concentration, algal dynamics, zooplankton dynamics, and of course fish.

Temperature controls the distribution, growth, survival, reproduction, every major rate of fish population, so it's very important. We wanted to evaluate how temperature might be related to the trends that we have seen in bass and walleye in Wisconsin.

For those of you who are not lake people, I thought I'd take a minute to talk about water temperature and lakes because if you want to know something about what is the water temperature of this lake, it's not a matter of knowing a single number.

Water temperature in lakes, the kind of lakes that we're most interested in, for the most part in Wisconsin is heterogeneous. Most of the lakes that we're dealing with that have bass and walleye in them stratify in the summer, meaning that the water segregates based on temperature.

With warm water in the upper region of the lake known as the epilimnion and cold water in the deeper waters, known as the hypolimnion. Those layers don't really mix because of the density differences. In water, they're really separated from each other for most of the summer.

This is important from a fisheries perspective because fish species have distinct temperature preferences. Largemouth bass are a warm water fish that are most likely going to prefer the upper waters of a lake, whereas walleye are a cool water fish.

Probably more likely to be found in the middle area of a lake, where the water is a bit cooler than you find at the surface. In trying to understand the role of temperature and explaining the trends that we saw, it seemed like it was important to understand temperature on a whole lake basis for our lakes in Wisconsin.

Unfortunately, we don't have a lot of data on water temperature in lakes, particularly over the time scale that we were interested in, the past three decades, at the resolution that we might care about.

So knowing something about temperature over the whole course of a season and certainly not for knowing temperature across the entire profile or depth range of a lake. We just don't have that data for most lakes in Wisconsin or really in the world I would say.

The approach that we have taken is to model temperatures from known conditions and try to hindcast what we think water temperatures in lakes were likely to have been in the past using a mechanistic thermodynamic model. I'm not going to talk a lot about the details of this model.

You can find those details in this paper listed here or contact me or Jordan Read or my other coauthors here later. We'd be happy to talk about it. For the purposes of this talk, I will say that this model uses air temperature and solar radiation and wind information from past days, where we have that information, combined with lake specific characteristics, like water clarity and canopy cover, which influences how wind will affect the lake. Then, like I said, uses a thermodynamic model to hindcast daily temperature profiles of lakes.

The output of this model is depth specific daily temperature values. We did this for about 2,400 lakes from 1979 through 2012 in Wisconsin.

This heat map shows an example of the data you'd get for one lake for one open water season, with warmer water at the top in the warm colors, cold water at the bottom in the cool colors.

Imagine we had this level of data for 2,400 lakes for 30 plus years. The model works quite well to hindcast water temperatures. We were pretty happy with the result. But we wanted to distill this vast amount of data into metrics that were biologically relevant for the species that we're interested in.

For example, instead of using daily temperature profiles, we would calculate metrics such as growing degree days, which is a measure of the cumulative water temperature in a lake, as well as a large number of other temperature outputs.

These are the metrics that we then try to associate with fish populations to see if temperature could explain the trends that we were seeing.

But as a side note, one thing that we found was that water temperatures were quite variable across Wisconsin, so when we look at this map of growing degree days, on this scale it's probably not surprising that you see lakes in the southern part of the state are more red.

Meaning higher growing degree days, meaning warmer water. Warmer water, higher growing degree days in the south compared to the north. That's probably not very surprising.

But if you drill in and zoom in a little bit closer...and I should note that the color scale here has changed, but it still represents a fairly large difference in growing degree days. When we zoom in close like this, you can see that lakes right next to each other can have very different temperatures.

Like if we circle this little group of three lakes here, three lakes almost right on top of each other that span a range of about 500 growing degree days. They're quite different.

Seeing this small scale heterogeneity in water temperatures was interesting, given that we saw small scale heterogeneity in walleye trends as well. So this was encouraging as we started our temperature modeling.

The next step was then to more formally try to relate water temperature metrics that we thought might be related to walleye and bass to the walleye and bass populations that we had data for across the state.

The way that we did that was using a statistical model known as a random forest model. Again, I'm not going to get too deep into the details of this modeling. I'm happy to talk about it later with anybody who's interested.

For the purposes of this talk I will say it is a tree based method that classifies data...in our case, what I'm showing here is probability of walleye recruitment success. In this case, a yes or no. Did recruitment happen or did it not happen?

So the random forest, it will look at a large number of predictor variables, and identify relationships between those predictor variables and recruitment success. Random forest is a great method for our purposes, because it can identify nonlinear relationships as well as interactions, which can be really important in complex systems like this. What I'm going to show you here is the relationship between a single variable and probability of recruitment success for the variables that we've selected using a model selection technique as the best predictors of walleye recruitment.

In random forest, the effects of one variable often depend on the level of another variable or of all the other variables, so what I'm going to show in these figures is the median effect of the variable of interest. In this case, lake area is what I'm showing.

So the black line is the median effect, and then the gray bars, the interquartile range, given all the other values of the other variables. What we see for walleye recruitment, this first most important variable was lake area. We see lakes with larger surface areas have a higher probability of walleye recruitment.

There were four other variables that came out as important in predicting walleye recruitment success. Three of those were related to water temperature, so we have the coefficient of variation of surface water temperatures, both 30 to 60 days post-ice-off, and 0 to 30 days post-ice-off.

So variability in water temperatures as walleye are spawning, as walleye are in their egg stage and then immediately following some up when they're fry and larval stage. That's these two CV metrics.

Then growing degree days, which I talked about before, which is the cumulative measure of water temperature in a year. Here we see lower growing degree days means cooler water. Walleye recruitment is more likely when degree days are lower.

Less likely in warmer waters when degree days are higher. For the variability metrics, walleye recruitment is more likely in both cases when variability is lower in spring water temperature.

Like I said, this random forest technique can also identify interactions between variables. The effect of one predictor, say growing degree days, may depend on the level of another predictor. In this case, the variability of water temperatures in that 30 to 60 days after ice goes off of the lake.

I'm showing you here is a contour plot where the darker purple colors represent higher probability of walleye recruitment, and the lighter pale blue represents lower probability of walleye recruitment.

Here we see there is this sweet spot for walleye recruitment, where degree days are less than about 2,400-2,500 and variability of water temperatures are below around 0.17.

In that sweet spot, walleye recruitment is more likely. Outside of that in any direction, the probability of walleye recruitment goes down. But because of some of the interactions, you can see a little bit darker colors in this region and this region than out here in the corner.

For example, you can still have a decent probability of walleye recruitment even with high degree days as long as your CV of water temperatures is low. And conversely, you can still have a decent probability of walleye recruitment at high levels of variability as long as your degree days are low.

These counter plots help us to identify interactions and what kinds of conditions are most conducive to walleye recruitment. What was interesting to see, what we then did was to look at how our walleye lakes in Wisconsin have changed over time in terms of these temperature variables.

That's what I'm showing here. This plots a path of the median of all Wisconsin walleye lakes in terms of these two water temperature variables. So you see a movement from this sweet spot purple zone out into the not so good blue zone.

Over time, we're moving away from places where recruitment is most likely. We did the same thing for bass. Same techniques to try to predict bass abundance from variables we thought might be important. Again, we see in this case only one temperature variable came out as important.

It was degree days once again. But in this case, the relationship was opposite. Largemouth bass abundance was predicted to be highest when degree days were higher, so in warmer waters.

Then some other variables really did, to lake morphometry and landscape position were also important. I thought it was interesting to plot the effects of degree days for both species side by side.

So we can see that they look like almost mirror images of each other with a threshold at around 2,400-2,500 degree days separating high probability of walleye recruitment from low and high probability of there being a lot of bass from low.

We found in both cases that the temperature effect was strongest in small lakes. So the effect of growing degree days was much higher in lakes of, say, 100 hectares, shown here for both species with the black line, than in bigger lakes, say, of 1,000 hectares, shown in the blue lines.

It's interesting to find, using totally independent data sets we found really similar results for both walleye and for bass, suggesting that maybe they're both responding to temperature in some of these lakes.

Again, I have to go back to my favorite slide, we can do this high level statistical modeling that provides some really great information of the types of conditions that are most associated with good walleye recruitment or high bass abundance.

But again, we're still working really with correlations and we don't know the mechanism in this case. When growing degree days gets high it's not like it's necessarily too warm for walleye to live.

There's some complex interaction going on there that we needed to drill a little deeper to understand the mechanisms. That's where my colleague, Dr. Isermann, will talk now.

Dan Isermann: All right, so as Gretchen mentioned early in her presentation with some of her slides, the interactions within these ecosystems can be pretty complex.

When we think about the relationship between bass and walleye there are two rather obvious mechanisms that come to most peoples' mind that could cause that to occur. That would be direct predation by bass on young walleye and then competition for available prey.

To assess the extent of those mechanisms we went out and collected diets from hundreds of largemouth bass and walleyes from four northern Wisconsin lakes with various combinations of walleye and largemouth bass abundance.

We did this from May to October and, for brevity's sake, I'm showing you summarized data here. We also used DNA bar coding to help us reduce error associated with partially digested diet items. What we've found is that largemouth bass rarely consumed walleyes.

We saw one incident of this in 945 largemouth bass diets, so fairly rare. This was true even when relatively strong year classes of age zero walleyes were present. Walleyes and bass shared a wide variety of prey items. The top five are summarized here.

As you can see the two species where we saw the highest level of niche overlap, or groups of species here, was sunfish and then yellow perch. Of course, our findings don't allow us to declare that competition is occurring because these resources would have to be limiting.

But it at least gives us an idea that these are the two groups where the highest potential for competition might be. As Gretchen also demonstrated that there's been these landscape level changes, probably in temperature regimes that have provided for increased bass recruitment over the last decade or more. Many previous studies have suggested that the growth of bass and the length that they attain in their first year of life can influence recruitment through size selective mortality processes.

And that these factors can be influenced by hatch timing. But there's very limited information on this for largemouth bass in northern lakes. What we did is went out to seven lakes across the state of Wisconsin. We've been doing this over the last four years.

We've collected age zero largemouth bass of approximately this size and then we've removed their otoliths so that we can use the daily rings pictured here to estimate their hatch dates.

We're collecting these bass at the end of July, early August, and counting their daily rings and their otoliths to see. Are we seeing trends in hatch dates that could lead maybe to increased size and eventual recruitment. I'm going to show you two years here. 2012 was the first year we did this.

This was the year in the upper Midwest where we had some 80 degree water temperatures at the end of March. Fairly early ice out, even early April. Then in 2013 this was a year where people were ice fishing in some places on the walleye openers. So, two very stark years in terms of temperature regimes.

You can see that the median hatch date in 2012 was much earlier than the median hatch date in 2013, although we didn't really see any major differences in hatching duration which is depicted in this other graph here.

Now the important part about this is whether it equated to anything in terms of the size of the bass at the end of summer. Certainly when we look at early hatched fish, middle, and late hatched fish, in 2012 we do see a trend that these early hatched fish were slightly larger but the differences are pretty minor.

We're talking on the order of three to six millimeters. Then in 2013 with the late ice out we did not really observe any, or we didn't observe any significant differences in the average size of these fish at the end of their first summer.

We've got two more years of data to add to this analysis, so we've continued to collect these fish from these lakes. One of the other questions Gretchen hinted at is, we know that we're losing these walleyes essentially in the first year of life based on not catching them in age zero electro fishing surveys.

One of the primary questions is when exactly in their development are we losing them? Then these lakes that have different recruitment histories, do we see variation in abiotic and biotic factors such as temperature or water clarity?

Hadley Baum, who's one of our current grad students, is working on this project. We selected four lakes in northern Wisconsin, two that have a history of sustained walleye natural reproduction, meaning that it continues at a variable rate as would be expected. That's Escanaba and Big Arbor Vitae lakes.

Then two lakes where we've seen declining natural reproduction of walleyes to the point that we have not observed any walleyes in these systems in a couple of years. Then we essentially went to these systems and threw everything but the kitchen sink at them.

In terms of trying to collect walleyes in their first year of life. This included egg mats, larval towing and light traps, staining, micromesh gill nets, and then our typical age zero electro fishing that occurs at the end of each summer in the early fall.

This allowed us to develop a method for assessing walleyes in these lakes, which includes larval towing at night in late May, these micromesh gill nets in mid-July to late-July, and then the typical age zero electro fishing to sample them at the end of the summer.

What we also found is that in these lakes where we're seeing sustained natural reproduction, we always encountered adults, we always captured eggs on the egg mats and we observed both larvae and juveniles in both years.

But on the declining NR lakes there were some adults still present, and we did collect relatively low numbers of eggs in both years, but we never encountered a larva walleye or a juvenile fish in age zero electro fishing. This makes us think that the bottleneck is probably at the larval stage or earlier.

We're still processing zooplankton samples, so the differences in these lakes in terms of temperature, water clarity, and zooplankton are yet to be determined. However, we do know the two declining NR lakes are generally clearer than our two sustaining, natural reproducing systems.

With that Gretchen's going to take back over here.

Gretchen: It's still you, Dan, for a couple more slides.

Dan: Next we're going to talk about this next phase of the project, which is these management actions. Of course, one of the things Gretchen mentioned is that the DNR has liberalized bass harvest regulations on some systems in some locations.

To try to potentially alleviate any effects that might occur between the two species. Then additionally, for the sake of bass management, increasing abundance does pose some problems in terms of density dependent growth and maybe our ability to provide quality sized fish for anglers.

On the four lakes where we did the diet work we also wanted to simulate what effects do fishing mortality have on bass abundance and what would it take to reduce bass abundance? This is in light of the fact that most anglers release most of the bass they catch.

At best guess, we're talking about exploitation rates that are probably, on an annual level, five percent or less. On these systems, we collected a variety of data that included mark recapture, population estimates, otolith based estimates of fishing mortality and growth trajectories.

We developed some stock recruit relationships and then put these in to age structured models to simulate the effects of fishing mortality under different harvest regulations that were chosen by the Wisconsin DNR's bass management team.

One of the first things we learned is that bass in these northern lakes can live a really long time. This is the oldest fish that we captured in the study. You'll see 21 annuli here, at least I see 21, and then if you add a year you get a 22-year-old fish. They regularly live beyond 10 years of age.

That means that a strong year class can persist for a very long time and influence abundance estimates well into the future. A lot of these really large fish, say fish over 18 inches long that anglers really want to catch, they're generally over 15-years-old.

It's taking them quite a while to get to those larger sizes. When we look at the results of our simulations, I'm going to show you one lake here so you can get a feel for this. These white dots here represent a 25 percent reduction in initial abundance.

You can see, regardless of the harvest regulation, they require a pretty substantial amount of fishing mortality relative to what we're seeing on the landscape now. In terms of reducing abundance while still maintaining size structure to some level.

These two middle harvest regulations probably offered the best case scenario. Certainly a no minimum length limit was the best option and required the lowest amount of fishing mortality to get the 25 percent reduction in abundance.

A substantial increase in fishing mortality would be needed in order for this to really work effectively. All right, now I'm going to pass it on to Gretchen.

Gretchen: Thanks Dan. I'm going to wrap up with a couple more, mostly ongoing and future projects. Let me get my little pointer back. I mentioned in the beginning we have initiated an adaptive management experiment in collaboration with many of our biologists throughout the state who've been willing to work with us to try to understand what's going on out there in the landscape.

As I said in the beginning, this whole research project started because there were a lot of reports coming in of lake specific declines in walleye and increases in bass.

There were a lot of places where the stakeholders and the biologists wanted regulations to be changed in order to try to reverse those trends. We designed an adaptive management experiment to try to do these regulation changes in a way that will allow us to learn if they work or if they don't.

What we've done is we have 20 experimental lakes and 10 reference lakes. Sorry, let's start with the experimental. So, we have 20 experimental lakes where we've seen these declines in walleye and increases in bass, where the regulations have been changed in three important ways.

First, increased stocking of those extended growth, large walleye fingerlings is going on. Also, more restrictions on walleye harvest to try to protect adult walleye populations and then a liberalization of largemouth bass regulations to try to encourage more bass harvest.

We're really throwing the three major tools that we might use in the state of Wisconsin to try to change the trajectories of sport fish populations.

We're throwing all three at them at once to see if the trends in these lakes can be reversed. Importantly, for the prospect of learning we also have 10 reference lakes. In these lakes the same trends have been observed but we're not doing any of those three regulation changes.

So, this will allow us to track overtime things that we care about, like walleye recruitment, in both the reference and the treatment lakes and see if there's any difference in response in the places where we've done these regulation changes compared to the places where we haven't.

This is ongoing and hopefully we'll have at least some preliminary results in the next couple of years. Then another thing we're doing is to try to use the statistical models that we've developed to help prioritize management actions.

One example of this that's already occurred is we have used the walleye recruitment model that predicts the probability of natural walleye recruitment for really any lake in Wisconsin. We've used that to help prioritize stocking under the Wisconsin walleye initiative.

There were a large number of lakes, several hundred lakes, that were proposed for stocking. We ran them through our model to say what is the probability that these lakes could support natural recruitment?

Places where the probability was high, so conditions seemed good that walleye natural recruitment could occur but it wasn't happening, those were prioritized for stocking with the idea that stocking should be prioritized in places where maybe natural recruitment could be restored.

Ongoing work now is to take our water temperature model that I described earlier and extend that out into the future. So, what I talked about before was hindcast water temperatures and we also have developed forecast water temperatures under various climate models.

In progress now is to use that information to make projections about future fish populations, future walleye recruitment, and hopefully use that information to help prioritize management to places where it's most likely to be successful.

Identify where we expect resilient walleye populations to exist and maybe focus our protection efforts on those lakes and also identify lakes where they might not have as great of a chance. That's ongoing. Now I'm going to sum up. Like I said in the beginning, we separated our project into three major areas of research. We identified patterns and we discovered that walleye's adult densities and recruitment have declined over time while largemouth bass abundance has increased over time.

But that in both cases these trends can be somewhat specially variable, not going in the same direction or at the same magnitude in every lake. We have looked at a number of hypotheses and generated some new ones. We found that walleye recruitment is most likely in large, cool lakes.

Largemouth bass abundance is highest in small, warm lakes. We have some evidence that walleye recruitment failure is occurring at the fry stage or potentially even earlier in some lakes.

Also, we found that adult largemouth bass rarely consume walleye, suggesting that direct predation is not the mechanism operating here. We also found that largemouth bass and walleye share prey and have a substantial degree of overlap between the prey resources.

But we can't really say if competition is happening or not because we don't know if those resources are limiting. We found that ice out timing influences hatch timing of largemouth bass, but that hatch timing seems to have fairly little influence on the length of those bass at the end of their first summer.

Finally, in terms of management, we have identified that substantial increases in angler harvests are going to be needed in order for angling to reduce largemouth bass abundance because most anglers release most of the bass that they catch and because bass are so long lived and have low mortality.

Our adaptive management experiment will allow us to evaluate the effectiveness of the regulation changes that have already been implemented. We hope that the predictive modeling we continue to work on will help to identify locations where management and success can be most likely. So, that's it.

Looks like we have about 10 minutes for questions. Here's the contact information for both me and Dan. I should say, I cut off the end of his beautiful pike here in the first picture, so I thought I had to put it on in the last one to try to...And I had to throw a picture of myself with a fish, too.

Ashley will take over to moderate the question asking.

Ashley: Yes. Thank you very much Gretchen and Dan, wonderful presentation. From Henry, it says, "What about northern pike population trends?"

Gretchen: Unfortunately, we don't have great data on northern pike populations over time in Wisconsin. We do have some research scientists working on that on a smaller scale basis, but I haven't worked much on it, so I can't really say much more.

Dan: I would say in the course of our diet work we did, when we encountered pike, often look at their diet items. We did not see any walleye predation during the study. Although, we have seen some predation in additional samples that have come through the office.

So, we certainly know they can be a predator for walleyes, but whether their abundance is up or down is a little more difficult to tease out of our sampling gears.

Ashley: We have another question coming in from Sean.

It says, "You said you're planning to increase the harvest of largemouth bass, but elsewhere you said there was no direct predation by largemouth bass on the walleye and little competition for food resources. Just wondering why you think this will help?"

Gretchen: Yeah, that's a good question, Sean. One answer is that, Dan alluded to this a little bit, that in addition to having concerns about potential direct effects of largemouth bass on walleye.

There are additional concerns about the increased densities of largemouth bass causing changes to their size structure that are not desirable. That by decreasing densities you can improve the largemouth bass fishery, in terms of its size structure.

That's one answer. Another would be that some of these regulation changes were put in place before those predation results were attained. I don't know if Dan has anything more to add to that?

Dan: I think a lot of the initial changes in the regulations were a good example of a management agency being proactive in responding to the changes, and also were somewhat experimental as part of a recovery effort.

If we make these changes to management on some system, do we garner a response from the walleyes in the system, and then maybe sort out the causative mechanisms later because it does take more time to do that.

There hasn't been any more, to my knowledge, anymore real recent liberalization attempts. A lot of these happened very early in this research where the first thing we was these trends between the two species.

Ashley: We have another question from Patrick, and it's "Was there any insight gained into the potential effect of zebra mussels on the walleye recruitment?"

Gretchen: We don't have a ton of lakes with zebra mussels in Wisconsin, and that wasn't something that I looked at in the large scale analysis, so my gut response is zebra mussels are not a major mechanism.

That said, clarity does seem to potentially be a mechanism, so certainly zebra mussels could be an influence, but it's not something that has really been focused on here in Wisconsin.

Ashley: Another question comes out on the chat from Rick, and it says, "Are lakes with decreasing recruitment of walleyes the same as the lakes with decreasing trends of the walleye adults?"

Gretchen: Yes, sometimes. We don't have as much data on adults. We measure adults doing mark-recapture studies in most cases, in Northern Wisconsin in particular. Those are, as you can imagine, pretty resource intensive.

We do many more recruitment surveys per year than we do adult density surveys, so we don't necessarily have good time series data on both walleye recruitment, and walleye adults in all of the lakes, but yes, in places where we do see declining adults, we generally also see declining recruitment. Usually we see recruitment declining first.

Ashley: Thank you. From Gregor, it says "Have there ever been efforts to establish walleye populations south of their historical range?"

Dan: Certainly that would be true within the state of Wisconsin, and across North America. They've been stocked probably, I'm going to say in most of the 48 contiguous states, so certainly in southern reservoirs, including places like Tennessee and elsewhere, where they've been stocked outside of their...

They may have occurred there, but they've been stocked into systems where they did not previously occur.

Ashley: A further comment on that. It says, "Such efforts might be analogous to efforts to retain walleye in the southern parts of their historical range, as temperatures warm, and so might provide useful information for efforts to resist the effects of warming."

Gretchen: I would say that natural recruitment in those southern populations is probably not occurring, at least in small inland lakes, like we're talking about here, so that is a useful system to look at.

Ashley: I have two more questions, one from Darrel. It says, "Are the efforts of the Walleyes for tomorrow aiding walleye reproduction?"

Dan: One of the additional studies that we have, that's been ongoing, is looking at availability of spawning habitat in relation to recruitment. This, I know, is something that Gretchen's working towards as well.

A lot of these groups are either stocking, or making some effort to improve spawning habitat. With regards to the spawning habitat end of it, we've had one initial study where we looked at 16 lakes in Northern Wisconsin, and were really unable to find any strong evidence that the amount and the quality of spawning habitat was really influencing walleye recruitment in those 16 lakes. That data's really lacking at a large scale because collecting habitat data in the past has been a time consuming task, so we are working to develop side scan sonar to do the substrate mapping.

Ashley: Thank you. Our last question comes from Heath.

It says, "During the past two decades WDNR has been stocking two inch walleye in large numbers in the lakes with declining walleye abundance with limited recruitment success. Any thoughts on why these fish would not survive if the recruitment bottleneck is at the fry stage?"

Dan: I would say that there could be multiple bottlenecks, and the only one we're seeing in those two lakes we're working on is that they're just not making it to the fry stage. We've discussed how to address Heath's question with an additional exercise.

Our hope is we're going to expand the work that we have been doing, and do sampling on more lakes. It would be interesting to see if possibly you injected fry into a system, do they make it beyond that stage, or if two inch fingerlings are going into a system, are they making it beyond that phase as well?

Gretchen: That's really the million dollar question, of why they're not surviving. That's what we're continuing to work on.

Ashley: Excellent. Thank you. Did Dan, Steve or Gretchen have any closing remarks?

Dan: No. Thanks for everybody attending. I was impressed.

Gretchen: Thank you very much for your attention, and your time.