Session Two : THE PEST FISH THREAT

SESSION CHAIR : Don Atkinson, Chair LakesWater Quality Society

THE PEST FISH THREAT
AND THE GREAT LAKES EXAMPLE

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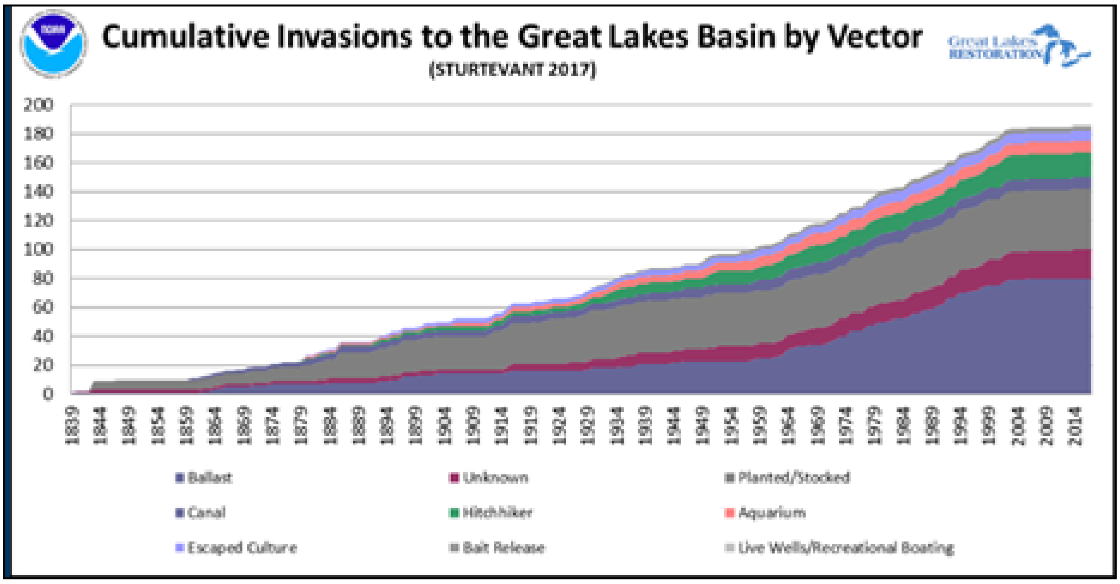
TRANSCRIPT

Today I will talk about some of the innovations and lessons from the Great Lakes with regard to managing pest fish. I will start by putting the region into context from a New Zealand perspective and then I will focus on some surveillance tools, surveillance planning and control methods being developed in the region. I believe that many of the problems you face are the same as those in North America. However, there is significant investment occurring in the U.S. to manage a variety of species and overlap in issues may provide opportunities for collaboration. David Hamilton talked about linking this region to the world for water quality and monitoring and I believe the same applies to pest fish management. Certainly, the Great Lakes region has already gained from ongoing aquatic plant management collaborations with Paul Champion (e.g. Gantz et al 2015).

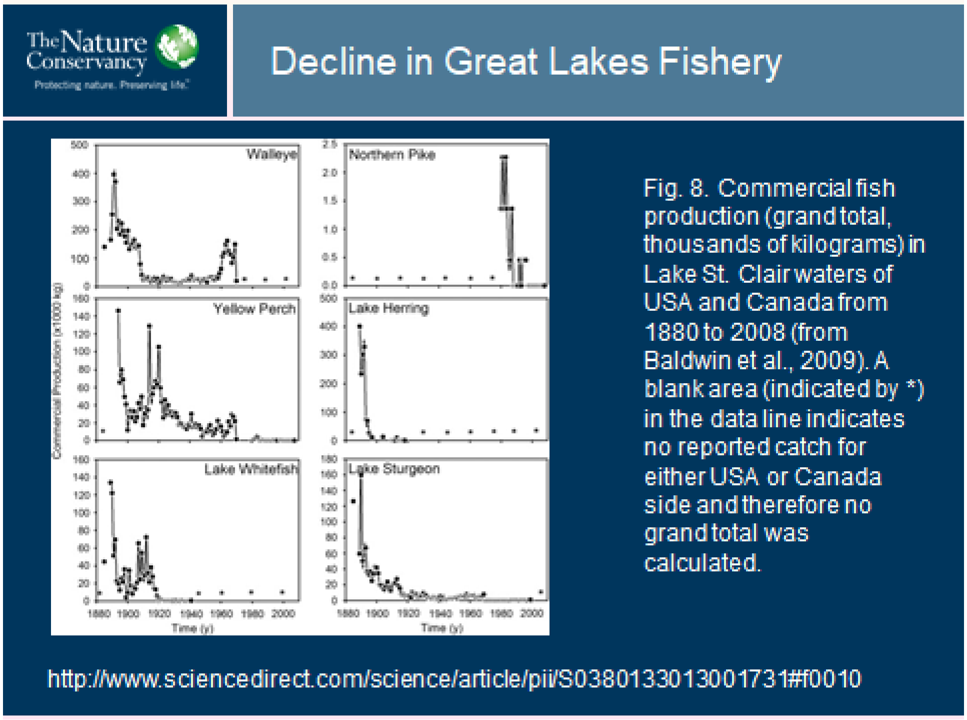
The North American Great Lakes, are five lakes, the largest, coldest and deepest of which is Lake Superior in the north. Lake Michigan and Lake Huron flow into Lake Erie, the smallest and warmest of the lakes, the latter flowing into Lake Ontario and then down the St Lawrence River and into the Gulf of St Lawrence and Atlantic Ocean. The region is bounded by two countries, eight states, two Canadian provinces, 54 million people and $4.5 trillion economy, and about 20% of the earths freshwater. These are large water bodies but in many ways the issues that they face are similar to those faced by the Rotorua Lakes District.



The Great Lakes has the distinction of being one of the most heavily invaded fresh water systems in the world. There are over 180 non-native species in the system of which about 30 are what we would call invasive. That means they cause net harm to the environment, economy or human health and cost the region hundreds of millions of dollars a year.

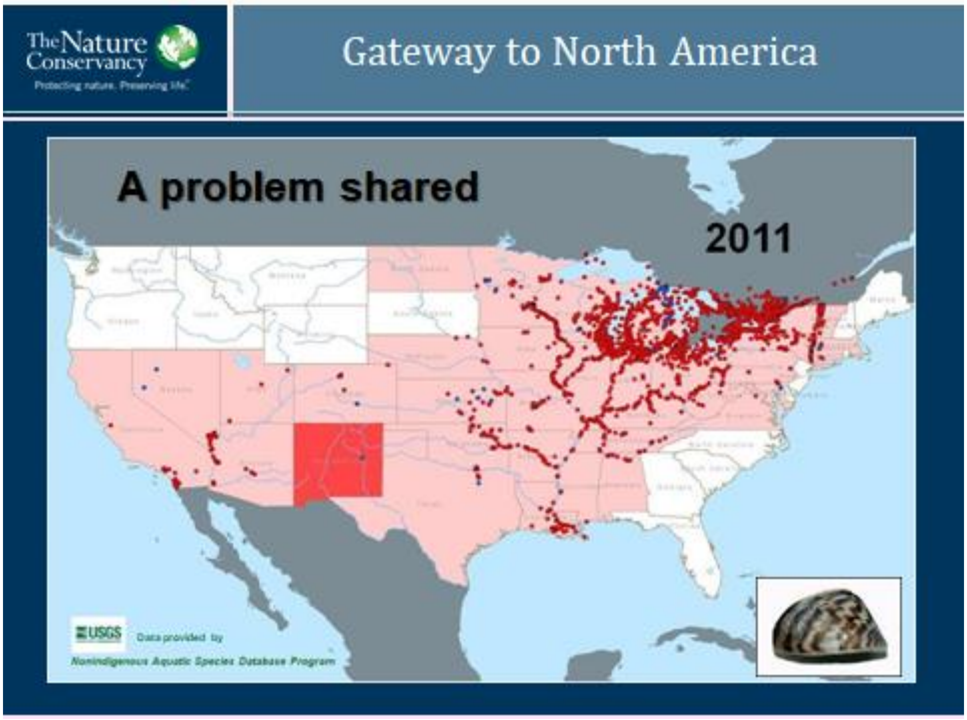
How do they get here? There are a number of pathways of introduction. The lakes are linked to the sea by the St Lawrence Seaway, maritime shipping and the discharge of ballast water has been an important pathway for introduction to the basin. In addition, stocking and the other live trades (e.g. water garden aquarium, bait, live food), canals and recreational boating have also been important.

The impacts on the lakes' systems has been dramatic resulting in wholesale changes to communities and food webs. These are now primarily based on invasive species. These graphs show historic fisheries data - the black areas represent native fisheries; Lake herring, chubs, lake whitefish, lake trout and yellow perch. (The scale is in millions of pounds). There were major fresh water fisheries within the Great Lakes but these have largely disappeared.



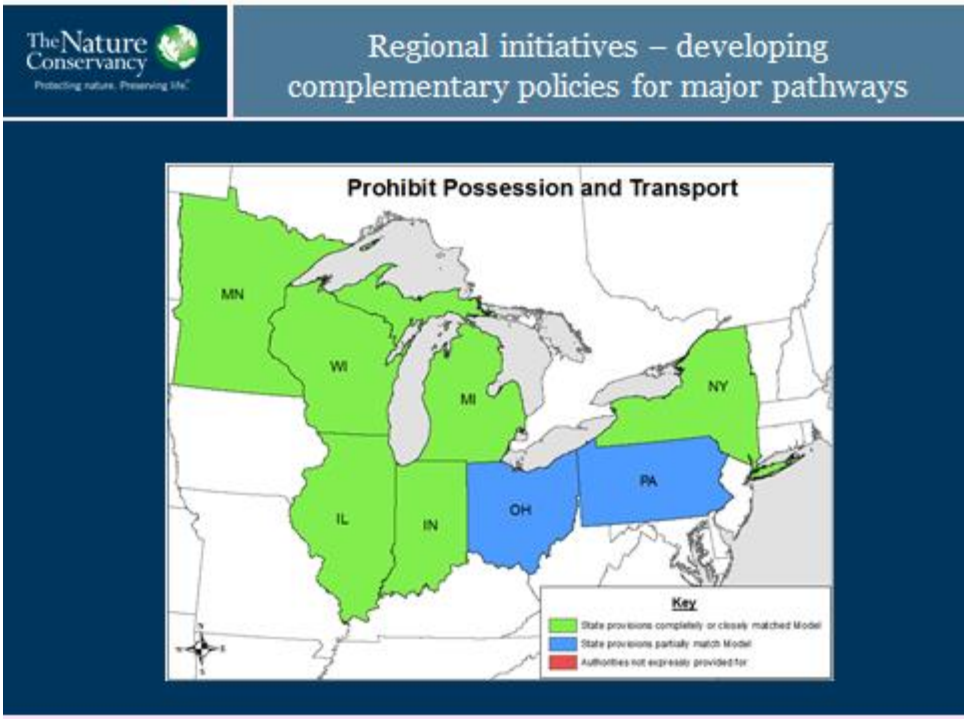
The Lake Trout fishery had largely declined by the 1950s a combination of over fishing, pollution and impacts from sea lamprey. The invasion of sea lamprey into the upper Great Lakes through the Erie and Welland Canals contributed to the decline. The other key species that has impeded lake trout recovery has been alewife, another introduction that entered the upper Great Lakes through the canal system. Alewife is an important prey species but the dependency on Alewife can cause a vitamin B deficiency that leads to aquatic plant management early mortality syndrome. Lake trout that feed heavily upon alewife produce eggs and larvae that die soon after hatching. So the fishery is now largely dependent on stocking.

The Great Lakes are also a gateway to North America. The next slide shows the history of spread for zebra and quagga mussels. These two species of mussel were introduced into the Great Lakes via maritime shipping. They spread rapidly throughout the great lakes and then into the Mississippi River Basin via the Chicago Area Waterway System, and then on trailer boats they have crossed the divide first introduced into Lake Mead and the Colorado river and they are now rapidly spreading through western states. These species



impact any major water user and also change the way nutrients move through lakes systems, having a devastating effect on the Great Lakes and elsewhere.

Over the last ten years management in the Great Lakes has primarily been focused on policies and getting the states and provinces to work together with a complimentary set of regulations to shut down these key pathways of invasion.



However, over the last 3 or 4 years there has been a growing emphasis on developing a region wide surveillance plan. The Bi-national Great Lakes Water Quality Agreement, a federal agreement between the Canadian and United States Government, was re-signed in 2012. It was a commitment to work on aquatic invasive species including the establishment of a regional wide surveillance plan.

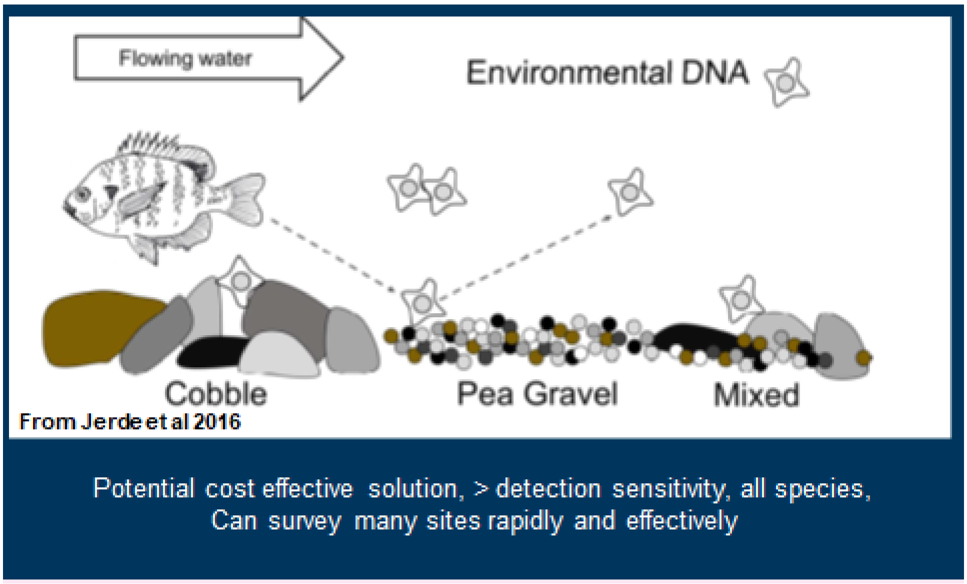
The plan considers the major pathways of invasion to identify key introduction hotspots. We combine data on surrogates for each of the major pathways of invasion. Slide 10 indicates the predicted problem areas – with the highest probability of new introductions. The red areas are the nexus of high population densities, major ports, canals, large marinas and recreational boating areas and large catchments with stocked ponds.

It is no coincidence that we see Chicago, which also has a link to the Mississippi River, Toledo, another key port in the basin that is associated with both Detroit and Toledo City, as regional surveillance priorities. These tools allow us to identity locations to work in and the information can be used to quantify how much effort might be required to monitor all high risks sites. Data important when making the case for federal investment in surveillance across the basin.

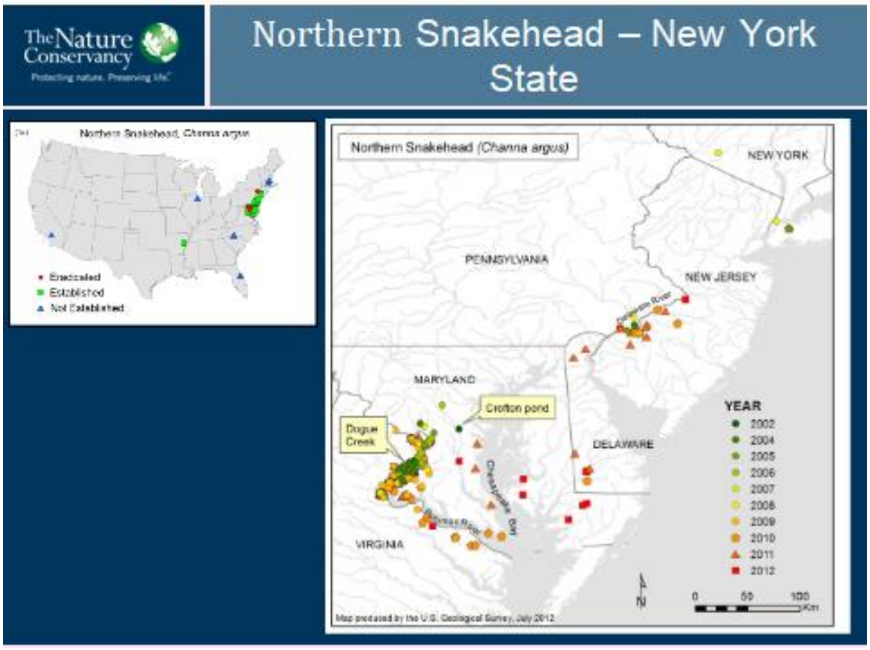
We know from work that USEPA and USFWS have undertaken that any site takes about a week to sample with traditional methods to provide an acceptable level of detection sensitivity (Hoffman et al 2011). Duluth Harbour is in the very western end of Lake Superior, about 10 to 12 kilometres long and the same inland. The Environmental Protection Agency monitor this area and estimate they need about 75 - 150 samples per year for a high enough detection sensitivity that there is a strong probability that an incipient species will be detected (Hoffman et al 2016). The problem with traditional sampling is it is incredibly resource intensive and costly.

How do we make surveillance more efficient and cost effective? To improve the probability of detection there are two choices. Either increase the effort or come up with smarter more efficient way to sample.

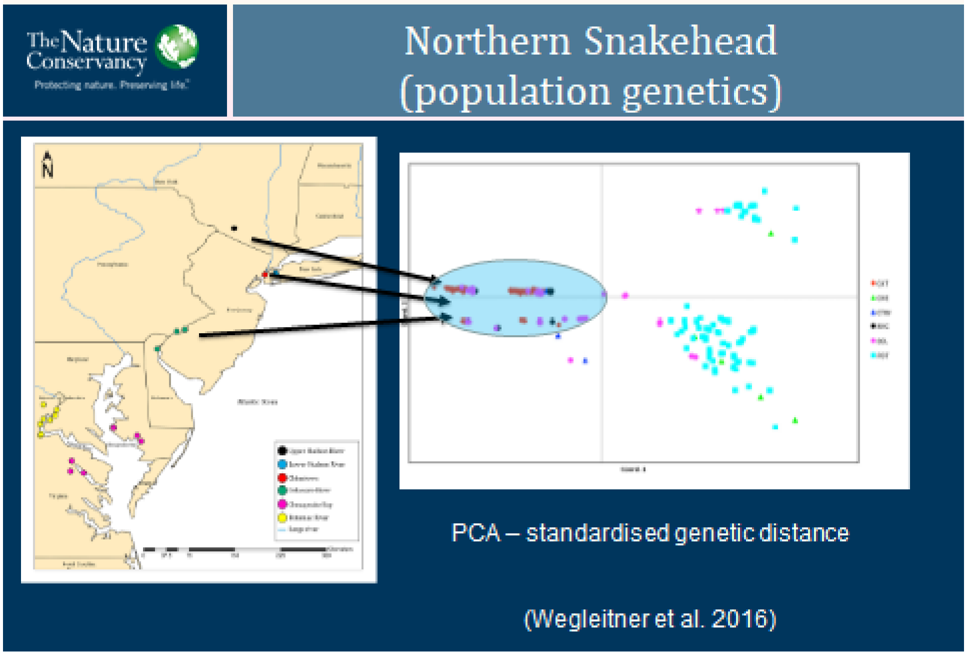
We all shed DNA. The same applies in the aquatic environment. Fish shed cells in their urine, in faeces, as water flows across their gills and as they lose scales. Some of that DNA is retained in flowing water. The heavier particles may settle out and the cellular material with more lipids may float and settle on the surface. In a new incursion traditional sampling methods aim to detect the small numbers of adults and/or juvenile fish in an incipient population. Whereas sampling can focus on more abundant early life stages or like larvae, or in this instance sampling could focus on a plume of DNA produced by the target organism. eDNA has the potential to be more cost effective, increasing detection sensitivity for all species and enable agency to survey sites more rapidly and more effectively.



This slide shows the eDNA method, starting with the collection of water samples that are then either centrifuged or filtered. It is the filtrate, the material left on the filter that is of interests. The DNA is extracted from the filtrate, amplified and then screened for the presence of the target species (see Jerde et al 2011).



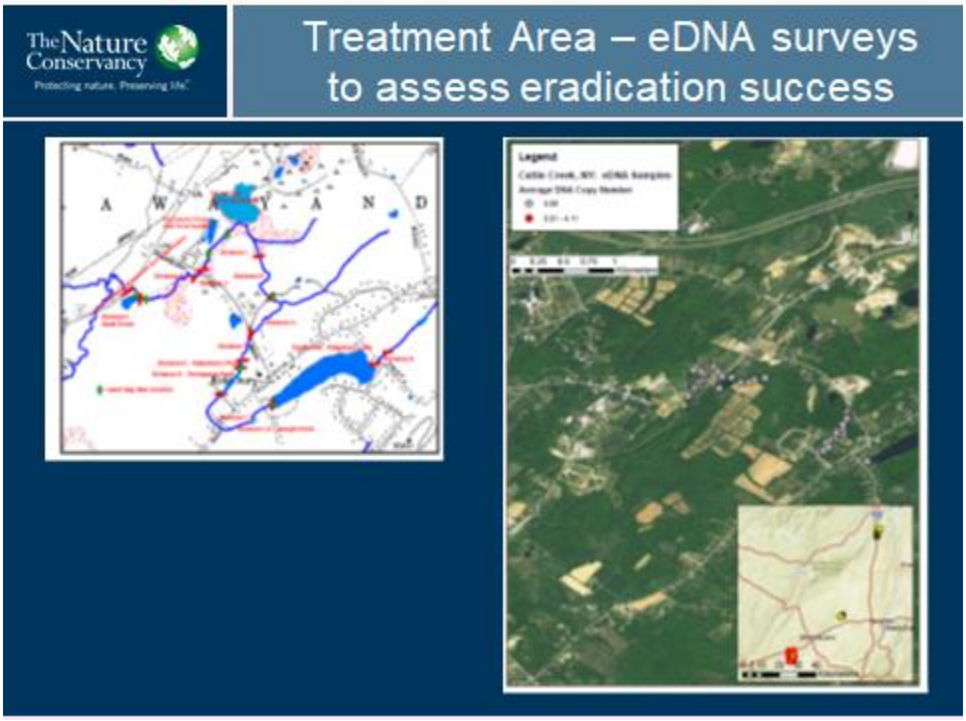
The Northern Snakehead is an example of a fish that is predicted to be an imminent invader for the Great Lakes. It is native to South East Asia, a large predatory fish and well established in Washington DC, Maryland area – first introduced in the Potomac. It has spread throughout the Chesapeake and then appeared in the Delaware system and up into New York City. We know from genetic analyses (Wegleitner et al. 2016) that we are dealing with at least two introductions into the United States. It is believed that they were illegally introduced primarily for food as it is a delicacy within some cultures. The trouble is this really large predatory fish has potential to do a lot of damage and be very invasive.



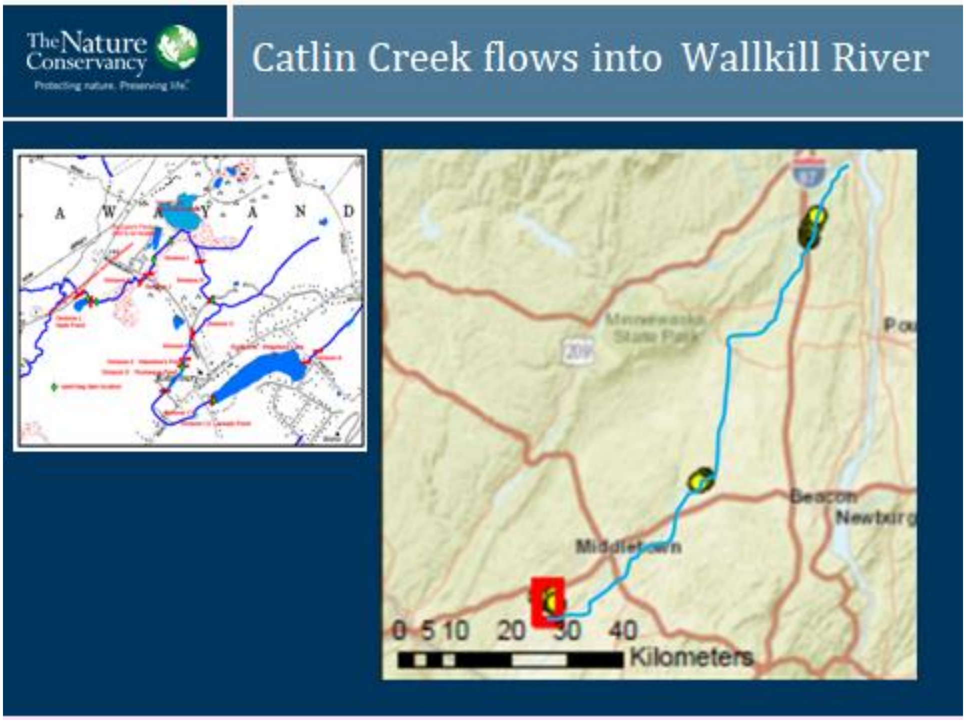
We were interested in the new introduction into Catlin Creek and Mid State New York. We know from genetic analyses that the fish in Down State New York and up in New York City originate from Delaware (Wegleitner et al 2016). What is not clear is where the introduction pathway is. We do know that in 2008 a new population of northern snakehead turned up in Catlin Creek in the Central Hudson Valley system. The fish were abundant in Ridgebury Lake and down through that river system.

The New York State Department Environmental Conservation put in a barrier and in 2008 they twice treated the system with Rotenone and they appear to have successfully eradicated all the fish in the treatment area. NYSDEC asked our team to survey the system using environmental DNA to confirm whether their eradication programme was successful. For 3 years we repeatedly sampled the system. The grey dots are samples we took about 4-5 months ago. Over the time we failed to detect the presence of fish so we are pretty confident that within this system the eradication programme was successful.

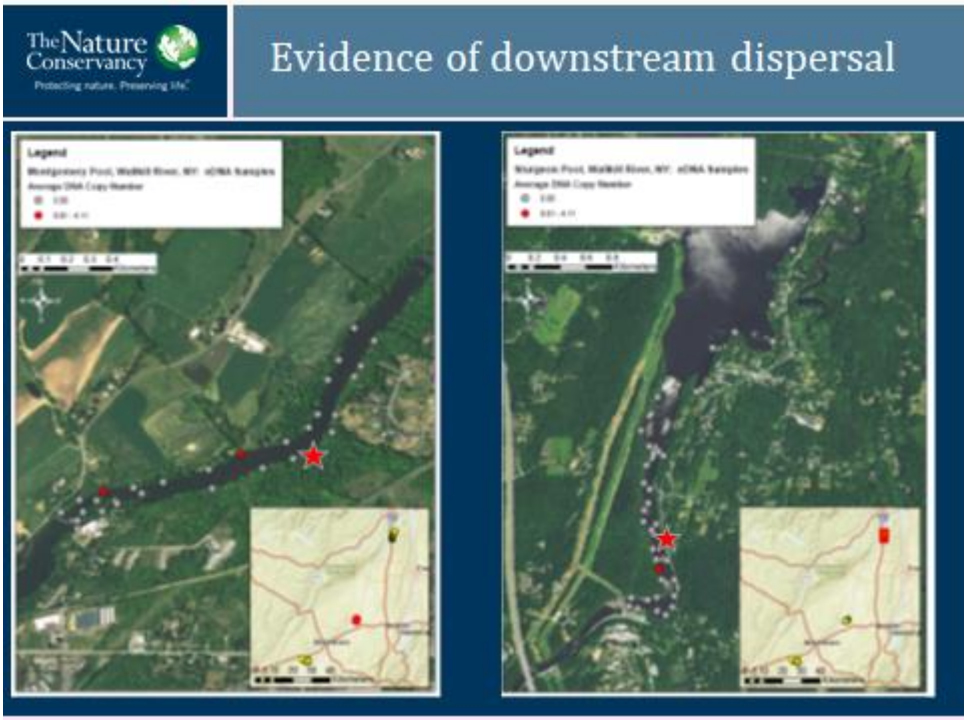
The next slide shows that this river system connects to the Wallkill River and flows down to the Hudson River and on to New York. We repeatedly sampled the Wallkill because we were concerned that by that time the barrier around the fish had been in the system for 2 to 3 years. We know from tag work done in the Potomac River that 30% of the snakehead population is prone to long migrations so there was a strong possibility that some fish may have leaked out of the system and moved downstream. While there may have been successful eradication of the core population there could well be individuals elsewhere in the system capable of creating a new population.



Unfortunately we found two reaches in Montgomery Pool and Sturgeon Pool where we detect snakehead DNA. In 2014 we had one detection in each pool and repeated sampling in 2017 showed repeat detections in both Pools. The fact that we have been able to detect the DNA of snakehead repeatedly provided fairly strong evidence that at least a small number of fish are probably present. The number of detections within that pool had not really changed over the 2 year period suggesting that hopefully we are dealing with a population that is not increasing – hopefully individual fish.



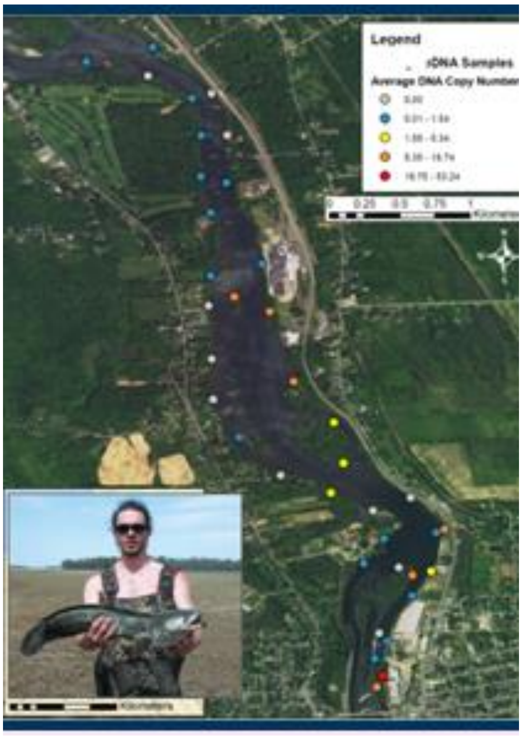
All this work has used a species specific primer to screen the sample for a single species. We are now moving to high throughput sequencing or next-gen sequencing methods (Olds et al 2016). The method enables the sample to be screened for the DNA of all the fish species in the sample (i.e. the whole community). An example of recent research is the study of Olds et al 2016. University of Notre Dame where researchers monitored Juday Creek through their campus for 17 years and 18 species have been detected using electric fishing nets. In a single eDNA survey they picked up 16 species and the two missed were single individuals collected once in 1 year over that 17 year period. It is highly probable that those species are not even present in the system at the moment.



Next-gen sequencing has a lot of potential to cost effectively enable whole communities to be surveyed, not just for invasive or pest fish, but also for other rare and threatened species of interested.

The last slide is another side in the system high risk site/system we investigated. There had been some general surveillance of that system using high throughput sequencing. We screened that and were not expecting to pick up DNA but we did from Northern snakehead. When we re-screened those samples with the marker we failed to detect the DNA and were confused. We then re-surveyed this reach. Two independent labs, two different trips, two new species specific markers and we detected the presence of snakehead DNA in both trips. Taken together those three independent detections suggest that snakehead are present and now the challenge is to confirm that. There are Fish and Wildlife Service Teams out there looking at this reach to confirm the presence of this fish. Hopefully it means we have detected this population early enough to do something about it.

Another advantage of using quantitative PCR, a method that allows you to quantify the amount of DNA in the sample, is where there are multiple detections, you can plot the copy numbers spatially. The red and orange indicate high copy numbers of DNA. The grey indicates no DNA was detected. This data suggests a plume of DNA in the system with fish perhaps concentrated in the upper reaches of the system. This sort of data can be used to focus survey effort – help identify where sampling should occur to maximise probability of capturing a live fish. i.e. where the highest probability of detecting fish is within the system?



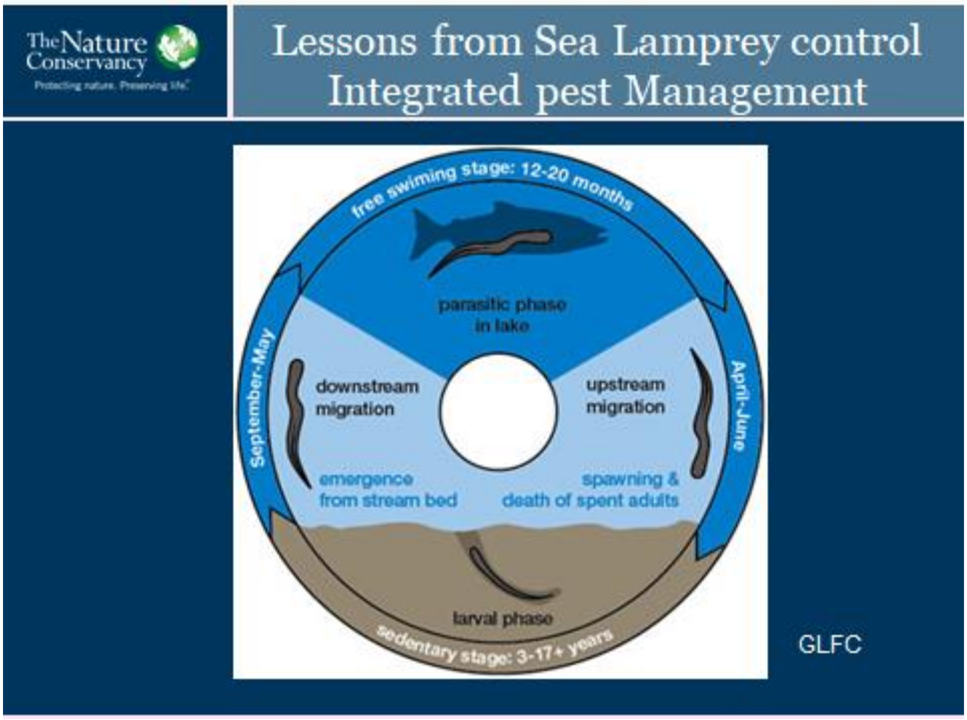
There are lots of unresolved issues with the management use of eDNA. This site and results are an example of some of the issues around management acceptance of this new tool. At this site we originally detected snakehead DNA during part of a general surveillance program – the samples were screened using High Throughput Sequencing and northern snakehead were detected.

- False positives – Because our initial detections effectively was a single positives - we could not completely rule out that this was a result of contamination.

- False negatives – i.e. failure to detect when the DNA is present. When the samples were resampled using a species specific marker we did. The marker that was used only worked with very high densities DNA so it failed to detect the presence of the fish.

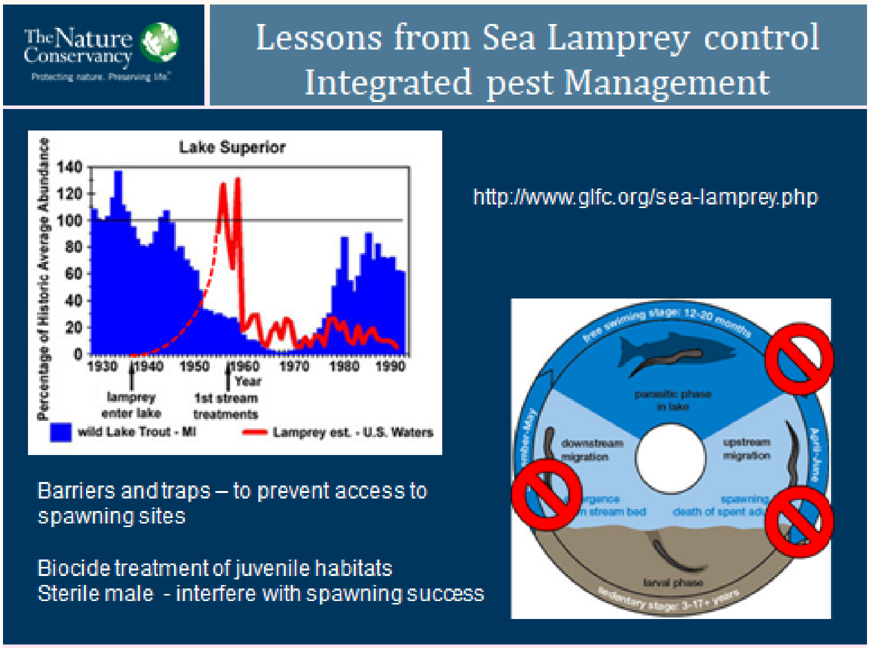
- eDNA capacity. The original samples were collected in 2014 – but results were not analysed and reported until 2016. Much of this work is being done through universities and there is no capacity to turn these samples around rapidly which affects the ability to operationalise the tool – provide results in a management timely manner.

Unfortunately too often we have found that when we detect the DNA of a problem species there has been minimal response efforts – in part because of mistrust of the method (i.e. need to see a fish before the results are believed). But there is also fatalism – owing to the fact that the response tools available are centuries old techniques like netting, fishing and the general fish toxin rotenone. They are pretty blunt tools that may not always be acceptable to the broader community.



However, there are lessons we can learn from the North American situation. A good example of an integrated pest management programme of an introduced fish is the Sea Lamprey control programme in the Great Lakes. This fish colonised the upper Great Lakes through the opening of the Welland and Erie Canals. It is in a parasitic phase when out in the lake, it moves upstream, spawns and the adults die. The larvae spend 3-17 years growing within the stream and then head back out to the Great Lakes. They have huge potential impacts upon the fishery. The Sea Lamprey Control Programme uses a combination of dams, barriers and traps to prevent adults lamprey moving upstream and accessing spawning habitat. Lampricide treatments are used to take out the larval phase before they recruit into the fishery. Sterile males have been used to interfere with spawning success. This programme has been incredibly successful and successfully supressed sea lamprey for the last 50+ years.

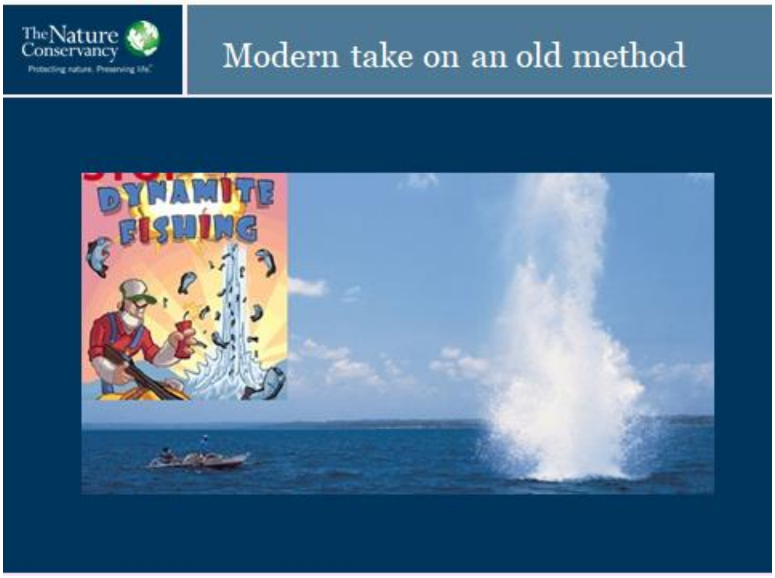
The slide below shows decline in the lake trout population. The introduction of sea lamprey coincided with the massive decline of that fishery but in the late 1950s the instigation of the Sea Lamprey Control Programme saw that population crash and it has been successfully sustained to about 10% to 20% of its original biomass. That programme continues to evolve with research into pheromone attractant and repellents that can be used to improve the success of the traps. Also there are efforts to refine the barriers to allow the native fish through but prevent sea lamprey passage.



The seemingly imminent invasion of the Great Lakes of Bighead and Silver Carp has seen a significant investment from the Federal Government in new response tools over the last six years. Researchers at United States Geological Survey (USGS) are working on novel toxin delivery systems, a micro matrix based on approaches used by the pharmaceutical industry. The approach aims to deliver particles scaled to the preferred food size for Asian carp. USGS are developing a particle with the toxin encapsulated to release into the water body. They have also looked at the feeding time and stomach enzyme activity of these fish and initial research suggests bighead and silver carp are active earlier than the native filter feeders. The results suggest it may be possible to treat selectively and take out bighead and silver carp with minimal impact upon the native community.

This is another tool we and others have been exploring - seismic technology.

It was originally developed by geologists and used by the oil industry to search for offshore oil reserves. The seismic guns put a pulse of sound into the water column. It was found that this could be associated with fish kills. USGS have tested this tool as both a control method and as a way to drive fish into nets.

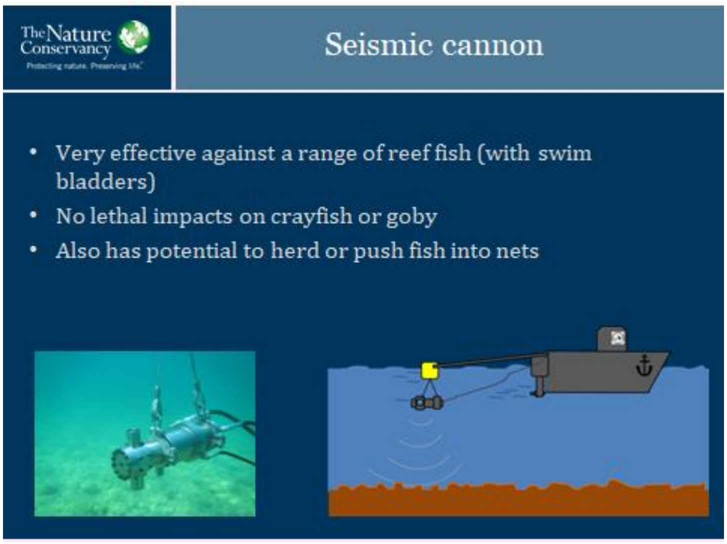


It is a modern take on an old fishing approach but it is nowhere near as exciting.

We have found it very effective against a broad range of fish as long as they have a swim bladder. But we were not able to detect any lethal effects on crayfish and goby, which was what we were trying to control.

It might have potential to selectively remove pest fish in the Rotorua Lakes without impacting koura and bullies.

Perhaps this technology has potential to target brown bullhead with few negative impacts on native species. It also has the potential to herd or drive fish using sound. It may be possible to drive fish into nets.



One of our target pest fish is round goby, a Ponto Caspian species. Within the Great Lakes system there are native fish spawning reef where lake trout, whitefish and herring lay their eggs. This species introduced through the ballast water pathway is now the dominant species on these reefs and makes up about 99.9% of the biomass. When we do underwater video counts on the reef this is all we see. We are lucky if we any other species. It is a key native fish egg predator and competitor feeding on a broad range of invertebrate prey.

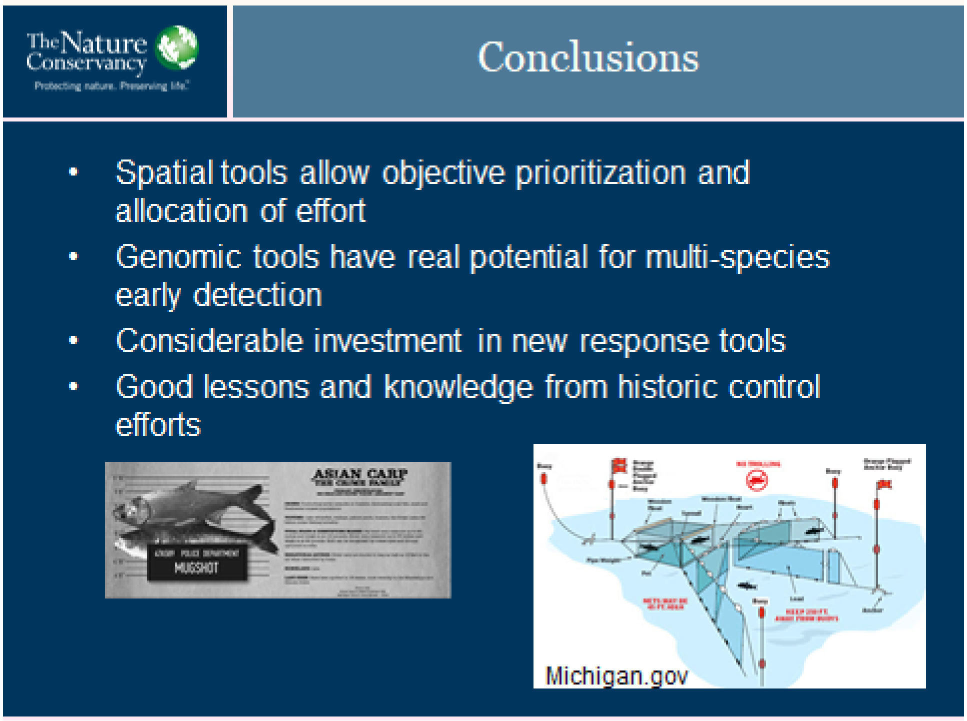
We tried seismic technology which did not work. And now we are testing electricity as a way of control. This shows a Benthic electrical ray used to suppress goby which is a grid laid on the bottom. We electrify it to hold the fish in the field for a time resulting in mortality. If we hold the fish in the field for 3-4 minutes we get 100% mortality. Those little white things are dead goby. But the killing field is small, only 10-15 centimetres above and around the array – we see 100% survival of fish 0.5m from the array. If we bait the array, (on the right) and leave it for 10 minutes we attract large numbers of goby rapidly into the field. So rather than relying on a set of passive tools and the natural movement of the species we can attract goby into this killing field, hold them there, and remove significant numbers quickly. This method may also have potential here particularly given the benthic behaviour of catfish.

In conclusion, in the Great Lakes there is an increasing emphasis in developing spatial tools to allow surveillance efforts to be prioritised.

Genomic tools continue to be refined for surveillance and appear to have great potential for a multi species early detection. Enabling quick coverage of large areas, cost effectively and probably a higher detection sensitivity than many of the traditional tools.

There is ongoing investment in new response and control tools and I think likely plenty of interest in interacting with New Zealand – given overlap in issues. That is something that my colleagues and I can help facilitate.

There are lots of good lessons we can learn from historic management efforts in the Great Lakes. Slide 34 shows a pound net set in the Great Lakes for lake trout. These are massive, structures set for extended periods - continuously fishing over multiple days. This may have potential for controlling brown bullhead within Lake Rotoiti if designed to allow escapement of non-targeted species.



Finally I want to acknowledge the LakesWater Quality Society. It is a pleasure to be here and I also want to note that The Nature is establishing a programme in New Zealand with links to its North American programmes. There may be opportunity for the Rotorua region to engage with my US counterparts and collectively share solutions and knowledge. Lastly I want to acknowledge that most of the work today is from multiple partnerships with my work colleagues and many agencies within the States. Thanks very much.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