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Conservation Genetics on the Frontline

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CONSERVATION GENETICS ON THE FRONTLINE: HOW ONE LAB IS SEEKING
SOLUTIONS TO BIG CONSERVATION PROBLEMS

By

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BA, Montana State University, Bozeman, MT, 2009

Professional Paper

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Environmental Science and Natural Resource Journalism

Conservation Genetics on the Frontline: How one lab is seeking solutions to big conservation problems

Chairperson: Lee Banville

Abstract Content:

Conservation genetics stands out as an effective tool for discovering and monitoring rare, endangered or invasive populations of plants and animals. Particularly when compared to traditional search and capture methods, it provides more holistic studies to preserve the disappearing biodiversity of the American West and the world.

Three stories highlight the work done to preserve biodiversity through the use of conservation genetics:

1. Trout Rescue: A new hope for westslope cutthroat in Montana

How to save a disappearing westslope cutthroat trout through genetic rescue by adding genetic diversity to ensuring future survival in increasingly warming waters more harm than good.

2. New Invaders, New Solutions: Tracking invasive species movements with environmental DNA

Tracking the struggle to stop the spread of invasive species in Montana and the West through a process called environmental DNA, which can find if a single cell of an organism is carried in a drop of water.

3. The True Home of Alaskan Salmon: DNA reveals surprising insight into the birthplace of America's most consumed fish

How finding where a salmon was born through DNA brings up complex questions about sustainability and labeling of fish sold in grocery stores and restaurants.

(Extended project is online at: <https://conservationgenetics.atavist.com>)

Conservation Genetics on the Frontline: How one lab is seeking solutions to big conservation problems with new tools



Flathead Lake

My journey into science journalism first started on a dock on Flathead Lake, where I spent many summers looking out at the immense lake, one of the largest in the West.

I leaned over, and looked into the clear green water as hundreds of native Northern pike minnow swim through gaps in the timber structure. In the warming water of spring, the fish are spawning. I've watched them since my childhood, carrying out the same cycle year after year, playfully swirling around each other.

How long will these fish keep their annual meetings under the dock? How long will the water stay clear?

A few years ago, I heard an alarming statistic. The world stood on average to lose 52 percent of total biodiversity by 2050 to climate change and a host of other human factors.

The world I know of complex ecosystems is changing as new species replace those that can't compete and others slowly disappear into extinction. Aquatic ecosystems are especially vulnerable to increasing temperatures, mainly because species have no place to go.

New solutions are needed to face these challenges.

After reading about this stunning loss of whole species of animals and plants in the [“Living Planet Report”](#) by the World Wildlife Fund, I met Gordon Luikart, a conservation geneticist at the University of Montana. Luikart and his small team of scientists based in Missoula and on Flathead Lake are experimenting with new ideas in species management.

Conservation genetics stands out as an effective tool for discovering and monitoring rare, endangered or invasive populations of plants and animals. Particularly when compared to traditional search and capture methods, it provides more holistic studies to preserve the disappearing biodiversity of the American West and the world.

The technological advancements and falling costs of DNA technologies have allowed development and integration of genetics and genomics research into ecology and conservation, while before it was most commonly used in human health.

Stories

Of the hundreds of stories contained in DNA in vials filling the coolers of the small basement lab these are the ones I chose to explore:

Trout Rescue: A New Hope for Westslope Cutthroat in Montana

How to save a disappearing westslope cutthroat trout through genetic rescue by adding genetic diversity to ensuring future survival in increasingly warming waters more harm than good. Investigation into the future of westslope on this scale hasn't been attempted before as researchers move from maintaining a species to actively helping them to adapt to climate change.

Reporting on this story started as an introduction to Luikart's lab in a class called Story Lab. What developed was a story that showed how science and technology could be used in novel ways to affect the real world. Adding fish to a stream might seem like a simple task but Luikart is striving for a way to do it right.

New Invaders, New Solutions: Tracking invasive species movements with environmental DNA

Tracking the struggle to stop the spread of invasive species in Montana and the West through a process called environmental DNA, which can find if a single cell of an organism is carried in a drop of water.

Work on this story began as part of the Crown Reporting project, an initiative to report more stories centered on conservation issues within the Crown of the Continent. Along with mentor Chris Joyce of NPR a hybrid written/photo story on eDNA and Montana's already present invasive species was produced in 2015. Reporting in multiple locations in Montana and boat trips took place over the summer. The story was published for both a local audience in Daily Inter Lake newspaper in Kalispell, Mont. and Solutions Journal, an international magazine highlighting innovative problem solving.

In 2016, I began to repackage the photo essay and updated reporting on invasive mussels in Lake Powell and California into a new article that also expanded coverage in the progress of eDNA's successes and shortcomings. The resulting photo story and interactive invasive species maps are meant demonstrate to readers the great threat of invasive species and also to introduce invasive species that are already found in Montana. Reworking the material into another story was a particular challenge but ultimately the inclusion of what an invasion looks like made for a powerful story.

The interactive maps aided in reporting and demonstrating invasive species movements. Producing the map required some data wrangling from public databases designed to track observations. I took data from roughly 50,000 invasive species reporting points to create a map for 4 major invasive species already in Montana and 2 mussels.

The True Home of Alaskan Salmon: DNA reveals surprising insight into the birthplace of America's most consumed fish

How finding where a salmon was born through DNA brings up complex questions about sustainability and labeling of fish sold in grocery stores and restaurants.

This story started in an investigative journalism class. To understand salmon labeling and its connection to ensure the sustainability of the fish, I worked as a salmon sample collector for Luikart's lab. This helped me to learn valuable details about a species with which I wasn't very familiar. The data collection or investigating was a good springboard to the issues that underlie salmon management and its importance as a commercial product.

Ethics and Approach

The three stories show the development of genetic science to solve problems and the process of seeking knowledge with the intent of saving species and places. Recognizing that science itself may never have all the answers, fields like conservation genetics allow a movement toward knowledge of how to ensure the survival of as many species as possible on an Earth wounded by human use.

Stories that leave readers with new insight into genetics and species that often fly under the radar can generate answers to why this research and efforts to help a species or prevent the introduction of an invasive one matter.

As a photographer, visual storytelling tied to a person, place or even a fish at the center of each story is an important approach to draw the reader's attention to complex topics.

As a journalist, I tackled these three stories as problems that need to be looked at and understood by the general public in order to address the future of these species. If you asked someone why a species was important to them they may not have an answer and if you asked them about how genetics had shaped their world you might be met with a blank stare.

My intention with these stories is to tell a reader why they might begin to care about invasive species, salmon and cutthroat trout and what kind of powerful weapon genetics may be in the fight.

With all of the stories centering on the research of one lab, I started with initial sources from a small group of geneticists and biologists working on similar problems.

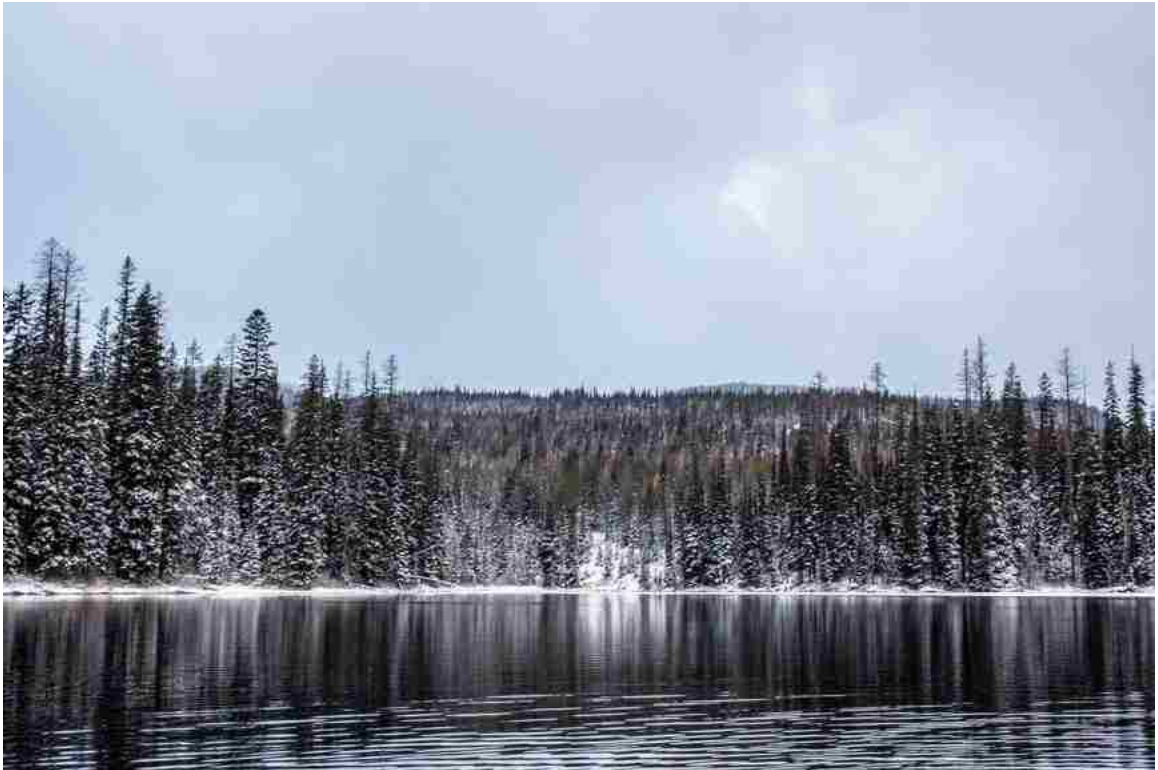
It was a challenge to work closely with one lab, which is important to gain knowledge of the research and particularly of a dense genetic topic. Genetics has its own language often only understood by fellow researchers. Dissecting research and papers took serious translation both in reporting and in the written stories.

From there, I found that there were many opinions from within the broad scope of an issue. Government managers, researchers, advocates and citizens are all trying to reach the same goals of species conservation but with different approaches.

Publication

All three of the stories are currently published as multimedia stories in the online platform Atavist at conservationgenetics.atavist.com and will be pitched to local and national publications.

Part 1: Trout Rescue: A new hope for westslope cutthroat in Montana



At Bunyan Lake in Montana, Conservation Geneticist Gordon Luikart and a team of scientists are working to test the effectiveness of genetic rescue of a small enclave of Westslope cutthroat trout for further use on the larger struggling population.

In the Mission Mountain Range of Western Montana, Herrick Run flows in the shadow of Lindy Peak. The small, snow-bound stream tumbles down a series of steep drops into Lindbergh Lake and eventually the Swan River. But here above the lake is a population of stranded westslope cutthroat trout and the home of an important experiment aimed at saving them.

How the fish ended up here is unknown, since fish cannot make their way up the steep cascade. Somehow, the small populations in the creek as well as in nearby Meadow Lake and Bunyan Lake are hanging on. But stagnant population growth and a lack of genetic diversity leave the trout at risk of disappearing.

It's the kind of situation Gordon Luikart, a conservation geneticist at the University of Montana, needs to develop to boost the population of fish through a process called genetic rescue. Above his desk in his office overlooking the shoreline at the Flathead Lake Biological Station are two large fish prints, one a bull trout, the other a cutthroat. As both a fisherman and biologist, these are two fish he cares about.



Map of Herrick Run in the Mission Mountain Range ([NorWeST](#))



Herrick Run, a tiny stream in the Mission Range of Montana

Across Montana and the West, there are thousands of small fish populations that have been isolated by shrinking habitats. Scientists until now have seen habitats disappear, as populations get thinner. There is now a movement to start actively helping the fish survive and restore them to new areas.

“Right now the mindset in salmonid fish at least, they home to their natal [birthing] streams and they are very locally adapted,” says Luikart. “You don’t dare move them.”

But that thinking may have to change as ecosystem changes place the fish in hotter water. Luikart is one of the scientists leading that charge.

Among the boulders of the trickling Herrick Run and the closed-in lakes are a few fish that otherwise might have been forgotten. To help the declining population, Luikart and his research team are testing the effectiveness of introducing small numbers of trout to

enrich the genetic diversity of the isolated fish. Adding new fish genes into the population may help the entire population fight disease and perhaps to adapt more easily to changing conditions

Native bull and cutthroat trout, including westslope and its distant cousin the Yellowstone cutthroat, are in peril as climate change has increased air temperatures by 1.4 degrees Celsius in the last 50 years, water temperature closely follows air.

Westslope cutthroat trout reside on both sides of the Continental Divide from the Upper Missouri watershed to the Columbia River Basin. But the westslope's range is shrinking as waters warm. They are estimated to occupy 10 percent of their historic range.

These trout have also struggled to compete with species like brook and rainbow trout that were introduced widely for sport fishing.

As a result, westslope were considered several times for listing under the Endangered Species Act and still remain a potential candidate for listing.



Juvenile Westslope cutthroat trout raised for release at Creston National Fish Hatchery in Montana



Matthew Boyer (left) talks to a conservation ecology class at Sekokini Springs hatchery near Coram, Montana. In the small warehouse, workers raise westslope cutthroat trout for conservation and restoration projects across Montana.



Hatchery Manager Scott Relyea demonstrates the artificial crossbreeding process, while scientist Gordon Luikart looks on.



Scott Relyea squeezes eggs from a female westslope after making a small incision in the abdomen.

Eggs are then combined with sperm from males.



The fertilized eggs are placed in incubation trays for several weeks in constantly circulating cold spring water to simulate stream conditions. From there, with already developing eyes they are placed in the RSI buckets in Herrick Run.

Further up the rutted road from Herrick Run is Bunyan Lake. The sky above the tiny lake swirls with snow and swath of fog hanging in the air in the nearing dark of a winter evening.

The lake, though quiet, is an active laboratory to gauge how effective introducing a less inbred fish into the population might be, thus enlarging its gene pool and increasing overall survival.

The researchers hope introducing new fish into the population will change the close relations, or “cousin problem,” for the remaining trout by injecting new blood into the stream.

In 2014, Luikart and his team collected eight trout from Herrick Run and crossbred them with westslope from a remote and genetically pure population in the South Fork of the Flathead River.

The breeding was done at the small Sekokini Springs hatchery, where biologist Matthew Boyer and Montana Fish Wildlife and Parks fisheries technicians work diligently to fertilize the eggs.

Amid the roar of rushing water from circulating pumps in fish rearing tanks, Luikart and his students from a summer conservation biology class watch the slicing and squeezing of each westslope to remove its eggs or sperm before combining the two into bowls. In a process that resembles a strange cooking show, the year-old fish, carried to the hatchery from distant mountain lakes are sacrificed for future generations of healthy fish. The team then carefully places the eggs in trays to develop for a few weeks.

The hope is that, once released, the crossbred fish will restore healthy genetic diversity to Herrick Run and surrounding lakes. Boyer knows that if a small population can be helped this way there are other fish that will benefit as well.



Remote stream-side incubators at Herrick Run
(©Seth Smith)

“East of the Divide, the cutthroat populations almost invariably are at very low levels of genetic variation,” Boyer says, “but what we need to know and this experiment will hopefully help validate or inform is where, when and how often do we need to have assisted migration and genetic rescue and then how do we quantify the results?”

With an excitement equal to that of his students, Luikart peeks at the tiny

salmon-colored eggs that will eventually grow into fish in Herrick Run. For the past two summers, scientists raised new batches of cross-bred fish and moved them into the stream.

The trout are placed inside in-stream buckets called remote stream-side incubators, or RSIs, in the upper part of Herrick Run to ready them for release in the lakes and stream.

The effects of introducing new genes over the last few years should be immediate, but so far the crossed fish they have introduced are elusive, and only a few have reappeared in follow-up surveys. But the researchers are confident that the population will improve as they continue the work. Over time, researchers believe, they will be able to recognize the different genetic traits of the introduced fish working their way into the populations naturally, and hopefully increasing the population size.

But they also know they need to be careful.

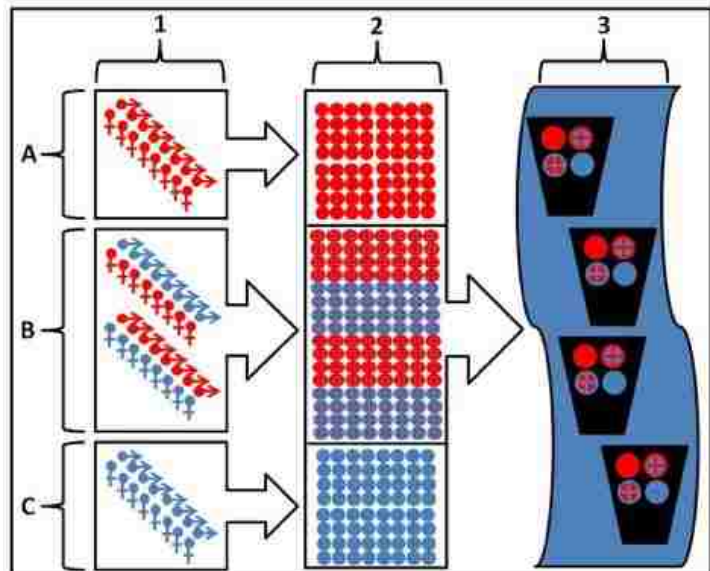
If they introduce a new population of fish too quickly, they may overwhelm the already localized population's ability to adapt to the local temperature and environment. Done wrong, these introductions could easily erase good genes.

It's a balancing act that Luikart has performed before. He first used genetic rescue to stabilize a population of Bighorn sheep at the National Bison Range in Moiese, Mont.

The effort strengthened the herd and helped researchers understand how populations can be increased through introducing more diverse genes.

Fish, he finds, are a bit easier to deal with. Moving fish around the state is a far less onerous bureaucratic task, as long as there is little potential for further damage to an already imperiled fish. Plus, their work may help fishery managers in the entire westslope region.

On the western side of the Continental Divide, there is a focus on conserving and maintaining the populations, but east of the divide the situation is more dire and fish introductions like those at



A graphical representation of the experiment to cross inbred residents with fish from other locations. The four black buckets represent those shown in the photo above. (Luikart)

Herrick Run to increase the populations are needed.

Relocating any species can come with a cost; the same part of human nature that is trying to solve the problems of genetic diversity for the fish to Herrick Run is the same that caused the problems through initial alteration of the ecosystem, says Robb Leary, a fisheries geneticist for the Montana Fish, Wildlife and Parks.

“We are darn good at moving fish around,” he pauses and adds, “in fact we are suffering from it.” Rainbow trout and other fish in new locations are a product of once-thought positive introduction goals.

Warming streams can accelerate introduced species’ population growth. Rainbow trout that displace and hybridize with westslope cutthroat have a competitive advantage in warmer climates.

Luikart adds to this, “Go to a fish hatchery and see the fish that are swamping them out.” There is considerably more production in hatcheries to introduce rainbow trout than westslope trout.

Fisheries biologists can only try to correct past mistakes, while not making new ones, and maintain the populations that are surviving.

Leary says, “We are making the best decisions we can with the data we have,” much of the data on hybridization and health of populations in Montana is incomplete. But as new data comes in, Leary says he feels that even in western Montana the situation for cutthroat trout is dire, and immediate action is required.

Where native trout have been pushed to the cooler water, these tributaries are their last refuge.



A fish fry raised in Herrick Run in a remote stream-side incubator



Half of the fry are released and the other half are preserved to be compared genetically to future generations.



Seth Smith prepares genetic samples for PCR testing at the Montana Conservation Genetics Lab in Missoula.



Seth Smith inserts the chip into the PCR machine. After several hours the data appears on the screen.

Leary says, “Isolation is our friend and enemy.”

Researchers like Seth Smith are hoping to minimize the downside for those fish.

At the University of Montana’s Montana Conservation Genetics Lab, in the basement of a small research building in Missoula, Smith is using a household salad spinner to mix a chemical solution.

As he pulls a tray used in DNA testing out of the spinner, he gestures to the expensive, but broken, plate spinner labeled ‘MPL1000’ in the corner. The salad spinner labeled in marker ‘Roto-DNA’ with a skull and crossbones, rarely fails and does much the same job.

Smith sits at the bench and goes through a series of dilutions lasting many cycles. It’s an exercise in repetition, pulling the bottles of chemical solution from the shelf above the bench and filling the pipette lines with additional chemicals in different dilutions.

He has assembled 96 DNA samples from fin clips or flesh of different fish. Each chip is set into a clear plastic tray are combined with 96 wells of chemical solutions designed to identify different genes, looking for variations in the genetic code.

“It’s like baking 96 times 96 different cakes at once,” says Smith as he looks at the messy lab bench for a calculator and corrects himself, “9216 cakes.”

Each “cake” is a tiny square that looks like a transparent black computer chip on a clear plastic tray. The chip has wells on the side to hold genetic samples and assays that will be combined through tiny, almost invisible tubes in the center. Essentially, once each of the genetic samples is in the chip a photograph is taken that will test for the presence of differing alleles, or versions of gene.

A large blue box opens suddenly, looking and sounding like a CD drive, waits for the tray with samples to be inserted.

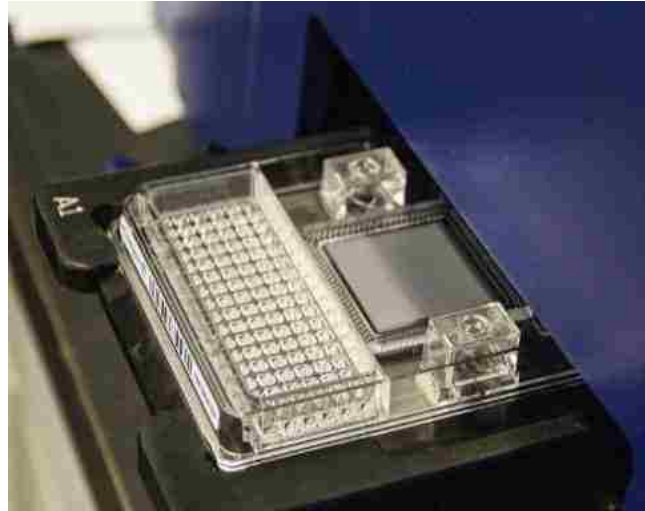
This is when skin cells, hair, or dung become a set of data that a geneticist can use to infer what cannot be seen or measured through observation. Once the sample enters what Smith calls the “magic box” you can start to see the invisible fluids come to life. A few hours later the chip emerges from the box.

The power of the SNP test or Single-nucleotide polymorphism, representing the change of a single molecule in all of the fish genome, is its speed.

Once the tests for thousands of SNP variations are run, the data generated can be instantly viewed and processed. Smith looks over the mountain of numbers in a spreadsheet, but the numbers are combinations of only ones and twos.

'1' represents westslope and '2' represents rainbow trout genes in an individual fish. He is looking at a simple test to measure the amount of hybridization between the differing species.

Smith measures the inbred level and hybridization level in these small populations to prepare for introducing a more genetically diverse westslope trout this summer. The fish above Herrick Run have remained 99 percent pure based on genetic testing, which is a positive for the fish.



The chip where genetic combinations take

Often, barriers such as a steep cascade or diversion dams can both help and hinder a population, shielding them from hybridization but also cutting them off from broader gene pool on the other side of an obstacle. Even extremely genetically pure fish populations are walled off intentionally to preserve their genetics by biologists.

Luikart soon hopes to start genetic rescue of westslope populations east of the Continental Divide with the same techniques used in Herrick Run. They also want to gauge the difference between crossing a genetically healthy Missouri River-based trout versus a Columbia River fish, species that have several thousand years of genetic divergence, to gauge which rescuer is more effective. But that might mean moving fish over evolutionary boundaries that would otherwise take ice ages and geologic timescales to cross. Now science can accomplish this with only a few years of hatchery breeding.



The plate spinner

When the snow clears, the field crew will go up to Herrick Run to continue genetic testing on the isolated populations of westslope. The introduction of new genes into the small stream may mean a stronger population, but a problem can come from mixing in populations that are not locally adapted to the stream conditions, such as temperature and habitat. Maintaining natural local adaptation that can take thousands of reproductive cycles is tantamount.

Although it's difficult to reverse the effects of humans altering natural adaptation, it might be the only way to maintain a struggling population.

Still, Luikart believes the technique to correct inbreeding could serve as a model for reviving westslope in areas where they continue to struggle, like across Eastern Montana, by gently introducing new genes that should ensure stronger survival traits into the already imminent future of climate change in Montana's streams.

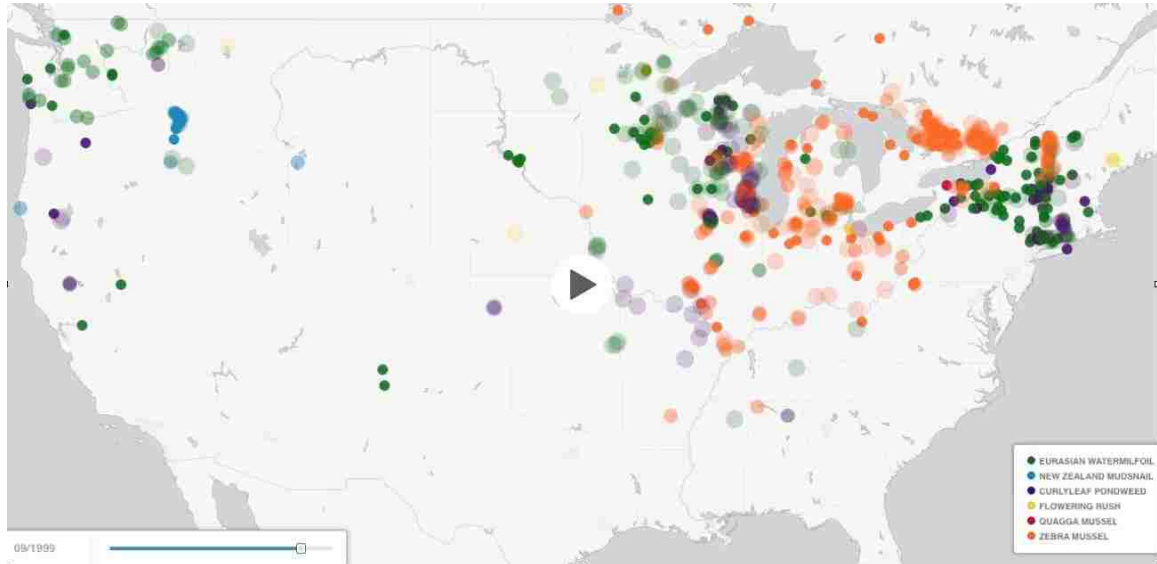
"We have to do this slowly and carefully," says Luikart, without that measure they could do more harm than good.



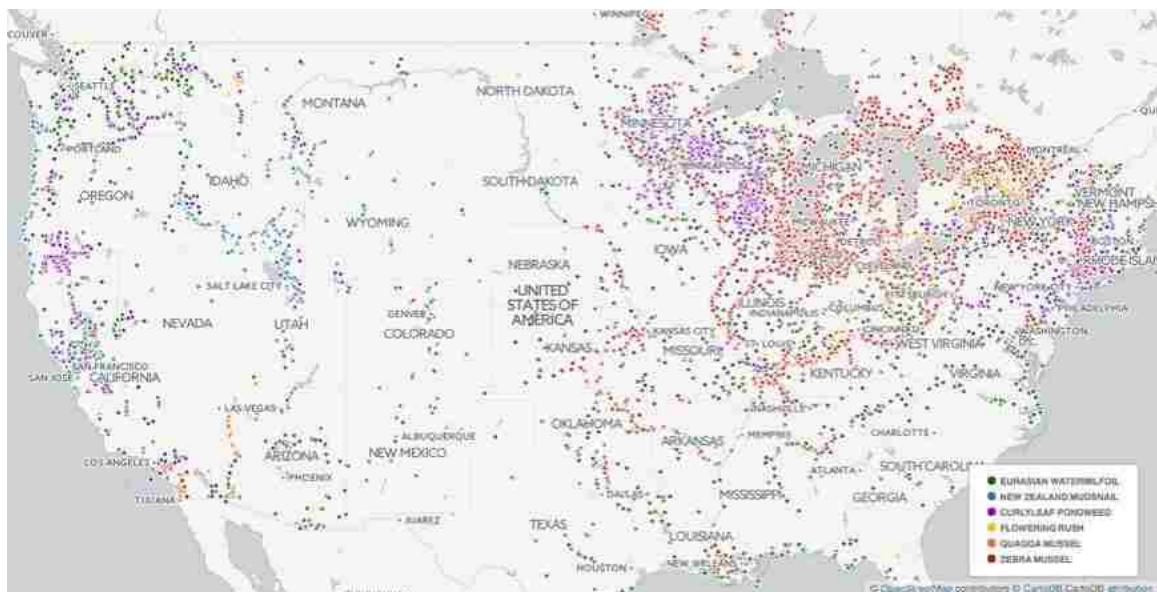
Looking towards the isolated lakes in the forest of the Mission Mountain Range

Part 2: New Invaders, New Solutions: Tracking invasive species movements with environmental DNA

How did invasive species spread in the U.S.?



DNA can be used to track the wide variety of aquatic invaders including plants, fish, amphibians, pathogens, and invertebrates like mollusks and snails. Quagga and zebra mussels aren't yet established in the Northwest but will destroy any ecosystem they populate. (Ken Rand/[CartoDB](#) Data Source: [USGS-NAS](#), [UGA-EDDMapS](#))



Aquatic invasive species threatening Montana have already arrived with the exception of zebra and quagga mussels. The clickable points represent invasive species observations; some introductions failed, while other locations don't show the full extent of infested waterways. (Ken Rand/[CartoDB](#) Data Source: [USGS-NAS](#), [UGA-EDDMapS](#))

Environmental DNA and Aquatic Invaders: A powerful tool in invasive species detection

Environmental DNA (eDNA) has the potential to detect any species from a single drop of water.

This power has the potential to vastly improve early detection of invasive species, which is more commonly done through visual microscopy.

eDNA can distinguish plants and animals more readily than the human eye allowing detection of minuscule juvenile dreissenid mussels called veligers that threaten waterways.

The sensitivity of the test also creates potential for errors often through differences in collection methods resulting in changed detection rates. Despite these challenges eDNA is advancing species detection, allowing for quick results and finding species that may be overlooked.



Lake McDonald in Glacier National Park is a popular recreation area with high potential for invasive species introductions. The park requires self-certification for all boats and manages several seasonal boat inspection stations near entrances, but the system is not without some gaps. Boat ramps are the most likely places for invasive species to pop-up if introduced.

“If you detect a cancer early, like an invasion or tumor, you can excise it early from the body or ecosystem,” says Luikart, who hopes to establish regular testing for invasive species of Montana’s waterways.

Often, invasive species can go years undetected until discovered and by then the chances of removal are nearly impossible due to the rapid ability for species to reproduce.

Luikart hopes to monitor large scale lakes and rivers in Montana, including where he works on Flathead Lake. His research group also received funding for a stationary device to collect sediment samples at sites that receive heavy human use to monitor for invasive species.

The state already spends \$1.1 million a year on aquatic invasive species prevention, most of it on boat inspection stations that dot Montana highways.

Invasive species can do real damage to lakes and streams by clogging waterways and forcing out native species. However, the strongest argument for preventing invasive species is an economic one.

According to the Pacific Northwest Economic Region Group: Hydroelectric dams, water quality, agriculture, recreation, and fisheries and other ecological systems will all be negatively affected and incur additional costs that are passed on to consumers, electric bills and tourism losses.

To look at what an invasion might look like I headed to a place that had failed to keep mussels out and was now trying to keep them in.



Gordon Luikart, a conservation biologist based at the Flathead Lake Biological Station near Woods Bay, Montana, is working on perfecting environmental DNA, a test to quickly detect aquatic invasive species. “We developed our own test from DNA sequences on zebra and quagga [mussels] and just started applying it,” says Luikart. “So far, the test is sensitive enough to detect invasive species in controlled environments. Outside the laboratory there are many barriers that make accurate tests much more difficult.”



Zebra mussel (top) and quagga mussel

Time-lapse maps of individual species:

[Zebra mussels](#) (*Dreissena polymorpha*)

[Quagga mussels](#) (*Dreissena bugensis*)

[Eurasian watermilfoil](#) (*Myriophyllum spicatum*)

[Curlyleaf pondweed](#) (*Potamogeton crispus*)

[Flowering rush](#) (*Butomus umbellatus*)

[New Zealand mudsnails](#) (*Potamopyrgus antipodarum*)

Lake Powell and quagga mussels: Keeping them out means keeping them in place



A colony of exposed quagga mussels at low water in the winter. By Memorial Day, when most visitors to the lake arrive, the water level has been brought up and the mussels aren't as visible. Yet the shore of lake beneath the surface is quickly being covered. Estimates place the mussel at taking another 5 years before they are found in every part of the 200-mile-long lake.



In 2007, an eDNA test pointed to mussels in Lake Powell but the precise test didn't lead to visual confirmation that mussels were in the vast waterway on the Colorado River in Arizona and Utah. State and park officials endured several years of detection of mussels in genetic testing, but diver surveys that turned up no mussels. In 2012, a small colony of quagga mussels were thought to be eradicated, through treatment of infested areas. In 2013, the National Park Service found hundreds more quagga mussels growing in the waters of the reservoir. They had been there for years. After years of intense eradication, education and monitoring efforts, park officials were forced to admit defeat. The mussels had won. Instead of being a target for incoming mussels from millions of visitors per year, Lake Powell was now on the list of places that might start spreading the mussels to other states. Inspectors now check boats entering for new species, and boats going out are decontaminated and quarantined for up to a month before they can go in another lake.



A total of 2.4 million people visited the park in 2014 with thousands launching or renting boats. The cost for containment through boat inspections and decontamination of exiting boats may soon reach \$16 million a year, not including maintenance and removal of mussels from beaches, docks, boats and the pipes and screens at Glen Canyon Dam. The large number of boats are also responsible for moving the mussels to new parts of the lake. The movements on the lake and in the Colorado River are tracked by tow net samples that collect sediment that is then examined through a microscope. DNA tests are used to confirm visual results.



Wayne Gustaveson, a Utah state biologist, manages the sport fishery on Lake Powell and keeps track of how the mussels are colonizing the lake. For him, seeing mussels arrive was only a matter of time. Lake Powell had a target on its back, he says, as the lake was under heavy pressure from visiting boaters.



Quagga Mussels at Lake Powell, Utah. Larvae of the small bivalve are undetectable with the naked eye. DNA can be a powerful tool for finding what other detection methods miss.



At the Castle Rock Cut, an area once under 150 feet of water, the park service cut a canal into the red-sandstone rocks for boats to pass to the main part of the lake. The cut, built in 2014, is one of the best places to watch how quickly mussels are colonizing the lake. Upon newly exposed rocks flooded in the summer they have formed dense colonies.



Wayne Gustaveson suspects the name Lake Powell will soon be synonymous with mussels, much like Lake Mead and Lake Havasu. “We’re on the naughty list now,” he says. It’s hard for him to watch quagga mussels take over. They are expected to be in every part of the lake within five years.



Wayne Gustaveson, a Utah fisheries biologist looks at colonizing quagga mussels at the Castle Rock Cut on Lake Powell. The mussels will take food away from other organisms like fish that feed on the same nutrients.



Wayne Gustaveson looks at rental boats near Wahweap Marina for signs of mussels. Lake Powell has an incredible number of boats. Many of the large houseboats that stay in the water or in storage for the winter must be cleaned once or twice a year to reduce buildup of mussel colonies.



Lake Powell remains a popular destination for international visitors to nearby national parks. The introduction of mussels won't slow the millions of tourists, but it has already increased costs to boaters.



Water levels in Lake Powell have fallen by 150 feet since reaching full capacity in 1980. The lake is now at 50-percent of normal levels, exposing a white calcium bathtub ring and in areas where the lake fluctuates seasonally, the quagga mussels that hide beneath the surface.



The Glen Canyon Dam may incur extra costs from mussels clogging pipes. The costs come from removing and clearing mussels from intake systems and also installing mussel prevention systems, such as screens, resistant paint, and UV light filters. Despite these systems being in place, the quagga mussels are now on both sides of the dam and possibly moving into the Colorado River.



As the Colorado River sees less runoff, declining water availability puts Lake Powell (and Lake Mead) in jeopardy. Maintaining enough water to operate dams and fulfill the needs of municipal and agricultural water users will be a problem in the future. An influx of mussels may further degrade the value and effectiveness of the dam due to increased maintenance costs.



French and Chinese tourists driving between Bryce Canyon and the Grand Canyon take a tour of Glen Canyon Dam in December. The chill of winter doesn't deter thousands of international tourists from visiting the region a few days after Christmas.



The Colorado River below Glen Canyon Dam reveals what the canyon now under Lake Powell once looked like. Some advocates say the declining water levels are here to stay and that the dam should be removed. One thing is clear: the reservoir at full capacity is not likely to be seen again as millions of gallons of water are lost to evaporation each year. The loss of more water will make the lake harder to navigate and launch boats on and threatens effective operation of the dam. The mussels will endure rising temperatures and, even without the dam and reservoir, could thrive in the river.



The future of Lake Powell's water is uncertain, but one with quagga mussels is guaranteed.

San Justo Reservoir and Zebra Mussels : Closed for 9 years, future treatment may be first large-scale eradication



San Justo Reservoir near Hollister, California is one of the only Western sites of zebra mussels. In 2007, a fisherman came across a few mussels in the lake. Within a few weeks officials permanently closed the small lake to the public; it has remained so ever since. The reservoir was closed to prevent further spread of zebra mussels (seen on the shore), particularly to larger nearby waterways such as San Luis Reservoir and the California Aqueduct. The mussels are thought to have been introduced from fishing bait sold from out of state.



Kelley Aubushon, California Department of Fish and Wildlife Environmental Scientist, inspects tiny zebra mussels growing on the underside of rocks, as Dave Meraz of San Benito County Water District looks on at San Justo Reservoir near Hollister, California. The small size of the reservoir makes possible treatment with potash, a non-chemical method for killing bivalves, while still using the water for agriculture in the surrounding valleys. The water is very important to agriculture in the area during the current drought.



San Justo was closed in 2007 to prevent further spread of the mussels to canals and waterways. "The risk of these getting out was too great. They're too afraid that if they got into the Central Valley Project we'd be billions of dollars in the hole," says Kelley Aubushon, a California Department of Fish and Wildlife Environmental Scientist.



Dave Meraz of San Benito County Water District leans in to look at Zebra Mussels in San Justo Reservoir. As manager for the agricultural district, Meraz keeps the reservoir levels low to kill off the mussels in the winter, starving them in oxygen-poor water that limits growth. Despite being closed for many years, San Justo still serves agricultural and municipal water users.



Each female zebra mussel has the ability to produce up to a million offspring in a lifetime of several years. The tiny larvae are no larger than a fingernail and often invisible. The cost to eliminate the mussels from the reservoir is estimated between \$3 to \$4 million. “There’s not going to be a do-over. That’s what we need to remember. There isn’t going to be a second chance to so it’s gotta be done correctly,” says Kelley Aubushon.



Kelley Aubushon holds a juvenile zebra mussel, shown here at San Justo reservoir near Hollister, California. These are often the first visible sign of a new invasive species introduction. When the mussels were found in San Justo they may have already been established for three to four years. Aubushon works in the Quagga-Zebra Mussel Program to prevent mussel introduction, but hasn't found eDNA helpful in detecting in the 12 counties she serves. Lab results often come up with false positives that can't be confirmed. Instead, her lab uses microscopy from plankton tow-nets to look for small mussels. The goal is to keep invasive species from spreading. Southern California has the quagga mussel from Lake Mead; another mussel would come at a huge cost to agriculture and other resources in the area. By focusing on detecting mussels before they become established, scientists may be able to stop invasive species before it is too late to extirpate them.



The boat launch of the popular local fishing and recreation area has been closed for nine years due to an introduction of zebra mussels. There is no timeline for treating, eradicating, and reopening the area, but a treatment plan is now drafted. Once funding is available, officials will treat the lake, knowing that they only have one chance for eradication. The first successful treatment of mussels was at Christmas Lake, a small pond in Minnesota.

In Montana: 'looking for a needle in a haystack'



Flathead Lake, one of the largest freshwater lakes in the American West, remains a particularly clean water source and one of the most popular recreation areas in Montana. Introduction of an aquatic invasive species might change the lake forever. "Flathead Lake is by far the most likely location of invasion," says scientist Gordon Luikart.

Invasive aquatic plants don't get as much attention as mussels, pathogens or fish, but the potential for damage is great.

Invasive plants, like Eurasian watermilfoil, have been blending into Montana's waters for decades. Many people miss the early signs often thinking a plant was there to begin with and cannot do as much damage.

Still aquatic plants can be detected by eDNA just the same as any other, but the response to finding them may be different.

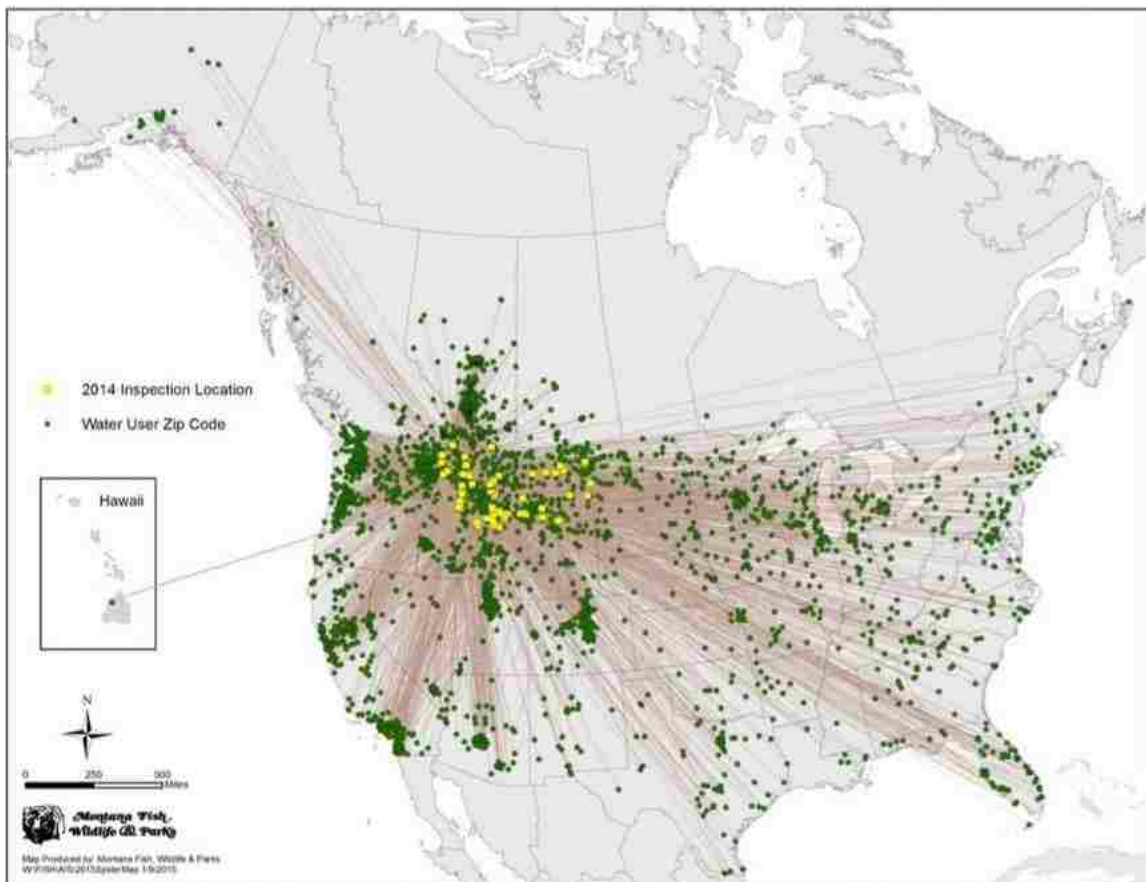
An introduction of an invasive mussels effectively means the end of an aquatic ecosystem. Mussels will rapidly alter water quality and changing species composition and habitat forever.

This brings back the importance of early detection for all invasive species, plant or animal, especially for Luikart and his team.

Caryn Miske director of Flathead Basin Commission is optimistic the future of eDNA and looks forward to putting it to use in protecting the Flathead Lake.

“You’re looking for a needle in a haystack,” says Miske “with mussels, even if you detect early, you’re often not able to save that lake, but you can save other lakes, and with invasive plants there is likelihood that we can actually do something.”

Luikart and fellow scientists currently test lakes and rivers in the region at the request of many groups with an interest in preserving water quality and ecosystems. The tests they run from sampled water always include a known species like a trout, a possible one like Eurasian watermilfoil and quagga or zebra mussels, just to be sure.



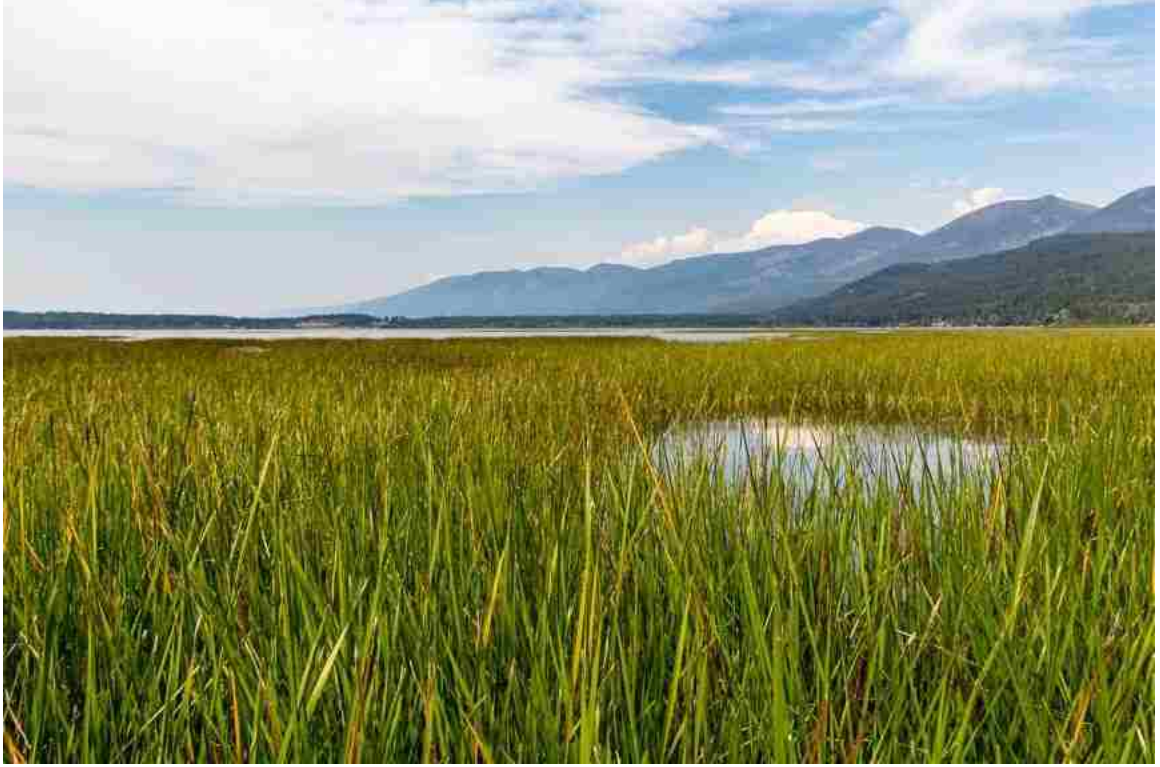
Potential invasive species in boats converge on Montana. This map shows a survey of boat inspection stations in yellow in 2014 connected by lines to where visiting boats are arriving from recorded by zip code in green. ([Montana Fish, Wildlife, & Parks](#))



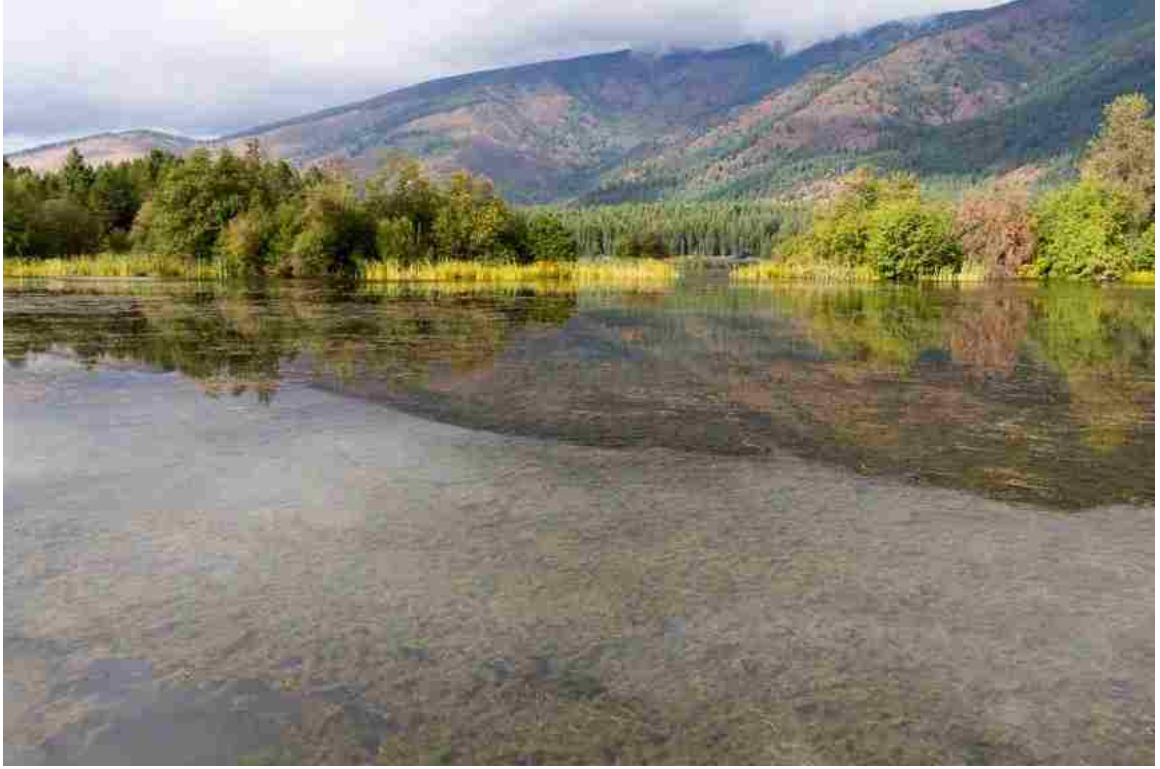
Two boats arriving at Flathead Lake in March each had a single mussel on the bottom of their hulls. The boat and mussel pictured above were traveling from Lake Havasu. Within the first two weeks of operation a boat inspection station in Pablo, Montana found the mussels as part of a pilot project to intercept boats that travel to the state before Memorial Day. Currently, the only way boats will be stopped is if an inspector sees them or if trained mussel dogs deployed in a few places throughout the state sniff them out. If boats carrying invaders reach Flathead Lake, a mussel colonization is possible. eDNA could be another tool to monitor for invasive species that get past boat inspections or travel when the stations are closed. (© Flathead Basin Commission)



Virgil Dupuis, Extension Director at Salish Kootenai College, looks at an invasive flowering rush plant that forms dense mats in parts of Flathead Lake. The plants are visible on the south shore of the lake as they emerge from the water. “I hate this stuff,” he says with a laugh.



Flowering rush, seen here, can be identified by a triangular stem section and flowers. By late summer, the plant has entirely overtaken the boat launch on the south shore of Flathead Lake near Polson, Montana. “This kind of a habitat favors invasive fish like bass and perch,” says Dupuis. These fish are not native to the lake, but they thrive by breeding in the flowering rush. They outcompete native fish like endangered bull trout and declining westslope cutthroat trout, Dupuis says.



Eurasian watermilfoil has overtaken sections of the Lower Clark Fork River where it runs wide behind a dam. The waterway is unnavigable by boat as large swaths of the shoreline and shallow backwaters are overtaken with dense chains growing in the Cabinet Gorge and Lake Pend Oreille and at Noxon Reservoir, seen here.



Eurasian watermilfoil on the Clark Fork River blocks the light and growth of other plants by forming a dense drifting mat. Parts of a flowering rush plant break loose and float away. Each floating piece, called a rhizome, is a potential rooting plant that will drift to a new location and take root. The non-native milfoil can potentially choke an entire waterway if left unchecked, and can stretch up to 30 feet from the floor of a lake to the surface.



In 2007, invasive Eurasian watermilfoil was discovered by accident in Beaver Lake, an isolated lake northwest of Whitefish, Montana. Since then, the lake has been treated yearly to eliminate infested areas, and the unwanted plant is thought to be nearly eradicated. eDNA was able to successfully confirm the difference between a native milfoil and the invasive version in the lake and to ensure that it wasn't traveling to other lakes in the region.

For more on invasive species in Montana and eDNA, see my story originally published in [Solutions Journal](#) and the [Daily Inter Lake](#).

Part 3:

The True Home of Alaskan Salmon: DNA reveals surprising insight into the birthplace of America's most consumed fish

The silver skin and pink flesh of a salmon may be labeled “Alaskan Wild” but researchers have found that the truth may be harder to label.

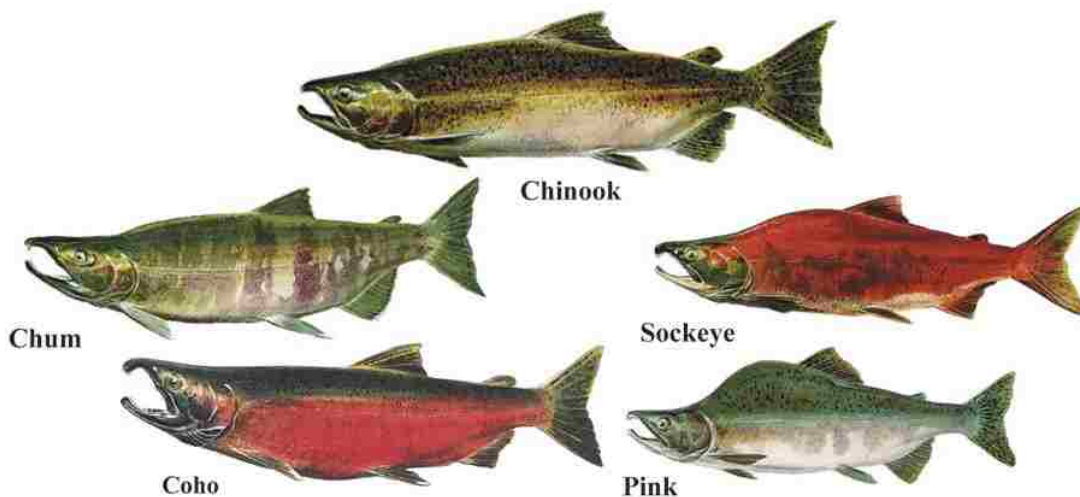
Conservation geneticist Gordon Luikart and research scientist Seth Smith at the University of Montana’s Montana Conservation Genetics Lab are using a quick genetic test to determine the probability of where individual salmon originate to better understand how large demand for salmon affects dwindling stocks.

And their early results raise real questions about how suppliers can and should label salmon. An initial study found that 10 percent of chinook salmon collected at grocery stores in 2014 came from threatened or endangered populations, including those from the Upper Columbia River, Willamette River and rivers in the Puget Sound.

The analysis found that since the fish swim long distances, the point where fish are caught is often less important than the place where the salmon are born.

Or put another way, the ‘Alaskan Salmon’ sticker at the fish counter could actually read, ‘Columbia River salmon, by way of Alaska.’

The results raise new concerns about how to help stabilize salmon species, including: sockeye, pink, chinook, coho, chum, all of which are imperiled at least in some local populations. Chinook salmon in the Puget Sound and Strait of Georgia inside Vancouver Island, for example, have declined by 60 percent since 1984, according to the Pacific Salmon Commission.



Pacific Salmon Species [USFWS-AK](#)

Despite these problems the heavily regulated and monitored Alaskan salmon fishery has not seen the same problems and so wild-caught Alaskan Salmon are sold in grocery stores. But the research finds that while they may be caught in Alaska, many of the fish are not from Alaska.

And this is the problem. The true origin of a salmon is more important than the place of catch if the goal is to ensure the pressured species of salmon. Without knowing the source of the fish sustainable labels cannot inform better consumer choices.

And yet having the genetic facts about a fish complicates the decisions for fisheries manager tasked with ensuring fishing totals abide by international quotas set by the Pacific Salmon Commission. The commission restricts harvest amounts to ensure endangered populations aren't being caught in large proportions.

Seeing Past the Label

A silver-backed salmon labeled as caught in Alaska might bring to mind a boundless ocean teeming with runs of the fish dodging icebergs and grizzly bears. But many of those fish spent a life eluding dams, warm water, and fishing nets on their journey to the ocean. But Smith, who grew up fishing for salmon in Washington State, says his testing paints a different picture. He runs the salmon tests in a small basement lab amid freezers crammed with genetic samples in Missoula, Mont.

Looking over his shoulder, he points out the places where fish came from versus where they were caught and where they're bought. He's part of a team that collect salmon samples from Alaska, Washington, Oregon and California. Most fish labeled as 'wild-caught' in the store will come to his lab.

Smith processes thousands of genetic samples that come to the lab each year. He deals in percentages and probabilities.

The 63 salmon samples tested in 2014 didn't turn up any mislabeled species, a more common practice for verifying grocery store accuracy, but rather found that 55 percent of Alaskan caught chinook salmon were born in Oregon, California or Washington. Another 31 percent came from British Columbia. Only 14 percent were actually from Alaska.

Alaska chinook salmon sold on ice at the Good Food Store in Missoula, Mont. were actually



Salmon collected for the genetic study from local grocery stores in Missoula, Montana. Inside of each vial is the secret to where each of the ocean migrating were born.

fish born on the West Coast of Vancouver Island, the Fraser River in British Columbia, the Trask River in Northwest Oregon and a hatchery near Juneau, Alaska.

Genetic tests at fishing ports in Alaska compiled by the Alaska Department of Fish and Game in 2013 had similar results, with West Vancouver Island and the Columbia making up a sizable proportion of fish. The two surveys, while troubling, do not mean there is a definite trend of catching non-Alaskan fish in Alaskan waters.

Season, year and harvest location can skew the smaller study of grocery store fish. Smith used the same microsatellites, DNA identifier sequences, used by Alaskan fisheries to determine what distinct population a salmon is from.

Wild salmon populations don't broadly mix genes. Offspring spawn in the same tributaries year after year. So the birthplace of each fish sample is determined from data banks on salmon populations from California to Alaska which show unique gene traits.

Sometimes the results raise more questions than they answer. A few Alaskan-labeled salmon tested by Smith came from California and Oregon streams where many populations are endangered or in decline. Salmon from the Feather or Klamath Rivers in California are unlikely migrate up into Alaskan waters. It's impossible to know how they were mislabeled as Alaskan salmon. Either they were caught in another place and mislabeled, or were a statistically rare visitor to Alaskan waters.

Alaska's salmon fishery is considered 'mixed stock' meaning they are made up of salmon from many different places.

"The whole idea of a mixed stock fishery brings up some ethical questions. I don't think [consumers] know what they are getting. We expect a certain number of fish to come from other waters according to the stock assessment. However, a certain number will come from populations that have never been in Southeast Alaska," says Smith.

Finding Home

The idea of testing for species grew out of efforts to stop the illicit animal trade.

Nick Gayeski, who also collects samples for the project and is an aquatic ecologist at the Wild Fish Conservancy in Washington State, and his collaborators were inspired by a Stanford University species identification study of whale meat in Japan in the 1980s and 90s. In that research, Dr. Steve Palumbi ran DNA tests in a suitcase-sized mobile lab uncovering illegal catches of whale meat sold in Japan and other countries, including the United States.



A salmon sample of fish collected for genetic research for the Missoula lab. Often, there isn't any indication of where a fish was born or where it was caught. In this case, the printed label indicating 'farmed' was crossed out and replaced with 'wild.'

The study led to widespread changes in monitoring of fisheries, including by the U.S. Food and Drug Administration. The FDA uses DNA testing on many international seafood imports.

Gayeski thought, “We can do that for chinook.”

He hopes the same kind of testing for salmon can lead to more sustainable fisheries and accountability as to where catches of salmon are harvested.

But that will mean a change to the current system. All commercial salmon catches in Alaskan waters are considered sustainable by the Alaska Department of Fish and Game, since the state has an interest in seeing salmon survive into the future. To help ensure sustainability, the Marine Stewardship Council has stepped in.

The MSC is an independent non-profit certifying body that verifies fishery health and marks seafood products sold in stores with a ‘blue label’ to indicate sustainability. The organization charges a fee for the value added to carrying a certified sustainable label. The MSC and other similar organizations worldwide declare fish sustainable through guidelines modeled on the UN’s Food and Agriculture Organization’s “Code of Conduct for Responsible Fisheries.”

The MSC began to certify the entire Alaska salmon fishery as sustainable in 2000, based on the returning number of fish and future projected harvest. Alaskan salmon were one of the first major fisheries certified under the program.

“Alaska wanted to certify everything,” says Gayeski, adding certification helps consumers make sustainable choices buying seafood.

The label itself, often indicating only “wild-caught Alaskan salmon” and the method of certification, does not fully tell where all fish come from and how harvest can affect distinct populations that are threatened or endangered.

It’s a problem that the MSC already knows about, says Gayeski, who points to an evaluation report from 2015 prepared for the Marine Stewardship Council by independent evaluator Intertek Fisheries Certification that acknowledges 96 percent of Southeast Alaskan salmon, which has few rivers itself, are not from Alaska. To maintain Alaska’s sustainability rating the MSC defines fish born in other waters that migrate in swirls across the Pacific Coast as “inseparable or practically inseparable” or IPI catches from those born in Alaska.

This exception allows harvests to other populations that include a small amount of endangered or threatened salmon as sustainable salmon, according to MSC. Since fish cannot be separated without each individual fish genetically tested.

The MSC is trying to address the issue, says Jim Humphreys, a Global Fisheries Coordinator at MSC.

“The salmon fisheries up and down the coast are inherently mixed in population,” says Humphreys. “We try to minimize the impacts endangered stocks” that are included in sustainably labeled harvests and the proportion of endangered salmon is tiny in comparison to overall harvest.

“We have a strict requirement that, if declared, IPI catches cannot exceed 5% of the total combined catches,” adds Dan Averill, Senior Fisheries Manager for MSC.

In addition to dealing with the verification of where the fish is caught, the MSC must also spend much of its efforts tracking what happens when the fish is caught. It traces all fish sold under certification through the harvest, processing, distribution and sale of a fish.

But a connection to the place a fish comes from in a grocery store and the health of populations is absent in labeling. The best way that consumers can ensure they aren’t harming a fish population is to make sustainable choices. But inaccurate labels make this choice less useful.

This has prompted seafood advocates to up the pressure on the organizations that govern labeling. In October 2015, the conservation and advocacy organization Oceana released a study of 87 salmon collected from December to March, finding that fish were mislabeled

20 percent of the time in grocery stores and 67 percent in restaurants. The highest incentive to mislabel is in the offseason when salmon stocks run low or are non-existent.

“Oceana is advocating for full supply chain tracking of our seafood, from the time it was captured or harvested from a farm, through the whole supply chain,” says Kimberley Warner, a senior scientist at Oceana.

“That’s very promising research,” says Warner of the home stream data that pins a fish to place with genetic data. Traceability of fish caught from an endangered Washington State or Oregon salmon population would be valuable, especially throughout the supply chain, says Warner.

Warner would like to see descriptive labels that contain date and place of catch on labels and possibly ones that include genetic data, home stream or harvest source in markets can help consumers make better seafood choices.

“Salmon is one of the few fish that are supposed to be sold by a species name, like chinook, sockeye or pink,” says Warner. “So, in the case of salmon, it benefits from having this very species specific labeling, and when we looked at grocery stores that sell under this country of origin labeling rule the mislabeling rates, regardless of season, were quite low because they were required to tell you what kind of salmon it was.”

Warner hopes that giving consumers this information on each label will allow consumers to connect fisheries from ‘boat to plate,’ since FDA country of origin labels usually require the place of processing or alteration to be indicated.

Overall, there are many reasons for seafood traceability. “We import 90 percent of our seafood,” says Warner. “Most of what we catch is exported for processing and then it comes back as an import of another country, rather than where it was caught.”

Reimported salmon crosses the ocean twice, being frozen, unfrozen, processed, refrozen, and then thawed once more before reaching a plate. It’s hard to track how much of seafood is reimported since altered or prepared products are harder to track.

For example, an Alaskan salmon filet found at Walmart with a “Made in China” label with a sustainable rating, adding to some of the confusion since country of origin rules require relabeling, when less costly processing is done overseas.

The work done by Smith and others in Montana isn’t any less contentious when compared to the struggle to track species within a supply chain. They have yet to turn up any species mislabeling, but found more than a few surprising home streams for Alaskan labeled salmon.

Smith’s own opinion is the most sustainable salmon to eat are those raised in hatcheries since harvest doesn’t take from a wild population that needs a rest. A large portion of salmon in samples come from hatcheries, which are by some seen as an unnatural

surrogate for declining wild populations, but they are also the best chance for salmon to maintain both a healthy population and a commercial harvest.

Smith also hopes tests may allow for more accurate labeling in the future but he is quick to add that knowing where an individual fish came from is no help if it's too late to put back in the ocean if it's from an endangered or threatened population.

He sees value added for the already expensive fish in eventually having genetic tests on more fish, particularly as the cost of testing decreases and the technology becomes more portable.

Ultimately, the responsibility for ensuring salmon's survival into the future rests on consumers getting the whole story on the salmon they purchase, and fisheries providing this information, be it species, place of catch or home stream from a genetic test.

Without DNA testing, consumers are fishing in the dark.