Mysis Project Frequently Asked Questions (FAQs)

August 21, 2020

About *Mysis*

How deep do the *Mysis* reside?

Mysis do a daily vertical migration away from light. The depth to which they descend is dependent on water clarity (light penetration) and the depth of the water body. In Emerald Bay the *Mysis* swim down to the bottom each day (60m, 200 feet). In Tahoe, the *Mysis* live as deep as 300m (~1,000 feet) during the day. However, if the *Mysis* encounter the bottom shallower than 300m that is where they will spend their time. It is possible to see *Mysis* <100 feet deep while scuba diving. These are *Mysis* that were near shore when they began their downward migration.

Are there seasonal influences on the *Mysis* population?

The *Mysis* respond to seasons primarily through their reproductive life cycle. Adults breed in the late summer and fall. Males die after breeding while females live through the winter, carrying eggs and developing embryos in their brood pouch. Pregnant females die after releasing juveniles in the late winter or early spring.

Mysis daily migration is also influenced by season. During summer lake stratification, the *Mysis* remain below the thermocline depth (~20m in Tahoe and 15m in Emerald Bay). In winter they are not limited by warm temperatures and are able to rise all the way to the surface.

Are *Mysis* throughout the lake or in specific areas? How patchy are *Mysis* and zooplankton data across the lake (i.e. do you have good synoptic x temporal data)?

Mysis are present throughout the lake. Something we need to determine is how patchy their population is. Current and past data is collected by vertical net tows in specific locations around the lake giving us only localized densities. We need to begin using acoustic survey techniques to determine population densities over a broader portion of the lake.

Trawling for *Mysis*

What are the specific methods for harvesting *Mysis*?

Mysis harvest is done with a large trawl net. The net is pulled behind a boat at night when the shrimp come up from the depths. Using bioacoustics to find them within the water column greatly increases harvest efficiency.

How effective are the methods?

UC Davis was able to remove 25 pounds of *Mysis* in a 4-hour period using a small trawl net just to validate the concept. Exactly what harvest efficiencies are achievable at commercial scale remains to be seen. However, a commercial operation in Lake Okanagan, BC was able to harvest 300 kg (660 pounds) of *Mysis* per night. The actual harvest will depend on the size of the trawl, the speed of the boat, the hours fished, and the density of the *Mysis* population.

In trawling for *Mysis* how do you avoid/exclude non-target species?

The capture of non-target species (animals other than *Mysis*) is called bycatch. Because large trawls are indiscriminate in what they catch, there are some small fish that end up in the net. Fortunately, in Lake Tahoe the *Mysis* occupy a depth where there are few fish. The *Mysis* are just below the thermocline (see above) while pelagic fish are in the thermocline or just above. UC Davis trawling in Emerald Bay captured very few native minnows and juvenile kokanee. This is true of the commercial operation at Lake Okanagan as well. The fish can be released on site as soon as the trawl is pulled in. Based on our experience very few fish are captured and they swim away once released. A commercial harvest of *Mysis* will require permits with reporting of all bycatch.

Native zooplankton are too small to be captured in the trawl net and pass through the mesh.

What kind of dent in the Mysis population can be anticipated and wouldn't the populations bounce back readily?

We are looking to decrease the Mysis density to ≤ 27 *Mysys*/m^2. It is unclear if this goal can be achieved in Lake Tahoe as we do not currently have any harvest efficiency data. We believe it would be possible to reach this target in Emerald Bay with a commercial operation in a matter of months.

When we discovered the *Mysis* had disappeared from Emerald Bay in 2011 (they were gone before this time) it took several years before they returned in abundance. A population rebound in Lake Tahoe would be expected to take longer as the Mysis have a 3-4-year life cycle with < 25% of the population reproducing every year.

How long do you think it will take to remove all *Mysis* from the lake?

It will not be possible to remove *Mysis* completely. They continue to reproduce and Tahoe is a big lake. The goal of the project would simply be to reduce the *Mysis* population enough to allow the Daphnia to return. We need more data before we can make estimates of how long it will take to reduce the population in Tahoe (see above).

W**ould the trawling be automated?**

The long-term goal would require developing some automated system to *Mysis* harvesting. This would initially involve automated survey craft that would map *Mysis* densities allowing for more efficient harvest. It could eventually involve automated harvesters but that is a long way from even the developmental stage.

If all *Mysis* shrimp were removed from Lake Tahoe, how much clarity could be gained?

This is still an unknown for Lake Tahoe. When daphnia returned to Emerald Bay the clarity doubled (12m to 24m, a 40 foot improvement). There is little doubt the clarity of Tahoe would improve with daphnia present, the unknown is just how much. Since land-based restoration of the past 40 years has only been seen to level off the decline of clarity, it seems prudent to explore bringing back the native zooplankton to see how effective they can be at bringing about positive clarity improvements.

About Daphnia

How do we know daphnia will return if we remove *Mysis*?

Daphnia have made rare, brief appearances in Lake Tahoe over the past 40 years. Other lakes in the Lake Tahoe Basin have daphnia populations and act as seed sources for Lake Tahoe. When Emerald Bay had a return of daphnia, they moved into Tahoe and were found along the south end of the lake with a low abundance as far north as Homewood.

Daphnia also can produce resting eggs. These eggs sink to the sediments and can remain dormant for a decade before hatching.

Daphnia probably have a food preference for the small centric *Cyclotella*, which are the primary culprit of decreased clarity. If another alga species replaces the *Cyclotella*, do you have any idea if Daphnia can still be useful to improve clarity?

Daphnia are indiscriminate feeders. They use their feathery "hands" to pull particles from the water into their mouths. This is why they consume both inorganic fine particles (clay) as well as the small algae cells they desire. As long as the new algae species were the size consumed by daphnia, we would expect them to continue to clear the water at the same rate.

About Project

Why dog treats?

- Several reasons: 1) The dog treat market is large enough to generate necessary demand for the removed Mysis. 2) People love dogs, people love talking about their dogs, and there is something about our dogs that connects us to nature. It is a great vehicle for creating awareness of invasive species. 3) People want healthy treats for their dogs, and the Mysis are a great source of essential Omega-3 fatty acids that can improve dog joint, skin, and coat health. 4) Environmentally conscious consumers increasingly want their pets to be part of the solution. This is a growing trend in dog treats, and Tahoe Mysis treats invite dogs to join the cause and help save Tahoe. 5) The unit economics have potential to scale. Mysis aren't cheap to harvest, and any product that's 100% Mysis will be very expensive. Dog treats provide a nice avenue to explore different treat formulations that can feature the Mysis while keeping cost of goods reasonable.

Have any dogs tried the Mysis treats?

- We have limited taste testing to a very small group of dogs for the time being, as we are still completing all the necessary food safety tests. That said, 100% of the dogs that have tasted or even just sniffed the Mysis have loved it.

How many treats do you think you can produce from the Mysis currently in the lake?

- From Emerald Bay alone, we expect to produce ~25,000 – 30,000 five-ounce bags. The broader Tahoe lake has enough Mysis to produce more than 500,000 units annually. Given how large Tahoe is and how many Mysis are there, the question isn't if there's enough Mysis, but whether we can trawl quickly enough to disrupt their reproductive patterns.

What about cat food? Flamingo food?

- There are plenty of markets we could pursue in the future, but the dog treat market is the largest pet treat sector within the US. Strategic focus is important in creating brand identity and operations alignment, which is why we're focusing on just one pet for now. If it makes sense to branch out in the future, we'll certainly look into it!

Would it be feasible to develop a joint venture with the Humane Society of Truckee Tahoe to test the dog treats (and maybe cat treats!)

- Great idea! Partnering well is the only way this social enterprise will be successful, and we need all the help we can get. If local agencies (environmental or pet) are interested in partnering, let's do it!

What channel do you predict these amazing dog treats will be sold through?

- These dog treats will primarily be sold direct to consumer through online sales. Our customers can subscribe to regular treat deliveries, follow our story online, and track our progress as we tackle the Mysis the problem.

Wouldn't pure Omega-3 would be very marketable for humans? What has pushed this towards dog food?

- The Mysis have an amazing lipid composition, with Omega-3 fatty acids making up 32.4% of their total lipid content (point of comparison, salmon fat is about 15.9% omega-3's). However, while their lipid composition is great, Mysis is 85% water and contains just 3.17% lipids. This means that it would take a lot of Mysis just to make one gram of Mysis oil. It could be the purest Omega-3 supplement on earth, but the price point would be super premium and likely wouldn't gain enough market share to sufficiently reduce the Mysis population.

Any chance of Mysis becoming human food delicacy that would be served in all Tahoe restaurants becoming a Tahoe delicacy? Could Mysis make a fine tiny ceviche? Could a celebrity chef (Gordon Ramsey, Hell's Kitchen) put the Mysis on the map??

- Sure! The Mysis have a strong flavor profile, but a professional chef could potentially do something creative with it. Anything that helps draw attention to the Mysis problem would be helpful! We're focusing on dog treats first, but welcome any chefs interested in exploring Mysis as a delicacy.

What is the estimated quantities expected to be harvested? Two values are of interest. Initial volumes (reducing the Mysis concentrations), ongoing long-term quantities (sustainable harvest).

- Current Mysis densities in Tahoe are roughly 50 individuals/sq.m. The goal is to suppress this number down to 27 ind/sq.m. Given the size of Tahoe, that's A LOT of Mysis (10's if not 100's of billions). Since our #1 goal is environmental restoration, we want to outpace the Mysis reproductive rate and reduce their numbers as much as possible. Exact harvest efficiencies are still unknown, which will be the key factor in just how far we can reduce their densities before the trawling ceases to be economically viable. There are plenty of other lakes in North America with the same Mysis problem, so assuming we're successful in reducing Mysis densities at

Tahoe, we could take our operations to restore another lake and only return to Tahoe as needed.

What volume of Mysis might there be to sustain a business?

- See above.

What dollar amount, would it truly take, to fully mitigate these issues?

- This project uniquely has the potential to pay for itself in the long run, but it all depends on trawl efficiency, market demand, and how quickly we can disrupt the Mysis reproductive cycles. Since we don't have actual data on these key elements just yet, we're proposing baby steps on this project in order to gain additional information one milestone at a time. The first of these milestones, a proposed full-scale pilot trawl on Emerald Bay, would give us great data on all three factors above, and we'd be able to project longer term cost estimates from there. Best case scenario, we're net positive and we use the returns to support other local environmental and community efforts. Worst case, we aren't quite break-even but we're at least offsetting some of the restoration costs.

Is there an endgame to the harvesting?

- See above on 'estimated quantities to be harvested'

What happens when the Mysis are gone? How is it sustainable if you collect all the shrimp?

- See above on 'estimated quantities to be harvested I don't think it would be possible to remove all of the Mysis (they continue to reproduce)

Have you established a timeline on getting to market?

- We're targeting a full-scale pilot trawl of Emerald Bay in Fall of 2021. This means we hope to have our initial prototypes ready for pets to taste test by late Q1 of 2020, and pre-ordering of our Mysis treats available by end of Q2 2020.

<u>Other Ideas</u>

Introduce another species? Can you introduce North American Paddlefish (filter feeder) to the lake to improve clarity? They eat zooplankton.

- No! This is what got us into trouble in the first place. It is never a good idea to introduce new species to a system because they will likely have unintended impacts.

<u>Concerns</u>

Won't the lake fish species be negatively affected if *Mysis* are removed?

The native fish in the lake are likely to benefit from a return of a native prey species. The presence of daphnia in would also likely improve conditions for Lahontan cutthroat trout restoration.

Mysis provide an abundant food resource for introduced lake trout, especially younger year classes. Therefore, lake trout would likely grow slower until they grew large enough to feed on other fish.

However, the lake trout would not disappear. They were introduced to Tahoe in the 1880s and survived just fine for 90 years before *Mysis* were fully established.

I am suspicious of single solutions, especially with biology for which we have many bad failures of a promising conservation approach. Is there no longer a holistic approach to protecting Lake Tahoe?

You are wise to be suspicious of single solutions. What we are proposing is a multifaceted approach to restoring Tahoe's water clarity. For the past 50 years the approach has been to reduce the nutrient loading to the lake primarily through erosion control. While the efforts utilized many techniques (street sweeping, curb and gutter projects, infiltration basins, wetland restoration, stream restoration, etc.) it can be seen as a single solution approach; keep sediment out of the lake. We believe that by returning aspects of the native aquatic food web, additional gains can be realized. We see the efforts to reduce Mysis allowing the return of daphnia as additive approach to reaching Tahoe's water clarity goals. It will take the cumulative effort of novel approaches to return clarity to 100 feet.

Has the science describing the relationship between *Mysis* and clarity been peer reviewed?

There have been several peer reviewed articles about daphnia's ability to clear aquatic systems. There have also been peer reviewed papers describing the loss of clarity (increased primary productivity) following the establishment of *Mysis*. We have recently submitted a paper that reviews 40 years of limnological data at Lake Tahoe in light of the changes we observed in Emerald Bay following the loss of *Mysis* and the return of daphnia.