Tahoe Science Advisory Council: External Peer Review of "Planning for Removal of Mysis Shrimp from Emerald Bay and Lake Tahoe as a Means of Ecosystem and Clarity Restoration"

Adrian Harpold, Peer-review chair
David Beauchamp, USGS, External reviewer,
Michael Brett, University of Washington, External reviewer
Walter Dodds, Kansas State University, External reviewer

This short summary is meant to give an overview of the three reviews. The individual reviews are given in an appendix below. The review charge sought to address five questions with three reviewers' response summarized here.

1. *Does the project report, appendices and/or associated analyses provide evidence that Mysis can be reduced in Emerald Bay using boat trawling and echosounder methods?*

There is some skepticism that the catch rate can be scaled up using larger nets. The reviewers did not feel that the logistical challenges of using larger nets was sufficiently addressed. Also, the unintended consequences of larger-scale trawling operations, particularly bycatch, were not fully explored. Because Mysis catch efficiency will be reduced as Mysis populations decline the potential financial offsets are not sustainable.

2. *Does the project report and/or associated analyses provide evidence that deliberate Mysis removal via trawling or similar methods could lead to increases in native Cladocera populations in Emerald Bay?*

The case could have been made stronger that Mysis removal will lead to long-term and sustainable increases in Cladocera populations. Evidence that factors other than Mysis influence the trophic state of the Lake is well known, such as climate, land use, and atmospheric deposition. Bycatch effects on Cladocera from the trawling operations were not discussed.

3. *Does the project report and/or associated analyses provide evidence that increased Cladocera populations can improve clarity in Emerald Bay?*

There is modest reviewer agreement with long-term improvements in clarity based on in situ observations. While previous work suggest that higher Caldocera biomass does improve lake clarity, there are multifaceted controls on water clarity that are not considered in the report.

4. *Does the project report and/or associated analyses provide evidence that the dynamics between Mysis, Cladocera, and clarity in Emerald Bay would hold true for Lake Tahoe?*

A lack of new lake-scape observations, and many uncertainties, do not provide evidence that dynamics in Emerald Bay would hold true for Lake Tahoe. Specifically, positive and negative feedbacks in the fish-invertebrate food web would be important to consider at large scales. Moreover, whether the trawling operations are scalable to the entire Lake are questioned by the reviewers.

5. *Does the project report and/or associated analyses offer evidence that pursuing lake-wide Mysis control is a potentially successful method for improving Lake Tahoe's clarity?*

At this point there are too many ecological unknowns and operational uncertainties to justify a lake-wide Mysis control effort. Reviewers were particularly skeptical that commercial scale operations at the Lake were feasible and cost-effective given declining populations over time. Several reviewers raised the issue of unintended consequences to the food web, which would need much more careful consideration. The reviewers agree with many of the next research steps offered in the report, including characterizing the seasonal and areal distribution of Mysis and developing population models.

Appendix: Individual reviews

Review 1: David Beauchamp

Review of Report on efficacy of Mysid suppression on return of native Cladocerans and lake clarity in Lake Tahoe:
Schladow, G., Forrest, A., Sadro, S., Allen, B., Senft, K., Cardoso, L., Tanaka, L., Watanabe, S., Daniels, B. and Trommer, S. (UC Davis) and Chandra, S. and Bess, Z. (UNR) 2020. Planning for Removal of Mysis Shrimp from Emerald Bay and Lake Tahoe as a Means of Ecosystem and Clarity Restoration. Draft Administrative Report to California Tahoe Conservancy and Nevada Division of Environmental Protection.

Review Questions

1-Does the project report, appendices and/or associated analyses provide evidence that Mysis can be reduced in Emerald Bay using boat trawling and echosounder methods?

Yes, if scaled up to the commercial level in Emerald Bay as described on pages 77-79 should be capable of depleting the mysid densities to $<27/m^2$ over 2-3 months of intensive commercial-scale effort.

Declining catch rate as the population becomes locally depleted by trawling is a very real concern and these responses are often nonlinear due to behavioral responses by population. I suspect such responses would be much less by mysids compared to fish populations, but this is still an important lingering uncertainty. An independent survey boat dedicated to scouting near-term shifts in density and distribution might be needed to focus harvest on the most effective regions within Emerald Bay.

2-Does the project report and/or associated analyses provide evidence that deliberate Mysis removal via trawling or similar methods could lead to increases in native Cladocera populations in Emerald Bay?

Yes, reasonable evidence comes from the *in situ* observations in Emerald Bay, and to a lesser extent in the main basin, over the years of this study. Similar results have been reported in via time series and directed studies in ~similar large western lakes sharing similar zooplankton-mysid-zooplankton communities (e.g., Flathead Lake, Lake Pend Oreille).

3-Does the project report and/or associated analyses provide evidence that increased Cladocera populations can improve clarity in Emerald Bay?

Yes-This is supported by the Emerald Bay mesocosm experiment and somewhat by the *in situ* observations. Increased and persistent transparency associated with the emergence/resurgence of cladocerans, especially Daphnia is well documented in other meso-oligotrophic lakes. Perhaps the best example is Lake Washington as it transitioned out of a human induced eutrophic state back to historical transparency (3-m Secchi depth) initially in the early 1970s until Daphnia became established in 1975 and increased transparency to 6-7 m (Edmondson and Litt 1982) which have now persisted for 45 years.

4-Does the project report and/or associated analyses provide evidence that the dynamics between Mysis, Cladocera, and clarity in Emerald Bay would hold true for Lake Tahoe?

While the existing evidence is suggestive, too many uncertainties remain regarding how these interactions might play out in the main basin. The processes driving these interactions should be the same; however, when scaling up to the main basin, the practical applications of whether significant mysid depletions could be achieved are quite uncertain. Overlaid on this is the complexity of the biotic interactions which include both positive feedbacks and negative feedbacks in the fish-invertebrate food web which can lead to unintended consequences that could extend beyond the focal species to the native fishes like Lahontan Redsides, Tui Chub, and Paiute Sculpin.

Non-native lake trout rely very heavily on mysids from juvenile through relatively large adults (Fork Length ≤ 625 mm [25 inches]). Their annual population-level consumption of mysids was estimated at 350-400 metric tons across the lake. This approached the estimated annual production rate of mysids without tapping into the standing stock biomass.

However, as mysids are depleted, the response by lake trout will be a crucial element to investigate with several alternative (but not necessarily mutually exclusive) hypotheses:

-Mysid suppression could be accelerated by depensatory predation mortality from lake trout.

-Mysid suppression might increase self-regulations of lake trout via cannibalism (e.g., as in the reverse of Flathead Lake).

-Mysid suppression might shift predation to Kokanee and native fishes with significant increases in mortality

-Mysid suppression might induce an ontogenetic shift to earlier or more extensive predation on Cladocerans, thus dampening the potential “predation release” expected from a simple linear decrease in predation risk with declining predator abundance

Most, but not all of these hypotheses have important ramifications for a resurgence in Cladocerans or transparency of the main basin.

5-Does the project report and/or associated analyses offer evidence that pursuing lake-wide Mysis control is a potentially successful method for improving Lake Tahoe’s clarity?

Not yet. The authors rightfully identify a number of critical knowledge gaps that need to be explored through an adaptive management framework in order to evaluate the feasibility and efficacy of such an endeavor.

Some of the most important considerations relate to the long- term commitment to an effort like this. Assuming that no logistical impediments emerge, that mysid depletion progresses acceptably, and potential ecological impacts are either minor, neutral or beneficial, as the mysids decline and reduce catch rates, the program will require increasing subsidies to sustain it. The nature of such population suppression efforts must be continued into eternity or suffer a rapid rebound by the mysids. The authors are clearly aware of this and have done a good job of keeping this transparent. It’ll be up to the policy folks to assess the level of commitment they are willing to shoulder.

Specific Review Comments

P15 Section 3.0—The 2011-2017 Emerald Bay Natural Perturbation

The extraordinary Mysid crash and then rebound does indeed provide an unique opportunity to explore relations among Mysids, Cladocerans and other bottom-up or top down effects on the food web of Emerald Bay with potential implications for the main Basin of Lake Tahoe.

Any hypotheses about the cause of the mysid crash? Seems like an epizootic is a likely candidate worth investigating.

P20- Mysid sampling: Conical “Mysid” net (0.75 m diameter 0.5 mm mesh)

Nocturnal vertical tows: 0-60 m depth-integrated vertical tow in EB; 0-100 m at LTP and 0-200 m tows (MLTP & South Shore)

Zooplankton sampled with conical 0.75 diameter 0.080 mm mesh net. Were zooplankton tows also conducted at night or during daylight? I assume during daylight as is standard practice for lake monitoring, but confirmation would be appreciated.

CONCERN-Depth-stratified zooplankton sampling would have been very informative, especially for monitoring Cladocerans, which frequently exhibit highest densities above the thermocline, about 50%

lower density within the thermocline, and very low densities below the thermocline, often 10% or less of epilimnetic densities.

P21 Fig 4.2. Use same Y-axis range (0-400) for both Mysids (mysids/m2) and Cladocerans (#/m3)
During 2019, can a plausible cause-effect narrative be developed between trawl removals of mysids (during Sep-Dec 2018 and May-June 2019), depressed mysid density to ~40/m2 during Win-Spr-Sum (resurgence in fall), the very limited increase in Cladocerans and increased Secchi transparency?
For instance, how do trawl removals in terms of biomass and numbers of mysids compare the population reduction that must have taken place to result in declines from 100-200 mysids/m2 to 40 mysids/m2. What fraction of this reduction can be credited to trawling removals versus natural mortality?

P22-24. Proportions of reproductive female mysids peak in Dec through winter in Emerald Bay at 70-80% whereas only 20-30% of females reproductive in main basin of the lake (similar temporal pattern as in EB).
-Mean brood size ~13 eggs/female, but size-dependent fecundity with no significant mortality from egg through development to juvenile release from brood pouch.
-Where is the evidence that the life span in Emerald Bay is only 1 year? A temporal series of length frequency distributions in the South Shore showed a strong 2-year life span (McCoy 2015)
-Comparable mortality of free-swimming juveniles to annual survival rate reported by McCoy 2015 (17.7%)

P33. Hydroacoustic methods
FYI-"hull mounted" implies that the transducer is permanently mounted in a through-hull position. What is displayed is a temporary Pipe mounted configuration
I believe you meant to say the echosounder resolved 1.8 m (not mm) depth bins. Target resolution with a 200 kHz transducer would be roughly 0.3 m at a standard pulse width of 0.4 milliseconds. Was echo-counting or echo-integration used?
Presumably these surveys were conducted at night, but this needs to be stated explicitly. This isn't clarified until page 41.
More specifications are required regarding how the hydroacoustic data were acquired, specifically, depth range over which targets were accepted, ping rate, pulse duration, were one or both frequencies used? I assume just the 200 kHz was used for mysids. It looks like data acquisition ceased below depths of 150 m based on the degrading signal-to-noise ratio. But this information is buried down on page 37 instead of up front where all these settings should be summarized.
Again, clearly state which frequency was used for these surveys (presumably 200 kHz), because the relationship of frequency, target strength, and mysid size vary considerably among frequencies.
We finally learn that data were analyzed via the echo-integration method, again several pages later than expected.
Using a -60 dB maximum target strength threshold to eliminate fish targets might not be low enough to filter out the pelagic larval stages of sculpin (which lack swim bladders). I'm not certain whether the native Paiute Sculpin express a pelagic larval stage, but many other westerns species do and can be abundant at some times.
-Nocturnal depth distributions of mysids were located much shallower in Emerald Bay during peak thermal stratification in August than was reported in South Lake Tahoe during August (McCoy 2015) where the mysid layer spanned 40-85 m relative to the 20-40 m (top-bottom) thermocline.
-The dynamics of nearshore-offshore densities and potential influence of ontogeny could be clarified in the future by simply examining the mean, variance and frequency distribution of target strength as functions of distance from shore, bottom depth, and depth of target among months or seasons.
P47-49 Hydroacoustic methodological refinements. The authors are on the right track here. It sounds like some initial system configurations during data acquisition precluded some of the normal target strength analysis that would ordinarily address many of the Target Strength questions posed. Evaluating the TS

frequency distribution from each survey should provide straightforward data regarding mean target strength values to apply specifically to each survey and whether mono-modal or bi-modal distributions require some modifications to their calculations.
This should relieve the reliance on concurrent midwater trawl catches of mysids to enable biological calibration. While the trawl samples would become less important for the population assessment element, midwater trawl samples will be essential for providing biological measures for mysids and of course would be the primary focus for the suppression program

P52-Assuming a maximum survey depth of 100 m for nocturnal surveys should be fine, based on data observed from various months and seasons (thermally stratified and destratified).

P70-Emerald Bay Trawling Results:
TERC had a (3 m x 3 m) Isaacs-Kidd midwater trawl built in the early 1990s to sample kokanee and mysids, but was never used seriously-very little time devoted to refining techniques or modifications. If still intact, it would be a good net to try as it is a single-wire hydrodynamic trawl that can be towed much faster than trawls requiring doors.

P74. We have never witnessed very narrow bands of suspended mysid (e.g., 2-3 m high) as would be desired. Even during summer stratification, the nocturnal layers were 30-45 m high (August 2012; McCoy 2015)
P75. If 80% of adults in Emerald Bay reproduce during peak season, then harvesting them anytime they are vulnerable to efficient capture before reproduction (even many months earlier) would have the most impact on the population.
However, in the main basin of Tahoe, with only ~20% of adults reaching reproductive status, and given the limited harvesting power relative to the potential harvesting area, a strategy to focus on the reproductive adults in time and space could be a strategy for most effectively focusing harvest effort. If reproductive adults don’t segregate from others, then simply target the highest-density regions that can be effectively harvested.

Harvest:
Emerald Bay-Highest CPUE with large trawl in Fall-early winter, very low in spring (adult die-off and juveniles nearshore)
Main Basin Lake Tahoe has limited shallow nearshore habitat relative to deep pelagic, and adults live 2-4 years, so any spring die-offs don’t result in major reductions in abundance. See temporal length frequency series from McCoy 2015 below:

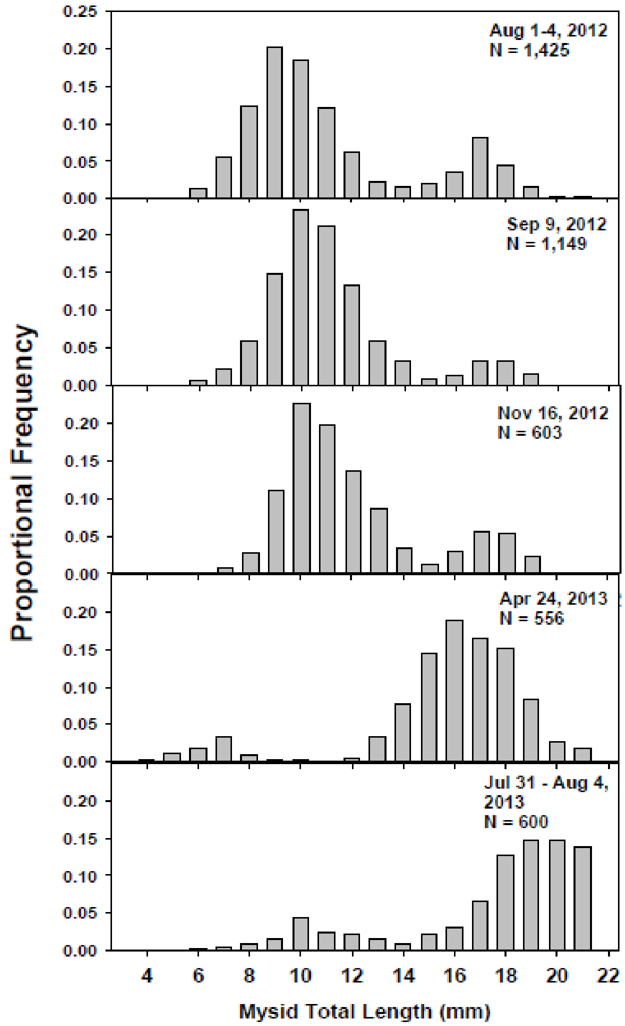

Figure A1. Seasonal length frequencies of mysids in Lake Tahoe sampled during 2012-2013.

P103-Mysid Diets
The diet data (Tables 7.1 & 7.2 [mislabeled as Tahoe, should be Emerald Bay]) should be stratified into large and small mysids, since stable isotopes and other information suggest an ontogenetic shift to more zooplankton predation by larger individuals.
In the main lake basin, the identifiable diet contents indicate a high degree of herbivory or perhaps detritivory with episodic seasonal pulses of zooplankton predation (the predominant copepod Epischura and the rotifer Kellicottia in spring with Cladocerans contributing a minor fraction. Diets in Emerald Bay showed much lower zooplankton predation.

Lessons Learned P111-

Mysid life span: Mysids only exhibit 2 distinct size modes in the main basin of Lake Tahoe based on length frequency distributions. While it's possible older (age 3-4) adults might exist and simply not grow beyond the length achieved by age-2, I would expect a bit messier frequency distribution with more variability around the larger mode if there was significant survival beyond age-2.
I think that either aging via hard parts or some bio-accumulative biomarker would be needed to resolve this issue definitively.

Hydroacoustic surveys and observations of behavior and distribution of mysids (and fish) are an absolutely essential element of any effort to suppress mysids, but also to gain invaluable quantitative

understanding of temporal-spatial-ontogenetic patterns in abundance, distribution and movement of mysids and pelagic fishes that can influence them.
Exploring the potential applications of AUVs or ASVs is a great idea for this and many other future applications.

Review 2: Michael Brett

Review of DRAFT ADMINISTRATIVE REPORT "Planning for Removal of Mysis Shrimp from Emerald Bay and Lake Tahoe as a Means of Ecosystem and Clarity Restoration" by Schladow et al.

Thank you for asking me to review this draft report. I will respond to this review request by directly addressing the five questions outlined in the review charge. These are:

1. Does the project report, appendices and/or associated analyses provide evidence that Mysis can be reduced in Emerald Bay using boat trawling and echosounder methods?

No. The Mysis removal attempted in the original project failed to meet its objectives for a variety of reasons, but the authors of this report claimed that with a factor 30 higher harvest rate they anticipate they could reduce the Mysis population in Emerald Bay. A 2X portion of the hoped-for increased harvest rate would be due to trawling for Mysis twice as long each night. That would be easy enough to accomplish. However, the other 15X increase in harvest rate would be achieved by using a trawl net that is 15-times larger than was used in the test trawling. It remains to be seen whether this will be successful. For reasons explained in the original report, trawling a net with a very large opening is difficult and perhaps even dangerous in a system like Emerald bay, and especially in Lake Tahoe. The report I read did not adequately explain how this research team would be able to trawl using a net that was 15 times larger. Presumably this would require a much larger boat, much more rigorous equipment, and an experienced crew. It is always a huge challenge to dramatically scale up from an experimental to an actual full-scale system. I would need more information to be convinced that it will be possible to trawl a 15 times large net effectively and safely in Emerald bay.

2. Does the project report and/or associated analyses provide evidence that deliberate Mysis removal via trawling or similar methods could lead to increases in native Cladocera populations in Emerald Bay?

Maybe. I believe the figure that is supposed to make this point is Fig. 3.1 on page 15. This figure shows that during a 2 1⁄2 year period when Mysis abundance was quite low, there was a marked increase in Daphnia abundance after about one year and this increased Daphnia abundance persisted for about 1 and 1⁄2 years until Mysis abundance recovered. Based on prior research in Lake Tahoe, and many other lakes, it seems quite plausible that a high abundance of Mysis in Emerald Bay could suppress Daphnia biomass to low levels. But just because Daphnia increased one year after Mysis declined to low levels does not mean there will always be a high Daphnia abundance when Mysis levels are low. Also, as noted in my response to question #1, it is not yet clear whether trawling can reduce Mysis abundance enough to allow Daphnia to recover. That is still a major point of uncertainty.

3. Does the project report and/or associated analyses provide evidence that increased Cladocera populations can improve clarity in Emerald Bay?

During the time when Daphnia were more or less abundant in Emerald Bay Secchi depth increased from about 14-15 m to 20-21 m. It is plausible that some or even most of this increased clarity was due to Daphnia grazing. Elsewhere in the report it was claimed that low Mysis abundance and high Daphnia abundance were associated with a 11 m improvement in water clarity. It is unclear what this claimed 11 m improvement is based on. I am guessing that is was based on comparing the lowest clarity in the pre-Daphnia period to the highest clarity observed during the time when Daphnia were abundant. However, the data I summarize above suggest an improved water clarity of about 6 m is more representative for the overall trends for these two time periods. Although it is plausible that Daphnia grazing played a substantial role in this improved water clarity, I believe the factors that control water clarity in Emerald Bay and Lake Tahoe are multifaceted and complex. This time series alone does not convince me that increased Daphnia abundance will all by itself lead to a consistent 6 m improvement in water clarity. Furthermore, I think the claimed 11 m improvement in water clarity is not supported by the totality of the data presented in this report. Based on the evidence presented in this report, and the general literature lake food webs, I believe a substantially higher Daphnia biomass would benefit water clarity in the Lake Tahoe system.

4. Does the project report and/or associated analyses provide evidence that the dynamics between Mysis, Cladocera, and clarity in Emerald Bay would hold true for Lake Tahoe?

This report did not present new evidence that high Mysis abundance can suppress cladoceran abundance in Lake Tahoe. However, this was already established in previous research from Lake Tahoe done in the late 1970s and earlier 1980s. The report does not present any original evidence that low Mysis and high cladoceran biomass is associated with great water clarity in Lake Tahoe. It seems likely that high Mysis abundance is associated with low cladoceran biomass based on previous Tahoe research. Additionally, based on the Trophic Cascade Hypothesis and the substantial research done on that topic in many lakes, it is also plausible that high Daphnia biomass would also be associated with greater water clarity in Lake Tahoe. However, on page 151 of the report, the authors claimed that without the loss of cladocerans "Lake Tahoe's clarity could conceivably have been largely similar today to what it was historically." This same paragraph suggests that the expected improvement in Lake Tahoe clarity if cladoceran biomass was at pre-Mysis levels would likely be 11 m greater. I think these conclusions go well beyond the supporting data presented in the report! High Daphnia biomass might improve Lake Tahoe water clarity by up to » 6 m, but the claim of an 11 m improvement seems to be greatly over-stated.

5. Does the project report and/or associated analyses offer evidence that pursuing lake- wide Mysis control is a potentially successful method for improving Lake Tahoe's clarity?

No. As previously noted, a successful Mysis control trawl effort in Emerald Bay would require a 30X improvement in Mysis harvest. However, the surface area of Lake Tahoe is 250 times greater than that of Emerald Bay! So successful Mysis control in Lake Tahoe would require a » 8,000 times greater Mysis removal effectiveness than was previously demonstrated in field sampling at Emerald Bay. Based on this alone, I am guessing Mysis control in Lake Tahoe would require a fleet of ocean sized trawlers at a huge cost.

The report also claimed in several places that Mysis trawling could pay for itself. I think this claim is a logical-fallacy. Any Mysis harvested from Lake Tahoe would likely have a high omega- 3 fatty acid content, and could be easily sold for a variety of purposes. However, in order for the trawling to have a limnologically meaningful impact on water clarity in Lake Tahoe it would have to reduce Mysis abundance to quite low levels. If this happened the trawling program would no longer be economically viable because the Mysis CPUE would plummet. The trawling program would only be economically viable when the Mysis population is high and it is possible to harvest a large biomass with a modest effort. I will also note, that under the best of circumstances, the test trawling carried out in Emerald Bay only yielded about 3 kg Mysis per hour of trawling. Assuming Mysis could be sold for a few dollars per kg, a massive improvement CPUE would be needed to recoup the expenses associated with trawling (i.e., purchasing a suitable boat, fuel, hourly wages for the crew, nets and other materials, insurance, etc.) under the best of circumstances.

Review 3: Walter Dodds

Evaluation of the Draft Administrative Report: Planning for Removal of *Mysis* Shrimp from Emerald Bay and Lake Tahoe as a Means of Ecosystem and Clarity Restoration

27 Sept 2020 Summary of Review:

The report is a good synthesis of past research and ongoing efforts to assess the role of *Mysis* in the food web of Lake Tahoe and the potential for *Mysis* removal as a tool to improve lake clarity that has been lost over historical levels.

This report is a continuation of exploration of feasibility of removal of *Mysis* shrimp as a method to increase clarity of Lake Tahoe and Emerald Bay. The idea is based on several lines of evidence.

1. In lakes where *Mysis* has been introduced, there have been large decreases in other large zooplankton populations (Cladocera).
2. In Emerald Bay there was a drastic decline of *Mysis*, followed by an increase in Cladocerans and water clarity
3. In Lake Tahoe, *Daphnia* and *Bosmina* all but disappeared after *Mysis* introduction
4. Clarity has continued to decline in Lake Tahoe.

The idea relies upon the idea of trophic cascades in lakes being able to reduce phytoplankton abundance if large grazing zooplankton (primarily Cladocera) can be increased upon removal of their predators. We need to keep in mind that the idea of abating eutrophication with a trophic cascade is controversial in evolutionary terms (e.g. Wetzel 2001) as well as in very oligotrophic lakes, where grazing may not limit phytoplankton production, as food density is so low for zooplankton that they are limited by food production rather than limiting algal production.

More specifically, the idea of successful *Mysis* control that could be followed by increases in water quality is based heavily on the idea that Emerald Bay is an analog for the entire Lake Tahoe. There are a number of reasons to suspect that this may not be true, or at least that we do not have enough data to establish confidence in the similar nature of both systems. In this report alone the authors find different *Mysis* behavior in both lakes, different responses in the mesocosms, and different levels of chlorophyll with maxima at different depths. The data I found in the report were not sufficient to evaluate if the phytoplankton communities were similar.

The second general area that casts doubt upon the potential for *Mysis* control leading to increases in lake clarity is the fact that development has continued in the watershed of the lake throughout the monitoring period, the lake is seeing continued increases in recreational pressure, the lake is experiencing climate change that influences temperatures and stratification, and particulate inputs as well as nutrient inputs could be increasing via atmospheric deposition (e.g. greater upwind urban activity, more frequent fires). The fact that periphyton in the littoral zone of the lake appears to continue to increase also suggests that factors in addition to alteration of the zooplankton community by *Mysis* could be influencing trophic state of the lake. All these suggest that there are a number of other potential explanations for decreased lake clarity that do not involve, or are acting in concert with, disruption of the food web by *Mysis* introduction.

One area where the report does not provide enough information is with respect to the unintended consequences of the trawling operations. I saw no data on bycatch. Thus, fishes could have been impacted. Additionally, the nets could have caused considerable Cladoceran mortality. It is possible that the trawling could remove enough Cladocera that it would preclude their bouncing back even if *Mysis* abundance was lowered to a level where they had modest impact as predators on the Cladocera.

I just get the sense that there could be the potential to make a large ecological mistake here. The initial introduction of *Mysis* was well intentioned, and that led to bad results. Large-scale manipulation in response may not be appropriate. What if someone suggested getting blue whales conditioned to freshwater and letting them do the filtering? This is a "baleen in cheek" comment, but essentially the current proposal involves adding the function of a very large filter feeder into the food web to produce high dollar dog treats. Putting the light comments aside, I do not get the sense that there are enough data yet to be certain that 1) the trawling would be effective at the scale needed to see a strong effect, and 2) what exactly the effect would be even if you could use the trawls to substantially reduce the *Mysis* populations.

A piece of information that might be the most important of all is why exactly did *Mysis* abruptly decline in Emerald Bay? If this could be figured out, it might point to an alternative method of *Mysis* control.

In reading this report I do not find completely compelling evidence for ultimate success of a *Mysis* removal project on Lake Tahoe, but based on the evidence so far I do support many of the recommendations of the report. My comments on each of the suggested actions follow the suggestions from the report in italics. After my comments on suggested actions, I provide more detailed comments on specific points in the report.

Comments on Suggested Actions

- As Emerald Bay could be used as an analog for Tahoe for future management and scientific questions, a baseline monitoring program should be established in order to identify deviations and synchronies between the two. Emerald Bay will be quicker to respond to changes than the main lake and could serve as a sentinel for Lake Tahoe.

This will be necessary before results can be extrapolated to Lake Tahoe. However, I am somewhat skeptical that the bay is an adequate analog.

- The measurement of annual PP in Emerald Bay should be considered as part of future monitoring, including the relative contributions of benthic and pelagic sources of production to ecosystem totals. *This is important because prior research suggests that Emerald Bay is substantially more productive than Lake Tahoe. As mentioned already, trophic cascades may be ineffective in ultra- oligotrophic lakes.*

- More thoroughly characterize the seasonal areal distribution and age distribution of *Mysis* within Lake Tahoe. This will enable the determination of whether *Mysis* can be efficiently harvested in the spring in Lake Tahoe.

This is a huge data gap so far.

- Develop a population model for *Mysis*, particularly for Lake Tahoe, where the 3-4 year life

cycle introduces greater complexity.

This will also be important in understanding effective methods of Mysis population control.

- Develop population models for *Daphnia* and Bosmina to better allow planning in a future condition where *Mysis*, *Daphnia* and Bosmina could coexist. These models would need to take into account future temperature changes (as water temperature provides different barriers to each species).
This is important as well.

- ASV and/or AUV surveys of *Mysis* distribution in Lake Tahoe are a critical priority. The size of the resource needs to be better quantified, and in particular its areal distribution and how this changes seasonally. The detailed planning, optimizing and costing of *Mysis* removal depends directly on knowing this.

Agreed, although this is a verily high-tech endeavor and covering a substantial portion of the lake would require a large effort.

- Develop real-time, operational bioacoustics to optimize harvest efficiency.

This would increase the probability of success.

- Archiving bioacoustic data for calibration and validation of three-dimensional particle tracking models, along with other physical data needed for modeling studies.
This would be necessary for retrospective analysis of success

- Conduct bioacoustic surveys of Lake Tahoe focusing on littoral – pelagic differences seasonality, and differentiating between *Mysis* age classes.

Agreed, this is probably the largest information gap currently, as we simply do not know where Mysis congregates in Lake Tahoe at different times and as a function of life stage.

- Determine whether littoral *Mysis* populations are evenly distributed around the lake *Agreed*

- A high priority will be to monitor the abundance of Cyclotella and fine inorganic particles both before and after future *Mysis* removal efforts.
All phytoplankton should be monitored

-A "full scale", commercial trawling experiment in Emerald Bay is the only way to evaluate the economics and benefits of *Mysis* removal, and necessary steps for up-scaling to Lake Tahoe. It had originally been anticipated that a "research-scale" approach could provide that information, but that proved to be insufficient effort. Based on the experience of this project, the actual trawling for Emerald Bay may take less than one month if the appropriately designed equipment is used.

This might be a bit premature if we do not know if Emerald Bay is indeed an analog for Lake Tahoe

- A monitoring program to determine the changes to physical, chemical, biological and ecological components should be integrated with the above experiment, with monitoring both before and after trawling. The monitoring should include the entire food web (phytoplankton to fish), and the harvested *Mysis* should be used toward developing a marketable product that can either offset or fully cover *Mysis* control costs in the future.
This would be necessary to test feasibility of moving the harvest to the whole lake

Develop a three-dimensional *Mysis* distribution model to be operated both in conjunction with the operational bioacoustics, and to permit longer term planning.

This would be necessary.

Specific comments on document (page numbers refer to numbers on the bottom of the pages, as they do not always correspond to the page number of the Adobe PDF I received)

Page 11. There is a good bit of data suggesting that inert particles are mostly rejected by *Daphnia*, and they can survive in environments with relatively high inorganic turbidity.

Page 12. Acknowledgement that nutrient increases could be important Page 12. It looks like Secchi has flattened since the late 1990's

Page 13. Why specifically did Carney and Elser (1990) and Elser and Goldman (1991) reject the importance of grazing in Lake Tahoe?

Page 21. The figure 4.2 does not allow good comparison of *Mysis* and zooplankton numbers as they are presented per unit area and volume respectively. More important the link between decreases in *Mysis* and increases in *Daphnia* and *Bosmina* is not very clear in this figure. Also, scales that would allow seeing the Cladoceran numbers more clearly would be helpful.

Page 22. The diferring life history patterns of *Mysis* in Emerald Bay and Lake Tahoe suggest that Emerald Bay may not be such a great analog for Lake Tahoe.

Page 39. First full paragraph. Evidence of what?
Page 47. While there is a distinct layering, the proportion of the population is not clear.

Page 53. Figure 4.31. The chlorophyll maximum is at a substantially different level of the main lake. This is another piece of data that suggests that Emerald Bay is not an analog.

Page 56. Figure 4.35. Here is a figure that suggests there are intense feeding zones where pulling a very fine mesh net through areas that have high biomass density will capture many organisms that are not necessarily targets.

Figure 4.42 The y axis is labeled as biomass, but this is relative abundance.

Page 63. The idea that *Mysis* could be a grazer of cryptomonads casts doubt on the potential of control of primary production via a trophic cascade. Omnivory is one of the main arguments against the trophic cascade.

Figure 4.45 and 4.46. I think something is wrong with y axis labels

Page 67. The argument that Emerald bay is an analog to the main lake would be buttressed if the phytoplankton communities were similar.

Page 76. This is an important point, and totally agree that understanding differences in life cycles between the main lake and Emerald Bay is key.

Page 76. This would be an important place to note any bycatch of the different mesh sizes.

Page 84. The DIN/ SRP ratios are often useless because they do not say anything about flux rates (Dodds 2003).

Page 85. The mesocosm experiment suggests *Mysis* control will not cause a trophic cascade that goes through to phytoplankton in Lake Tahoe.

Page 86. If N is excreted as ammonium, and P as particulate materials, then the stoichiometry is incomplete, and the dissolved inorganic ratios could only reflect this fact.

Page 89. There are paradoxical effects of *Daphnia* P excretion on P availability that have not been resolved as far as I know (Dodds et al. 1991).

Figure 6.1 Legend. Do not understand what "removals are" or how PPR can be <1 in the figure.

Figure 6.5 Not sure the utility of the NMDS plots

Page 103. While proponents of the amino acid stable isotope method have argued that you do not need food sources from a specific area to apply the method, I am highly skeptical of that claim. I simply do not believe that some isotope ratios from the amino acids of a few terrestrial plants or cultures of algae or fungi can tell you what those ratios will be in nature. We know as a fact that bulk isotope ratios vary widely among habitats, and that factors such as diffusive flux rates can alter 13C composition of algal producers.

Page 103. Gut contents suggest few zooplankton are consumed by *Mysis*, indicating they may not be playing the ecological role previously thought. However, the pollen and *Kellekottia* are pretty recalcitrant and may simply not be digested.

Page 109. I think the food source conclusions are tenuous at best without analysis of isotopic composition of potential food sources.

Page 110 ended abruptly in my copy.

Page 111. This is still a correlation between *Mysis* increase, *Daphnia* decrease, and clarity decrease.

Page 112. Much of your data suggest that Emerald Bay is not a great analog for Tahoe. Also, I did not see direct comparisons of phytoplankton community structure in this report. Finally, the mesocosm experiments suggested substantial differences.

Page 121. "These hypotheses are highly relevant for and applicable to Lake Tahoe, but can be tested far faster and more easily in Emerald Bay", true, but this assumes Emerald Bay is a reliable analog.

Dodds, W. K. 2003. Misuse of inorganic N and soluble reactive P concentrations to indicate nutrient status of surface waters. Journal of the North American Benthological Society **22**:171-181.

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Wetzel, R. G. 2001. Limnology: Lake and River Ecosystems, third edition. Academic Press, San Diego.