

Recommendation for a “No Effect” Selenium Standard for the Great Salt Lake

The following Great Salt Lake Steering Committee Members recommend that the Water Quality Board adopt a No Effect selenium standard for the Great Salt Lake of 5 mg/kg dry weight:

Nathan Darnall, U.S. Fish and Wildlife Service (Federal Government)
Dave Naftz, U.S. Geological Survey (Federal Government)
Clay Perschon, Utah Division of Wildlife Resources (State Government)
Chris Montague, The Nature Conservancy (Environmental Organizations)
Maunsel Pearce, Great Salt Lake Alliance (Environmental Organizations)

The aforementioned Steering Committee members would like to publically recognize and express our deep appreciation to the State of Utah, the Utah Division of Water Quality and to Walt Baker for undertaking this groundbreaking effort to develop a selenium water quality standard for the Great Salt Lake. We also appreciate the Water Quality Board’s time and attention in considering our recommendation, and we trust that the Board will recognize our position as the most prudent course of action which would allow the State to both fully protect the Lake and its many beneficial uses and meet society’s and industry’s need to discharge contaminants into the Great Salt Lake.

We acknowledge that our “No Effect” recommendation deviates slightly from many on the Science Panel and hence with many on the Steering Committee; however, our position does not conflict with the science. Instead, it is a policy decision about how much protection should be afforded the Great Salt Lake. Our desire to *fully protect* the Lake is based on many factors including: the current condition of Great Salt Lake; the many uncertainties identified by science; the unique conditions, processes and birdlife associated with Great Salt Lake; the hormetic effects of selenium; and the potential future condition of the Lake. And while some may argue that precedents set here may harm the State and its ability to set future water quality standards, we respectfully disagree.

- Setting a No Effect standard would provide a “cushion” to allow a *doubling* of selenium loads to the Great Salt Lake (meeting society’s needs) and would also fully protect the Lake’s beneficial uses. Setting a higher EC10 standard would allow up to five times more selenium to enter the Lake than is currently present, while also causing harm.
- Many assume an EC10 will be protective; however, *an EC10 would allow harm to occur* via a “take” of 10% (or more) of the eggs along the shoreline at Great Salt Lake. Additionally, there are species for which an EC10 standard may not be protective, and there are also many uncertainties not fully considered with an EC10. A No Effect standard would be a more appropriate level of protection for the resources of Great Salt Lake.
- *The Great Salt Lake is unique*: it is a terminal, saline lake where assumptions for freshwater may not apply, where species are adapted to life on the saline environments, and with all the research to date we are still learning about the Lake, including potential increases in selenium concentrations throughout the ecosystem.
- Setting a No Effect standard *will not* set a “dangerous” or irreconcilable precedent for Utah or EPA; rather a No Effect standard is appropriate given the unique resource.
- In 2004 the public was against discharging selenium to the Jordan River, and in 2008 the vast majority of public comments have expressed a preference for a No Effect standard.
- The public is interested, and the State has obligations under the Public Trust Doctrine.

Current Conditions

Currently, concentrations of selenium measured in Great Salt Lake water and in eggs of birds nesting on the Lake are low and are within appropriate ranges (i.e., not toxic, not deficient). For example, the geometric mean concentration measured in all bird eggs during 2006 and 2007 is 2.7 mg/kg¹. This value is nearly half that of our recommended value of 5 mg/kg which we believe to be a reasonable estimate of the “No Effect” concentration. At current conditions, it would be necessary to almost *double* the amount of selenium in eggs before reaching a level of impairment under our recommendation, and even this seems unlikely since volatilization appears to be a significant, natural process of selenium removal at Great Salt Lake (Johnson et al., 2008). Given the current conditions and given selenium removal processes, we believe the probability of reaching our No Effect concentration is small, even with some additional loads. Of course, this may not hold true if selenium loading is radically increased, whether by point or nonpoint sources; however, a significant increase (e.g., doubling or tripling of all selenium loads) would not characterize prudent management of this lake and hence is not likely to occur. Therefore, the two-fold difference between current conditions and our recommended No Effect standard provides adequate flexibility to allow some additional loading to the lake while at the same time fully protecting the Lake’s beneficial uses.

Uncertainties and Conservatism

Based on the results of scientific studies over the last two years, we now know that concentrations of selenium in Great Salt Lake water are less than 1 part per billion and that concentrations of selenium in avian eggs at most locations around the GSL are below what the U.S. Fish and Wildlife Service considers background levels (<3 mg/kg) (National Irrigation Water Quality Program, 1998). Based on these studies, we also know that brine fly larvae, rather than brine shrimp, appear to be the preferred food item of shorebirds breeding on the shores of the Lake; however, brine shrimp contain about twice as much selenium as brine fly larvae.

While the Science Panel agreed that reproductive effects are acknowledged as the most sensitive endpoint for selenium, the Panel also agreed that non-reproductive effects could occur but that there was little information available and that these effects may be difficult to detect. We agree that basing the selenium standard on egg hatchability is a conservative approach and that basing the standard on the mallard toxicity curve adds additional conservatism²; however, we are concerned that species such as the eared grebe that eat brine shrimp for an extended period of time may be affected, especially if concentrations in eggs were allowed to approach the EC10 value of 12.5 mg/kg recommended by a number of the Science Panel members. At 12.5 mg/kg in eggs, the model predicts 18.4 mg/kg in brine shrimp (as a geometric mean). The fact that eared grebes and other species could be exposed to these high dietary concentrations for weeks or months is of concern, especially since the science has *not* informed us about the effects. At these higher concentrations, spring migrants that stage on Great Salt Lake prior to breeding might also accumulate enough selenium to potentially affect reproduction at locations far removed from the Lake. However, at our recommended No Effect standard, concentrations in brine shrimp are modeled to be 7.5 mg/kg which would obviate many of the concerns regarding non-reproductive effects and would still allow for nearly a doubling over existing concentrations.

¹ All tissue concentrations are presented as dry weight unless otherwise specified.

² Mallards are more sensitive to selenium than many other species for which there are data, but mallards are likely not the most sensitive (Skorupa, 2008), and there are many species that use the Lake for which we have no data.

The selenium studies at Great Salt Lake found elevated concentrations of both *selenium and mercury* in livers and blood of gulls and shorebirds. The Science Panel did not provide any solid conclusions as to the importance of these findings, other than it is a concern and needs additional evaluation. Previous studies (Heinz & Hoffman, 1998) have shown that mercury and selenium, acting together, are substantially more toxic to avian reproduction than either one alone; this “synergism” is more potent than simply additive. Since we do not fully know mercury’s role in selenium toxicity at the Great Salt Lake, we believe the State should strive to keep both elements near background or No Effect concentrations.

There are a number of other uncertainties and concerns including that concentrations of selenium in water, sediments, (Johnson et al., 2008) brine shrimp and grebe livers (Darnall & Miles, 2008) appear to be increasing over time. These increases, if real, may be cyclical and perhaps we will see a decline in the future, but perhaps the Lake is slow in responding to additional loads and we are only now seeing the impact of historic discharges. Since we do not understand how the Lake responds to additional selenium loads, nor do we know how fluctuating Lake elevations affect selenium cycling, we believe it would be prudent to set a conservative standard that would keep the amount of new or additional loads that could be added to the Lake at a reasonable level until we are more certain about how the Lake responds to these additional loads. Again, setting a No Effect standard would still allow additional selenium loads and be fully protective of the Lake’s beneficial uses.

The Lake’s Unique Conditions, Processes and Birdlife

It almost goes without saying that the Great Salt Lake is unique, but it is worth remembering some of these remarkable characteristics: the Lake is a highly saline environment; it is a dynamic system; it is used by millions of birds annually; and the Lake is full of surprises and much about the Lake is not fully understood. The uniqueness of the Lake and its “surprises” may serve to reduce the toxic effects of selenium, but they may also create circumstances that facilitate greater or unexpected effects. It is this uncertainty associated with these unique features that advocates for a more protective standard.

The Science Panel only studied selenium at the Lake during a brief “snapshot” of conditions, yet there were a number of surprises. One surprise was that concentrations of selenium in bird blood were many times higher than what would be expected given the concentrations measured in diet and in eggs. This was an unexpected finding and unfortunately we do not fully know the reasons why this has occurred or what the implications might be. Another result is that volatilization may be a significant selenium removal mechanism for the Great Salt Lake; this finding is of interest because volatilization plays an apparently insignificant role in wetlands, yet for the Lake it may act to keep concentrations lower. It was also unexpected to find that there may be a significant, unmeasured, additional load of selenium to the Lake. Again, these numerous revelations may benefit the Lake (e.g., by removing or reducing selenium toxicity), but they may also exacerbate the toxicity or sensitivity of wildlife (e.g., synergism with mercury). The above mentioned items (selenium in blood, volatilization rates and unmeasured loads) were identified within a short two-year span, but there may be additional unknowns that could benefit the Lake or be a detriment. Implementing a No Effect standard would minimize any potential, unknown harm.

The Great Salt Lake is so saline that only a few salt-loving organisms use it; however, what may be lacking in diversity is made up for in density with massive biomass of brine shrimp and brine

fly larvae. Brine shrimp are the highest life form whose life cycle is totally dependent on the open waters of the Great Salt Lake. They also provide the basis for the Brine Shrimp Cyst Industry, and the food base for millions of birds such as eared grebes, phalaropes, and waterfowl. A few bird species like the eared grebe are uniquely suited to the Lake. The physiology and annual migration of eared grebes is also unlike any other species. These birds arrive at the Lake in late summer, lose their ability to fly, undergo a molt, radically change their body composition, and eat nothing but brine shrimp for three to four months. Up to half of the world's population of eared grebes rely on Great Salt Lake. Given their unique relationship with the Lake, if selenium concentrations in brine shrimp were to reach 18.4 mg/kg (based on the modeled value associated with 12.5 mg/kg in eggs), the concentrations in grebe livers may increase many times over. With an elevated load of selenium, the birds could experience difficulties during migration or even surviving on the Lake due to factors such as Winter Stress Syndrome. It is also important to realize that during the past 10 years, concentrations of selenium in brine shrimp have risen substantially, nearly doubling, while concentrations in the livers of eared grebes have also risen substantially (Darnall and Miles, 2008). Increasing concentrations in brine shrimp another 4-5 times over current conditions would likely have profound impacts on these millions of birds. Data collected by the U.S. Fish and Wildlife Service show a similar pattern of increasing concentrations of mercury in eared grebes that mimic those of selenium, and in fact may be intimately correlated. And data collected by the UDWR in recent years have shown that mercury is prevalent enough in some species of waterfowl that health alerts have been issued. Raising the standard for selenium may have impacts on mercury contamination of birds. Setting a No Effect standard would keep brine shrimp under 7.5 mg/kg which would very likely protect eared grebes and other avian species and still allow for an increase in selenium loadings.

Again, it is also worth reminding ourselves that there is a lot we do not yet know about the Lake and that we are amazed by it on a regular basis. The unique conditions (e.g., salinity), processes (e.g., volatilization), and birdlife (e.g., eared grebes) deserve special consideration. We should also recognize that there are unknowns such as the potential impacts that global climate change might have on the Lake, selenium cycling and avian species. Together, these factors suggest that a No Effect standard is the appropriate approach.

Hormesis

Hormesis refers to the qualities of selenium whereby too little leads to deficiencies and too much leads to toxicity. It is this narrow balance between too little and too much that has been lacking in previous consideration in the development of toxicity curves. Dr. Joe Skorupa, U.S. Fish and Wildlife Service Clean Water Act Biologist and Science Panel member, provides a detailed description of hormesis in his recommendation to the Steering Committee (Skorupa, 2008) and how factoring these properties into the toxicity curves for mallard ducks changes the location of the EC10. Based on Dr. Skorupa's analysis, we believe the hormetic effects of selenium are an important consideration and should be considered in setting a standard for the Great Salt Lake. If the State were to adopt an EC10, we strongly encourage the State to incorporate and consider the hormetic effects of selenium. We believe the Science Panel recognized the importance of hormesis in selenium toxicity and in its potential influence on the toxicity curves generated from previous toxicity studies, but unfortunately the Panel did not have access to a peer-reviewed, published manuscript at the time that the range of toxicity values were considered. Including hormesis in the toxicity curves moves the EC10 (8 mg/kg) much closer to our recommended No Effect standard (5 mg/kg).

Summary

Given the current low selenium conditions of the Great Salt Lake, the vast number of uncertainties that have been identified and those that have potentially not been identified, the many unique conditions and processes and birdlife associated with the Great Salt Lake, and the influence of hormesis in selenium toxicity, we believe that a precautionary approach is warranted and mandated, and we advocate for a standard that will be *fully protective* of the beneficial uses of Great Salt Lake, not just partially protective. Because of this, we recommend a safe standard be set in avian eggs at 5 mg/kg on a dry weight basis. With this No Effect standard, we believe it would be unnecessary to establish a multi-tiered assessment methodology. Instead, a stepped-up monitoring program could be implemented when concentrations reach 80% (4 mg/kg) of the standard.

Finally, we recognize that the effort to set a selenium standard for Great Salt Lake has involved significant funding which was provided by many partners, has benefited by the consistent dedication of many individuals, and has required the steadfast commitment by all involved, especially the Division of Water Quality. It is all truly appreciated.

Reference List

1. Darnall, N. L., & Miles, A. K. Dynamics of mercury in eared grebes on the Great Salt Lake. 10th International Conference on Salt Lake Research & Friends of Great Salt Lake Issues Forum.
2. Heinz, G. H., & Hoffman, D. J. (1998). Methylmercury chloride and selenomethionine interactions on health and reproduction in mallards. *Environmental Toxicology and Chemistry*, 17(2), 139-145.
3. Johnson, W. P., Naftz, D. L., Diaz, X., Beisner, K., Oliver, W., & Fuller, C. (2008). Estimation of selenium removal fluxes from the South Arm of the Great Salt Lake. Salt Lake City, Utah: University of Utah.
4. National Irrigation Water Quality Program. (1998). Guidelines for interpretation of the biological effects of selected constituents in biota, water and sediment. (Report No. Information Report No. 3). National Irrigation Water Quality Program.
5. Ohlendorf, H. (2007). Threshold values for selenium in Great Salt Lake: selections by the Science Panel. CH2MHill.
6. Skorupa, J. (2008). Great Salt Lake selenium standard: written recommendation to the Steering Committee. Arlington, Virginia: U.S. Fish and Wildlife Service.

Appendix to the Report -- The following section provides a series of specific Questions and Answers to address the reasons we are recommending a No Effect standard rather than an EC10.

Question: Are mallards more sensitive to selenium than other bird species?

Answer: Based on the best data we have mallards are more sensitive to selenium than many of the birds that regularly nest around the Great Salt Lake (e.g. American avocets, black-necked stilts, and snowy plover). However, American coot and chickens are more sensitive to selenium than are mallards; therefore, mallards may be at near a 75th percentile for selenium sensitivity rather than the 95th percentile (Skorupa, 2008). Since we do not have data on all species utilizing the Great Salt Lake (a few examples include eared grebe, Wilson's phalarope, red-necked phalarope, common goldeneye and northern shoveler) there may be other species for which the mallard toxicity curves do not sufficiently protect. In addition, non-reproductive effects for eared grebes, phalaropes and waterfowl have not been fully studied.

Questions: By using the mallard toxicity curves, are we being too protective?

Answer: No. Mallards are not the most sensitive species to selenium and there are many species for which we have no data. In addition, the water quality standard for the Great Salt Lake should not be considered a mallard standard or an avocet standard or a gull standard, but rather should be thought of as an ecosystem protection standard. The mallard toxicity curves help us identify what may be necessary for ecosystem protection. Due to the uniqueness of the Lake and its birdlife, non-reproductive effects may be a more important consideration, and in the future as conditions change at the Lake, there may be species more sensitive to selenium than mallards that will nest at Great Salt Lake. Similarly, species that stage at Great Salt Lake during spring migration just prior to breeding may accumulate sufficient selenium to affect reproduction even though nesting occurs many miles away from the Lake.

Question: Why is hormesis an important consideration in setting the selenium standard?

Answer: The negative effects of selenium are associated with both too little selenium (deficiency) and too much selenium (toxicity). Toxicity tests have often incorporated a control diet with no (or too little) selenium which results in deficiency that affects the endpoint (e.g., reduces hatchability) similar to that of toxicity. Since the effect occurs at both the lower and upper end of the dietary exposure, this changes the shape of the curve and influences where the EC10 falls on the axis. If the influence of hormesis is considered in evaluating the toxicity curves, the actual EC10 for mallard egg hatchability is near 8 mg/kg rather than 12.5 mg/kg.

Question: If hormesis is so important, why didn't the Science Panel consider it?

Answer: The Science Panel did review hormesis but did not have access to a published, peer-reviewed paper at that time. In 2008, a paper was published and available for consideration; however, we feel that due to pressing deadlines for reports and recommendations, the Science Panel was not encouraged to review additional material that might better inform them of hormesis. Had there been time for the Science Panel to consider hormesis, we believe it could have affected the recommendations from the Science Panel.

Question: Is reproduction the most sensitive endpoint?

Answer: Reproduction is considered the most sensitive endpoint; however, we know little about the effects of selenium on species such as eared grebes that feed on brine shrimp for three to four months during a stressful period of starvation, migration and cold, winter temperatures. Every year, roughly one half of the world's population of eared grebes stage on Great Salt Lake for three to four months and eat brine shrimp almost exclusively. The physiology and migration

chronology of eared grebes is truly unique and must be considered when setting a standard. Until we know more about the grebe's sensitivity to selenium, we should apply a precautionary approach and not summarily rule out that it is not a more sensitive endpoint than reproduction.

Question: Is it appropriate to implement a precautionary approach?

Answer: Yes. Currently, we have capacity to continue discharging and could allow additional loads to the Lake. We can set a "No Effect" standard now and revisit if needed. This gives us a chance to make small changes and not over-commit. If GSL were contaminated, it would be extremely difficult and costly to cleanup.

Question: Is 5 mg/kg a reasonable estimate of the No Effect on mallard egg hatchability?

Answer: Yes. The No Effect concentration is likely to occur somewhere between the upper bound of a normal background concentration (3 mg/kg) (National Irrigation Water Quality Program, 1998) and the best estimate of an EC10 that incorporates the effects of hormesis (8 mg/kg). So the No Effect occurs somewhere between 3 and 8 mg/kg. The Science Panel considered 6.4 mg/kg to be an estimate of an EC3 (without hormesis), while the U.S. Department of Interior considers 6 mg/kg to be a "toxicity threshold" above which effects are likely to occur (National Irrigation Water Quality Program, 1998). The 5 mg/kg number is just below these lower effects thresholds and is a reasonable estimate of the No Effect.

Question: If most of the Science Panel recommended an EC10 value of 12.5 mg/kg, why recommend a "No Effect" standard?

Answer: It is a policy and risk management decision, not simply a science decision. In fact, the Science Panel did not intend to commit to a level of protection but rather wanted "to know what level of protectiveness the State and EPA will apply...so that the Science Panel can most effectively make recommendations" (Ohlendorf, 2007, p.7); however, neither the State nor EPA specified the level of protectiveness to employ. For a few members of the Steering Committee, an EC10 may be a "comfortable" standard due in part to "tradition" and due to the ability to detect effects in the field. But while a 10% effect may be easier to detect in the field, there is still harm below the observed EC10. Our No Effect approach strives for *no harm* and is intended to be fully protective of the Lake's resources. A re-reading of the public comments in 2004 and those submitted recently in this process, leaves no doubt that there is a public desire and expectation for full protection of the avian resources of the Great Salt Lake. We also believe that the Selenium Standard-setting Process itself was initiated under the charge to be fully protective of this resource. Though Steering Committee members clearly represented their constituencies, the Water Quality Board represents the public.

It is our opinion (and one we feel is shared by the public) that the entire selenium standard-setting process was created and charged with the clear directive to determine a standard that would fully protect (prevent impairment and cause no damage to) the globally-important avian resources of the Great Salt Lake. The Majority Recommendation for a 12.5 mg/kg standard includes a high degree of confidence that a 10% hatchability effect will occur at this level of contamination. Acceptance of this level of damage has at times been termed by its proponents as "acceptably protective," "responsibly protective," "adequately protective" and "significantly protective" (a contrasting opinion offered "tolerably toxic"). We maintain that as long as a standard has a "built in" level of impairment or damage, then it has not met the primary purpose and criteria of the process itself: the resource needs full protection, not partial protection. In support of this position, we assert that setting a numeric standard that contains some damage to a valid beneficial use of the Great Salt Lake is contradictory to the Public Trust Doctrine which

creates the fundamental state responsibility to manage these resources on behalf of the public for long-term conservation and sustainability with no diminishment to any of its beneficial uses.

Question: Would setting a "No Effect" standard set an undesirable precedent?

Answer: During a Steering Committee meeting on June 4, 2008, EPA stated that setting a No Effect standard for the Great Salt Lake would not set a precedent that affects other standards since states have discretion in setting standards and since the Great Salt Lake is such a unique waterbody that its standards would not apply elsewhere. In setting a standard, we recommend the Water Quality Board apply an ecosystem approach, rather than the typical point source discharge approach where the impact/effect is limited to a short segment of the stream. In other waterbodies (e.g., streams and rivers) concentrations of a pollutant fluctuate due to stream flows, discharge flows, changes in discharge activities, and "refugia" areas outside of mixing zones. This means that the system is not exposed to a constant concentration of the pollutant. For Great Salt Lake, the exposure to selenium (via a tissue-based standard) would be a constant exposure. These factors make the standard for the Great Salt Lake unique from standards elsewhere.

Question: Is EPA willing to approve a "No Effect" standard?

Answer: Yes. During the last joint Science Panel – Steering Committee meeting, EPA indicated that it would be willing to approve a No Effect standard. EPA also stated that setting a No Effect standard would not set a precedent (either for the State or EPA).

Question: Would setting a "No Effect" standard impact current and future discharges?

Answer: No. With a No Effect standard, existing concentrations (and loads) would need to nearly double before the State would be required to take action, and then only if increased concentrations were reflected in water, shrimp and eggs. Current loads could be increased and still meet the No Effect standard.

Question: Would setting a "No Effect" standard limit the State's options?

Answer: Water quality standards can be reviewed and changed through the normal triennial review processes. There is currently enough capacity under the No Effect level to nearly double the selenium discharge to the Lake. It would be prudent to implement a No Effect standard and in the meantime gather additional information to verify selenium dynamics and potential impacts, rather than to *encourage* selenium loading with a higher standard to only later determine that the outcomes of selenium contamination are difficult or impossible to reverse.

Question: Is their value in an assessment method?

Answer: Every standard will require some level of assessment, which will include the collection of samples and methods for analyzing the data. Regular monitoring of water, brine shrimp and occasional sampling of avian eggs will be needed to assess the Lake's status. Those with experience on the Lake and with sample collection should help develop the assessment methods and may also be useful in the collection of data. The public should also be able to provide input and participate in the development of the assessment methods. With the No Effect standard, we believe it would be unnecessary to establish a multi-tiered assessment methodology. Instead, a stepped-up monitoring program could be implemented when concentrations reach 80% (4 mg/kg) of the standard. To help evaluate the Lake, it would be prudent to increase new selenium loads slowly over time to determine how quickly the Lake responds to the new loads or determine if there is a lag time between new loads and changes in selenium concentrations.