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DATE: 24 September 2009

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SUBJECT: ***AUGUST 2009 AMMONIA SUMMIT SUMMARY***

What follows are some preliminary conclusions after reviewing abstracts and presentations made at the August 18-19 Ammonia Summit and talking with key presenters. It is important to recognize that most of the information presented at the summit has not been peer reviewed or published in final reports. This review of information presented at the Summit is intended to help answer two questions:

1. *Does ammonia cause beneficial use impairments in the Delta*?
2. *Are additional studies needed to answer the above question?*

Elevated ammonia concentrations have been hypothesized to cause three beneficial use impairments. The first is that elevated ammonia may cause acute and/or chronic toxicity to Delta fish and invertebrates, including POD species and their primary prey. The second is that ammonia may inhibit diatom primary production. Diatoms are an important food source for the aquatic food chain in the Delta. Decreases in diatom food production could contribute to the collapse of the food chain. Finally, elevated ammonia levels may cause a shift in the algal community from nutritious species such as diatoms to less desirable forms like *Microcystis*. A consensus at the Summit was that the Sacramento Regional Wastewater Treatment Plant (SRWTP) was a major source of ammonia to the Delta.

Toxicity A suite of acute toxicity tests has been completed with delta smelt at the UC Davis Aquatic Toxicology Laboratory (ATL) by Dr. Inge Werner. The tests demonstrate that ammonia levels in the Sacramento River below the SRWTP are not acutely toxic to smelt. There is currently no standard method for assessing chronic toxicity to delta smelt. In such situations, acute to chronic ratios (ACRs) developed with other fish species are used to assess the potential for chronic instream toxicity. The ATL completed an ACR evaluation and concluded that chronic smelt toxicity could be occurring at ambient ammonia levels present in the River below the SRWTP (Werner *et al*., 2009). As shown by Dr. Diana Engle, LWA, ammonia concentrations in the Sacramento River do not exceed the chronic concentrations in U.S. EPA ammonia toxicity criteria. The ATL test results also suggest that additional toxic contaminant(s) were present in the effluent. The additional contaminant(s) have not yet been identified. The no and low acute effect concentration of the unknown contaminant(s) (effluent mixed into upstream river water) are 9 and 18 percent effluent, respectively. The SRWTP discharge flow volume is typically two to three percent of river flow volume, but may on occasion be as high as seven percent. The present no and low effect values are based on only

one set of bioassay measurements. Additional studies are needed to better characterize the range of no and low effect concentrations of the unknown contaminant(s). This information is needed to assess the likelihood of chronic toxicity to delta smelt in the river and determine whether a toxicity identification evaluation is needed.

Dr. Swee Teh of UC Davis conducted acute ammonia toxicity testing with *Eurytemora affinis* and *Pseudodiaptomus forbesi*, two invertebrate species that are important forage organisms for larval fish in the delta, including POD species. Ten percent mortality occurred to both species at ambient ammonia concentrations present in the river below the SRWTP. However, toxicity was only observed at a lower pH (7.2) than commonly occurs in the River (7.4 to 7.8). Toxicity was not observed when toxicity testing was done at higher pH levels. Dr. Swee Teh concluded, based on the 10 percent mortality and an ACR analysis, that ambient ammonia concentrations below the SRWTP may cause chronic toxicity to both species. In addition, previous toxicity testing with *E. affinis* identified toxicity at several Delta sites. Additional studies are needed to determine what contaminant is responsible.

David Fullerton of the Metropolitan Water District of Southern California showed that there were statistically significant inverse correlations between the abundance of both copepod species and ammonia concentrations in the Delta and Suisun Bay. These correlations could be the result of direct ammonia toxicity to the copepods as shown by Dr. Teh or of indirect food web effects mediated by ammonia suppression of phytoplankton production and subsequent copepod food limitation as described below.

At the Summit, three research groups lead by Drs. Michael Johnson, Inge Werner and Swee Teh independently concluded that U.S. EPA ammonia criteria are not sufficiently protective of sensitive resident species in the Delta. All will be completing reports within the next six months. Their conclusions rely upon ACR evaluations and there is always uncertainty about whether the correct ACR has been selected. The conclusion that U.S. EPA criteria may not be protective of aquatic resources in the Delta is important because the Regional Board relies upon U.S. EPA criteria in setting limits and evaluating data for various programs. The U.S. EPA recommends the use of more strict effluent limits if important sensitive species are present. A robust set of toxicity tests should be completed to document whether the EPA criteria are adequate to protect these sensitive species. Full life cycle tests with both *E. affinis* and *P. forbesi* could be completed within the next six to eight months at UC Davis and the results would confirm whether U.S. EPA criteria are likely to be low enough to protect these species. The results should also indicate what concentration might be appropriate to protect the species.

Inhibition of Phytoplankton Primary Production Wilkerson *et al* (2006) and Dugdale *et al*. (2007) report that ambient ammonia levels inhibit nitrate uptake by the diatom-dominated phytoplankton community in Suisun Bay and as a result and can prevent diatom bloom formation even when conditions are otherwise favorable. David Fullerton found statistically significant negative correlations between ammonia and chlorophyll concentrations in Suisun Bay. High ammonia levels were associated with low chlorophyll concentrations. Fullerton's results are consistent with the findings of the Dugdale Laboratory. High filtration rates by the introduced clam *Corbula* and high turbidity levels are additional factors responsible for reducing phytoplankton production and biomass in Suisun Bay. A combination of the above three factors may explain the low diatom abundance now present in the Bay. Different combinations of the three factors are likely important at different times of the year.

Ammonia concentrations are higher in the Sacramento River below the SRWTP and in the Delta than in Suisun Bay. An important question that was partially addressed at the summit was whether the higher levels of ammonia in freshwater would inhibit phytoplankton nitrate uptake and growth in the same way as has been published for Suisun Bay. To answer this question, Drs. Richard Dugdale, Frances Wilkerson, and Alex Parker of the SFSU Romberg Tiburon Center completed multiple transect studies along the Sacramento River between the I-80 Bridge at the Yolo/Sacramento county line and Rio Vista. The SRWTP discharge is between the two locations. Incubation experiments with river water from transect sites demonstrate that, similar to the published Suisun Bay findings, ammonia from the SRWTP reduces phytoplankton nitrate uptake. In contrast to Suisun Bay, however, it appears that river algae are able to take up and grow on ammonia downstream of the SRWTP. A final unanswered question is whether the river algae growing on ammonia are diatoms or some other less nutritious form. Water samples from above and below the SRWTP have been preserved and are available for algal identification and enumeration.

The emerging paradigm at the Summit was that elevated ammonia levels inhibit phytoplankton production in brackish Suisun Bay but a similar inhibition was not demonstrated in the freshwater Sacramento River upstream of Rio Vista. There is disagreement among attendees at the summit whether the Delta behaved more like the river or the Suisun Bay. The Dugdale laboratory collected water samples along two transects between the I-80 Bridge and San Francisco Bay and measured nitrogen drawdown and carbon fixation rates. In addition, six sets of grow out experiments have been conducted at Rio Vista. Results from some of these studies were shown at the summit but questions have arisen about the interpretation of the results. Follow up discussions are planned among researchers to help clarify how phytoplankton at and downstream of Rio Vista in the freshwater delta are responding to the ammonia.

Shift in Algal Communities In the last several years, annual blooms of *Microcystis sp.* have been reported in the Delta. This is a problem because high concentrations of *Microcystis sp.* can be toxic. A hypothesis is that the elevated concentrations of ammonia in the Delta are responsible for shifting the competitive advantage to bluegreen algae such as *Microcystis* in late summer. The data collected to date is ambiguous. Dr. Peggy Lehman, DWR, reported at the Summit that *Microcystis* cell abundance sometimes, but not always, increased in nutrient addition experiments with increasing ammonia concentrations. In contrast, Dr. Cecile Mioni, SFSU, concluded, based upon limited data collected between June and October 2008, that increasing cell densities of *Microcystis* were correlated with increasing concentrations of ammonia, albeit only weakly. Dr. Patricia Glibert from the University of Maryland reviewed algal nutrient studies conducted by her laboratory on the east coast. She concluded that increasing concentrations of nitrogen compounds, principally urea and ammonia, often resulted in increasing concentrations of noxious algal blooms. Dr. Glibert is going to advise the State Water Contractors on what kind of algal nutrient experiments should be conducted next.

In summary, no evidence has yet been collected demonstrating that ammonia concentrations are causing beneficial use impairments in the Sacramento River or Delta. Ammonia concentrations in the River and Delta are too low to produce acute toxicity to delta smelt or the invertebrate copepods *E. affinis* and *P. forbesi*. However, there is only a small margin of safety and chronic toxicity is possible to all these species. Algae present in the Sacramento

River upstream of Rio Vista are able to grow equally well on ammonia or nitrate. In contrast, algal growth in Suisun Bay is suppressed by ammonia and phytoplankton biomass never surpasses the range associated with zooplankton food limitation. Discussions are underway to help decide whether algae in the Delta follow the River or Suisun Bay ammonia paradigm. Finally, due to the lack of data on phytoplankton community composition, there is no consensus yet demonstrating that elevated ammonia levels in the Delta have caused a shift in the algal community from diatoms to less nutritious forms.

Additional Studies Staff recommends that additional studies be conducted in three areas. The recommendations are briefly summarized below. Staff will discuss these recommendations at the IEP contaminants work group along with recommendations of other parties.

Delta Smelt Conduct two to four additional toxicity tests with delta smelt and SRWTP effluent to determine the no and low effect concentration range of the unidentified toxicant. These studies could be conducted next spring at the ATL and a final report produced by the fall of 2010.

Invertebrate Life Cycle Tests Full life cycle tests should be conducted with both *E. affinis* and *P. forbesi*. The no effect concentration will be compared with the large body of emerging ambient ammonia data for the Sacramento River and Delta. The results could be used to set lower ammonia limits in NPDES and non point source permits. The State Water Contractor sponsored the acute invertebrate testing. They should be approached to ascertain whether they might be willing to cost share with the Water Board on the invertebrate whole life cycle tests. In addition, studies are needed to follow-up on previous studies that identified *E. affinis* toxicity at sites in the Delta.

Algal Cell Counts Algal species identification and cell counts are needed on water samples collected on transects down the Sacramento River and across the Delta. The purpose of this work would be to determine whether ammonia concentrations are responsible for changing the algal community from a nutritious diatom based food chain to one that is less palatable. Staff from the San Francisco Regional Board has expressed an interest in using some of their SWAMP funds to identify algal species composition in samples collected in their region. Funds would be needed for identification work in the Sacramento River and freshwater portion of the Delta.