980 Ninth Street, Suite 1500
Sacramento, CA 95814
www.deltacouncil.ca.gov

Lead Scientist's Report

Summary: This report covers six items:

Collaborative Science Activities: (1) Review of the report on Net Delta Outflow (NDO);

Science Communication: (2) Summary of two journal articles on hatchery genetic management and harmful algal blooms; (3) Two synthesis articles from the San Francisco Estuary and Watershed Science (SFEWS) journal on predation and changing landscapes in the Delta; (4) Brown Bag Seminar on California's drought; (5) One poster from the Delta Independent Science Board meeting on levee hazards; and (6) the "By the Numbers" summary.

Collaborative Science Activities

Science Review of a Report on Estimating Net Delta Outflow

The State Water Resources Control Board (SWRCB) is currently undertaking a four-phase process to develop and implement updates to the Bay-Delta Plan and flow objectives for priority tributaries to the Delta to protect beneficial uses in the Bay-Delta watershed (Comprehensive Review). The Bay-Delta Plan identifies beneficial uses of Bay-Delta waters, water quality objectives for the reasonable protection of those beneficial uses, a program of implementation for achieving the water quality objectives and an associated surveillance and monitoring program.

Phase 1 of the Comprehensive Review of the Bay-Delta Plan is focused on southern Delta water quality and San Joaquin River flows. Phase 2 is focused on other changes that may be needed to update the remainder of the Bay-Delta Plan in order to protect beneficial uses, including fish and wildlife beneficial uses. One of the important parameters affecting fish and wildlife beneficial uses is NDO.

As part of Phase 2, the SWRCB has requested that the Delta Science Program facilitate a peer review of a report provided by the Department of Water Resources, which provided technical analysis of appropriate methodologies for determining NDO. Measuring NDO is extremely challenging because tidal dynamics within the Delta move large quantities of water into and out of the Delta, but only a small component of this water is net outflow. NDO, however, serves as a regulatory parameter in the Bay-Delta Plan, and accurate estimates are important. The Delta Science Program received the finished peer review report on Sept. 26, and the report will be available to the public in the near future.

Science Communication

Fish Hatchery Genetic Management Techniques: Integrating Theory with Implementation

Kathleen M. Fisch, Christine C. Kozfkay, Jamie A. Ivy, Oliver A. Ryder & Robin S. Waples. North American Journal of Aquaculture, June 2015

Fish hatcheries are important management and conservation tools. Hatcheries produce fish for supplementing wild populations and/or preserving threatened or endangered species. When preservation is the goal, certain considerations are critical to ensure that the population succeeds in the wild. The Delta Plan recommends development and implementation of scientifically sound hatchery operations with genetic management plans to reduce risks to wild populations. Just like in zoos that mate threatened or endangered species for population management, care must be taken to avoid inbreeding. Avoiding inbreeding increases genetic diversity. Higher genetic diversity prevents disease and makes the species more fit to survive and propagate in the future. Another important consideration is minimizing adaptation to captivity so that when fish are released back into the wild, they are prepared to survive in non-captive environments.

Hatcheries use many well researched strategies to increase the chances of successfully conserving fish species. These strategies include a variety of types of random mating, using genetic markers to select matings, and controlling the size of fish families. A recent review surveyed 36 hatchery programs to determine which techniques are used and should be used, depending on the size and goals of the hatchery operation. This research is very applicable in our efforts to protect endangered species like the delta smelt and spring-run and winter-run Chinook salmon.

Kathleen Fisch, the lead author, performed this research while she was a Delta Science Fellow. The American Fisheries Society (AFS) recently recognized the value of this research by declaring this review the winner of this year's Stevan R. Phelps award for the best genetics paper published in an AFS journal. Support from the Delta Stewardship Council enabled this research and publication, and this award winning paper shows the value of investing in early career scientists doing research in the Delta.

Mitigating Cyanobacterial Harmful Algal Blooms in Aquatic Ecosystems Impacted by Climate Change and Anthropogenic Nutrients

Hans W. Paerl, Wayne S. Gardner, Karl E. Havens, Alan R. Joyner, Mark J. McCarthy, Silvia E. Newell, Boqiang Qin, J. Thad Scott. Harmful Algae, April 2016

Outbreaks of algae are normal summer occurrences. This year, the size and frequency of these algal blooms are worse than ever, worrying water managers in more than 20 states including California. These blooms are often observed as

expanses of green film on the surface of the water. In addition to being unsightly, the blooms are also dangerous. Current readings of toxins caused by the algae have been as high as 7,500 times greater than what would normally be considered worrisome.

Cyanobacteria are a common group of bloom forming microbes found in water all over the world, including the California Delta. Cyanobacteria harmful algal blooms (CyanoHABs) release toxins that threaten human and animal health, aquatic ecosystems, recreational water use, and drinking water supplies. In a recent review of global research, scientists examined how climate change might affect CyanoHAB occurrence and the success of methods used to manage them.

Climate change alters water movement, water temperature, precipitation patterns, and nutrients (nitrogen and phosphorus) in ways that favor CyanoHABs over other more beneficial organisms. For example, a precipitation pattern associated with climate change is prolonged drought followed by high rainfall and runoff. This creates a “perfect storm” for CyanoHAB formation because it allows for nutrients to build up and then run off into water bodies during storms. This creates a high load of nutrients, which cyanobacteria use to grow and produce dense blooms.

Approaches to alleviating CyanoHABs include physical, chemical, and biological approaches. Physical techniques include skimming and collecting blooms from water surfaces, enhancing water movement, and promoting mixing. Chemical approaches include algaecides directed at killing cyanobacteria. Biological techniques include changes to the aquatic food web that promote beneficial organisms, so they can out-compete cyanobacteria. Climate change will likely negatively affect the efficacy of these various techniques, but it is currently unclear to what degree.

In summary, this article points to the need for more research examining the effects of climate change on CyanoHABS. Critical knowledge gaps are: 1) how changes in precipitation patterns will affect nutrient inputs; 2) how changes in air and water temperature affect CyanoHABs; 3) new approaches for nutrient control strategies to suppress CyanoHABs; and 4) evaluation of the effectiveness of existing and emerging novel CyanoHAB control measures.

2016 Volume 14 Issue 2 of the SFEWS Journal: Special Section on the State of Bay-Delta Science

San Francisco Estuary and Watershed Science is an open access journal, funded by the Council, and is a key venue for publishing the latest research addressing Delta scientific questions. The current issue of the SFEWS journal includes a special edition section that also is the first part of the State of Bay-Delta Science (SBDS) series of papers. The next two issues of the journal will include the rest of the SBDS papers.

SBDS is a synthesis of the best available science about the Delta, emphasizing progress made on key research questions and remaining knowledge gaps. The first edition of SBDS, edited by CALFED Bay-Delta Program lead scientist Michael Healey, Michael Dettinger of the United States Geological Survey and Scripps Institution of Oceanography, and Richard Norgaard of the University of California at Berkeley was published in 2008. Topics for this edition of SBDS address the most relevant scientific issues for the Delta identified by senior scientists and managers. Two articles from the SBDS 2016 Special Issue, Part 1, are summarized below.

Predation on fishes in the Sacramento-San Joaquin Delta: Current knowledge and future directions
Grossman, Gary D.

Predation has been identified as a potential factor contributing to the decline of native fish populations, such as delta smelt and salmonids. However, there is little information on the interactions between predators and prey in the Delta. What we do know is that native and invasive fishes encounter a number of potential predators, such as multiple bass species, garter snakes, bull frogs, river otters, herons, egrets, terns and gulls. This analysis identifies 32 different predator categories and 36 different prey species. The main finding is that most predators consume a variety of both native and invasive fishes, indicating a lack of specialization. For example, striped bass and largemouth bass were found to consume from 32 and 28 prey categories, respectively (including themselves and each other). Most fish predators identified were invasive species, most non-fish predators were native species, and most prey fishes consumed were invasive species (which were also the most abundant species).

Predator-prey relationships are not static entities, and there is a great deal of uncertainty surrounding predation in the Delta. Quantifying the effects of predators requires a complex set of biological and physical data, including: predator and prey abundance; predator efficiency and prey susceptibility to predators; seasonal changes in prey abundnace; and variation in flow, turbidity and prey shelter. These causes of mortality interact in complex ways that remain largely unknown.

Predation involves several components, which are affected by a variety of changes that have occurred in the Delta. Predation is almost always context-dependent, meaning the effects of predators on both individual prey and their populations vary based on the location and timing of the interaction. In the Delta, predation is also affected by reduced spatial variation in habitat, reduced and reversed flows, structural modification, contaminants and invasive species. Such changes in physical conditions (e.g., unnatural or reversed flow patterns, structures such as fish ladders, pipes, modified channels or impoundments) can combine to make predation hot spots. Thirteen hotspots have been identified in the Delta.

Control of invasive predatory fish is a common management strategy, but it has not had a high success rate**.** Predator removal, even in less dynamic systems like reservoirs and lakes, is a difficult and costly management technique. The lack of success in lakes and reservoirs illustrates the challenges inherent in functionally eliminating invasive fish populations in more complex systems. As part of a study on the Mokelumne River that removed predatory fishes using boat electrofishing, Chinook salmon displayed higher survival in the removal section than in the un-shocked control section after the first predator removal. Predator densities in the removal section tripled after the first removal, underscoring the ability of other predatory species to invade when a single predatory species is removed. The second removal did not result in increased Chinook salmon survival. Given the dynamic and highly modified environment of the Delta, careful study should be undertaken before any predator removal or suppression techniques are applied.

The Delta as Changing Landscapes
Wiens, John; Grenier, Letitia; Grossinger, Robin; Healey, Michael

Landscape ecology provides a broad perspective for ecological restoration in the Delta that encompasses the multiple, interacting components of functional landscapes. By emphasizing that the lands and waters of the Delta, while physically distinct, are functionally interconnected, such an approach will foster more resilient and enduring outcomes that benefit the people and the wildlife of the Delta. “Landscapes” do not stop at the water’s edge.

Landscapes can be viewed in multiple ways that can lead to different perceptions of how the same landscape is structured. To a landscape ecologist, these perspectives are characterized by spatial heterogeneity and patches of landscape and waterscape delimited by boundaries and linked together in various ways. They are defined by spatial patterns in hydrology, land uses, vegetation, human infrastructure, and geology.

The science of landscape ecology offers a perspective on management and restoration that integrates the spatial relationships of ecological processes and the functional interconnections of land and water in the Delta. Three dimensions of landscapes - structure, function, and change – are the elements of a scientific approach for the study and management of landscapes. A focus on individual places may fail to recognize and incorporate interactions across entire landscapes.

The historical ecology perspective (using the knowledge of past landscape structure and function) can contribute to the restoration and management of contemporary landscapes. Historically, there were three primary connected landscapes in the Delta – a riparian-lined landscape of flood basins in the north Delta, a landscape of tidal islands in the central Delta, and a landscape of distributary rivers in the south Delta - that shifted between wet and dry periods throughout the year. As Delta ecosystems and landscapes were changed from

their natural states, their resilience decreased, making them more vulnerable to large disturbances like the effects of sea-level rise and climate change. Given the magnitude of changes in the Delta, the goal of management and restoration should not be to replicate the historical state, but to use historical information to help determine where re-establishment of more natural habitats and processes could most effectively support desired ecosystem functions.

Currently, the state of landscape science in the Delta could be characterized as general awareness of landscapes and multiple perspectives about what is important about them. Building on this awareness will require a greater depth of understanding of landscape structure, function, change, and scale as they apply to the Delta. Recommendations include:

- develop a holistic landscape vision across broad areas or regions of the Delta to integrate aquatic and terrestrial habitats;
- foster interagency collaboration for a landscape perspective;
- enhance scientific capacity in landscape modeling and quantitative analysis;
- use spatial analyses and landscape maps to overlay projects, agency responsibilities, key resources, land uses, ownership, species distributions and ecological functions;
- develop a spatial information management system;
- consider the scale of management or restoration actions and anticipated/actual responses; and
- use landscape analyses to ensure the compatibility of the scales of actions and the desired outcomes.

Ideally, applications would include the social sciences to link human actions and land use to ecology, hydrology, and environmental management.

Brown Bag Seminar – <u>Deconstructing the Current California Drought</u>

California, currently in its fifth year of severe drought, is now faced with shifts towards persistent dry periods, separated by large storms, and accompanied by record-breaking warm temperatures. These conditions are characteristic of droughts projected to accompany climate change.

Dr. Michael Dettinger, a US Geological Survey Senior Scientist and Research Hydrologist, presented his analysis of the multi-year deficits that have accumulated during this drought, including deficits in precipitation, snowpack, streamflow, reservoir storage, and hydropower generation. Specifically, he compared the “normal”, long-term average (e.g., 1981-2010; years defined by available data) for each water resource with the average for the drought years 2012 through 2015. He also examined new changes to the deficits through June of 2016.

Converting these deficits into comparable units (where one unit was equivalent to one normal year’s worth of that resource) allowed Dr. Dettinger to assess the collective

effects of the drought and identify which resources are recovering and which are not. For example, he showed that for 2012-2015, the Delta catchment region is behind in water resource levels by:

- ~1.25 years for precipitation,
- ~2.5 to 2.8 years for April 1 snowpack in the Sierras,
- ~2 years for streamflow,

and approximately 1.4 years ahead for groundwater pumping rates in the Central Valley, although this value is likely an underestimate because it does not account for newly established wells.

Compared to conditions during 2012-2015, he found that for 2016:

- The statewide temperature average was a runaway record breaker,
- Snow water equivalent deficits were worse than for previous drought years,
- Streamflow deficits decreased for Northern California but increased in Southern California.

Dr. Dettinger also emphasized that although droughts are typically discussed as a lack of precipitation, it is equally important to consider changes in evaporative and transpirative (evapotranspiration) demand for water. For 2012-2015, there was 2.5 years extra evapotranspiration demand for the Delta catchment area. Moreover, despite regional increases in precipitation levels for Northern California in 2016, the hot temperatures fueled the continuation of an “evapotranspiration demand drought” in many locations. Moving forward, precipitation and evapotranspiration will continue to vie to determine drought severity, and characterizing the drought will require comparing such deficits, which can amplify as they pass through the water cycle.

Poster Summary from the Delta Independent Science Board Meeting on Delta Levee Hazards

The following poster was presented at the July 2016 Delta ISB meeting.

> **Seismic Deformation Potential of Sherman Island Peat, and Fragility Functions for Levees on Peat Soil**
> *A. Shafiee, Y.T. Tsai, S.J. Brandenberg, and J. Stewart*
>
> The potential for earthquakes to deform, or decrease the volume of, the organic soils (peat) underlying many Delta levees has not been studied in as much detail as it has for inorganic soils such as sand, silt, and clay. As a result, the fragility of Delta levees associated with seismic activity is uncertain. This study presents a laboratory testing program that identifies a new deformation mechanism. Specifically, through the application of repeated stress as in an earthquake, peat slumps and spreads out under the strain. This occurs because under repeated stress pressure builds up, causing expulsion of water from the peat, followed by an additional (secondary) compression under lower strains. This secondary

compression occurs with peat but not for inorganic soils. Through modeling of their described deformation mechanism, the authors predicted that a 4 meter levee sitting on top of 11 meters of peat at Sherman Island would potentially deform by up to 0.2 m (about 8 inches) one year after a simulated earthquake. This settlement rate would be in addition to any other sources of deformation. Finally, the authors characterized the seismic fragility of two levee systems in Hokkaido, Japan, one that experienced a 7.6 magnitude earthquake and one that experienced an 8.2 magnitude earthquake. They divided the levee systems into 50 meter segments and used damage and ground motion records to derive the fragility functions for each segment. Preliminary results from the Hokkaido study suggest that, in general, levee systems resting on peat may be more susceptible to damage than those resting on inorganic soil.

By the Numbers

Delta Science Program staff will give a summary of current numbers related to Delta water and environmental management. The summary (Attachment 1) will inform the Council of recent counts, measurements, and monitoring figures driving water and environmental management issues within the Delta and the Delta catchment.

List of Attachments

Attachment 1: By the Numbers Summary *(report to be provided at the Council meeting)*

Contact

Dr. Cliff Dahm
Lead Scientist
Phone: (916) 445-0463