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Delta Primary Production Forum Summary
Held January 31, 2017, Sacramento, CA

Introduction and Forum Purpose

Primary production is the ecosystem function that forms the basis of food webs, and the Sacramento-San Joaquin Delta has unusually low primary productivity (Jassby et al. 2002, Cloern et al. 2014). Food availability has been identified as one contributor to the multi-stressor problem of pelagic organism decline in the Delta (Baxter et al. 2010). However, the constraints on primary production and the relative importance of different production sources to the food web remain major uncertainties in this system. Newly available spatial data developed as part of the Delta Historical Ecology and Delta Landscapes projects (www.sfei.org/projects/delta-landscapes-project) make it possible to explore the effects of landscape configuration and hydrodynamics on primary production in a way that was not previously possible. In a workshop convened during late 2015, an array of experts was asked to develop a science plan to investigate how these data might be used to quantify the effects of landscape change on the capacity of the Delta to provide food for wildlife.

On January 31, 2017, a "Delta Primary Productivity Forum" was held to communicate with Delta restoration practitioners and decision-makers and discuss the science plan generated during the October 2015 workshop. Forum participants were asked to evaluate the merit and potential applications of this approach, and how their input might be solicited as the approach moves forward. Sponsored and hosted by the Delta Science Program, the goal of the Forum was to provide an opportunity to align research questions between scientists and implementers through "co-discovery" (Walker et al. 2002), allowing for implementation partners from agencies and practitioners to be involved in the science process during the early phases of proposed research. Forum attendees (see Appendix) included managers from the California Department of Fish and Wildlife, Delta Science Program, Environmental Protection Agency, Metropolitan Water District, Sacramento Regional County Sanitation District, State and Federal Water Contractors Water Agency, The Nature Conservancy, US Fish and Wildlife Service, and others. This document summarizes the proceedings of the Forum.

A Proposed Science Plan

The Forum commenced with a brief presentation of the science plan from the 2015 workshop. Detailed summaries of the science plan are available in an essay, "Primary Production in the Delta: Then and Now" (Cloern et al. 2016) and a workshop summary "Primary Production in the Sacramento-San Joaquin Delta". Both are available at http://www.sfei.org/news/delta-primary-production-workshop.

The science plan identifies two major complementary hypotheses of how landscape change has affected the capacity of the Delta to provide food for wildlife:

Hypothesis 1: Landscape change has significantly reduced Delta primary production available to support fish, birds and other wildlife. The magnitude of primary production available to wildlife is hypothesized

to have been greatly reduced by the habitat loss that resulted from landscape transformation, and therefore the capacity of the Delta to support large populations of native wildlife has been reduced proportionally.

Hypothesis 2: The Delta has been transformed from an ecosystem largely dependent upon marsh-based production to one dependent upon production by aquatic plants and algae. While the number of primary producer groups is probably roughly the same, the proportion of their contribution to total primary production has likely shifted. This is important for two reasons. First, the quality and availability of organic matter to consumers varies across the primary producer groups (e.g., plants vs. algae). Second, if the portfolio of primary production has become less diverse, than resilience of food webs has been reduced by restricting the types of food available to consumers. Thus, shifts in primary producer communities are expected to drive shifts in the relative abundance of consumers that depend on food derived from specific primary producers.

The Delta Primary Production Project is aimed at investigating three topics:

What is the current amount of primary production available for wildlife in the Delta, and what was the amount available historically? Datasets of historical and modern land cover now available for the Delta provide a unique opportunity to identify the current and historical amount of primary production. By comparing first-order estimates of primary production among five major groups of primary producers, historically and today, we would be better able to identify the *potential* food production of different habitat types, and inform restoration actions that could increase food availability for wildlife.

What is the ecological value of primary production in the Delta? Production in the Delta can be thought of as a portfolio of food resources, with each type of producer providing different nutritional value, in different proportions, at different times of year. A resilient portfolio would provide a suite of available food for consumers over time and space. Estimating the energy available to primary consumers from the five producer groups can be approached by determining the caloric value for each type of producer in a 'common currency' (kcal or grams of Carbon/m-2/yr-1) based on its biochemical properties, then applying a trophic transfer efficiency to these estimates. There are additional considerations about the ultimate fate of the energy, i.e. which consumers benefit from the primary production, which this first step would not address.

How does physical transport of water between habitats affect food production in the Delta? The estimates of primary production and their food value to consumers provide a 'static' picture of food web dynamics. Yet, landscape morphology mediates local transport of water between wetland and aquatic areas, and affects residence time, area and magnitude of tidal exchanges, and mixing of water, which in turn affect processes of primary production. A first step in investigating the effects of transport on primary production is to develop a simple model that investigates only two factors: the exchange of water between channel and marsh habitats, and their effects on phytoplankton production.

Summary of Feedback on the Science Plan

There was a wide-ranging discussion at the Forum. Here we attempt to categorize feedback on the project and draw out specific advice we heard from managers.

Feedback from Forum participants suggested a general agreement that this project has the potential to **contribute to our conceptual understanding of the Delta**, in a way that could facilitate and improve current projects and programs, and inform restoration (but see caveats/limitations below). Order-of-magnitude calculations estimating primary production can 'bookend' the potential magnitude of production in the Delta, and inform what is possible in terms of restoration and management options.

This project attempts to broaden the discussion around primary production from a phytoplankton-centric view to a more holistic view that includes five producer groups. This project would quantify first-order estimates of the contributions of not only phytoplankton, but also non-phytoplankton microalgae, marsh vascular plants, submersed and floating aquatic vegetation, and riparian vegetation to food web support. The project highlights the food web support provided by freshwater emergent wetlands (tidal and non-tidal marshes) and other vegetated wetlands, as well as open water habitats. Together, these primary producer groups contribute to **a portfolio of food resources that is variable in time and space and may provide more stable food resources to consumers**. Managers felt this understanding could help advance management of diverse food resources in new ways.

The work proposed for this project would underline the importance of primary production to food web support for wildlife and people, and may help managers frame this issue within their organizations and with potential funders. The project would quantify the contribution of food production in terms of its relationship with landscape configuration and landscape change, and could **provide guidance to managers about ways to connect land with water** as part of a potential suite of management actions designed to promote primary production.

There was substantial discussion about how using an **ecosystem function-based approach to understanding Delta restoration** can guide and inform management questions and how we measure restoration success. Restoration is often measured in terms of acreages, and a process-based line of thinking opens up a different suite of potential metrics such as the amount and diversity of production. Understanding the scales at which these processes function could inform restoration targets. For example, it might be possible to explore the relationship between acreage and primary production using the two-box model proposed for this research by comparing production within a small patch and within a large patch; then further refinements can **incorporate the effects of transport and residence time to predict the effects of connectivity between habitat patches**. Active management to promote certain kinds of primary production may also be warranted as part of the suite of management options.

Using the estimates produced by this approach, managers may be able to roughly **estimate the potential for restoration projects to contribute to a diversity of producer groups**, both regionally and within projects. If an **ecological 'common currency' of food value** can be determined, it could be incorporated into adaptive management strategies.

Other functions that primary producers support, including habitat structure and carbon storage, can also be incorporated into regional and project specific planning. For example, there are multiple benefits for wildlife associated with large patches of marsh habitat, and marshes can provide ancillary reductions in other stressors. Management of the multiple functions that primary producers provide could be incorporated into adaptive management efforts.

Based on the workshop discussion, there is potential for this project to **contribute to current projects and programs in the Delta**. Example initiatives and programs that may utilize information gained from this project include: the Department of Water Resources and Bureau of Reclamation's mandate to restore and conserve thousands of acres of tidal marsh habitat through WaterFix; California EcoRestore; California Department of Fish and Wildlife's Delta Conservation Framework; Delta Stewardship Council's levee improvement policies; the Delta Smelt Resiliency Strategy; and the US Fish and Wildlife Service and Interagency Ecological Program conceptual models of tidal marshes. There is a strong emphasis on the use of life-cycle models in these programs, and primary production work could fit into these models.

Managers are increasingly employing monitoring and adaptive management in their restoration projects and put a great deal of consideration into what to measure to evaluate the progress and success of a project. Measurements that assess the provision of key ecological and geomorphic processes—such as primary productivity and transport—are thought to be particularly useful, but underutilized. This project could help promote and facilitate the collection of data about ecosystem processes, and in turn contribute to the community's understanding of the value of habitat restoration. Specific guidance on which producer groups to measure, and how, would be needed.

Additionally, the focus of restoration and mitigation programs is often on the number of acres restored to desirable land cover types. This research could reveal estimates for the scale (in area) needed to support food production to accomplish wildlife restoration goals.

Caveats and Limitations to the Approach

While Forum participants generally seemed to find the approach presented in the science plan valuable, they highlighted several caveats and limitations to the approach. The work for this project, if pursued, would focus on only one of the stressors of a multi-stressor problem (landscape change/habitat loss). This approach would not address changes to production due to changes in water quality, invasive species, etc. This was also framed by some as an asset, since the project would provide clarity around one stressor without introducing complex interactions between stressors.

The results of this approach would provide a snapshot of historical and modern primary production estimates that could provide managers with estimates for how much production is *possible* in the Delta.

These estimates will necessarily be based on many assumptions and as such will have some degree of uncertainty. Some variables are too complex to be adequately addressed in the next phase of this science plan, and some simplifying assumptions will need to be made (e.g., around conditioning times, net vs gross primary production, complex hydrodynamics, etc). These assumptions should be clearly articulated. There is a lot of variability in primary production data, and it will be important to capture the range of uncertainty around the production estimates. Knowing the range would be very important to managers, and results from this project would need to convey the uncertainty in the estimates.

There is a need for project-specific guidance around primary production, in terms of restoration design, restoration targets, and monitoring metrics. This research, because it focuses on order-of-magnitude changes at a landscape scale, will likely not be able to provide such project-specific guidance.

Though there is a movement toward function-based restoration within the practitioner community, management focus is often driven by specific laws, mandates, and regulations such as the Clean Water Act, Endangered Species Act, and Biological Opinions. These laws and regulations often have a single-species or single-habitat focus. As such, managers must tie their activities to the organisms and beneficial uses identified in regulatory contexts. As a result, it is likely that restoration will continue to be geared toward protecting specific taxa.

There was a lively discussion about the merits of setting restoration targets at the Forum; some participants cautioned strongly against prescriptive targets. Rough estimates of primary production might be used to describe potential benefits of restoration sites, rather than set prescriptive targets.

Specific Feedback on Phase 2

Several suggestions specifically relating to the proposed science plan were raised at the Forum; they are listed below.

- Although this project's focus is on food web support, we should also frame production in terms of other ecosystem services such as carbon storage and habitat provision. For example, in the context of subsidence reversal and carbon storage in Twichell and Sherman Islands, it made sense to look toward marsh vegetation that breaks down slowly, and can provide habitat benefits while building elevations.

- There was a suggestion that we could use the two-box model to explore the relationship between acreage and production. This would be a fruitful avenue to pursue and could help inform questions about the food value expected from projects at different scales.

- There was a discussion about framing for this work: the work can help define major drivers of ecosystem change and therefore the focus of restoration activities. The work could help managers communicate the importance of process-based restoration to funders and the public.

- It will be very important to clearly state the assumptions behind the estimates and to define the uncertainty associated with the estimates.

- There was interest in communication products as well as a technical journal publication.

Plan for Next Steps

As we move forward with the next phase of this (currently unfunded) project we will keep this group informed of our progress. Participants who were interested in actively engaging will be invited help shape the process and outcome of this project, likely through a series of calls or meetings that include the scientists doing the modeling and calculations. Individuals who would like to be less involved will be periodically updated via email as we move forward with the project.

Acknowledgments

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Appendix
Workshop Attendees

Name	Affiliation
Brooke Jacobs	CDFW
Christina Sloop	CDFW
Rosemary Hartman	CDFW
Leo Winternitz	Consultant
Tricia Lee	DSC
Cliff Dahm	DSP
Darcy Austin	DSP
Jessica Law	DSP
Karen Kayfetz	DSP
Lauren Hastings	DSP
Megan Brooks	DSP
Rainer Hoenicke	DSP
Steve Culberson	DSP
Erin Foresman	EPA
Curt Schmutte	MWD
Lynda Smith	MWD
John DeGeorge	RMA
Lisa Thompson	Regional San
April Robinson	SFEI
Amy Richey	SFEI
Robin Grossinger	SFEI
Sam Safran	SFEI
Laura Valoppi	SFWCA
Emily Howe	TNC
Judah Grossman	TNC
Erin Gleason	USFWS
Mike Chotkowski	USGS