Addendum to:

Development of a spatially explicit ecosystem model to explore physicochemical drivers of step changes in POD species abundance and distribution in the Sacramento-San Joaquin Delta and Suisun Bay

Proposal: 2010.01-0019 in the Delta Science Program PSP

Our proposal was forwarded directly to the Ecosystem Restoration Program (ERP) proposal solicitation process (PSP) from the Delta Science Program (DSP) PSP review panel. Consequently, the existing text does not directly address the goals of the ERP PSP. The purpose of this addendum is to very briefly describe how the proposal addresses topics of interest to ERP and to respond to some of the criticisms of the proposal that were identified during the DSP PSP review.

Our proposal was originally written to address the topics important to the DSP PSP. We chose to focus the proposal on the POD species, which was an area of interest to the DSP. In reality, the model we propose to develop will incorporate information on all trophic levels and many fish species in addition to the POD species. Such a food web model should have wide utility for understanding how changes in one part of the food web affect the other parts. Such a model should be useful in assessing the potential outcomes of large-scale management actions, especially those hypothesized to have positive effects on ecosystem productivity.

Our proposal relates to the topics of interest in the ERP PSP as follows:

Topic: Estuary food web productivity

Our proposal is to further develop a dynamic food web model for the Delta and Suisun Bay. This model will provide a tool for understanding how alterations in the food web, such as changes in primary productivity or invasions of introduced species, cascade through the rest of the food web. As a specific example, an increase in primary productivity could be simulated to determine how much energy would go to delta smelt and how much would go to other parts of the food web, such as invasive clams.

Project Type: Research

This is a research activity that will develop a model. We believe the model will be useful in assessing the outcomes of management activities.

Ecosystem Element: Bay-Delta Aquatic Food Web

Our research will develop understanding of how energy flows through the food web and will help assess probable outcomes of management actions intended to alter the food web.

The remainder of this addendum addresses criticisms identified during the DSP PSP review. We have reviewed the comments and summarized them into the following points. Each is addressed below.

1. The description of the background is sufficient but too limited.
    a. No mention of contaminants

This comment is somewhat difficult to assess but specifically mentions the lack of background on contaminants. The proposal is perhaps not explicit enough on two points. First, because this is a food web model, we are mainly interested in factors believed to have an effect on the food web. Second, there needs to be a time series of data for calibration of simulations. We agree that contaminants have been a focus of the POD investigations (Sommer et al. 2007, Baxter et al. 2008, 2010) but the conclusion has generally been that the data are insufficient to conduct a defensible statistical analysis (Johnson et al. 2010). There is evidence to suggest that sublethal effects on food web organisms may be important (Baxter et al. 2010); however, the lack of data from a consistent monitoring program for either contaminant concentrations in Delta waters or effects on organisms makes it impossible to include the majority of contaminants in the model. The one exception may be ammonia/ammonium. Recent studies have suggested that elevated ammonium concentrations may be affecting primary production and phytoplankton species composition in the Delta and Suisun Bay (Wilkerson et al. 2006, Dugdale et al. 2007, Jassby 2008, Glibert 2010). We will definitely consider integrating this factor into the model if the data are appropriate. The Ecopath suite of programs also includes a module for incorporating bioaccumulation of persistent contaminants. In the Delta such contaminants include mercury, selenium, and legacy pollutants including organochlorine pesticides and PCBs (Davis et al. 2003, Linville et al. 2002, Ostrach et al. 2008, 2009). In our original proposal, which concentrates on POD species, we did not emphasize this because the only POD species known to accumulate contaminants to a significant degree is striped bass (Ostrach et al. 2008, 2009). In addition, only young of the year striped bass are considered a POD species (Sommer et al. 2007) and bioaccumulation is mainly an issue for older adult fish. For the Delta in general, bioaccumulation by other species including largemouth bass, Sacramento splittail and sturgeon might be of interest (Stewart et al. 2004). If this aspect of the modeling is of interest to ERP we could include it in the proposal as a secondary objective, to be addressed after the basic model has been developed.

2. No mention of progress to date using the existing Ecopath and Ecosim versions. Authors do not present any output of the existing models nor do they describe them in any detail.

This is somewhat true. The proposal mentions some of our initial results in general. Marissa Bauer's thesis has now been completed (Bauer 2010); however, the journal article mentioned as in preparation has not been completed. There has also been substantial progress in understanding the distribution, abundance and food habits of fishes, particularly in the beds of submerged aquatic vegetation that dominate the littoral zone of the freshwater Delta. There has also been progress in understanding the suitability of various food items for delta smelt. This progress should be incorporated into the new model rather than continuing simulations with a model based on the data we started with in 2008. Much of this work is unpublished but we are familiar with the researchers conducting the research and have either worked with them during

the construction of the original Ecopath with Ecosim model or have had preliminary conversations with them regarding incorporating their findings. These researchers include Fred Feyrer (US Bureau of Reclamation, a collaborator on this project), Matthew Nobriga (US Fish and Wildlife Service), Louise Conrad (California Department of Water Resources), Matthew Young (University of California Davis), Steve Slater (California Department of Fish and Game), and Wim Kimmerer (Romberg-Tiburon Center).

3. The description of the approach is weak and vague

This is a valid criticism of the original proposal from the perspective of understanding the specific application of the model to the Delta and Suisun Bay. We mainly took care to describe the general modeling approach because we believed it would be unfamiliar to the reviewers. Thus, we put less emphasis on the specifics. The following two points relate to the specific applications of the modeling software to the Delta and Suisun Bay.

4. They justify (needing a spatially-explicit model) because it somehow makes simulating certain hypothesis easier than in a one-box, which I do not follow. With Ecosim they must using driving variables to simulate the effects (e.g., reduced chlorophyll). I do not see how a spatially-explicit version helps with this problem.

The one-box model assumes that changes to the system are spread evenly across the food web, which we know not to be true. For example, Grimaldo et al. (2009a) showed that the food web within beds of submerged aquatic vegetation is largely isolated from the pelagic food web. Similarly, increased export of production from Suisun Marsh is more likely to affect the food web in Suisun Bay rather than the food web in the Delta. Thus, including the spatial component allows for better evaluating spatially related hypotheses.

5. The authors do not provide much information on the spatial version:
    a. what are the spatial boxes,

For this model we conceptually divide the system into three "boxes". First is Suisun Bay, which basically encompasses the benthic and pelagic habitats of brackish water. Second is the offshore Delta, which includes the benthic and pelagic habitats of fresh water. Third is the littoral Delta, which includes submerged aquatic vegetation in the inshore waters of the Delta. The Ecospace model actually runs on a grid, where each box in the grid is assigned environmental characteristics that determine the species and processes that operate in that part of the grid. This will allow us to incorporate environmental variables such as salinity, turbidity, and water temperature.

    b. how will they know how to relate habitat in each box to process rates,

As mentioned in the response to #2, much recent data has been gathered that improves our understanding of the processes occurring within each of the boxes. In some cases we will have to make estimates based on the literature from other estuarine systems and professional judgment of local experts. This is typical of Ecopath with Ecosim models. One of the outcomes of the

modeling process will be identification of critical information needed to better understand the food web and improve the model. Thus, the model can be used to help identify future research and monitoring plans and programs.

c. will they use the default movement in Ecospace (which is very specific and has problems),

We believe the reviewer is asking about the default movement rate (300 km/yr) for all organisms. As a part of Task 1 – Ecospace module development, we will incorporate appropriate dispersal rates for each species/trophic group. The available monitoring data (e.g., fall midwater trawl, 20-mm survey, Bay study) and basic life history data should allow us to develop reasonable dispersal rates for species migrating through or within our model domain. Many species are considered resident, particularly those occupying submerged aquatic vegetation. See the response to item 6 for a contingency plan if Ecospace can't be successfully implemented.

d. what years will be simulated and how specific will the simulations be of historical conditions, and a listing of how each POD factor will be represented in the model simulations.

Available time series for constructing the model extend back to the early 1980s. In our present model we calibrated Ecopath using data from 1982 (Bauer 2010). We anticipate using the same start date for the updated model. We will model historical conditions from the start date to the present. A full listing of how each factor will be incorporated into the model is difficult because for some factors there may be multiple possible methods. As model development progresses, we will finalize the best approach for incorporating each factor. Some of these factors may well be addressed through sensitivity analysis using the Monte Carlo simulations. We will definitely test the effect of all of the major invasive species, particularly *Corbula amurensis*, *Limnoithona tetraspina*, and *Egeria densa*. This is accomplished by including these species in the model at very low levels of biomass and then letting them expand based on the time series of historical abundance data. These are easy to incorporate because they are part of the food web and have direct effects on other species. Some environmental variables such as salinity, turbidity, and water temperature are also relatively easy to incorporate because we have data on the variable and some understanding of species optima and how they affect distribution of organisms (Kimmerer 2004, Dege and Brown 2004, Feyrer et al. 2007, Nobriga et al. 2008, Grimaldo et al. 2009b). Other factors are difficult, for example it has been shown that upstream flows in Old and Middle River are a good indicator for entrainment of pelagic species at the export facilities (Grimaldo et al. 2009b); however, there is no agreement we are aware of regarding the population effects of entrainment, so incorporating such mortality into the model is difficult. This is an example of an issue we would approach through sensitivity analysis.

e. little information is provided on the Ecopath progress to date and the plan for going to Ecospace

These issues are addressed in #2 and the other responses above.

6. While Ecopath and Ecosim have been widely used; Ecospace has only been used in a few places and mostly always with the developer (Walters) involved. The code is tricky and it is not plug-and-play like Ecopath.
    a. do not cite a recent paper about Ecospace but rather only cite a 1999 paper that is very outdated.

This is a valid criticism and Ecospace has been an underutilized tool. The Ecopath modeling approach has mostly been used for multi-species fisheries management, so the majority of the literature only discusses the Ecopath and Ecosim modules, which are appropriate for such applications. As researchers and managers are becoming interested in full ecosystem-based management and spatial planning, more applications of Ecospace are being developed (e.g., Gribble 2005). With regard to the specifics of our proposal, we have several responses. First, Townsend has experience implementing Ecospace in Chesapeake Bay. This experience will be invaluable in implementing the model to the Delta and Suisun Bay. The proposal explicitly provides for collaboration of Townsend with Bauer to transfer this experience. Second, the developers of the software are approachable and interested in applications of the software to real world problems. Townsend has mentioned this project to the software designers and they are interested in providing advice and support. Third, in the event the Ecospace implementation proves too difficult we will have the data to develop separate Ecopath with Ecosim models for each of our three habitats. Although, these separate models would not have the interaction possible within a single Ecospace model, we anticipate that running the separate models in parallel will be useful in addressing many questions, particularly habitat-specific questions. For example, de Mutsert (2010) used salinity forcing functions to predict changes in species distribution and abundance within the framework of an Ecopath with Ecosim model. If ERP management desires, this contingency can be written into the deliverables of the final agreement.

    b. The authors also want to use Ecosim as a decision support tool, which seems very optimistic, and other than saying that as if they felt they needed to justify the modeling more, they have no clear mechanism for doing this.

We may be thinking of decision support tools in a different sense than the reviewer. We do not think of the model as something that would be useful in a real-time decision making situation. We are thinking of decision support in more of a planning context similar to the DRERIP models. We believe that management actions intended to improve food web support for the Delta and Suisun Bay could be simulated using the model to estimate the anticipated benefits for various components of the food web. So, a management action intended to benefit pelagic fish could be simulated to determine how much of the benefit would go to fish and how much might go to invasive clams.

7. Concerns about their ability to communicate effectively with each other, especially since they are located in different places

Brown and Bauer are located in the same office and will have regular contact if this project is initiated. The proposal allows for several face to face meetings among the project collaborators as the project progresses. If considered necessary, USGS has the ability to organize Webex conferences in addition to conventional conference calls. In a Webex conference, participants

can share computer screens (e.g., Powerpoint presentations, model outputs) with other participants, which is ideal for real time troubleshooting and sharing of results.

8. The PIs seem a little over-focused on salinity as a physico- chemical driver of patterns in the Delta.

In an estuary, salinity is obviously an important factor. In the San Francisco estuary, salinity has been emphasized because of the use of X2 in scientific research and management (Jassby et al. 1995, Kimmerer 2002 a,b). In fact X2 is a topic for this PSP. We are fully aware of the work assessing the importance of and trends in other environmental factors in the Delta and Suisun Bay, including turbidity, water temperature, and nutrients (Feyrer et al. 2007, Nobriga et al. 2008, Grimaldo et al. 2009b, Glibert 2010, Hestir 2010), and we will evaluate methods for incorporating these factors as well. For example, turbidity may act to affect visual acuity of predators, thus affecting food web interactions (e.g., Baskerville-Bridges et al. 2004). This type of factor can be incorporated in the model as a habitat-mediation function.

9. It would improve transparency of the process if some sort of external review was scheduled at some point during the development of the project with some outside reviewers.

We have not budgeted for bringing in outside reviewers for an outside, independent review of this project. Although not listed in the deliverables, we fully expect to get local review of the project through presentations to the Estuarine Ecology Team (IEP EET group), IEP Annual Workshop, and local and national meetings of professional societies, such as the American Fisheries Society and the Coastal and Estuarine Research Federation. If desired by ERP management we could add such presentations or a local stand-alone workshop to our deliverables. Such a local workshop would be held in conjunction with one or more of our face to face meetings so that all team members could participate. We would obviously be willing to participate in any review process desired by DSP or ERP leadership.

10. How does this effort fit into or compliment other ongoing or past efforts at modeling dynamics of the Delta.

See response to number 11.

11. No mention is made of many other modeling efforts under way or planned in the delta and I believe that they should have been acknowledged in this proposal, especially because they might provide valuable insights for the development and execution of this project.

Items 10 and 11 are closely related and addressed together. Because of Brown's membership on the IEP and POD management teams the team is well informed about ongoing modeling and research that could complement the Ecospace effort. We are not aware of any attempt to develop

a quantitative food web model for the Delta and Suisun Bay. The DRERIP food web conceptual model by Durand (2008) is a qualitative model and is acknowledged in the proposal. Mac Nally et al. (2010) developed a multispecies model for the POD species but that model was focused on identifying possible causes of the POD rather than understanding food web dynamics. We are aware of a number of ongoing research and modeling efforts. Some of the research efforts have already been mentioned in response to item 2. Bauer has already interacted with many of these researchers while developing the existing Ecopath model. Here we mention some of the more applicable research and modeling efforts we are aware of.

A delta smelt individually based model is being developed by Kenneth Rose, Wim Kimmerer and others. This model was part of a larger project that was not reinstated after the 2008 bond freeze. The model is not yet complete but early consultation with Kimmerer indicated there would probably not be much overlap with the Ecopath model.

Wim Kimmerer's lab is involved in various studies of delta smelt feeding and growth and population biology of zooplankton. Bauer consulted with Kimmerer regarding the intial Ecopath model and incorporated biomass data supplied by Kimmerer. We anticipate that Bauer will continue to interact with the Kimmerer lab if the Ecospace model goes forward.

Frank Loge and Eric Loboschefsky are developing individually based models for striped bass and longfin smelt. Bauer consulted with Loboschefsky during development of the Ecopath model and incorporated appropriate data for striped bass into the model. We anticipate data on longfin smelt and new data for striped bass can be incorporated into our model as their models are developed.

A large research effort exploring delta smelt feeding and food web interactions in the low salinity zone is currently underway and involves Wim Kimmerer's group and Janet Thompson with USGS. The results of this research effort are directly applicable to our modeling effort and data will be incorporated as the researchers make it available. Bauer will contact the researches involved to facilitate the sharing of available data.

Monica Winder and Alan Jassby have been conducting analyses of zooplankton data to understand historical and recent factors influencing zooplankton populations in the upper San Francisco Estuary (Winder and Jassby 2010). We have not consulted directly with these authors but their published results will be evaluated for incorporation into the model. We will also contact these researchers directly, if the project gets funded.

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