Report of the Delta Habitats Group
CALFED ISB Adaptive Management Workshop
19-20 March, 2002

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Introduction

The Delta Habitats Group was charged with developing an adaptive management experimental manipulation of delta habitat configurations. A large number of restoration actions are being taken or considered in the delta to restore or improve physical habitat, and many in the group had experience with design, construction or monitoring of these projects and the potential array of delta habitats.

The group began their deliberations with a brainstorming session on important types of delta habitats, their attributes and major uncertainties associated with their restoration. Suggestions for experimental habitat restoration were then put forward by individuals for discussion by the group. The three possible experiments considered were:

Concept 1. Provide floodplain habitat during dry season by opening all or part of Merritt, Sutter, or lower Grand Island, via gates or control structures, to allow inundation driven by tidal flow.

Concept 2. Create a large tidal marsh area by removing all or a significant portion of a delta island levee and grading the levee material onto the island. Material would be graded to create a gradual sloping land surface elevation from MLLW to something above EHHW at the opposite side of the island. The lower elevation (marsh) edge would front an active channel.

Concept 3. Provide dendritic tidal marsh habitat with attributes which will benefit native at-risk species, and discourage attributes (i.e., non-native SAV) that do not, while exploring the most effective ways to create such habitat across deltaic gradients

The group broke into 3 sub-groups to develop these ideas further and the results were presented back to the group for discussion. Concepts 1 and 2 were thought to provide promising ideas for further consideration and brief descriptions have been developed. The consensus of the group was that Concept 3 should be developed in more detail as an experiment. The approach to developing the experiment from the concept was to follow the adaptive management approach described in Chapter 3 of the ERP Strategic Plan (Final EIS/EIR Technical Appendix 2002).

This report includes a description the detailed experiment developed for concept 3 which has been reviewed and revised by the group. Short descriptions of Concepts 1 and 2 were developed from the breakout session notes and were reviewed and modified by the concept ‘champions’.

Delta Habitats Breakout Group

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Constructing Tidal Marshes with Dendritic Channels to Benefit Native Fishes: an adaptive management experiment.

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Concept

One of the major underlying assumptions of many tidal marsh restoration projects is that shallow subtidal and intertidal habitat is a significant factor limiting at-risk species in the Sacramento-San Joaquin Delta. However, this assumption has not been tested for many of these species. In addition, there is uncertainty about whether tidal marsh restoration will result in even further intrusion of non-native submerged aquatic vegetation (SAV) that marginalize marsh function for fish and wildlife. This adaptive management experiment seeks to reduce uncertainty surrounding this issue by testing some hypotheses regarding the design and location of such habitat restoration, and by assessing species-specific responses. Specifically, this project addresses the development of tidal wetlands with minimal non-native submerged aquatic vegetation and the value of dendritic tidal channels as fish habitat. This experiment has been designed in accordance with the adaptive management framework promulgated by CALFED ERP as articulated in Figure 2-4 of the 1998 Strategic Plan.

Problem Statement and Goals

This restoration seeks to address the problem of decline in native fishes in the Delta. The reduction in quantity, quality and diversity of habitat for native fishes has likely contributed to the listing of several species that are found in the Delta during parts of their life cycles. The ecosystem approach to species conservation adopted by CALFED calls for sustaining and enhancing the fundamental ecological structures and processes that support the species. **Thus, the goal of this project is to provide dendritic tidal marsh habitat with attributes which will benefit native at-risk species, and discourage attributes (i.e., non-native SAV) that do not.**

Conceptual Model

The conceptual model underlying the design of this restoration experiment is the link between the decline in natural dendritic intertidal marsh habitat, which historically dominated the Delta (Atwater, 1980), and the decline in native at-risk species, including delta smelt, splittail, chinook salmon and steelhead rainbow trout utilizing the Bay-Delta. The presence of extensive dendritic intertidal marsh habitat at a time when native at-risk species maintained healthy populations implies that habitat restoration will likely benefit the native species that coevolved over the development of the historic Delta. However, this is only one part of the conceptual model used here. Indeed, current conditions in the Delta mean we must question the benefits of restoring these habitats may provide for the native species because of the extensive invasions of non-native species and water management activities. Recent studies (Grimaldo et al., 2002) note an association between subtidal areas, frequently dominated by SAV, and non-native fishes that consume native fishes, or may displace or out-compete them.

The conceptual basis for this project is outlined in Figure 1. The figure shows how the hydrodynamic characters and physiographic setting of various geomorphic features in the Delta provide appropriate conditions, or not, for extensive SAV development. As a consequence, it is also assumed that those features associated with dendritic tidal marsh habitat also provide important functions that benefit native fishes. Essentially, intertidal marshes with extensive dendritic channels drain regularly compared to subtidal areas and thus less likely to be dominated by SAV. However these habitats prove beneficial to native fishes only if it is directly accessible (i.e., access is direct and not via a dense SAV bed adjacent to the marsh and channel system). Thus an important landscape component of the conceptual model is that active distributary or slough channels also exhibit conditions that are unsuitable (too deep or too turbid) for SAV growth. The final element of the conceptual model to be tested and developed using this experiment is that we have the geomorphic understanding and engineering to establish conditions promoting the development of dendritic tidal marshes with the attributes just described.

Uncertainties

The adaptive management experiment will be designed to address several key uncertainties contained in the conceptual model described above:

- Will SAV colonize and persist in and immediately adjacent to a dendritic channel system adjoining an active distributary channel?
- What are the important characteristics of dendritic channels and adjacent marsh that benefit native fishes?
- What are the process linkages that lead to these benefits?
- Can tidal action alone develop and maintain dendritic channels?
- Can we cost effectively design and construct tidal marsh plain channel systems that are stable and sustainable in the long term (over decades)?
- What are fish responses to dendritic tidal marsh habitat in estuarine vs tidal riverine dominated systems?
- What is the relationship between marsh channel pattern, hydrodynamics, and marsh plain vegetation characteristics?

Hypotheses

The above uncertainties will be addressed by testing the following hypotheses:

1. SAV coverage and density are lower or absent in tidal channels with stronger tidal flows and sandier substrate types.
2. Marsh with complex dendritic channel system will provide a greater quantity and diversity of more food for fish, (e.g., benthic and pelagic, macroalgal and microalgal) compared to open subtidal habitats. This effect may be direct or indirect via the provision of food for prey (e.g., chironomids or copepods).
3. Fish reproduction, growth and survival depend on geomorphological characteristics of the marsh tidal channel system, specifically:

- Channel density (hypothesized positive relationship)
- Channel shape in cross-section (hypothesized positive relationship with steep side slopes)
- Channel order
  - Hypothesized negative relationship for growth; however, this may depend upon the strength of flow out of the dendritic channel system, e.g., higher order may actually provide better overall habitat because fish are not entirely forced out of the marsh at low tide, but SAV may occupy the higher order channel[s] if flow is not sufficient to suppress SAV growth.
  - Hypothesized positive relationship for reproduction where dewatering at low tide may impact fish eggs.
- The ratio of marsh edge to marsh area (hypothesized positive relationship)

4. Hydrogeomorphic setting and construction of tidal channel systems can be optimized to minimize the impact of SAV
   - Grading can be used to design and construct functional tidal channels
   - Sedimentation from adjacent rivers will hasten the development of a dendritic tidal channel system

Experimental Design

The essential elements of the experimental design used to test these hypotheses will involve using different approaches to the creation of dendritic tidal marsh habitat, and testing these approaches in two areas:

- the eastern Delta (close to a riverine source of sediment). Possible location: McCormack-Williamson Tract
- the western Delta (remote from direct supply of sediments from riverine sources but close to sediments mobilized and transported by waves and tides). Possible location: Chipps Island

These sites have been selected for the suitability of their current elevations. Within each area land will be selected which is not greatly subsided (< 4 ft. below mean sea level - an elevation shallow enough for lateral colonization by tules.) and allocated into 3 parcels of 200 acres or greater in size. This size is considered a minimum to achieve the development of a mature (e.g., 4^{th} order or greater) tidal channel network. Initial elevations must be sufficiently high that achieving tidal marsh elevations through natural sedimentation processes is likely, and higher elevation areas may be included in one of the treatments that require grading. If necessary, some material may be added to achieve the elevations necessary to complete the treatments. The parcels must exchange directly into a deep distributary channel that is unfavorable for SAV growth (too dynamic or too turbid).

Each of these parcels will receive a different experimental treatment:

Treatment 1—No Intervention

At this site, tidal action will be introduced to the parcel via a very wide levee ‘breach’. No further action will occur and the site will be monitored to assess performance relative to the measures described below.

Treatment 2—Fill to Appropriate Elevations

At this site, the land will be graded or filled to achieve an elevation in the intertidal range and tidal action will be introduced to the site in a manner similar to Treatment #1.

Treatment 3—Fill and Excavate Channels

At this site, land will be graded or filled, as in Treatment #2, but in addition a proto-dendritic (i.e., "starter") channel system will be excavated to 'kick-start' the channel development process.

The replication of these treatments in each area will allow the experimental evaluation of the role of riverine vs. tidal sediment sources to bring elevations to appropriate levels (Treatment 1 – hypothesis 5) as well as allowing the testing of hypotheses 1, 2 and 3 across a range of delta salinity, turbidity and hydrodynamic conditions. Hypothesis 4 is tested through the comparison of the physical performance of the treatments within an area.

Performance Measurements

The active adaptive management nature of this experiment means that in order to meet the stated goal the project must achieve specific performance measures or changes will be made accordingly. Thus, it is proposed that these treatments should be assessed relative to these measures 5 years after project implementation. This should be enough time for dendritic channel formation to at least begin in treatments 1 and 2, and for some natural adaptation of the channels in treatment 3. In addition, it is likely that within 5 years the area in the eastern Delta will be subjected to at least a moderate flood, supplying riverine sediments to the treatments.

The performance measures are linked to the development and function of the dendritic channel system – the goal is not just to achieve a channel network but one with functions and use patterns that allow our hypotheses to be tested. In some cases these performance measures can only be assessed by comparing the treatment sites with adjacent reference areas (e.g., sluggish subtidal areas as described in Figure 1). Where this is the case monitoring measures (see below) must encompass not just the restoration sites but also appropriate reference sites.

1. Composition and coverage of SAV

   The coverage of SAV within the channel system must be less than coverage in sheltered subtidal areas close to the treatment. The composition of SAV that is present must include native species.

2. Development of channels

   Each treatment in each area must develop a dendritic channel network of at least a third order level within five years.

3. Net vertical sedimentation

   Treatments which were implemented below mean marsh plain elevation must show vertical accretion (via accumulation of organic matter and/or sediments) towards marsh plain elevation. Treatments which were implemented at marsh plain elevation must show elevation increase at a rate at least equal to relative sea-level rise.

4. Microalgal composition and production

   The benthic, epiphytic, and planktonic microalgal communities include high-quality food organisms for primary consumers (e.g., cryptophytes, certain diatoms, etc.). Such microalgal production in the restoration sites should be similar to (equal to or greater than) that found in adjacent sheltered subtidal channels and sufficient to support desirable consumer densities.

5. Reproduction, growth and survival of at risk native species

   Monitoring must show that reproduction, growth and survival of appropriate at-risk species within the treatment areas is equal to or greater than similar measures in adjacent sheltered subtidal channels.

Adaptive Management Measures

We recommend using the performance measures above to determine whether the project is progressing towards its stated goal within the five-year timeframe. If these measures are not met, contingency actions must be instituted to adjust the design/operation of this project, and to improve the design and operation of future tidal marsh restoration projects. Specifically, the key to this restoration action is the development of dendritic tidal channels without a significant presence of SAV. If Performance Measure #1 is not met five years after project implementation, the initial design specifications will be modified and the site reconfigured, e.g., marsh surfaces will be graded and sculptured to initiate channel development (similar to the approach proposed for Treatment #3). If channels are developing (e.g., measure #1 is being met) but Performance Measures #2-#5 are not met then this implies that the dendritic tidal channel habitat is not functioning as anticipated in the conceptual model (Figure 1). The reasons for this will likely be clear from the monitoring data (see below) and the testing of the hypotheses. Information derived from this monitoring maybe used to modify the conceptual model and structurally alter the channel systems to improve function, but unless clearly justified structural improvements can be made, it is recommended that the project be redesigned, rather than adapted from its original concept.

Monitoring to Reduce Uncertainty

The role of the monitoring program is threefold:

1. to provide data on project performance relative to the measures described above;
2. to provide data to test the stated hypotheses and thus reduce uncertainties surrounding the construction and use of dendritic tidal marsh habitat to benefit at-risk species; and,
3. provide direction for adaptive modifications to the experimental treatments that do not meet performance measures.

We recommend that the monitoring design for the project is both 'process-oriented' and examine the evolution of the sites and the resulting structure-process interactions. These sites must be viewed as "open" systems, both influencing and influenced by processes in adjacent and remote environments. Specific measurements should include:

- evaluation of physical structure and processes (geomorphic character, hydrodynamics, sedimentation);
- emergent plants (composition over time and coverage);
- submerged and floating plants (diversity, coverage, and change over time);
- organic carbon (OC) fractions (forms of OC produced within and exported from the sites);
- invertebrate use and change over time;
- benthic algae production
- occurrence of juvenile and small pelagic fishes;
- turbidity/light attenuation (i.e., because algal production is light limited);
- inorganic nutrients;
- spatial habitat complexity; and,
- fish response to various habitat components of the marsh.

In particular monitoring must evaluate what the fish are eating; where the food came from (local or imported); and, the base of the food source (e.g., epiphytes vs. benthic microalgae vs. phytoplankton). Such measures will be essential to determine the causal mechanisms behind the functional performance of the habitat for fish and ultimately what attributes of the habitat should be replicated in other habitat designs.

The detailed design of the monitoring plan should be undertaken by a monitoring team, including (at a minimum) an ecologist, engineer, and agency resource manager. The team would provide advice on monitoring and help with "adaptive modifications" of the monitoring program, as well as the restoration project itself. The team would also ensure monitoring is coordinated with other monitoring programs (in terms of procedures and protocols, timing), would take advantage of existing monitoring programs and data, and would be responsible for integrated reporting, analysis, and interpretation of data, ensuring a long-term commitment to monitoring. The team would also be responsible for communicating the results and interpretations to the CALFED, other scientists, and other interested entities.

Given the limited existing monitoring of tidal marsh habitats in the Delta, it may be necessary for the team to design an extra-intensive (high frequency) preliminary study to determine the appropriate time and space scales for sampling. Similarly, it might plan for periodic revisiting of extra-intensive sampling to evaluate the "evolution" of the marsh system over time (such as prior to the 5-year post-implementation evaluation). The identification of appropriate reference sites or sampling stations (e.g., to document non-project related changes in fish and/or SAV) should also be considered by the team in the context of existing monitoring programs.

It is essential that the monitoring program be integrated to link landscape changes and biological response (recognizing that the physical evolution of the landscape and the biology of the marsh go hand in hand) and that data be collected to address Hypotheses 1, 2 and 3 which specifically address these linkages. New technologies should also be considered that allow identification of critical system responses, such as aerial surveillance with multi-spectral sensing to detect biological responses (e.g., vegetation composition and landscape structure) to physical changes on a variety of scales, and "biomarkers" for determining carbon sources and pathways.

Results from the monitoring program should be reported annually and biennially a synthesis report should be produced, tracking project performance over time and testing the hypotheses posed here. In addition, presentations to the Bay-Delta restoration community and publication in peer-reviewed journals should be employed to inform restoration practitioners and managers. The ultimate goal should be to systematically reduce the uncertainties associated with the value of dendritic tidal marsh restoration in the Delta for at-risk native fishes.

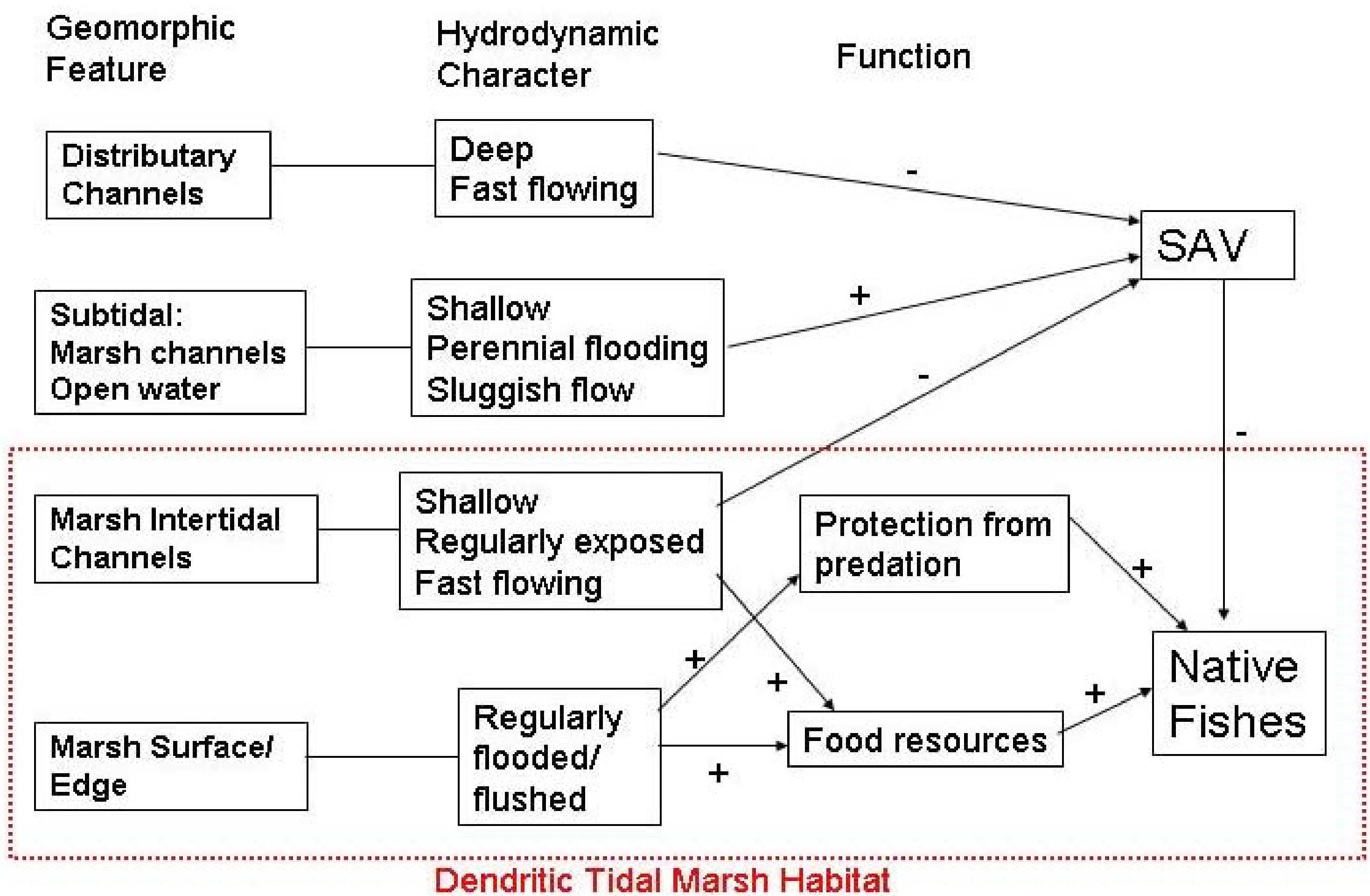

Figure 1. Outline of Conceptual Model relating geomorphic features to the success of native fish.

Additional Concepts for Delta Habitat Adaptive Management Experiments

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Concept 1. Tidal/Seasonal Floodplain

Concept
Provide floodplain habitat during dry season by opening all or part of Merritt, Sutter, or lower Grand Island, via gates or control structures, to allow inundation driven by tidal flow.

Conceptual Model
Floodplain benefits that are lost in dry years or during dry seasons can be reproduced by tidal inundation.

Target Species
- Salmon, Steelhead, Splittail, Delta Smelt

Uncertainties
- What is the benefit of the Sutter or Steamboat Sloughs to target species?
- Can benefits of floodplain inundation be mimicked using tidal flows?
- If full drainage were not possible would benefits outweigh potential stranding?

Possible Later Stages
- Realign the opening of Sutter Slough to enhance movement into the opening
- Add more acreage
- Open Sacramento River into slough above Merritt Island.

Concept 2. In-Delta Levee Removal and Grading

Concept
Create a large tidal marsh area by removing all or a significant portion of a delta island levee and grading the levee material onto the island. Material would be graded to create a gradual sloping land surface elevation from MLLW to something above EHHW at the opposite side of the island. The lower elevation (marsh) edge would front an active channel.

Conceptual Model
Development of large tidal marsh area in the delta would provide important missing habitat and ecological processes that would benefit at risk native species. Marsh edge facing active channel would not support significant Egeria habitat.

Target Species

- Salmon, Steelhead, Splittail, Delta Smelt

Constraints

- Subsidence
- Sufficient levee material
- Low fetch
- Active channel with suspended bedload

Uncertainties

- Active channel erosion (creating egeria habitat)
- Extent and change in unvegetated and emergent vegetation in intertidal area
- Non-native clam colonization
- Fish use
- Development of tidal channel system(s)
- Wave fetch

Hypotheses

- Egeria will not colonize intertidal and active channel edge.
- Native at risk fish species will benefit from intertidal area (refuge, prey resources, spawning).
- Higher density of primary producers and benthic-pelagic coupling.
- Alien clam colonization less than on “reflooded” islands.
- Reducing residence time of water-borne contaminants (vs. flooded islands).

Performance Measures (relative to reference)

- Egeria colonization
- Short-term growth of fish
- Empirical measures coupled to bioenergetic modeling
- Predation on key fish species
- predation rates
- predator presence/abundance
- Fish residence time (interrelated to growth measures)
- Non-native clam colonization
- Benthic primary production and water column (microalgal, macroalgal, emergent/riparian)
- Transfer of autochthonous primary production to upper trophic levels
- Reproduction – Delta Smelt eggs
- Splittail eggs and rearing
- Erosion/sedimentation