Sacramento-San Joaquin Delta
Regional Ecosystem Restoration Implementation Plan

EXCERPT FROM

Ecosystem Conceptual Model

Aquatic Vegetation Growth

Prepared by: Lars Anderson, USDA ARS Western Regional Research Center
lwanderson@ucdavis.edu

Date of this excerpt: January 18, 2008

Status of Peer Review: Conceptual model has not yet completed the peer review process. It is under final revision by the developer. Model may not be cited or circulated until that process is complete. The full model is available upon request and it may be used to support identification and evaluation of restoration options with assistance from content experts. However, this excerpt is not suitable for that purpose. It is provided only for the purpose of illustrating the forthcoming model.

Do Not Cite

For further inquiries on the DRERIP conceptual models, please contact Brad Burkholder at BBURKHOLDER@dfg.ca.gov or Steve Detwiler at Steven_Detwiler@fws.gov.

PREFACE

This Conceptual Model is part of a suite of conceptual models which collectively articulate the current scientific understanding of important aspects of the Sacramento-San Joaquin River Delta ecosystem. The conceptual models are designed to aid in the identification and evaluation of ecosystem restoration actions in the Delta. These models are designed to structure scientific information such that it can be used to inform sound public policy.

The Delta Conceptual Models include both ecosystem element models (including process, habitat, and stressor models); and species life history models. The models were prepared by teams of experts using common guidance documents developed to promote consistency in the format and terminology of the models
http://www.delta.dfg.ca.gov/erpdeltaplan/science_process.asp .

The Delta Conceptual Models are qualitative models which describe current understanding of how the system works. They are designed and intended to be used by experts to identify and evaluate potential restoration actions. They are not quantitative, numeric computer models that can be "run" to determine the effects of actions. Rather they are designed to facilitate informed discussions regarding expected outcomes resulting from restoration actions and the scientific basis for those expectations. The structure of many of the Delta Conceptual Models can serve as the basis for future development of quantitative models.

Each of the Delta Conceptual Models has been, or is currently being subject to a rigorous scientific peer review process. The peer review status of each model is indicated on the title page of the model.

The Delta Conceptual models will be updated and refined over time as new information is developed, and/or as the models are used and the need for further refinements or clarifications are identified.

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1. Introductory and Background Conceptual Model Text

A. General explanations and contextual information

The following conceptual models show the most important drivers affecting the establishment, growth, reproduction and dispersal of aquatic plants. Linkages between the drivers and responding plants, and between the aquatic plants and the aquatic environment are indicated by arrows coupled with either positive (+) = increase) or negative (-) = decrease) signs which indicate how the responding plants or environmental variables are affected. In many cases the linkages are bi-directional and may have positive or negative impacts and thus may constitute feedback systems. More details are provided in the legends of the specific sub-models. No attempt was made at this time to differentiate the temporal scale of the "driver>response" linkages (i.e. hours, days, weeks, seasons) although it will be important to identify, where possible, the time-scales associated with either proposed actions, or the "natural" changes in the drivers (e.g. seasonal flows, day length, temperature).

The conceptual aquatic vegetation "sub-models" were developed with the following assumptions pertaining to restoration actions in the Sacramento-San Joaquin Delta (a) both native and non-native aquatic plants are affected by identical "drivers" and types of linkages, although the magnitude and "direction" of the linkage may differ; (b) currently non-native ("exotic") invasive aquatic plants occupy a significant proportion of "available" habitats within the system. Thus, actions taken to "restore" native aquatic vegetation habitat will necessitate the eventual reduction in these exotic species to facilitate re-establishment of native plants, or to sustain "unvegetated" areas if that condition leads to a more sustainable and desirable (e.g. "pre-infestation") condition. These assumptions imply that actions taken to affect drivers or linkages in native plants will likely affect non-native (exotic) vegetation as well, *and* vice versa.

B. Sub model Explanations

A generic sub model for aquatic vegetation "Primary Drivers" was developed to provide an understanding of the three major types of aquatic plants: Submersed, Floating, and Emergent aquatic vegetation ("SAV", "FAV" and "EAV", respectively), and to show their similarities and differences in obtaining resources from the environment. The approach serves as a basis for the subsequent three pairs of "sub-models" developed for each of the three types of aquatic plant-growth forms or "growth habits". Thus for Floating, Emergent and Submersed aquatic vegetation, there is a sub-model for "Establishment, Growth and Dispersal" and for "Physical Environment Feedback".

Although there are several common drivers and linkages for the three types of aquatic vegetation, there are very important differences that are reflected in the sub-models.

C. Terminology Notes

The following terms are used within the sub models.

Bed Characteristics: This refers to the sediment/root/rhizome ("rhizosphere") conditions. Collectively, these conditions affect stability of the site and help dictate the likelihood of successfully establishing long-term (sustainable populations) of native plants.

Competition: Aquatic plants need a variety of resources (light, nutrients, stable space) for successful establishment and sustaining populations. When they vie for the same resource they compete, and a given species may be more capable of acquiring one or more resources than its neighboring species. Competition occurs between native plants as well as between native plants and non-native invasive plants. The overall result of this competition determines the relative abundance and distribution of aquatic plants.

Inundation regime: This refers to the timing and extent (depth and length of time) of seasonal and daily intrusion of water into a slough, channel or low-elevation shore. The duration and depth affect mainly establishment and dispersal of emergent plants, but can also impact submersed and floating plants dispersal at times.

Local Flow: The Delta is subject to both tidal flows (reversing flows) and "flow-through" (stream flows) dynamics. For example, long-distance dispersal of plants is mediated in via both tidal and stream flows. Local flow refers to any movement of water within plant patches and in their immediate vicinity (e.g. within about 50 meters of the patch edges.). This water movement has direct impacts on settlement of reproductive structures (see, tubers, fragments) and on import of water-borne sediment and nutrients as well as potential fish/plant interactions. Local flow can also affect water quality within plant patches (e.g. pH, dissolved oxygen).

Plant Canopy/Patch Architecture: Patches of plants, or large colonies of plants (depending on species) have characteristic physical structure, or "canopy characteristics". Architecture can vary from very open (few shoots, leaves per surface area to very dense such that light levels on or near the bottom are reduced to a small fraction of surface levels. In addition, the canopy may be distributed fairly uniformly vertically, or such that most of the foliage is in the upper two feet. Therefore, *where* plant foliage is distributed in the water column is important as well as biomass per unit area. The three dimensional space(s) occupied by submersed plants varies considerably due to inherent differences in the canopy structure (physical arrangement of shoot, leaves and branching habit), and due to seasonal developmental changes (phenology). Some species occupy and affect mainly benthic habitats; whereas most species can exert an effect throughout the entire water column. The main three exotic invasive submersed plants within the Delta, *Egeria densa, Myriophyllum spicatum,* and *Potamogeton crispus*, create dense canopies toward the middle and upper water column. These canopies slow and alter directions of flow (create turbulent flow), and increase surface water temperature. Dense aquatic plant stands can also elevate pH during the day and cause significant declines in DO from dusk to dawn. Dense canopies also prevent waterfowl access to benthic food sources (e.g. plants, plant propagules and invertebrates). They also provide large surface areas for exchange of nutrients and habitat for micro and macro invertebrates and fish. In general, the most invasive species tend to form more dense and expansive canopies than those produced by native submersed plants. For this reason, exotic plants such as *E. densa* and *Myriophyllum spicatum* can provide effective habitat for non-native predator fish, which in turn can reduce native fish populations.

Plant Patch: This refers to small or large colonies of mono-specific or mixed-species populations of aquatic plants, which are often in non-random, but non-uniform distributions on the bottom (SAV), along the shore or levee banks (EAV) or on the water surface (FAV).

Substrate: The bottom materials, such as grain size (rock, gravel, sand, clay) and organic matter collectively comprise the "substrate" (or substratum). This generally refers to the physical constituents, not the biological components within the sediment such as roots, rhizomes, and reproductive structures. Submersed (rooted) and emergent aquatic plants rely on sediments for anchoring and for sources of nutrients. Sandy and rocky substrates offer poor conditions for both these requirements; whereas sediments with moderate (e.g. 1 to 5 %) organic content and small particles support plant establishment and growth. High water velocity tends to dislodge and scour away small particles, thus leaving coarser materials behind, which typically discourage establishment of submersed and emergent plants. However, if plants can establish within small areas of low-velocity, increased population size will reduce water velocity and thus provide a positive feed-back toward a more stable substrate. This scenario also encourages greater importation and deposition of sediment-derived nutrients, which in turn drives more plant growth.

Fig.1 ***Aquatic Plant Resource Requirements*** **for Establishment, Growth and Dispersal**

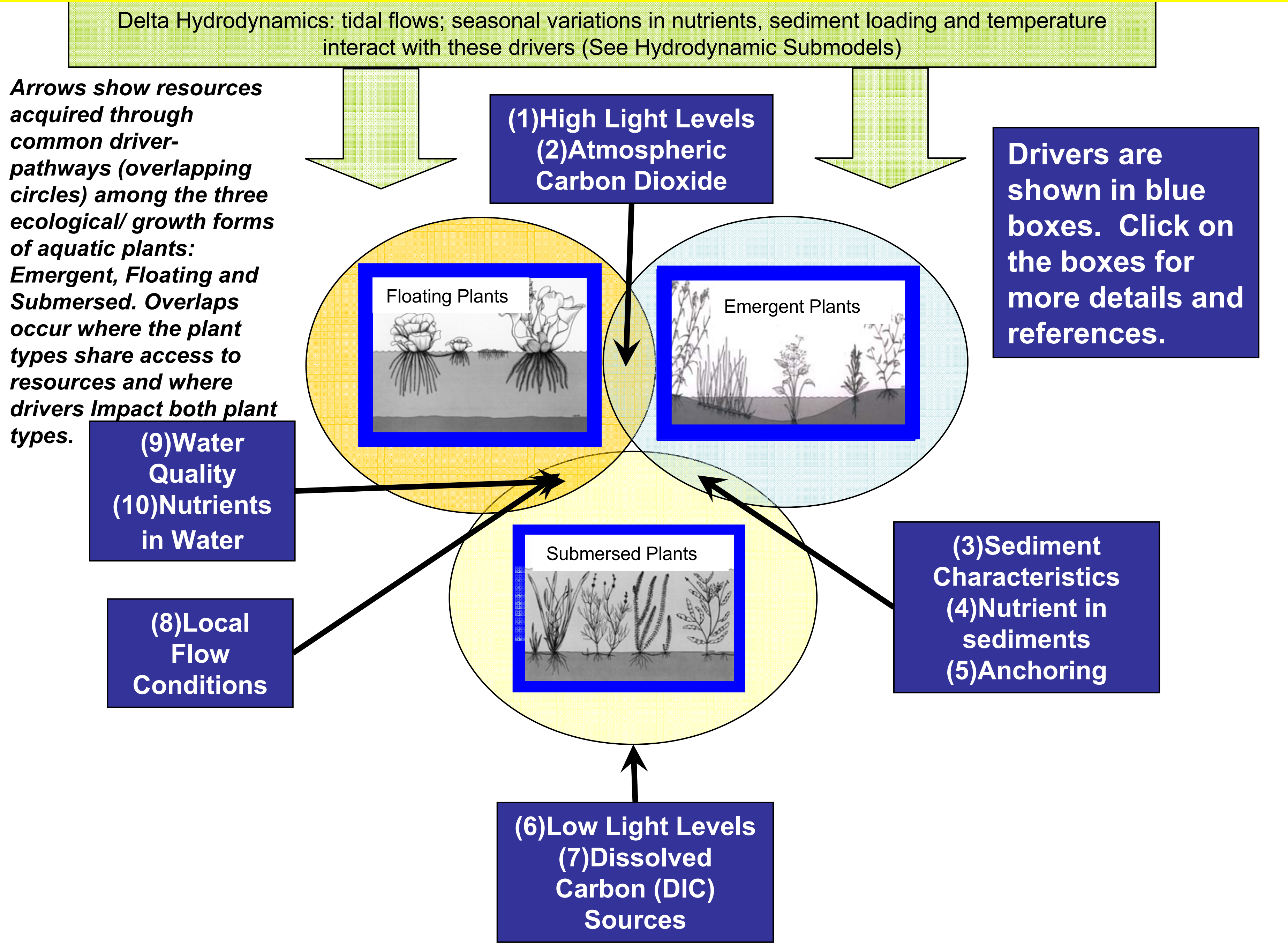


Fig.2 Submersed Aquatic Vegetation Establishment, Growth and Dispersal Sub Model

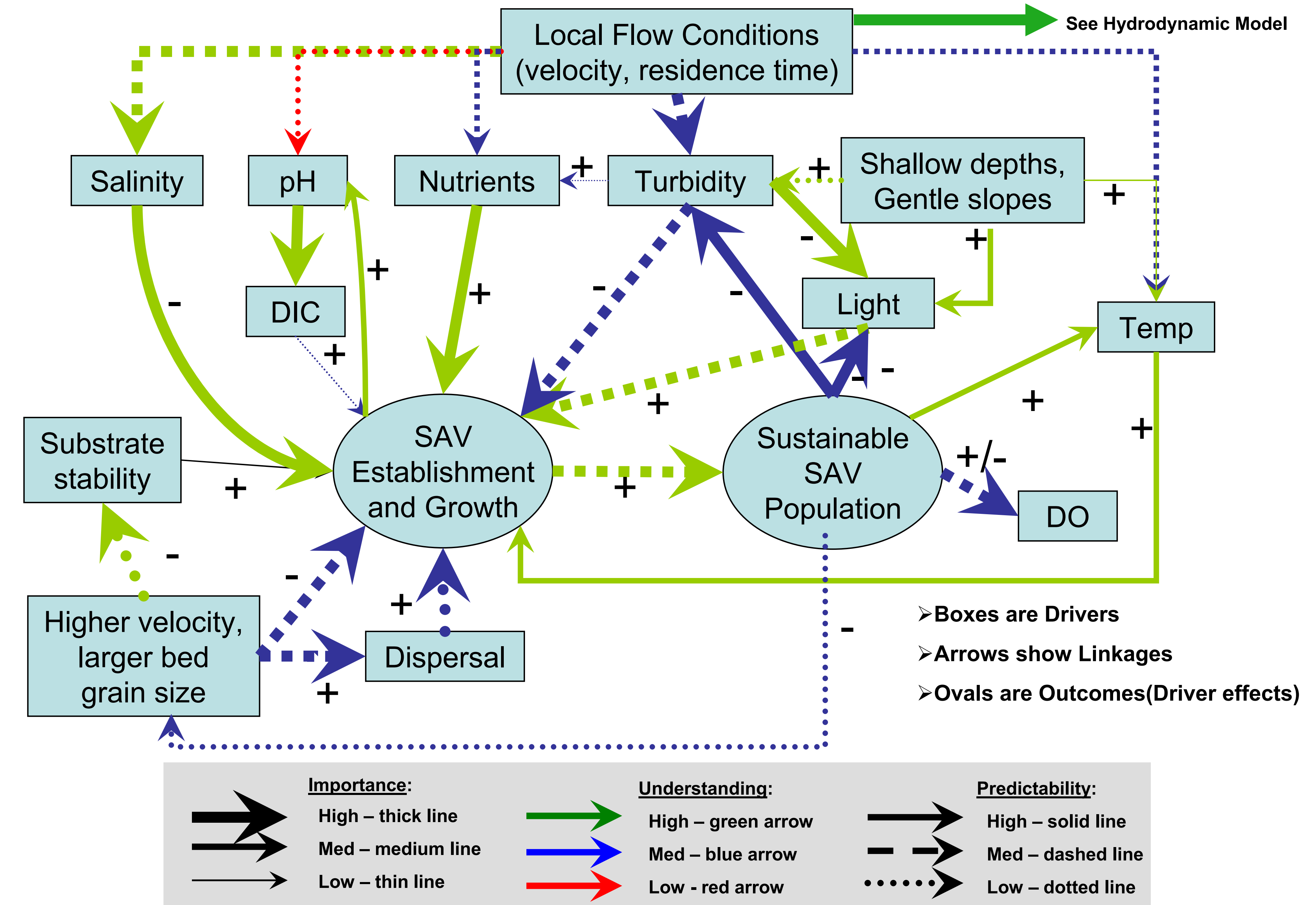


Figure.3 Floating Aquatic Vegetation Establishment, Growth and Dispersal Sub Model

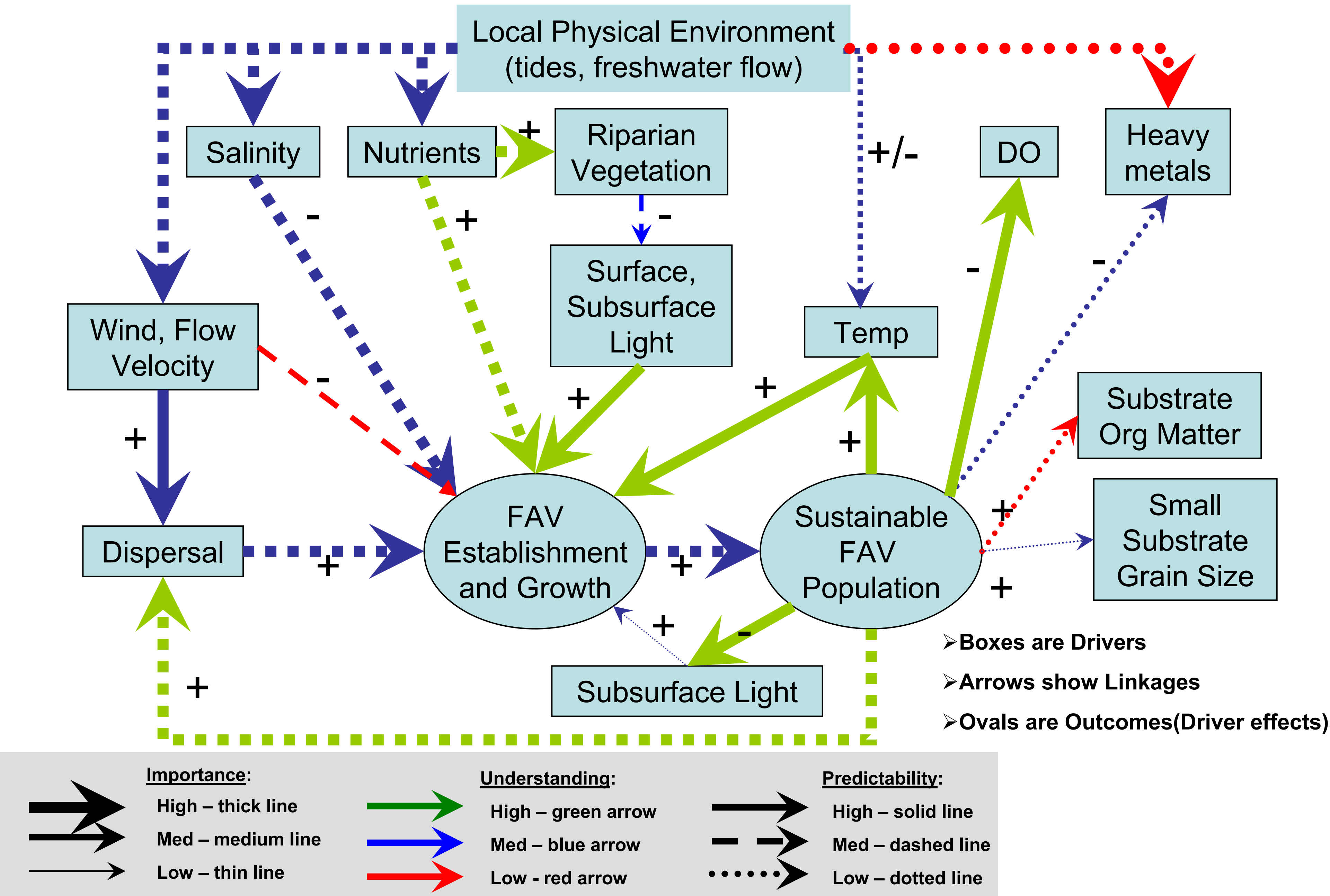


Figure 4. Emergent Aquatic Vegetation Establishment, Growth and Dispersal Sub Model

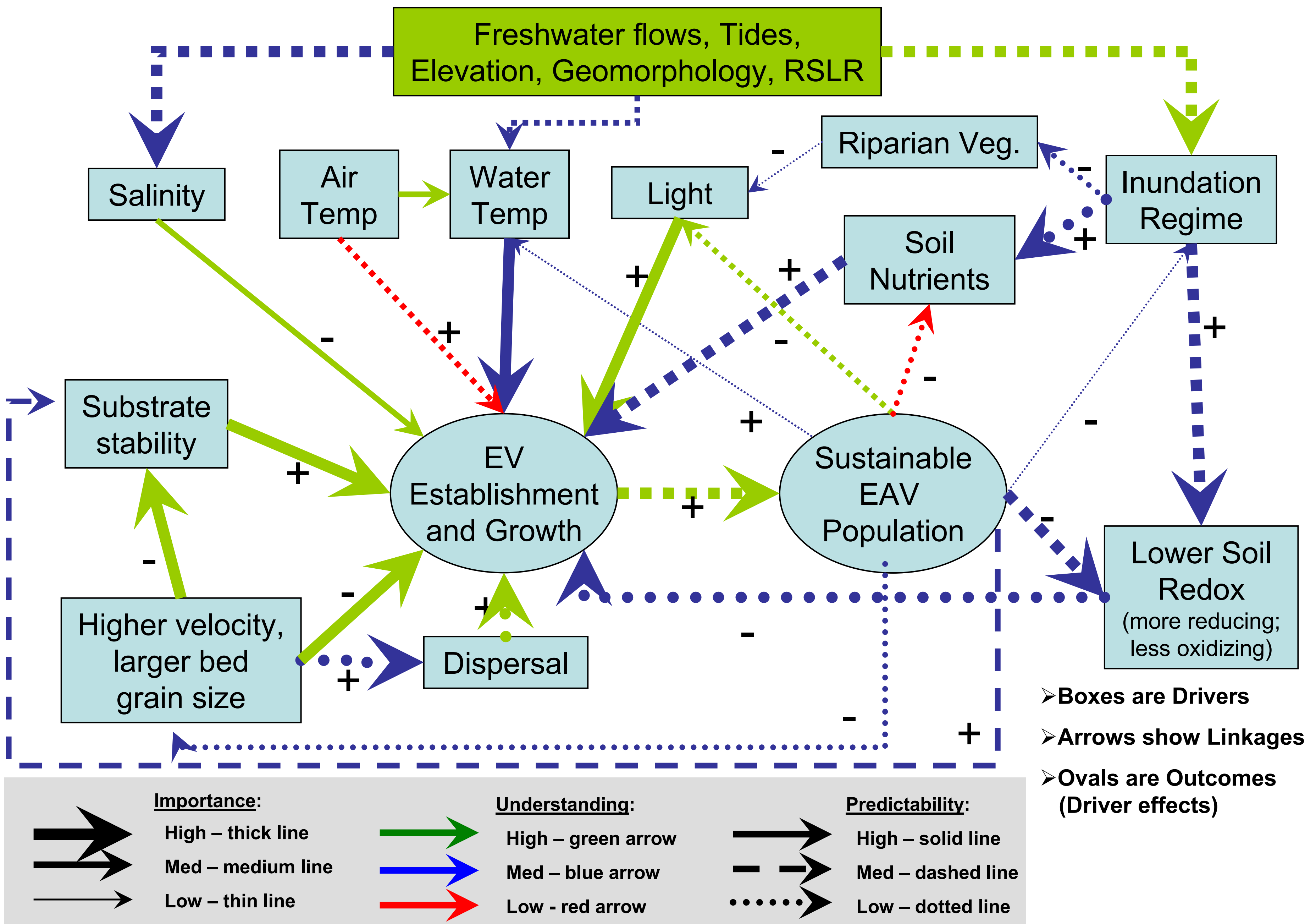


Fig.5 **Interactions Between SAV, FAV and EAV Affecting Establishment and Growth**

Arrows show direction and primary effect caused by interaction of each "ecological type" aquatic plant on neighboring ecological type:
Red (dashed)=Negative effect Green (solid)=Positive effect

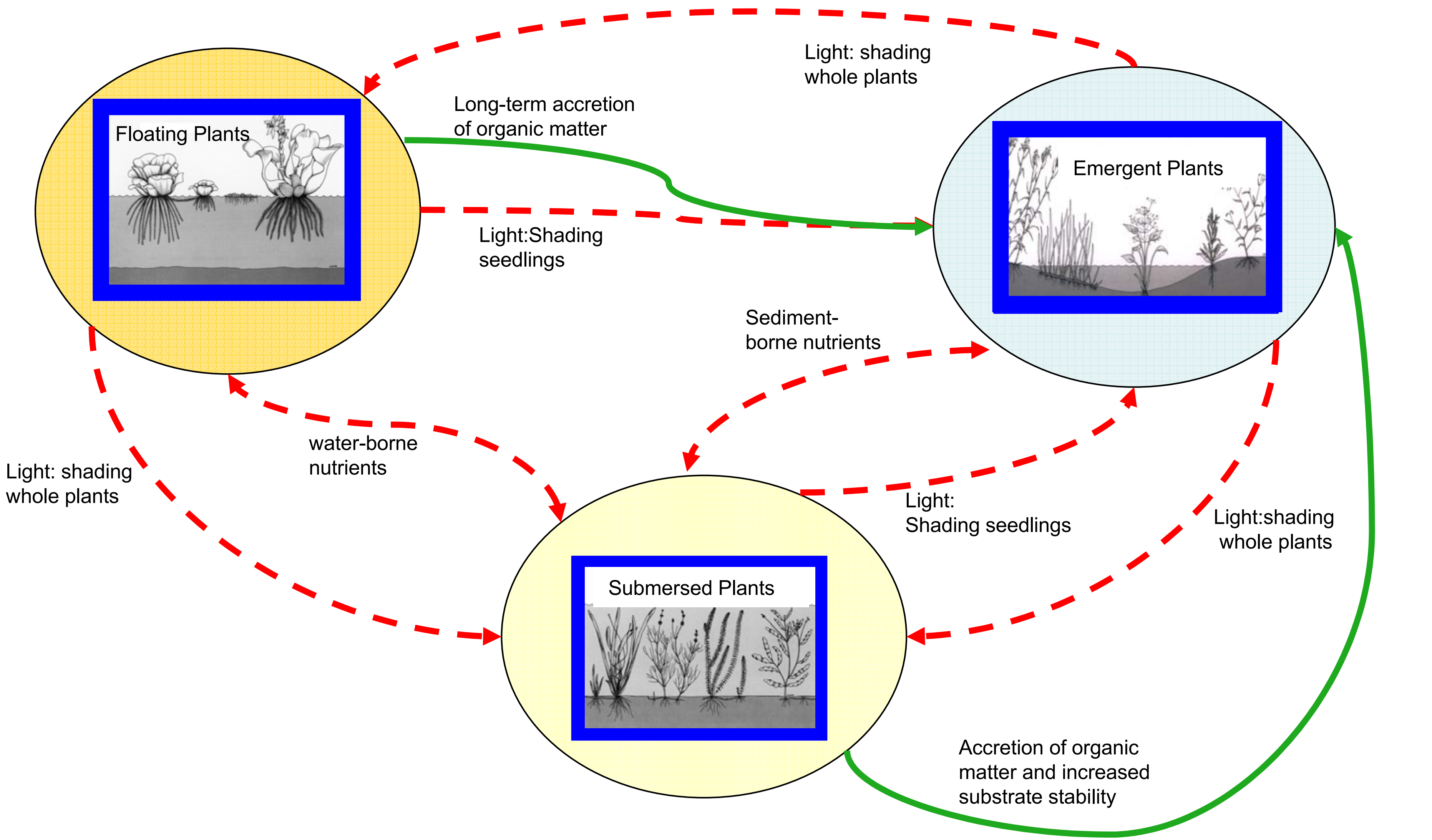
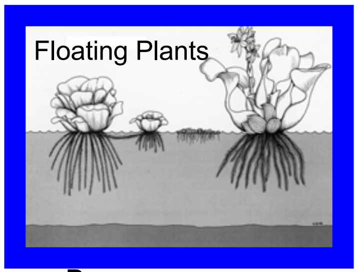


Fig.6

Interactions Between SAV, FAV and EAV Affecting Fish Habitat

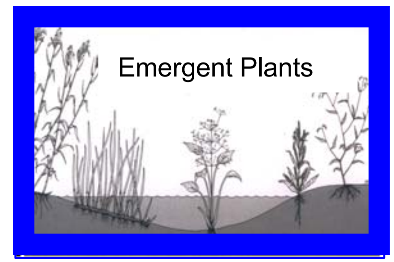
Arrows show direction and primary effect caused by interaction of each "ecological type" of aquatic plant on fish:
Red (dashed)=Negative effect Green (solid)=Positive effect

Sparse canopy provides refuges for native fish and habitat for fish food.



Dense canopy:
1.block light
2. decreases dissolved oxygen
3. Excludes native submersed plants

Diverse, patchy canopy provides refuges for native fish and habitat for fish food.



Dense, contiguous stands my limit fish food habitat or block flows.

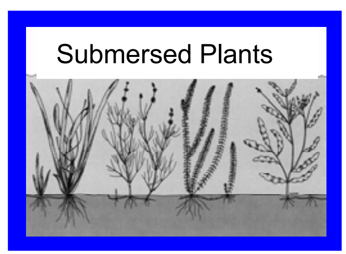
Dense,monospecific canopy:

1.reduces Dissolved oxygen at night

2.Harbors predators

3. Elevates temperature

4. Diurnal pH changes



Low density, open canopy (diversity of native plants):

1.Reduces DO extremes
2. promotes balanced preditor/prey system

3. Provides habitation for fish food.