FISH ASSESSMENT PROCESS WORKING DOCUMENT

CALFED
BAY-DELTA
PROGRAM

August 22, 1996

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INTRODUCTION

This working document presents information about fish assessment methods for each key species being evaluated in the CALFED Bay-Delta Program. The fisheries assessment process for the CALFED programmatic evaluation focuses on key assessment variables that are likely to be affected by potential CALFED actions and alternatives. The assessment process has been developed to evaluate and compare benefits and impacts that could result from implementation of the CALFED alternatives. CALFED alternatives will include actions such as habitat restoration; water transport, water storage, and fish protection facilities; water diversion management; fisheries management; and water quality management. These action alternatives will have direct and indirect beneficial or detrimental effects on fish habitats and populations.

The working document lists the key species, life stages, assessment variables for each life stage, and the methods available to evaluate the assessment variables. Assessment variables are arranged by species and life stage. Single page descriptions of potential assessment methods correspond to the assessment variables. The pages are three-hole punched for insertion into a three-ring binder, allowing for subsequent additions, deletions, and refinements during the development of this document.

CHARACTERISTICS OF THE FISH ASSESSMENT PROCESS

CALFED actions may directly affect a number of limiting factors or key variables (e.g., physical habitat, river flow, water quality, Delta hydrodynamics, Delta exports) that will lead to changes in an assessment variable (e.g., temperature survival relationships for juvenile chinook salmon). Effects of CALFED actions can be reasonably predicted for various life stages of a fish species. Within the timeframe available for the Phase II programmatic assessments, it is not currently feasible to predict changes in a species' adult population that might be caused by CALFED actions.

During program implementation, CALFED will ultimately require robust and well-validated assessments of ecosystem effects, including estimated changes in fish populations, especially to implement an adaptive management plan. Such assessment tools do not presently exist and cannot be developed within the timeframe for Phase II programmatic evaluations. Consequently, the Phase II fisheries assessment process proposes to use a balanced array of simple indices, relationships, and models to assess impacts on and benefits to fish life stages. Many of the indices and relationships could eventually be used in population models.

The fish assessment process proposed here has several fundamental characteristics:

Use of simple relationships, criteria, indices, models, weighting factors, and hypotheses. Complex relationships and indices will be avoided without a reasonable and supportable scientific basis. When possible, relationships and variables will be linked to improve reliability of assessment results.

Balanced and flexible application of qualitative (narrative), simple semi-quantitative (indices, criteria, relationships), and quantitative (models) tools. Available data sets and analytical tools vary tremendously for each species, life stage, and assessment variable. The proposed process will allow each key assessment variable to be evaluated at a specified level of detail, without assuming that output from a complex quantitative model is any more precise or accurate than a well-reasoned, scientifically based narrative description. Qualitative, semi-quantitative, and quantitative methods will be developed separately but used conjunctively to evaluate an overall effect on a species.

Reliance on existing assessment methods and relationships. CALFED's timeframe permits only limited development of new relationships and simple refinement of existing tools. Such limited refined tools and models can be ultimately developed to use in subsequent CALFED phases in an adaptive management plan.

Consideration of fish populations and habitats in the overall context of ecosystem restoration and management. The proposed fisheries assessment process will provide a balanced analysis of impacts on and benefits to fish populations, habitats, and ecosystem functions. Potential CALFED habitat restoration actions, such as riparian vegetation restoration, spawning gravel placement, and meander belt creation, represent key ecosystem components that will be assessed in relation to overall fisheries benefits in an ecological context.

Emphasis on assessment methods that can be applied to, and distinguish between, all alternatives. Efforts will be made to use analytical tools with common application to all alternatives, although this may not always be possible to the degree desired.

Selection of analytical tools suitable to refine components within alternatives. Optimizing ecosystem quality, water quality, water supply reliability, and Bay-Delta system restoration within each alternative is critical to CALFED's success. The analytical tools for fisheries must enable a reasonable assessment of CALFED actions, identify specific spatial and temporal effects on fisheries, and recommend adjustments to components for greater optimization of fisheries benefits.

Clear communication of results. Fisheries assessment methods are often extremely complex, for fisheries biologists as well as laypersons. A concerted effort will be made to simplify terms, develop simple graphics, and effectively communicate the results.

The fisheries assessment process for each species will generally consist of the following steps:

- identify target species,
- identify species-specific life history stages,

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- specify key assessment variables by life stage,
- define specific assessment methods (where available),
- identify significance thresholds for impact assessment and target levels for refinement of the components included in the alternatives, and
- analyze impacts and present the results.

SACRAMENTO RIVER FALL-RUN CHINOOK SALMON

Fisheries Assessment Variables by Life Stage:
Sacramento River Fall-Run Chinook Salmon

I. Adult Migration and Spawning (Riverine Habitat)
   A. Temperature Survival Relationship for Adult Salmon
   B. Temperature Survival Relationship for Pre-Spawn Eggs
   C. Flow Survival Relationship for Adult Migration
   D. Barrier Survival Relationship for Adult Migration
   E. Flow Habitat Relationship for Spawning Success **(see Methods)**
   F. Spawning Gravel Availability
   G. Spawning Dispersal
   H. Pollutant Mortality Relationships
   I. Sport Fishing Mortality **(see Methods)**
   J. Effects of Hatchery Fish Competition for Spawning Habitat
   K. Stock Recruitment Relationships **(see Methods)**

II. Incubation and Emergence (Riverine Habitat)
   A. Temperature Survival Relationship for Eggs and Larvae **(see Methods)**
   B. Flow Habitat Relationship for Incubation Success (e.g., scour, redd dewatering, water circulation)**(see Methods)**
   C. Spawning Gravel Quality (e.g., effects on dissolved oxygen, emergence)
   D. Pollutant Mortality Relationships
   E. Predation and Disease Mortality Relationships

III. Fry and Juvenile Rearing and Migration (Riverine Habitat)
   A. Temperature Survival Relationship **(see Methods)**
   B. Flow Habitat Relationship for Rearing Success **(see Methods)**
   C. Flow Transport Relationship for Out-Migration Success **(see Methods)**
   D. Diversion Mortality Relationship **(see Methods)**
   E. Dam Passage Mortality Relationship **(see Methods)**
   F. In-River Rearing Habitat Availability **(see Methods)**
   G. Riparian and Shaded Riverine Aquatic (SRA) Habitat Availability **(see Methods)**
   H. Flood Bypass Habitat Availability and Stranding Losses
   I. Predation, Competition, and Disease Relationships to Survival
   J. Pollutant Mortality Relationships
   K. Effects of Hatchery Fish Competition for Rearing Habitat

IV. Fry and Juvenile Rearing and Migration (Delta Habitat)
    A. Temperature Survival Relationship (**see Methods**)
    B. Flow Transport Relationship for Out-Migration Success (**see Methods**)
    C. Pathway and Barrier Survival Relationships (**see Methods**)
    D. Diversion Mortality Relationship (**see Methods**)
    E. Delta Rearing Habitat Availability
    F. Riparian and Shaded Riverine Aquatic (SRA) Habitat Availability (**see Methods**)
    G. Predation, Competition, and Disease Relationships to Survival
    H. Pollutant Mortality Relationships
    I. Effects of Hatchery Fish Competition for Rearing Habitat

V. Juvenile and Adult Rearing (Ocean Habitat)
    A. Natural Mortality Rate (i.e., ocean upwelling) (**see Methods**)
    B. Commercial Fishing Mortality (**see Methods**)
    C. Sport Fishing Mortality (**see Methods**)

What life stages would you include or delete? Why?

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Can you recommend any additional assessment variables for this species? If so, what are they?

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Are there any proposed assessment variables that you would recommend CALFED not use for this species? Why?

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Species/Life Stage: Sacramento River Fall-Run Chinook Salmon/Adult Migration and Spawning (Riverine Habitat)

Assessment Variable: Flow-Habitat Relationship for Spawning Success (and Spawning Habitat Availability)

Assessment Method: Flow-Habitat Relationship for Fall-Run Chinook Salmon in the Lower American River

Application to CALFED: CALFED actions may result in changes to the flow below Nimbus Dam on the American River that could affect depth, velocity, and spawning habitat availability for fall-run chinook salmon.

Description: The analytical relationship depicted in the figure below depicts the relationship of spawning habitat as a function of river flow based on IFIM studies. An index of spawning habitat can be calculated.

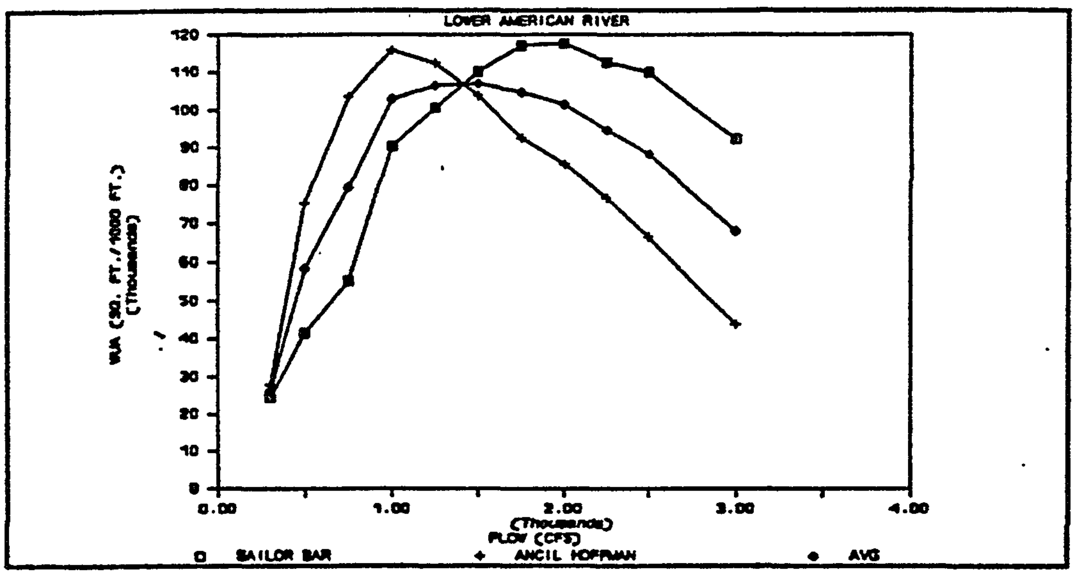


Figure 15. Relationships between flow and spawning habitat in Lower American River (from USFWS 1985).

Reference: BioSystems Analysis, Inc. 1989. Chinook salmon population model for the Sacramento River Basin - Version CPOP-2. Submitted to California Department of Fish and Game, Sacramento, California.

Input Data: River flow, flow-habitat relationship.

Modifications Necessary for CALFED Use: Although modifications to the model are not required with the existing river morphology, controversy regarding model validity should be clearly identified and, if possible, resolved. Potential changes to spawning habitat (e.g., spawning gravel restoration) under the CALFED alternatives may alter model usefulness.

Species/Life Stage: Sacramento River Fall-Run Chinook Salmon/Adult Migration and Spawning (Riverine Habitat)

Assessment Variable: Sport Fishing Mortality

Assessment Method: In-River Fishing Mortality Model

Application to CALFED:

Description:

Reference:

Input Data: Adult escapement, fishing regulations, and river flow

Modifications Necessary for CALFED Use:

Species/Life Stage: Sacramento River Fall-Run Chinook Salmon/Adult Migration and Spawning (Riverine Habitat)

Assessment Variable: Stock Recruitment Relationships

Assessment Method: Stock Recruitment Constraints on Juvenile Production

Application to CALFED:

Description:

Reference:

Input Data: Adult escapement

Modifications Necessary for CALFED Use:

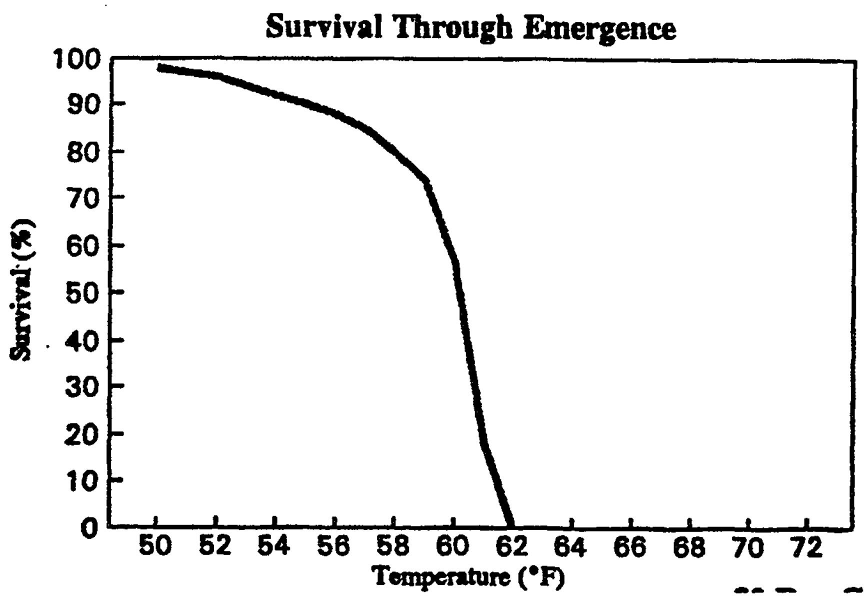
Species/Life Stage: Sacramento River Fall-Run Chinook Salmon/Incubation and Emergence (Riverine Habitat)

Assessment Variable: Temperature Survival Relationship for Eggs and Larvae

Assessment Method: Water Temperature Survival Relationship

Application to CALFED: CALFED actions may include changes to the flow below Keswick Dam in the upper Sacramento River, changes in Shasta Reservoir storage, and changes in operations of the water temperature control structure that could affect water temperature and the survival of eggs and larvae of fall-run chinook salmon.

Description: Survival is calculated using the relationship shown in the figure below that depicts survival through emergence as a function of water temperature. Incubation survival is based on simulated water temperatures in the river below Keswick Dam.



Reference: Brett, J. R., W. C. Clarke, and J. E. Shelbourn. 1982. Experiments on thermal requirements for growth and food conversion efficiency of juvenile salmon *Oncorhyncus tshawytscha.* (Canadian Technical Report of Fisheries and Aquatic Sciences No. 1027.) Department of Fisheries and Ocean, Fisheries Research Branch, Pacific Biological Station. Nanaimo, B.C., Canada.

Input Data: Simulated water temperature and temperature-survival relationship.

Modifications Necessary for CALFED Use: Modifications to the temperature survival model are not required. Changes in the existing river morphology (e.g., channel shape, riparian restoration), however, would require adjustments to the model used to simulate water temperature.

Species/Life Stage: Sacramento River Fall-Run Chinook Salmon/Incubation and Emergence (Riverine Habitat)

Assessment Variable: Flow Habitat Relationship for Incubation Success

Assessment Method: Mortality during Incubation Resulting from the Proportion of Redds Dewatered.

Application to CALFED: CALFED actions may affect river flows during the incubation period for fall-run chinook salmon.

Description: Model is based on the change in wetted area or spawning habitat area during the incubation period.

Reference: CVPIA - preliminary draft methodology; DFG data.

Input Data: River flow

Modifications Necessary for CALFED Use: none.

C-000339

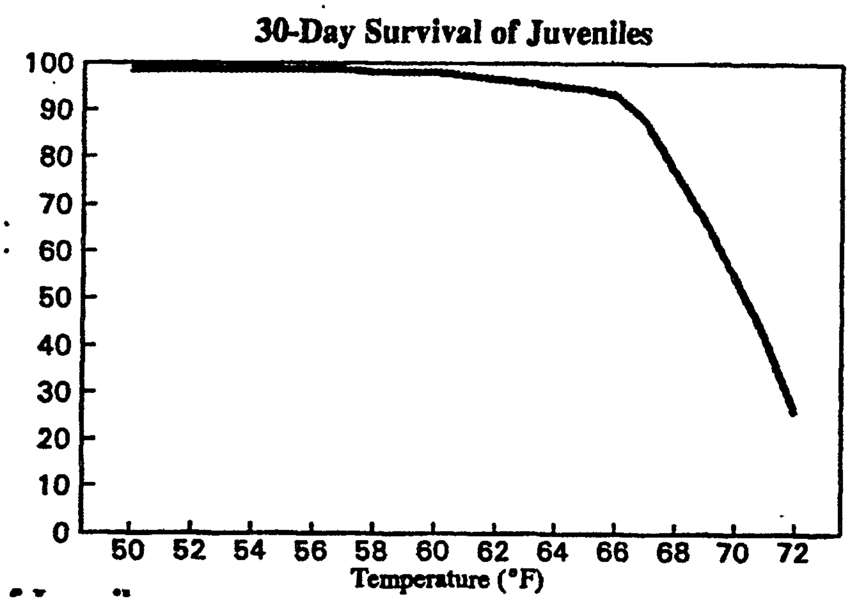
Species/Life Stage: Sacramento River Fall-Run Chinook Salmon/Fry and Juvenile Rearing and Migration (Riverine Habitat)

Assessment Variable: Temperature Survival Relationship

Assessment Method: Juvenile Temperature Survival Index

Application to CALFED: CALFED actions may include changes to the river or Delta.

Description: The analytical relationship depicted in the figure below depicts the analytical relationship between survival of juvenile salmon as a function of water temperature. An index of juvenile survival would be developed based on summer water temperatures in the river as predicted from flow-temperature relationships.



Reference: Raleigh, R. F., W. J. Miller, and P. C. Nelson. 1986. Habitat suitability index models and instream flow suitability curves: chinook salmon. (Biological Report 82 (10.122) September 1986.) U.S. Fish and Wildlife Service. Washington DC.

Input Data and Tools: Flow, flow-temperature relationships, temperature-survival relationship.

Modifications Necessary for CALFED Use: None unless actions taken substantially change the flow-temperature relationships in these rivers.

Species/Life Stage: Sacramento River Fall-Run Chinook Salmon/Fry and Juvenile Rearing and Migration (Riverine Habitat)

Assessment Variable: Flow Habitat Relationship for Rearing Success

Assessment Method: Flow Habitat Relationship for Fall-Run Chinook Salmon

Application to CALFED: CALFED actions may result in changes to the flow below reservoirs on the Sacramento River and its tributaries could affect depth, velocity, and rearing habitat availability for fall-run chinook salmon.

Description: The analytical relationship depicted in the figure shown for spawning habitat (SAC FR Chinook: I.E.1) illustrates relationships that may be similar for rearing habitat as a function of river flow based on IFIM studies.

Reference: Location dependent.

Input Data: River flow, flow-habitat relationship.

Modifications Necessary for CALFED Use: Although modifications to the model are not required with the existing river morphology, controversy regarding model validity should be clearly identified and, if possible, resolved. Potential changes rearing habitat (e.g., side channel creation and restoration) under the CALFED alternatives may alter model usefulness.

C-000341

Species/Life Stage: Sacramento River Fall-Run Chinook Salmon/Fry and Juvenile Rearing and Migration (Riverine Habitat)

Assessment Variable: Diversion Mortality Relationship

Assessment Method: River Diversion Model

Application to CALFED: CALFED actions may result in changes to flow and diversions and to fish screen efficiency. Entrainment of outmigrant juvenile chinook salmon would be affected.

Description: Diversion mortality is based on the assumed proportion of the population of juvenile salmon passing a diversion, proportion of river flow diverted, and fish screen efficiency.

Reference: CVPIA preliminary draft methodology document.

Input Data: River flow, diversion volume, fish screen efficiency, and juvenile migration pattern.

Modifications Necessary for CALFED Use: Although modifications to the model may not be required, site-specific information on individual diversions could be incorporated to improve prediction of mortality and improve the comparison between alternatives. More specific information on the vulnerability of juveniles, based on fish size and environmental conditions, could also improve mortality predictions.

C-000342

Species/Life Stage: Sacramento River Fall-Run Chinook Salmon/Fry and Juvenile Rearing and Migration (Riverine habitat)

Assessment Variable: Dam Passage Mortality Relationship

Assessment Method: Dam passage mortality relationship for Red Bluff Diversion Dam could be based on information collected by the USFWS.

Application to CALFED: CALFED actions may result in changes to dam operations, dam structure (i.e., improved fish ladders), and river flow.

Description:

Reference: U.S. Fish and Wildlife Service

Input Data: River flow, dam operations, mortality relationships, and fish migration patterns.

Modifications Necessary for CALFED Use:

Species/Life Stage: Sacramento River Fall-Run Chinook Salmon/Fry and Juvenile Rearing and Migration (Riverine Habitat)

Assessment Variable: In-River Rearing Habitat Availability

Assessment Method: Shallow Water Habitat in Lower River

Application to CALFED:

Description: The hypothesis is

Reference:

Input Data and Tools:

Species/Life Stage: Sacramento River Fall-Run Chinook Salmon/Fry and Juvenile Rearing and Migration (Delta Habitat)

Assessment Variable: Temperature Survival Relationship

Assessment Method: See SAC FR CHINOOK: IV.C.1

Application to CALFED: Although CALFED actions are unlikely to result in changes to Delta inflow sufficient to alter Delta water temperature, water temperature is critical to juvenile survival in the Delta.

Description: See SAC FR CHINOOK: IV.C.1

Reference: Kjelson, Greene, and Brandes, 1989.

Input Data: Channel flow, water temperature, export rates, and Delta Cross Channel operations.

Modifications Necessary for CALFED Use: See SAC FR CHINOOK: IV.C.1

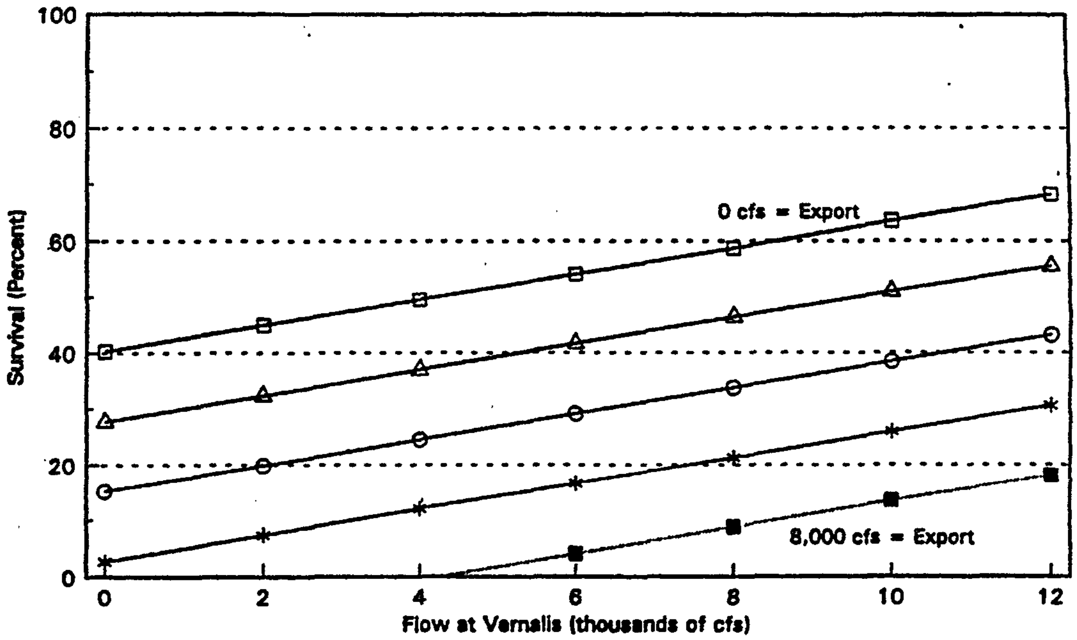
Species/Life Stage: San Joaquin River Fall-Run Chinook Salmon/Fry and Juvenile Rearing and Migration (Delta Habitat)

Assessment Variable: Flow-Transport Relationship for Outmigration Success

Assessment Method: San Joaquin River Smolt Survival Index Related to Flow and Exports

Application to CALFED: CALFED actions may include changes to the flow at Vernalis and export levels from the Delta that could affect salmon smolt survival through the Delta.

Description: The analytical relationship depicted in the figure below predicts the mortality of young salmon that move to the Delta from the San Joaquin River as a function of Vernalis flow through the Delta Cross Channel and export rate.



SOURCE: [illegible]

PREDICTED SAN JOAQUIN RIVER CHINOOK SALMON SMOLT SURVIVAL VERSUS FLOW AT VERNALIS AND COMBINED CENTRAL VALLEY PROJECT/STATE WATER PROJECT EXPORTS

Reference: Herrgesell, P. L. 1991. 1990 annual report, Interagency Ecological Studies Program for the Sacramento-San Joaquin estuary. California Department of Fish and Game. Stockton, CA.

Input Data and Tools: Vernalis flows, flow-survival relationship.

Modifications Necessary for CALFED Use: None under present Delta plumbing, but limited usefulness with major changes to habitat, fish protection measures, and plumbing in Delta.

Species/Life Stage: Sacramento River Fall-Run Chinook Salmon/Fry and Juvenile Rearing and Migration (Riverine Habitat)

Assessment Variable: Flow-Transport Relationship for Outmigration Success

Assessment Method: Flow/Transport Description

Application to CALFED: CALFED alternatives may include flow regimes for transporting juveniles downstream, and alternative components may affect existing SRA habitats through modified flows or construction activities.

Description: The hypothesis is that properly timed pulse flows of sufficient quantity, duration, and temperature increase the survival of downstream migrating (emigrating) juvenile salmon and steelhead.

Flow influences the distribution, abundance, and survival of emigrating juvenile salmonids. Generally, higher flows improve survival and migration success of juvenile salmonids by increasing migration rates, reducing exposure to diversions (i.e., reducing the proportion of flow diverted), and maintaining favorable water quality and temperature conditions. In recent years, increased flow releases from Keswick Reservoir (up to 14,000 cfs) and reduced diversions in May have been designed to assist the downstream migration of hatchery juveniles released in the upper Sacramento River. Correlations between Sacramento River flows during the chinook salmon smolt emigration period and the number of adults returning to Sacramento River tributaries (Dettman et al. 1987) and indicate that flow, or factors directly related to flow, significantly affect chinook salmon survival and abundance.

Several quantitative relationships exist between flow and various measures of salmon smolt survival or mortality in the Sacramento River and Delta. These indices are presented as other tools for describing flow/transport for fall-run chinook salmon fry and juvenile in-river rearing and migration. A narrative description will be necessary for other rivers that do not have these relationships. The complexity of quantitative flow-transport relationships also may require extensive narrative discussion to properly integrate and apply the various relationships.

References: U.S. Fish and Wildlife Service. 1993. Abundance and survival of juvenile chinook salmon in the Sacramento-San Joaquin estuary. Annual progress report. September 30, 1988. (FY 88 Work Guidance.) Fisheries Assistance Office. Stockton, CA.

Dettman, D. H., D. W. Kelley, and W. T., Mitchell. 1987. The influence of flow on Central Valley salmon. D. W. Kelley and Associates. Newcastle, CA. Prepared for California Department of Water Resources, Sacramento, CA.

Input Data and Tools:

1) Temporal distribution weighting for life stage periodicity in rivers
2) Spatial (geographic) distribution weighting for life stage periodicity

3) Monthly, weekly, and/or daily modeled flow and temperature data
4) Smolt survival model output, such as from the USFWS smolt survival model

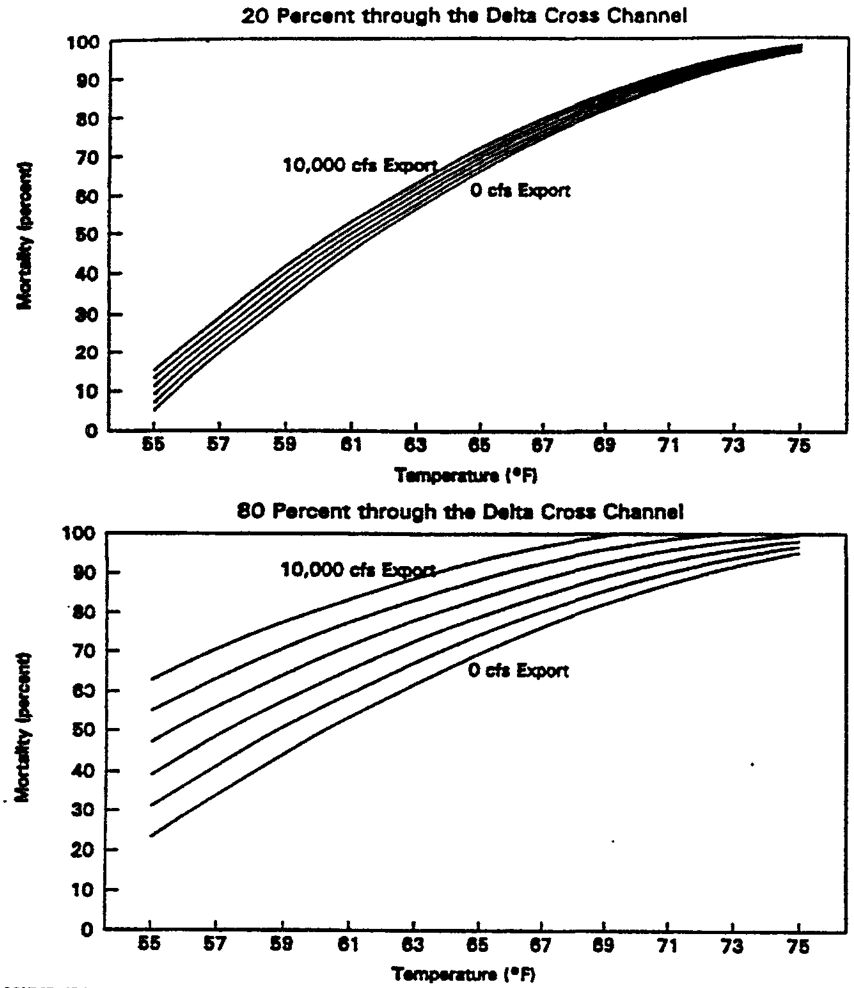
Species/Life Stage: Sacramento River Fall-Run Chinook Salmon /Fry and Juvenile Rearing and Migration (Delta Habitat)

Assessment Variable: Pathway and Barrier Survival Relationships (also includes Temperature Survival and Diversion Mortality Relationships)

Assessment Method: USFWS model for estimating mortality of fall-run chinook salmon smolts in the Sacramento-San Joaquin Delta.

Application to CALFED: CALFED actions may affect salmon smolt survival through changes to Sacramento River inflow and water temperature, the distribution of flow across the Delta, and Delta diversions. The mortality index could be used to compare mortality of salmon smolts among alternatives with variable flow and diversion patterns.

Description: The model uses analytical relationships developed by the USFWS from tag release-return studies conducted under variable inflow, export, and water temperature conditions. The analytical relationship developed from the tag-return data is depicted in the figure below. Mortality of salmon smolt that migrate through the Delta is a function of flow, Delta Cross Channel operations, export rate, and Sacramento River water temperature.



SOURCE: Kjelson et al. (1989).

PREDICTED SACRAMENTO RIVER CHINOOK SALMON SMOLT MORTALITY THROUGH THE DELTA VERSUS SACRAMENTO RIVER WATER TEMPERATURE AND DELTA EXPORT PUMPING RATES

Reference: Kjelson, M.A., S. Greene, and P. Brandes. 1989.

Input Data: Channel flow, water temperature, export rates, and Delta Cross Channel gate operations.

Modifications Necessary for CALFED Use: Although modifications to the model are not required with the existing Delta facilities and channel configuration, controversy regarding model validity should be clearly identified and, if possible, resolved. Potential changes to Delta channel barriers and diversion location under the CALFED alternatives may limit model usefulness.

Species/Life Stage: Sacramento River Fall-Run Chinook Salmon/Fry and Juvenile Rearing and Migration (Delta Habitat)

Assessment Variable: Pathway and Barrier Survival Relationships (also includes Diversion Mortality Relationships)

Assessment Method: Delta Hydrodynamic Data for Key Channels, Rivers, and Facilities

Application to CALFED:

Description:

Reference:

Input Data and Tools:

Species/Life Stage: Sacramento River Fall-Run Chinook Salmon/Fry and Juvenile Rearing and Migration (Delta Habitat)

Assessment Variable: Diversion Mortality Relationships

Assessment Method: Entrainment Indices at State and Federal Delta Pumping Facilities

Application to CALFED:

Description:

Reference:

Input Data and Tools:

Species/Life Stage: Sacramento River Fall-Run Chinook Salmon / Fry and Juvenile Rearing and Migration (Delta Habitat)

Assessment Variable: Diversion Mortality Relationships

Assessment Method: DWR Smolt Loss Model

Application to CALFED:

Description:

Reference:

Input Data and Tools:

Species/Life Stage: Sacramento River Fall-Run Chinook Salmon / Juvenile and Adult Rearing (Ocean Habitat)

Assessment Variable: Natural Mortality Rate

Assessment Method: Ocean Temperature and Upwelling Effects

Application to CALFED:

Description: The hypothesis is

Reference:

Input Data and Tools:

Species/Life Stage: Sacramento River Fall-Run Chinook Salmon/Juvenile and Adult Rearing (Ocean Habitat)

Assessment Variable: Commercial Fishing Mortality and Sport Fishing Mortality

Assessment Method: Ocean Mortality Model

Application to CALFED: CALFED actions may affect the number of juvenile chinook salmon entering the ocean. The effect of CALFED actions on adult population abundance may be influenced by commercial and sport fishing. Also, CALFED actions could alter ocean fishing mortality through recommended changes to sport and commercial regulations.

Description: DFG model to be added.

Reference: DFG

Input Data:

Modifications Necessary for CALFED Use:

C-000355

San Joaquin River Fall-run Chinook Salmon

Fisheries Assessment Variables by Life Stage:
San Joaquin River Fall-Run Chinook Salmon

I. Adult Migration and Spawning (Riverine Habitat)

- A. Temperature Survival Relationship for Adult Salmon
- B. Temperature Survival Relationship for Pre-Spawn Eggs
- C. Flow Survival Relationship for Adult Migration
- D. Barrier Survival Relationship for Adult Migration
- E. Flow Habitat Relationship for Spawning Success **(see SAC FR CHINOOK)**
- F. Spawning Gravel Availability
- G. Spawning Dispersal
- H. Pollutant Mortality Relationships
- I. Sport Fishing Mortality **(see SAC FR CHINOOK)**
- J. Effects of Hatchery Fish Competition for Spawning Habitat
- K. Stock Recruitment Relationships **(see SAC FR CHINOOK)**

II. Incubation and Emergence (Riverine Habitat)

- A. Temperature Survival Relationship for Eggs and Larvae **(see SAC FR CHINOOK)**
- B. Flow Habitat Relationship for Incubation Success (e.g., scour, redd dewatering, water circulation)**(see SAC FR CHINOOK)**
- C. Spawning Gravel Quality (e.g., effects on dissolved oxygen, emergence)
- D. Pollutant Mortality Relationships
- E. Predation and Disease Mortality Relationships

III. Fry and Juvenile Rearing and Migration (Riverine Habitat)

- A. Temperature Survival Relationship **(see SAC FR CHINOOK)**
- B. Flow Habitat Relationship for Rearing Success **(see SAC FR CHINOOK)**
- C. Flow Transport Relationship for Outmigration Success **(see SAC FR CHINOOK)**
- D. Diversion Mortality Relationship **(see SAC FR CHINOOK)**

E. Dam Passage Mortality Relationship (**see SAC FR CHINOOK**)

F. In-River Rearing Habitat Availability (**see SAC FR CHINOOK**)

G. Riparian and Shaded Riverine Aquatic (SRA) Habitat Availability (**see SAC FR CHINOOK**)

H. Flood Bypass Habitat Availability and Stranding Losses

I. Predation, Competition, and Disease Relationships to Survival

J. Pollutant Mortality Relationships

K. Effects of Hatchery Fish Competition for Rearing Habitat

IV. Fry and Juvenile Rearing and Migration (Delta Habitat)

A. Temperature Survival Relationship (**see SAC FR CHINOOK**)

B. Flow Transport Relationship for Outmigration Success (**see Methods**)

C. Pathway and Barrier Survival Relationships (**see Methods**)

D. Diversion Mortality Relationship (**see Methods**)

E. Delta Rearing Habitat Availability

F. Riparian and Shaded Riverine Aquatic (SRA) Habitat Availability (**see SAC FR CHINOOK**)

G. Predation, Competition, and Disease Relationships to Survival

H. Pollutant Mortality Relationships

I. Effects of Hatchery Fish Competition for Rearing Habitat

V. Juvenile and Adult Rearing (Ocean Habitat)

A. Natural Mortality Rate (e.g., ocean upwelling)(**see SAC FR CHINOOK**)

B. Commercial Fishing Mortality (**see SAC FR CHINOOK**)

C. Sport Fishing Mortality (**see SAC FR CHINOOK**)

What life stages would you include or delete? Why?

Can you recommend any additional assessment variables for this species? If so, what are they?

Are there any proposed assessment variables that you would recommend CALFED not use for this species? Why?

Species/Life Stage: San Joaquin River Fall-Run Chinook Salmon/Fry and Juvenile Rearing and Migration (Delta Habitat)

Assessment Variable: Pathway and Barrier Survival Relationships (Flow Transport Relationship for Outmigration Success, and Diversion Mortality Relationship)

Assessment Method: San Joaquin River Salmon Index

Application to CALFED: CALFED actions may result in changes to the San Joaquin River inflow to the Delta and to Delta diversions.

Description: to be provided.

Reference: USEPA 1994.

Input Data: Delta channel flows, San Joaquin River flow at Vernalis, CVP and SWP exports.

Modifications Necessary for CALFED Use: Although modifications to the model are not required with the existing Delta morphology, controversy regarding model validity should be clearly identified and, if possible, resolved.

C-000360

LATE FALL-RUN CHINOOK SALMON

C-000361

Fisheries Assessment Variables by Life Stage:

Late Fall-Run Chinook Salmon

I. Adult Migration and Spawning (Riverine Habitat)

A. Temperature Survival Relationship for Adult Salmon

B. Temperature Survival Relationship for Pre-Spawn Eggs

C. Flow Survival Relationship for Adult Migration

D. Barrier Survival Relationship for Adult Migration

E. Flow Habitat Relationship for Spawning Success **(see SAC FR CHINOOK)**

F. Spawning Gravel Availability

G. Spawning Dispersal

H. Pollutant Mortality Relationships

I. Sport Fishing Mortality **(see SAC FR CHINOOK)**

J. Effects of Hatchery Fish Competition for Spawning Habitat

K. Stock Recruitment Relationships **(see SAC FR CHINOOK)**

II. Incubation and Emergence (Riverine Habitat)

A. Temperature Survival Relationship for Eggs and Larvae **(see SAC FR CHINOOK)**

B. Flow Habitat Relationship for Incubation Success (e.g., scour, redd dewatering, water circulation)**(see SAC FR CHINOOK)**

C. Spawning Gravel Quality (e.g., effects on dissolved oxygen, emergence)

D. Pollutant Mortality Relationships

E. Predation and Disease Mortality Relationships

III. Fry and Juvenile Rearing and Migration (Riverine Habitat)

A. Temperature Survival Relationship **(see SAC FR CHINOOK)**

B. Flow Habitat Relationship for Rearing Success **(see SAC FR CHINOOK)**

C. Flow Transport Relationship for Outmigration Success **(see SAC FR CHINOOK)**

D. Diversion Mortality Relationship **(see SAC FR CHINOOK)**

E. Dam Passage Mortality Relationship (**see SAC FR CHINOOK**)

F. In-River Rearing Habitat Availability (**see SAC FR CHINOOK**)

G. Riparian and Shaded Riverine Aquatic (SRA) Habitat Availability (**see SAC FR CHINOOK**)

H. Flood Bypass Habitat Availability and Stranding Losses

I. Predation, Competition, and Disease Relationships to Survival

J. Pollutant Mortality Relationships

K. Effects of Hatchery Fish Competition for Rearing Habitat

IV. Fry and Juvenile Rearing and Migration (Delta Habitat)

A. Temperature Survival Relationship (**see SAC FR CHINOOK**)

B. Flow Transport Relationship for Outmigration Success (**see SAC FR CHINOOK**)

C. Pathway and Barrier Survival Relationships (**see SAC FR CHINOOK**)

D. Diversion Mortality Relationship (**see SAC FR CHINOOK**)

E. Delta Rearing Habitat Availability

F. Riparian and Shaded Riverine Aquatic (SRA) Habitat Availability (**see SAC FR CHINOOK**)

G. Predation, Competition, and Disease Relationships to Survival

H. Pollutant Mortality Relationships

I. Effects of Hatchery Fish Competition for Rearing Habitat

V. Juvenile and Adult Rearing (Ocean Habitat)

A. Natural Mortality Rate (e.g., ocean upwelling)(**see SAC FR CHINOOK**)

B. Commercial Fishing Mortality (**see SAC FR CHINOOK**)

C. Sport Fishing Mortality (**see SAC FR CHINOOK**)

C-000363

What life stages would you include or delete? Why?

Can you recommend any additional assessment variables for this species? If so, what are they?

Are there any proposed assessment variables that you would recommend CALFED not use for this species? Why?

C-000364

WINTER-RUN CHINOOK SALMON

Fisheries Assessment Variables by Life Stage:

Winter-Run Chinook Salmon

I. Adult Migration and Spawning (Riverine Habitat)

A. Temperature Survival Relationship for Adult Salmon

B. Temperature Survival Relationship for Pre-Spawn Eggs

C. Flow Survival Relationship for Adult Migration

D. Barrier Survival Relationship for Adult Migration

E. Flow Habitat Relationship for Spawning Success **(see SAC FR CHINOOK)**

F. Spawning Gravel Availability

G. Spawning Dispersal

H. Pollutant Mortality Relationships

I. Sport Fishing Mortality **(see SAC FR CHINOOK)**

J. Effects of Hatchery Fish Competition for Spawning Habitat

K. Stock Recruitment Relationships **(see SAC FR CHINOOK)**

II. Incubation and Emergence (Riverine Habitat)

A. Temperature Survival Relationship for Eggs and Larvae **(see SAC FR CHINOOK)**

B. Flow Habitat Relationship for Incubation Success (e.g., scour, redd dewatering, water circulation)**(see SAC FR CHINOOK)**

C. Spawning Gravel Quality (e.g., effects on dissolved oxygen, emergence)

D. Pollutant Mortality Relationships

E. Predation and Disease Mortality Relationships

III. Fry and Juvenile Rearing and Migration (Riverine Habitat)

A. Temperature Survival Relationship **(see SAC FR CHINOOK)**

B. Flow Habitat Relationship for Rearing Success **(see SAC FR CHINOOK)**

C. Flow Transport Relationship for Outmigration Success **(see SAC FR CHINOOK)**

D. Diversion Mortality Relationship **(see SAC FR CHINOOK)**

C-000366

E. Dam Passage Mortality Relationship **(see SAC FR CHINOOK)**

F. In-River Rearing Habitat Availability **(see SAC FR CHINOOK)**

G. Riparian and Shaded Riverine Aquatic (SRA) Habitat Availability **(see SAC FR CHINOOK)**

H. Flood Bypass Habitat Availability and Stranding Losses

I. Predation, Competition, and Disease Relationships to Survival

J. Pollutant Mortality Relationships

K. Effects of Hatchery Fish Competition for Rearing Habitat

IV. Fry and Juvenile Rearing and Migration (Delta Habitat)

A. Temperature Survival Relationship **(see SAC FR CHINOOK)**

B. Flow Transport Relationship for Outmigration Success **(see SAC FR CHINOOK)**

C. Pathway and Barrier Survival Relationships **(see SAC FR CHINOOK)**

D. Diversion Mortality Relationship **(see SAC FR CHINOOK)**

E. Delta Rearing Habitat Availability

F. Riparian and Shaded Riverine Aquatic (SRA) Habitat Availability **(see SAC FR CHINOOK)**

G. Predation, Competition, and Disease Relationships to Survival

H. Pollutant Mortality Relationships

I. Effects of Hatchery Fish Competition for Rearing Habitat

V. Juvenile and Adult Rearing (Ocean Habitat)

A. Natural Mortality Rate (e.g., ocean upwelling)**(see SAC FR CHINOOK)**

B. Commercial Fishing Mortality **(see SAC FR CHINOOK)**

C. Sport Fishing Mortality **(see SAC FR CHINOOK)**

C-000367

What life stages would you include or delete? Why?

Can you recommend any additional assessment variables for this species? If so, what are they?

Are there any proposed assessment variables that you would recommend CALFED not use for this species? Why?

SPRING-RUN CHINOOK SALMON

Fisheries Assessment Variables by Life Stage:

Spring-Run Chinook Salmon

I. Adult Migration and Spawning (Riverine Habitat)

- A. Temperature Survival Relationship for Adult Salmon
- B. Temperature Survival Relationship for Pre-Spawn Eggs
- C. Flow Survival Relationship for Adult Migration
- D. Barrier Survival Relationship for Adult Migration
- E. Flow Habitat Relationship for Spawning Success **(see SAC FR CHINOOK)**
- F. Spawning Gravel Availability
- G. Spawning Dispersal
- H. Pollutant Mortality Relationships
- I. Sport Fishing Mortality **(see SAC FR CHINOOK)**
- J. Effects of Hatchery Fish Competition for Spawning Habitat
- K. Stock Recruitment Relationships **(see SAC FR CHINOOK)**

II. Incubation and Emergence (Riverine Habitat)

- A. Temperature Survival Relationship for Eggs and Larvae **(see SAC FR CHINOOK)**
- B. Flow Habitat Relationship for Incubation Success (e.g., scour, redd dewatering, water circulation)**(see SAC FR CHINOOK)**
- C. Spawning Gravel Quality (e.g., effects on dissolved oxygen, emergence)
- D. Pollutant Mortality Relationships
- E. Predation and Disease Mortality Relationships

III. Fry and Juvenile Rearing and Migration (Riverine Habitat)

- A. Temperature Survival Relationship **(see SAC FR CHINOOK)**
- B. Flow Habitat Relationship for Rearing Success **(see SAC FR CHINOOK)**
- C. Flow Transport Relationship for Outmigration Success **(see SAC FR CHINOOK)**
- D. Diversion Mortality Relationship **(see SAC FR CHINOOK)**

E. Dam Passage Mortality Relationship (**see SAC FR CHINOOK**)

F. In-River Rearing Habitat Availability (**see SAC FR CHINOOK**)

G. Riparian and Shaded Riverine Aquatic (SRA) Habitat Availability (**see SAC FR CHINOOK**)

H. Flood Bypass Habitat Availability and Stranding Losses

I. Predation, Competition, and Disease Relationships to Survival

J. Pollutant Mortality Relationships

K. Effects of Hatchery Fish Competition for Rearing Habitat

IV. Fry and Juvenile Rearing and Migration (Delta Habitat)

A. Temperature Survival Relationship (**see SAC FR CHINOOK**)

B. Flow Transport Relationship for Outmigration Success (**see SAC FR CHINOOK**)

C. Pathway and Barrier Survival Relationships (**see SAC FR CHINOOK**)

D. Diversion Mortality Relationship (**see SAC FR CHINOOK**)

E. Delta Rearing Habitat Availability

F. Riparian and Shaded Riverine Aquatic (SRA) Habitat Availability (**see SAC FR CHINOOK**)

G. Predation, Competition, and Disease Relationships to Survival

H. Pollutant Mortality Relationships

I. Effects of Hatchery Fish Competition for Rearing Habitat

V. Juvenile and Adult Rearing (Ocean Habitat)

A. Natural Mortality Rate (e.g., ocean upwelling)(**see SAC FR CHINOOK**)

B. Commercial Fishing Mortality (**see SAC FR CHINOOK**)

C. Sport Fishing Mortality (**see SAC FR CHINOOK**)

What life stages would you include or delete? Why?

Can you recommend any additional assessment variables for this species? If so, what are they?

Are there any proposed assessment variables that you would recommend CALFED not use for this species? Why?

STEELHEAD TROUT

Fisheries Assessment Variables by Life Stage:

Steelhead Trout

I. Adult Migration and Spawning (Riverine Habitat)
   - A. Temperature Survival Relationship for Adult Salmon
   - B. Temperature Survival Relationship for Pre-Spawn Eggs
   - C. Flow Survival Relationship for Adult Migration
   - D. Barrier Survival Relationship for Adult Migration
   - E. Flow Habitat Relationship for Spawning Success
   - F. Spawning Gravel Availability
   - G. Spawning Dispersal
   - H. Pollutant Mortality Relationships
   - I. Sport Fishing Mortality
   - J. Effects of Hatchery Fish Competition for Spawning Habitat
   - K. Stock Recruitment Relationships

II. Incubation and Emergence (Riverine Habitat)
   - A. Temperature Survival Relationship for Eggs and Larvae
   - B. Flow Habitat Relationship for Incubation Success (e.g., scour, redd dewatering, water circulation)
   - C. Spawning Gravel Quality (e.g., effects on dissolved oxygen, emergence)
   - D. Pollutant Mortality Relationships
   - E. Predation and Disease Mortality Relationships

III. Fry and Juvenile Rearing and Migration (Riverine Habitat)
   - A. Temperature Survival Relationship
   - B. Flow Habitat Relationship for Rearing Success (cover, food, stranding)
   - C. Flow Transport Relationship for Outmigration Success
   - D. Diversion Mortality Relationship
   - E. Dam Passage Mortality Relationship

F. In-River Rearing Habitat Availability

G. Riparian and Shaded Riverine Aquatic (SRA) Habitat Availability

H. Flood Bypass Habitat Availability and Stranding Losses

I. Predation, Competition, and Disease Relationships to Survival

J. Pollutant Mortality Relationships

K. Effects of Hatchery Fish Competition for Rearing Habitat

IV. Fry and Juvenile Rearing and Migration (Delta Habitat)

A. Temperature Survival Relationship

B. Flow Transport Relationship for Outmigration Success

C. Pathway and Barrier Survival Relationships (e.g., DCC and Old River)

D. Diversion Mortality Relationship

E. Delta Rearing Habitat Availability

F. Riparian and Shaded Riverine Aquatic (SRA) Habitat Availability

G. Predation, Competition, and Disease Relationships to Survival

H. Pollutant Mortality Relationships

I. Effects of Hatchery Fish Competition for Rearing Habitat

V. Juvenile and Adult Rearing (Ocean Habitat)

A. Natural Mortality Rate (based on water temperature, ocean upwelling)

B. Commercial Fishing Mortality

C. Sport Fishing Mortality

What life stages would you include or delete? Why?

Can you recommend any additional assessment variables for this species? If so, what are they?

Are there any proposed assessment variables that you would recommend CALFED not use for this species? Why?

AMERICAN SHAD

C-000377

Fisheries Assessment Variables by Life Stage:

American Shad

I. Adult Migration and Spawning (Riverine and Delta Habitat)

- A. Temperature Survival Relationship for Spawning Success
- B. Flow Survival Relationship for Adult Migration
- C. Barrier Survival Relationship for Adult Migration
- D. Flow Habitat Relationship for Spawning Success (**see Methods**)
- E. Spawning Habitat Availability
- F. Salinity Effects on Spawning Success
- G. Pollutant Mortality Relationship
- H. Sport Fishing Mortality
- I. Stock Recruitment Relationships

II. Incubation (Riverine and Delta Habitat)

- A. Temperature Survival Relationship
- B. River Flow Survival Relationship (**see Methods**)
- C. Delta Flow Survival Relationship
- D. Diversion Mortality Relationship
- E. Lower San Joaquin River TDS Survival Relationship
- F. Pollutant Mortality Relationship
- G. Predation and Disease Relationships to Survival

III. Larval and Juvenile (Young-of-Year [YOY]) Rearing (Riverine and Delta Habitat)

- A. Temperature Survival Relationship
- B. Flow Transport Relationship for Rearing Success
- C. Pathway and Barrier Survival Relationships (**see Methods**)
- D. Diversion Mortality Relationship
- E. In-River Rearing Habitat Availability
- F. Riparian and Shaded Riverine Aquatic (SRA) Habitat Availability
- G. Delta Rearing Habitat Availability

H. Predation, Competition, and Disease Relationships to Survival

I. Pollutant Mortality Relationships

V. Juvenile and Adult Rearing (Ocean Habitat)

A. Natural Mortality Rate (based on water temperature, ocean upwelling)

What life stages would you include or delete? Why?

Can you recommend any additional assessment variables for this species? If so, what are they?

Are there any proposed assessment variables that you would recommend CALFED not use for this species? Why?

Species/Life Stage: American Shad/Adult Migration and Spawning

Assessment Variable: Flow Habitat Relationship for Spawning Success

Assessment Method: Flow Habitat Index for April, May, and June

Application to CALFED: CALFED actions may affect American shad survival through changes to river flow during the adult migration, spawning, incubation, and river rearing life stages. The Flow Need Index could be used to compare spawning success between Programmatic EIR/EIS alternatives.

Description: The model uses flow habitat needs identified for wet water-year types. The flow habitat index is the flow for a given river (Sacramento, Feather, American, Mokelumne, and Stanislaus Rivers) during April, May, and June divided by the wet-year flow need for the same month (for flows greater than the flow need, the flow habitat index is 1). Although the relationship is based on flow needs identified for April, May, and June river flow, flow during other months may also be important but is not reflected by the index. The specific factor controlling abundance cannot be identified.

Reference: Flow needs were identified by the U.S. Fish and Wildlife Service 1995.

Input Data: River Flow

Modifications Necessary for CALFED Use: Although modifications to the model are not required with the existing facilities and operations, changes in specific watersheds and to conditions outside of April, May, and June may affect model usefulness.

Species/Life Stage: American Shad/Incubation (may also reflect Adult Migration and Spawning, Larval and Juvenile Rearing life stage success)

Assessment Variable: River Flow Survival Relationship (encompasses to an unknown extent several other flow-driven relationships, including spawning habitat availability, temperature survival, flow transport, diversion mortality, river rearing habitat availability, and pollutant mortality)

Assessment Method: Regression of fall mid-water trawl index on average May-June Delta inflow

Application to CALFED: CALFED actions may affect American shad survival through changes to river flow, diversions, and water temperature. The abundance index could be used to compare abundance of young-of-year American shad among alternatives with variable flow and diversion patterns.

Description: The model uses analytical relationships developed by DFG from fall mid-water trawl indices for variable Delta inflow levels. Although the relationship is based on May-June Delta inflow, the effect of flow during other months may also be important but is not apparent because flow during preceding and following months may be correlated with flow during May and June. Also, the specific factor controlling abundance cannot be identified because flow level may be correlated with habitat availability, pollutant concentration, diversion effects, transport, and other factors in the rivers and in the Delta. The equation representing the relationship is:

$$\text{Log}_{10}\ \text{Shad Abundance Index} = 5.59 + 0.00093 * \text{Delta Inflow}$$

where the Shad Abundance Index represents the estimated fall mid-water trawl index and Delta Inflow is the average inflow for May and June in cubic meters per second.

Reference: Stevens and Miller 1983.

Input Data: Delta Inflow.

Modifications Necessary for CALFED Use: Although modifications to the model are not required with the existing facilities and operations, changes in specific watersheds and to conditions outside of May and June may affect model usefulness.

Species/Life Stage: American Shad/Larval and Juvenile Rearing

Assessment Variable: Pathway and Barrier Survival Relationships (includes Diversion Mortality Relationship)

Assessment Method: Delta Pathway Diversion Index

Application to CALFED: CALFED actions may affect American shad survival during fall out-migration of juveniles through changes to Delta flow patterns (e.g., DCC operations), Delta diversions, Delta inflow, and fish screens. The Delta pathway diversion index could be used to compare affects of variable flow, diversions, and fish screen efficiencies for alternatives included in the Programmatic EIR/EIS.

Description: The model uses Delta channel flows, diversions, and fish screen efficiency to estimate a Delta pathway diversion index for outmigrant American shad juveniles during October, November, and December (i.e., the primary months of juvenile out-migration from riverine habitats through the Delta). The primary assumptions are that Delta diversions affect outmigrant survival during October-December and that juvenile shad move with the net flow of water through the Delta.

Reference: Preliminary Draft Document, Jones & Stokes Associates 1996.

Input Data: Delta inflow and channel flows (net and tidal), diversion volumes, and fish screen efficiencies.

Modifications Necessary for CALFED Use: Modifications to the model would be required to reflect changes in Delta facilities and water project operations under each alternative of the Programmatic EIR/EIS.

C-000382

WHITE AND GREEN STURGEON

Fisheries Assessment Variables by Life Stage:

White and Green Sturgeon

I. Adult Migration and Spawning (Riverine Habitat)

A. Temperature Survival Relationship for Adult Sturgeon **(see Methods)**

B. Flow Survival Relationship for Adult Migration

C. Barrier Survival Relationship for Adult Migration

D. Flow Habitat Relationship for Spawning Success **(see Methods)**

E. Spawning Habitat Availability

F. Pollutant Mortality Relationships

G. Sport Fishing Mortality

H. Stock Recruitment Relationships

II. Incubation, Emergence, and Larval Distribution (Riverine Habitat)

A. Temperature Survival Relationship for Eggs and Larvae **(see Methods)**

B. Flow Habitat Relationship for Incubation Success (e.g., water circulation)

C. Spawning Substrate Quality (e.g., effects on dissolved oxygen, emergence)

D. Flow Transport Relationship for Rearing Success

E. Diversion Mortality Relationship

F. Pollutant Mortality Relationships

G. Predation and Disease Mortality Relationships

III. Juvenile Rearing and Migration (Riverine Habitat)

A. Temperature Survival Relationship

B. Flow Habitat Relationship for Rearing Success (cover, food, stranding) **(see Methods)**

C. Flow Transport Relationship for Outmigration Success **(see Methods)**

D. Diversion Mortality Relationship

E. Dam Passage Mortality Relationship

F. In-River Rearing Habitat Availability

G. Riparian and Shaded Riverine Aquatic (SRA) Habitat Availability

H. Flood Bypass Habitat Availability and Stranding Losses

I. Predation, Competition, and Disease Relationships to Survival

J. Pollutant Mortality Relationships

IV. Juvenile and Adult Rearing (Delta, Estuarine, and Ocean Habitat)

A. Diversion Mortality Relationship

B. Delta Rearing Habitat Availability

C. Suisun Bay Rearing Habitat Availability

D. Predation, Competition, and Disease Relationships to Survival

E. Pollutant Mortality Relationships

F. Fishing Mortality (Sport and Poaching)

What life stages would you include or delete? Why?

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Can you recommend any additional assessment variables for this species? If so, what are they?

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Are there any proposed assessment variables that you would recommend CALFED not use for this species? Why?

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Species/Life Stage: White and Green Sturgeon/Adult Migration and Spawning (Riverine Habitat)

Assessment Variable: Temperature-Survival Relationship for Adult Sturgeon

Assessment Method: No relationship currently available. Could develop relationships between river temperature and catch data (some information available)

Application to CALFED: CALFED actions may affect temperature regimes through the regulation of flow or habitat restoration projects.

Description: The hypothesis is that changes in water temperature magnitude or seasonal timing affect the initiation or timing of adult sturgeon spawning migrations. Use of sport and research catch statistics in relation to river temperatures, or a simple habitat suitability index could be used to evaluate relationship.

References: Haynes, J. M., R. H. Gray, and J. C. Montgomery. 1978. Seasonal movements of white sturgeon (*Acipenser transmontanus*) in the Mid-Columbia River. Transactions of the American Fisheries Society 107:275-289.

Kohlhorst, D. W. 1976. Sturgeon spawning in the Sacramento River in 1973, as determined by distribution of larvae. California Department of Fish and Game 62(1):32-40.

Input Data and Tools:

1) Catch statistics (location and timing)
2) River temperature data
3) Sex and maturity data

Modifications Necessary for CALFED Use: Method needs to be developed.

Species/Life Stage: White and Green Sturgeon/Adult Migration and Spawning (Riverine Habitat)

Assessment Variable: Flow Habitat Relationship for Spawning Success

Assessment Method: Use of habitat suitability indices in a qualitative manner

Application to CALFED: CALFED actions may affect flow, which in turn can affect water depths, water velocities, and substrate types. Habitat projects may also alter substrates. If Columbia River data are usable for Sacramento River sturgeon, relationships can be used to evaluate changes in rearing habitat availability.

Description: Water depth, mean current velocity, and substrate type can affect successful sturgeon spawning. See next page for relationships developed for Columbia River white sturgeon (Figure 2 from Parsley and Beckman 1994).

Reference: Parsley, M. J. and L. G. Beckman. 1994. White sturgeon spawning and rearing habitat in the lower Columbia. North American Journal of Fisheries Management 14:812-827.

Input Data and Tools:

1) General river flow changes for qualitative assessment
2) PHABSIM data for quantitative assessment

Modifications Necessary for CALFED Use: Possible criteria adjustments because of geographic differences.

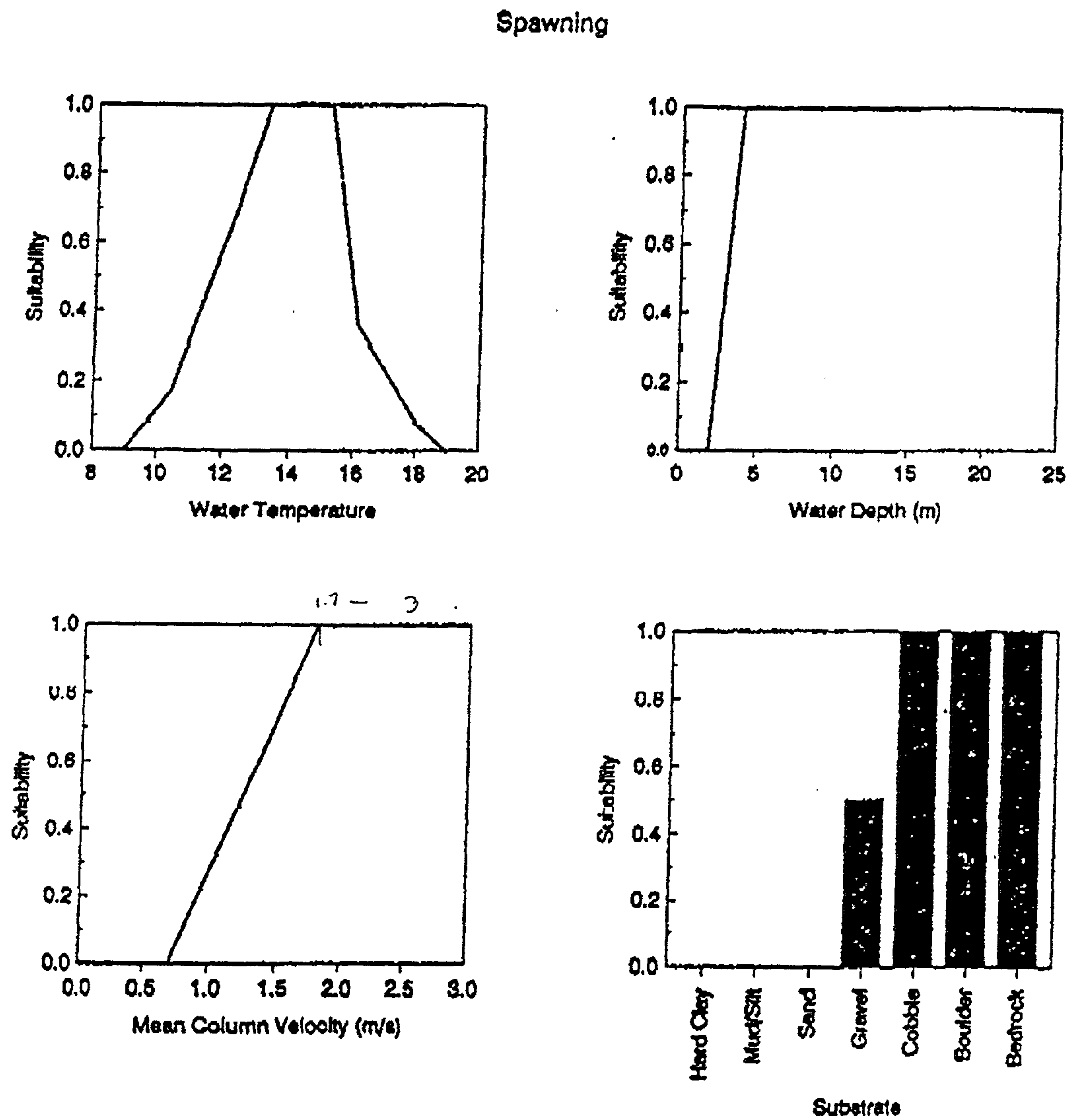


Figure 2. Microhabitat criteria curves depicting the suitability of water temperatures, depths, mean column velocities, and substrates for spawning white sturgeon.

Species/Life Stage: White and Green Sturgeon/Incubation, Emergence, and Larval Distribution (Riverine Habitat)

Assessment Variable: Temperature-Survival Relationships for Eggs and Larvae

Assessment Method: Developed relationships between temperature and embryonic development and hatching success

Application to CALFED: CALFED actions may change flow levels, which could affect water temperatures, at important sturgeon spawning locations.

Description: Changes in river temperature may affect sturgeon embryonic development, hatching success, and yolk depletion. Overall survival of sturgeon to the juvenile stage is assumed to be greatest within optimal river temperatures during development periods. See next page for relationships (Figures 2A and 4A from Wang 1984).

Reference: Wang Y. L. 1984. The effect of temperature on the early development of white sturgeon and lake sturgeon. M.S. Thesis. University of California, Davis. Davis, California.

Input Data and Tools: River temperature in spawning areas during spawning periods

Modifications Necessary for CALFED Use: None

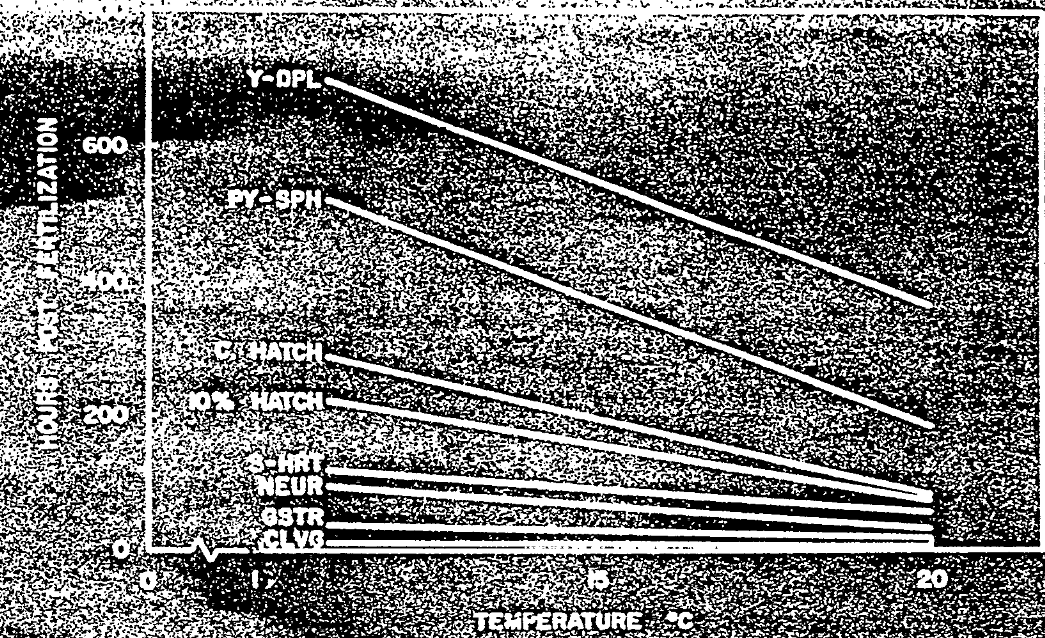
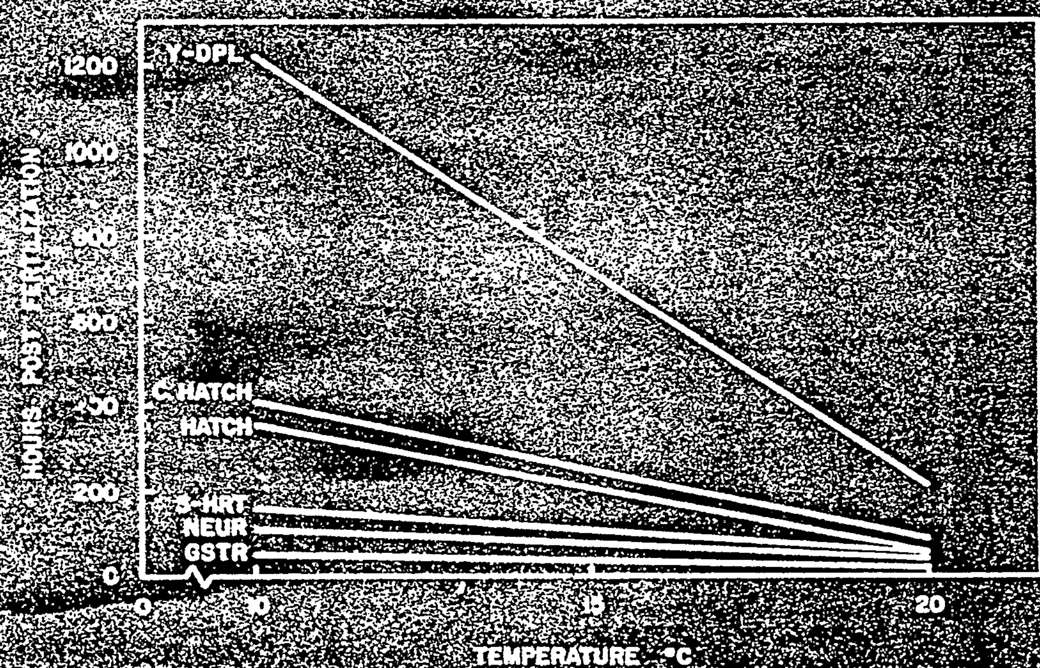


Fig. 2B Developmental Rate of Lake Sturgeon.



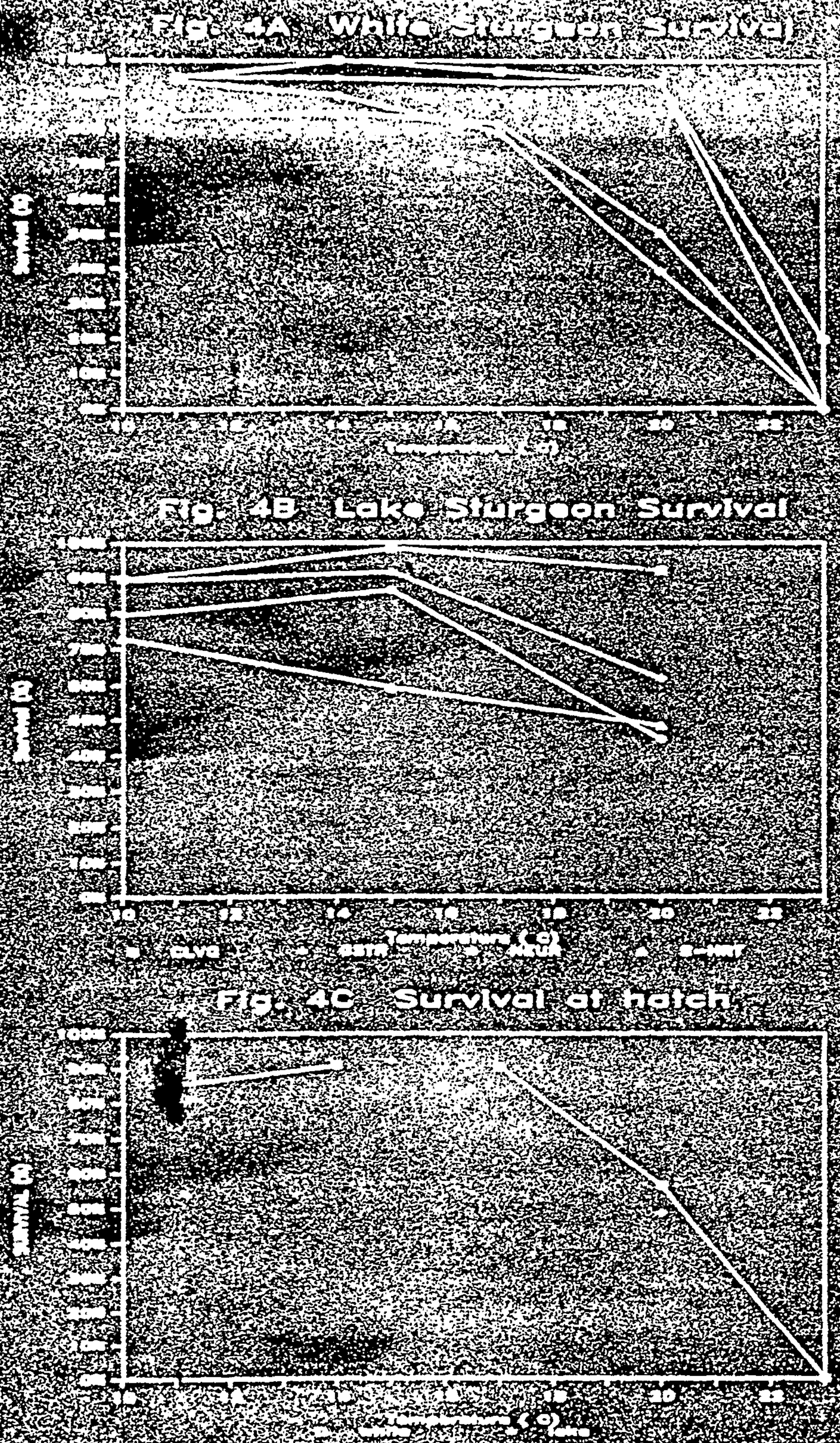


Fig. 4A White Sturgeon Survival
Fig. 4B Lake Sturgeon Survival
10
12
14
16
18
20
22
Temperature (C)
Fig. 4C Survival at hatch
Temperature (C)

Species/Life Stage: White and Green Sturgeon/Incubation, Emergence, and Larval Distribution (Riverine Habitat)

Assessment Variable: Temperature Survival Relationship for Eggs and Larvae

Assessment Method: Application of temperature/growth data presented by Kohlhorst (1976)

Application to CALFED: CALFED actions may change flow levels, which could affect water temperatures, at important locations for sturgeon incubation and larval development.

Description: Length of incubation and growth rate of larval sturgeon affect overall survival rate of sturgeon at these life stages. See next page for relationships developed for Sacramento River sturgeon (Figures 5 and 6 from Kohlhorst 1976).

Reference: Kohlhorst, D. W. 1976. Sturgeon spawning in the Sacramento River in 1973, as determined by distribution of larvae. California Department of Fish and Game 62(1):32-40.

Input Data and Tools:
1) Flow/temperature relationships
2) River temperature data
3) Fish survey data

Modifications Necessary for CALFED Use: None

C-000392

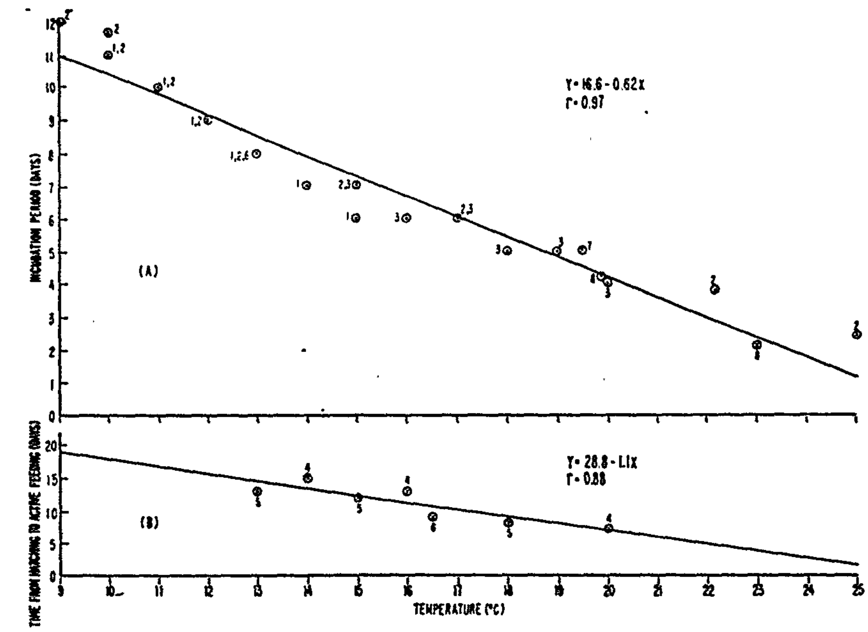


FIGURE 5. Relationship between water temperature and sturgeon larval development, derived from the following sources and species:
Geibel 1966
1. *Huso huso*
2. *Acipenser guldenstadti*
3. *A. stellatus*
Cherfas 1956
4. *A. guldenstadti*
5. *H. huso*
Nikolskii 1961
6. *H. huso*
7. *A. nudiventris*
8. *A. stellatus*
Line (A) was assumed to represent larvae 8 mm long and line (B) was assumed to represent larvae 18 mm long.

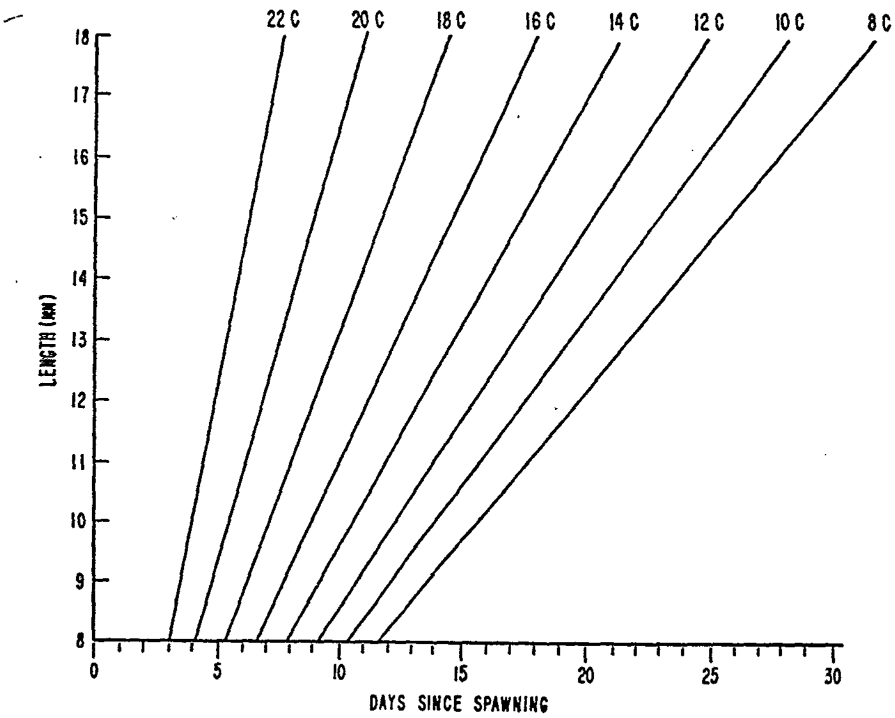


FIGURE 6. Relationship between age (since time of spawning) and length of sturgeon larvae at various water temperatures observed during sampling in the Sacramento River in 1973. These relationships were estimated from the regressions in Figure 5. If larval length and approximate developmental temperature are known, an estimate of larval age can be interpolated from this graph.

Species/Life Stage: White and Green Sturgeon/Juvenile Rearing and Migration (Riverine Habitat)

Assessment Variable: Flow Habitat Relationship for Rearing Success

Assessment Method: Use of young-of-year (YOY) habitat suitability indices in a qualitative manner

Application to CALFED: CALFED actions may affect flow, which in turn can affect water depths, water velocities, and substrate types. Habitat projects may also alter substrates. If Columbia River data are usable for Sacramento River sturgeon, relationships can be used to evaluate changes in rearing habitat availability.

Description: Water depth, mean current velocity, and substrate type can affect the survival of YOY sturgeon. See next page for relationships developed for Columbia River white sturgeon (Figure 3 from Parsley and Beckman 1994).

Reference: Parsley, M.J. and L.G. Beckman. 1994. White sturgeon spawning and rearing habitat in the lower Columbia. North American Journal of Fisheries Management 14:812-827.

Input Data and Tools:

1) General river flow changes for qualitative assessment
2) PHABSIM data for quantitative assessment

Modifications Necessary for CALFED Use: Possible criteria adjustments because of geographic differences.

Young-of-the-year

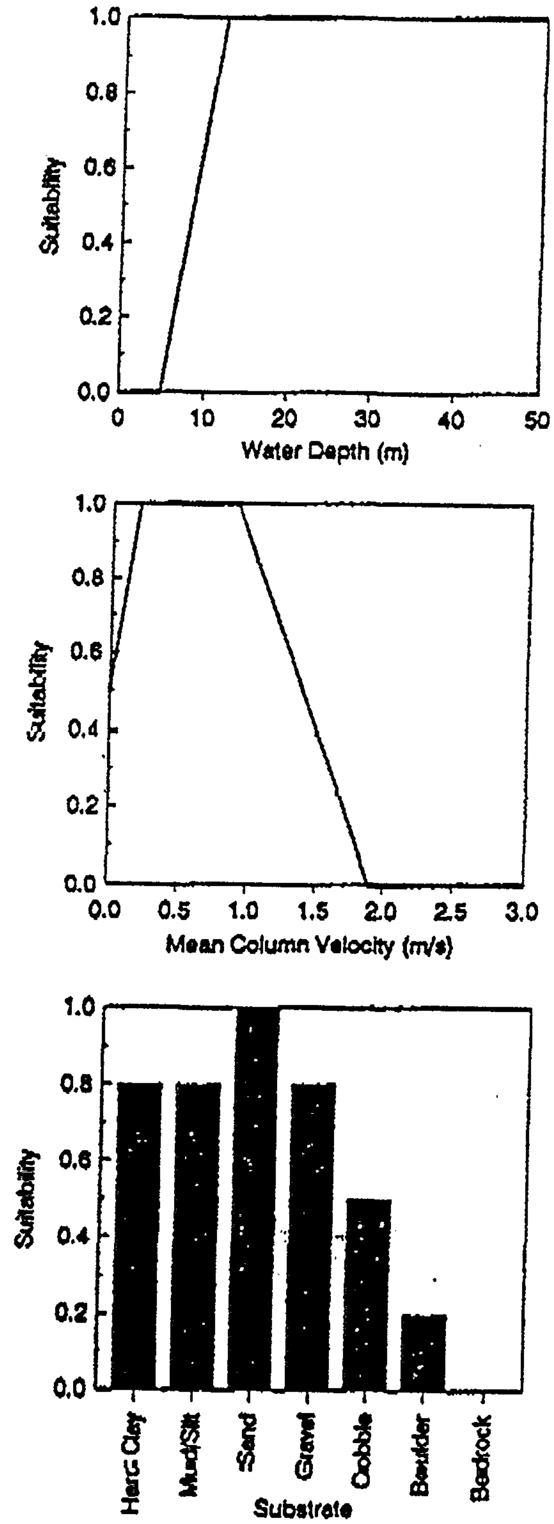


Figure 3. Microhabitat criteria curves depicting the suitability of water

Species/Life Stage: White and Green Sturgeon/Juvenile Rearing and Migration (Riverine Habitat)

Assessment Variable: Flow Habitat Relationship for Juvenile Rearing Success

Assessment Method: Use of juvenile habitat suitability indices in a qualitative manner

Application to CALFED: CALFED actions may affect flow, which in turn can affect water depths, water velocities, and substrate types. Habitat projects may also alter substrates. If Columbia River data are usable for Sacramento River sturgeon, relationships can be used to evaluate changes in rearing habitat availability.

Description: Water depth, mean current velocity, and substrate type can affect the survival of juvenile sturgeon. See next page for relationships developed for Columbia River white sturgeon (Figure 4 from Parsley and Beckman 1994).

Reference: Parsley, M.J. and L.G. Beckman. 1994. White sturgeon spawning and rearing habitat in the lower Columbia. North American Journal of Fisheries Management 14:812-827.

Input Data and Tools:

1) General river flow changes for qualitative assessment
2) PHABSIM data for quantitative assessment

Modifications Necessary for CALFED Use: Possible criteria adjustments because of geographic differences.

C-000396

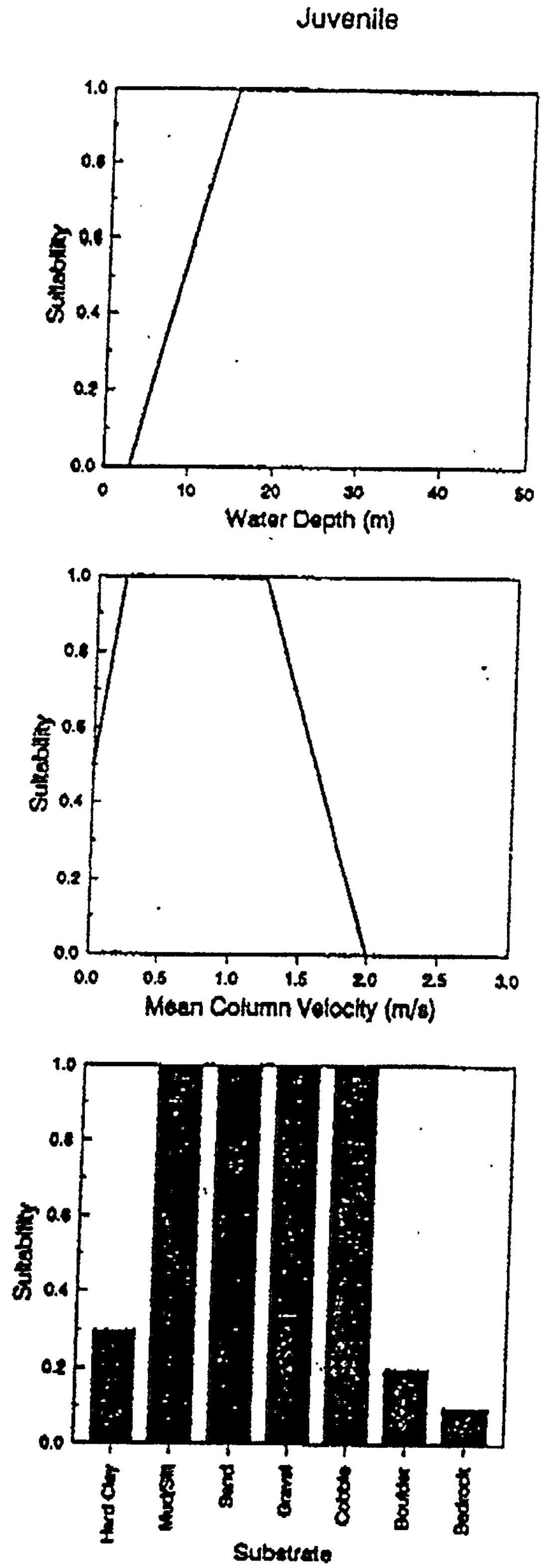


Figure 4. Microhabitat criteria curves depicting the suitability of water depths, mean column velocities, and substrates for juvenile white sturgeon.

Species/Life Stage: White and Green Sturgeon/Juvenile Rearing and Migration (Riverine Habitat)

Assessment Variable: Flow Transport Relationship for Outmigration Success

Assessment Method: Relationship between year-class strength index and Sacramento River outflow in spring and early summer (Kohlhorst et al. 1991)

Application to CALFED: CALFED actions may alter Sacramento River flows during periods when juvenile disperse downriver.

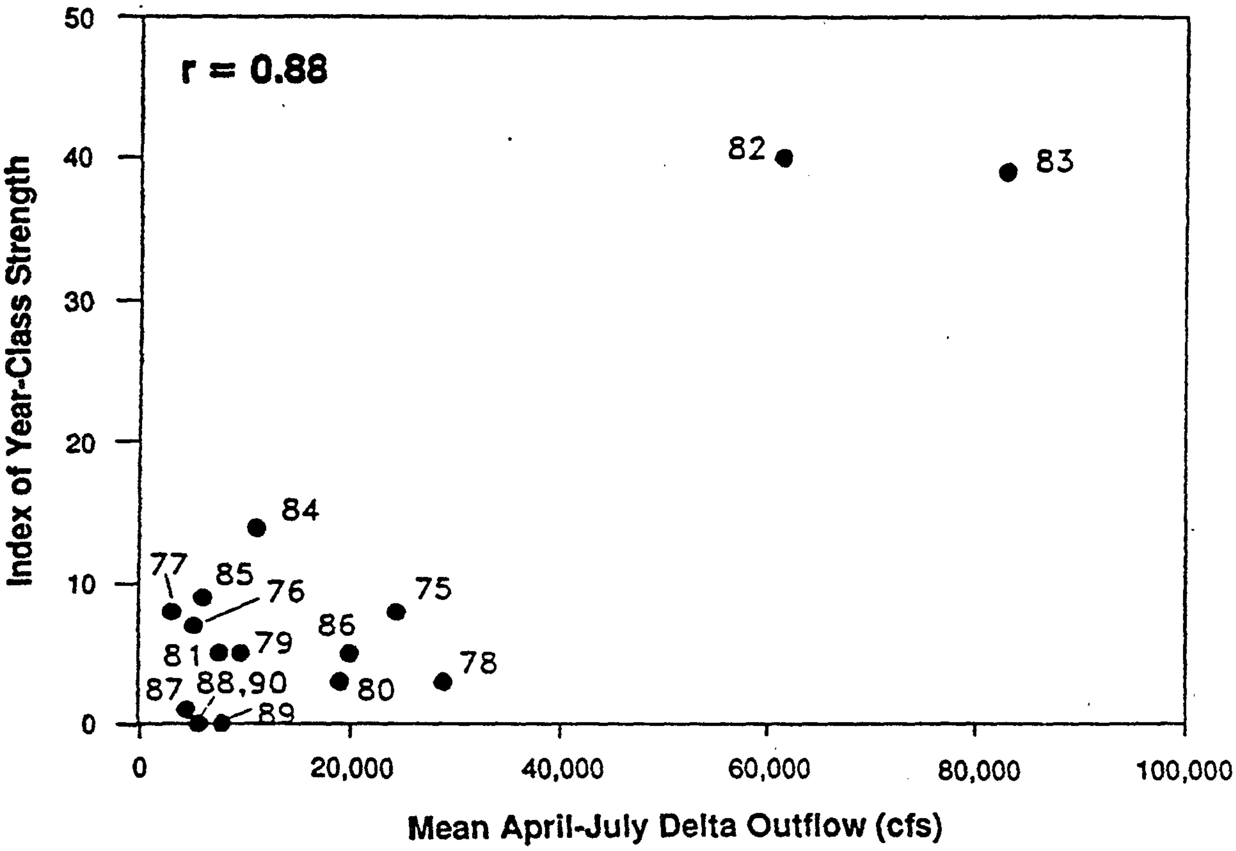
Description: Sacramento River flows may affect year-class strength of juvenile sturgeon (young of the year), possibly by dispersing the young to more productive or underutilized habitats. See next page for relationship developed for Sacramento River sturgeon by Kohlhorst et al. (1991). (Figure excerpted from CVPIA PEIS.)

Reference: Kohlhorst, D. W., L. W. Botsford, J. S. Brennan, and G. M. Cailliet. 1991. Aspects of the structure and dynamics of an exploited Central California population of white sturgeon (*Acipenser transmontanus*). In P. Williot (ed.): *Acipenser*: Acts of the First International Sturgeon Symposium. October 3-6, 1989. Bordeaux, France, Cemagref-Dicova, pp. 277-293.

Input Data and Tools: Delta outflow

Modifications Necessary for CALFED Use: Possibly, depending on alternative.

C-000398



Source: Kohlhorst et al. 1991.

Note: Year-class index determined from trawl catches.

WHITE STURGEON YEAR-CLASS INDEX VERSUS MEAN DELTA OUTFLOW FOR APRIL THROUGH JULY (1975-1990)

FIGURE 2-VII-35

Species/Life Stage: White and Green Sturgeon/Juvenile Rearing and Migration (Riverine Habitat)

Assessment Variable: Flow Transport Relationship for Outmigration Success

Assessment Method: Relationship between year-class strength index and Sacramento River outflow in spring (California Department of Water Resources 1990)

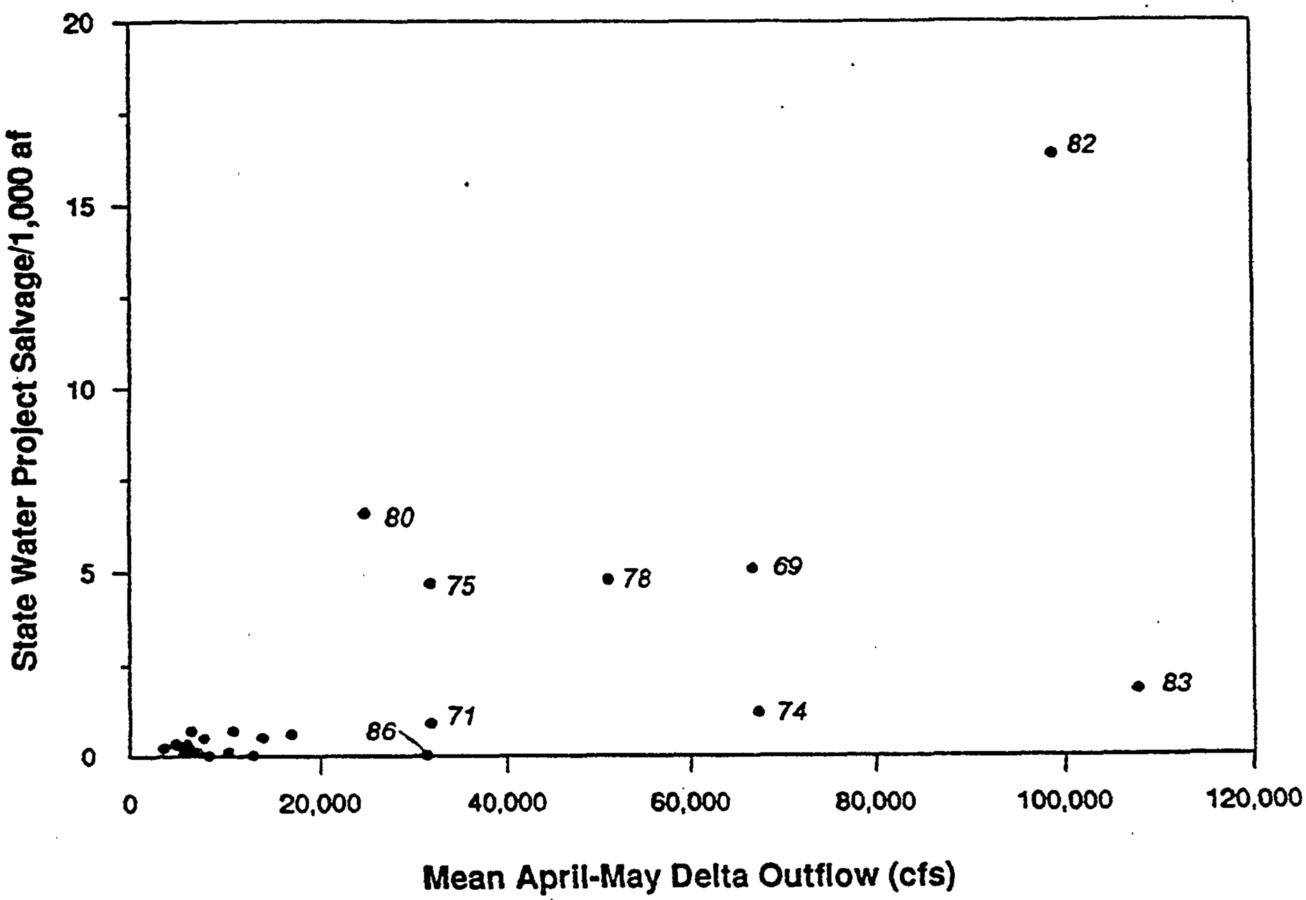
Application to CALFED: CALFED actions may alter Sacramento River flows during periods when juvenile disperse downriver.

Description: Sacramento River flows may affect year-class strength of juvenile sturgeon (young of the year), possibly by dispersing the young to more productive or underutilized habitats. See next page for relationship developed for Sacramento River sturgeon by California Department of Water Resources (1990). (Figure excerpted from CVPIA PEIS.)

Reference: California Department of Water Resources. 1990. Draft environmental impact report and environmental impact statement, North Delta program. Sacramento, CA.

Input Data and Tools: Delta outflow

Modifications Necessary for CALFED Use: Possibly, depending on alternatives.



Source: California Department of Water Resources 1990.

Note: Year-class index determined from salvage at State Water Project Skinner Fish Facilities.

WHITE STURGEON YEAR-CLASS INDEX VERSUS MEAN DELTA OUTFLOW FOR APRIL THROUGH MAY (1968-1987)

FIGURE 2-VII-36

STRIPED BASS

Fisheries Assessment Variables by Life Stage:

Striped Bass

I. Adult Migration and Spawning (Riverine and Delta Habitat)

   A. Temperature Survival Relationship for Spawning Success
   B. Flow Relationship for Adult Migration
   C. Flow Habitat Relationship for Spawning Success
   D. Spawning Habitat Availability
   E. Ocean Salinity Effects on Spawning Success
   F. San Joaquin River Salinity Effects on Spawning Success
   G. Pollutant Mortality Relationship
   H. Sport Fishing Mortality
   I. Stock Recruitment Relationships

II. Incubation (Riverine and Delta Habitats)

   A. Temperature Survival Relationship
   B. Sacramento River Flow Survival Relationship
   C. Lower San Joaquin River Flow Survival Relationship
   D. Diversion Mortality Relationship
   E. Lower San Joaquin River TDS Survival Relationship
   F. Pollutant Mortality Relationship
   G. Predation and Disease Relationships to Survival

III. Larval and Juvenile (Young-of-Year [YOY]) Rearing (Delta Habitat)

   A. Temperature Survival Relationship
   B. Flow Transport Relationship for Rearing Success
   C. Pathway and Barrier Survival Relationships (e.g., DCC and Old River)
   D. Diversion Mortality Relationship
   E. Delta Rearing Habitat Availability
   F. Suisun Bay Rearing Habitat Availability
   G. Predation, Competition, and Disease Relationships to Survival

H. Pollutant Mortality Relationships

I. Effects of Hatchery Fish Competition and Predation

IV. Juvenile (1 to 3 years old) and Adult Rearing (Delta, Estuarine, and Ocean Habitats)

A. Diversion Mortality Relationship

B. Delta Rearing Habitat Availability

C. Suisun Bay Rearing Habitat Availability

D. Predation, Competition, and Disease Relationships to Survival

E. Pollutant Mortality Relationships

F. Effects of Hatchery Fish Competition and Predation

G. Fishing Mortality (Sport and Poaching)

What life stages would you include or delete? Why?

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Can you recommend any additional assessment variables for this species? If so, what are they?

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Are there any proposed assessment variables that you would recommend CALFED not use for this species? Why?

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C-000404

Species/Life Stage: Striped Bass / Adult Migration and Spawning (Riverine Habitat)

Assessment Variable: Flow Relationship for Adult Migration

Assessment Method: Flow-temperature-migration description.

Application to CALFED: CALFED alternatives may include flow changes that would affect striped bass spring migration to spawning areas in the San Joaquin and Sacramento rivers.

Description: The hypothesis is that changes in flow will affect the migration of adult striped bass upstream of the Delta and the timing and success of spawning in known spawning areas, such as the Sacramento River upstream of the confluence with the Feather River.

The value of higher flows during the spring spawning migration of striped bass into the lower San Joaquin and Sacramento Rivers for attracting spawners into spawning areas is unknown. Once striped bass arrive in the spawning areas, temperature is known to be an important factor that stimulates spawning activity. Flows that are stable will allow at least a natural progression of migration and spawning; however, unstable flows may stimulate or hinder migration and spawning. Short term decreases in water temperature associated with cooler weather or increased reservoir releases could increase mortality of newly spawned eggs and recently hatched larvae.

Reference:

Input Data: River flow, flow temperature relationships, and timing of striped bass migrations.

Modifications necessary for CALFED use:

C-000405

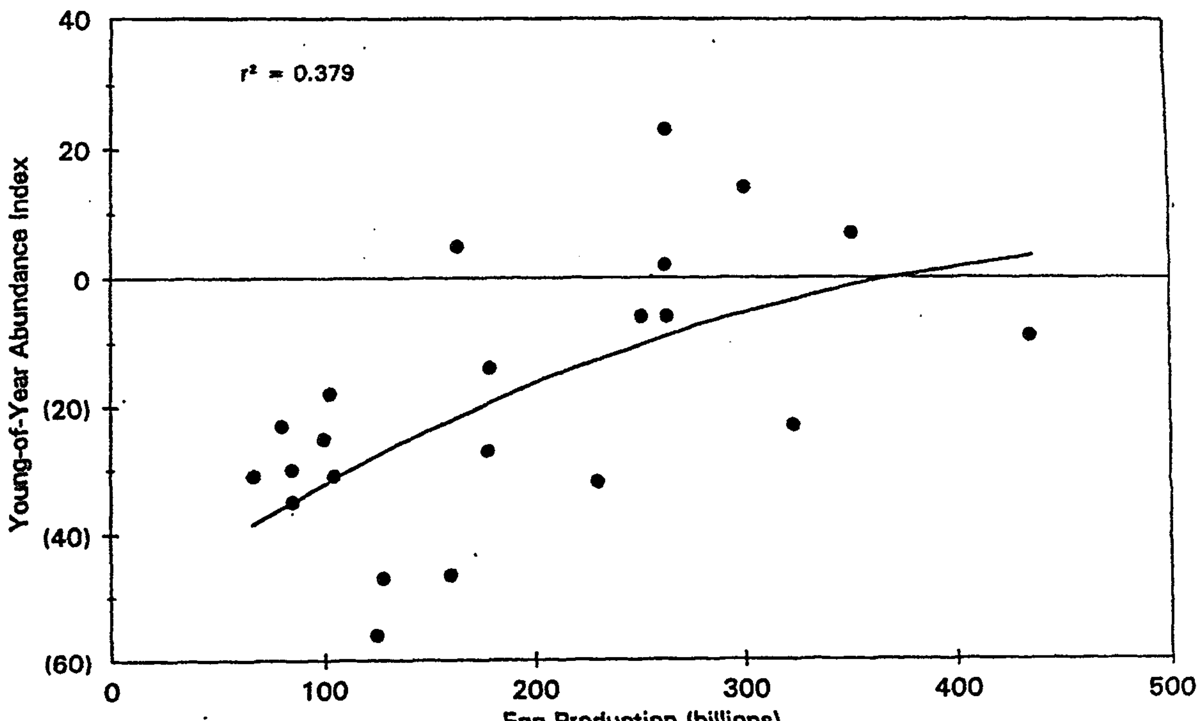
Species/Life Stage: Striped Bass/Adult Migration and Spawning (Riverine and Delta Habitat)

Assessment Variable: Stock Recruitment Relationships

Assessment Method: Adjustment to juvenile striped bass abundance index due to low numbers of eggs spawned

Application to CALFED: CALFED actions may alter Delta outflow and export levels from the Delta and adult population levels through fishery management actions: this tool translates effects on adult numbers and their associated egg production potential to expected shifts in the 38-mm juvenile production index.

Description: The hypothesis is that estimates of striped bass juvenile produced in the estuary should be adjusted if the numbers of adults and their associated egg production is low. Striped bass egg abundance appears to be related to young production in a linear way over the range of egg production shown in the relationship depicted below.



Source: California Department of Fish and Game (1992a)

RELATIONSHIP BETWEEN YOUNG-OF-YEAR ABUNDANCE INDEX AND EGG PRODUCTION IN THE SACRAMENTO-SAN JOAQUIN ESTUARY

Reference: U.S. Fish and Wildlife Service. 1995. Working paper on restoration needs: actions to double natural production of anadromous fish in the Central Valley of California. Volume 2.

C-000406

May 9, 1995. Prepared for the U.S. Fish and Wildlife Service under the direction of the Anadromous Fish Restoration Program Core Group. Stockton, CA.

Input Data and Tools: Adult population structure and egg production per female by age group.

Modifications Necessary for CALFED Use: None, unless habitat or other actions alter the basic underlying survival mechanisms for eggs and juvenile striped bass.

C-000407

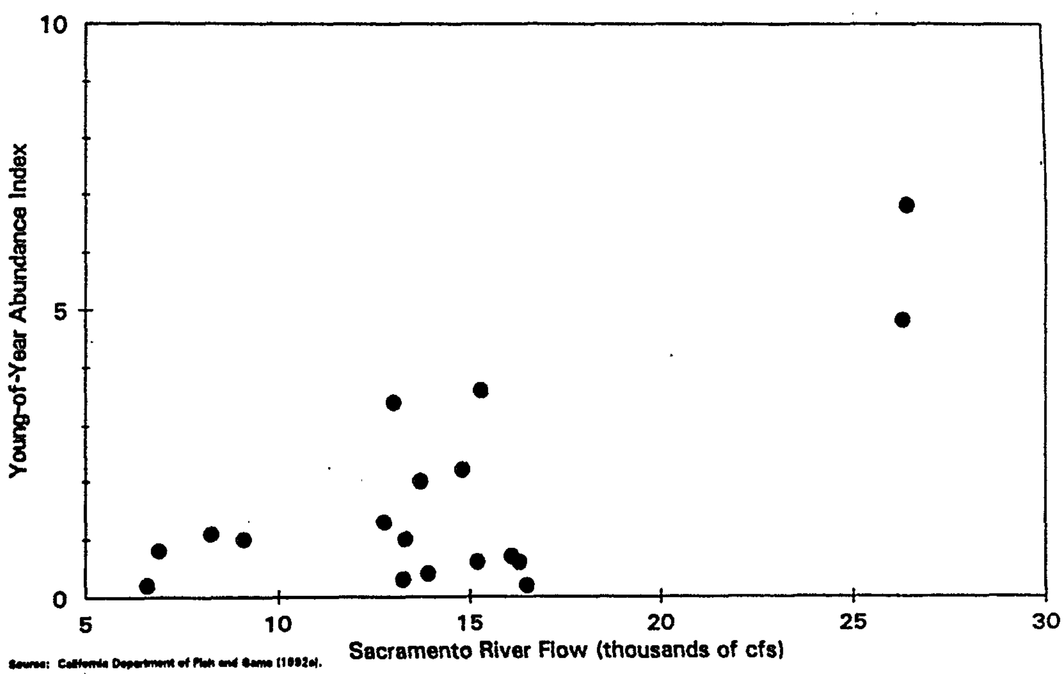
Species/Life Stage: Striped Bass Incubation

Assessment Variable: Sacramento River Flow Survival Relationship

Assessment Method: Sacramento River Flow-Survival Index is an indicator of egg survival to hatching potential in the Sacramento spawning population.

Application to CALFED: CALFED actions may change flow levels in the Sacramento River. This method directly translates flow levels into an index of early striped bass survival.

Description: The hypothesis is that striped bass survival between the egg and early larvae (6mm size) life stages is affected by flow in the Sacramento River near I Street (see relationship depicted below). Survival of eggs to early larvae is assumed to be higher at higher flows for a variety of reasons including eggs hatch better at higher flows that maintain them in suspension, predation is less at higher flow, or simply hatched larvae are transported more readily to the Delta at higher flows.



RELATIONSHIP BETWEEN SURVIVAL OF STRIPED BASS (EGGS TO 6MM) AND SACRAMENTO RIVER FLOW

Reference: U.S. Fish and Wildlife Service. 1995. Working paper on restoration needs: actions to double natural production of anadromous fish in the Central Valley of California. Volume 2. May 9, 1995. Prepared for the U.S. Fish and Wildlife Service under the direction of the Anadromous Fish Restoration Program Core Group. Stockton, CA.

Input Data and Tools: Flow data during spawning season in Sacramento River at I Street.

Modifications Necessary for CALFED Use: None, unless habitat or other actions alter the basic underlying survival mechanisms for eggs and early larval striped bass.

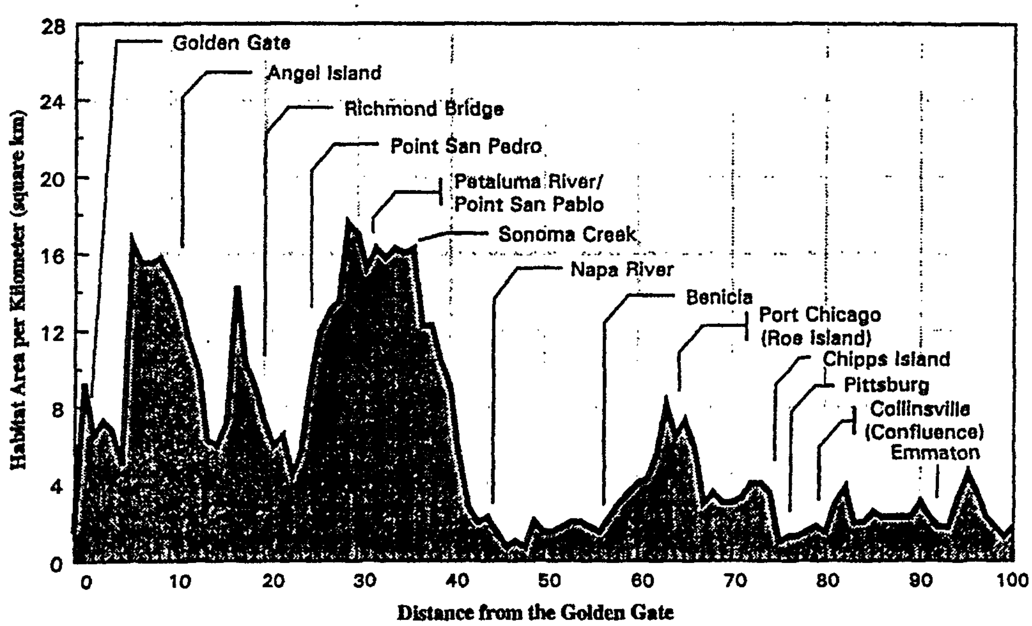
Species/Life Stage: Striped Bass/Larval and Juvenile (YOY) Rearing (Delta Habitat)

Assessment Variable: Suisun Bay Rearing Habitat Availability

Assessment Method: Estuarine Habitat Index Developed for CVPIA PEIS.

Application to CALFED: CALFED actions may change flow and salinity distribution in the estuary. This tool directly translates flow into an index of habitat area so that area of habitat produced can be compared among implementation levels of actions and alternative action packages.

Description: Given flow, salinity distribution can be determined and the area within the optimal range for striped bass juveniles can be calculated from the relationship depicted in the chart below.



Reference: CVPIA PEIS
Input Data and Tools: Flows, flow-salinity distribution relationship, and salinity-area relationship.
Modifications Necessary for CALFED Use: None.

Species/Life Stage: Striped Bass/Larval and Juvenile (YOY) Earing (Delta Habitat

Assessment Variable: Diversion Mortality Relationship

Assessment Method: Delta Export Survival Index: the loss rate of juvenile striped bass at export pumps as developed by DFG for the SWRCB water rights hearings in 1992.

Application to CALFED: CALFED actions may alter Delta outflow and export levels from the Delta: this tool translates flow and export levels into a loss-rate index of juvenile striped bass.

Description: The hypothesis is that the proportion of striped bass juvenile lost at the export pumps is related to Delta flow and export levels (see relationship depicted below). Estimated losses of 21- to 150-mm juveniles are divided by the abundance index for juveniles as determined from survey data to determine a loss rate.

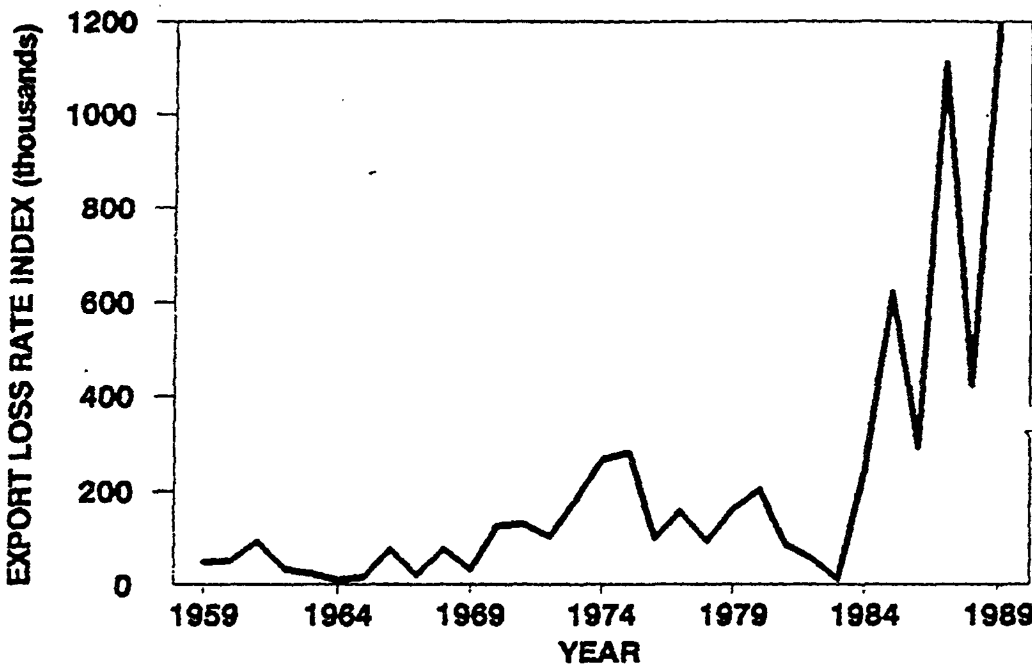


Figure 4. Trend in estimated loss rate of 21-150 mm striped bass to Central Valley Project and State Water Project export pumping after the time when the young-of-the-year index is set. Loss rate is the estimated export loss divided by the young-of-the-year index and represents the number of young bass lost per index unit.

Reference: Kohlhorst, D. W., D. E. Stevens, and L. W. Miller. 1992. A model for evaluating the impacts of freshwater outflow and export on striped bass in the Sacramento-San Joaquin Estuary. SWRCB 1992 Water Rights Phase of the Bay-Delta Estuary Proceedings.

Input Data and Tools: Flow and export levels, and salvage loss model and 38-mm juvenile index model.
Modifications Necessary for CALFED Use: None.

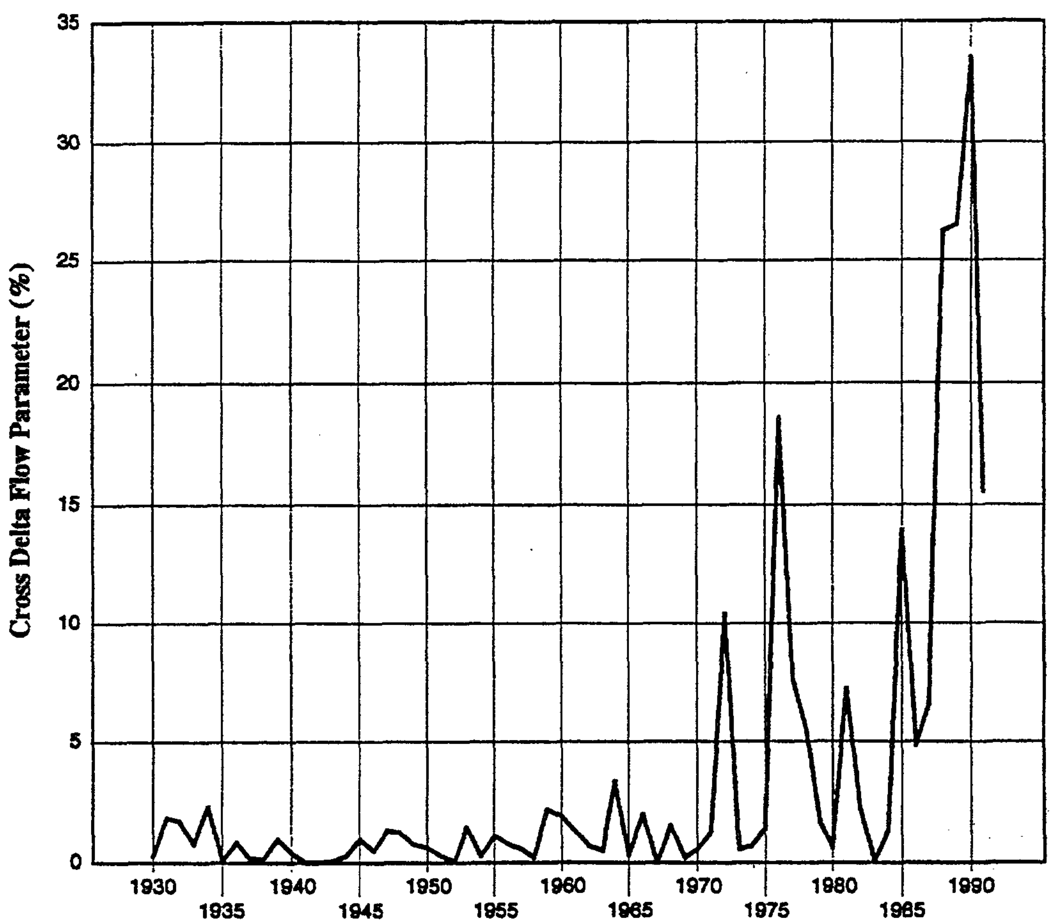
Species/Life Stage: Striped Bass/Larval and Juvenile (YOY) Rearing (Delta Habitat)

Assessment Variable: Diversion Mortality Relationship

Assessment Method: Larval and Early Juvenile Entrainment Index Developed for the Delta Wetlands EIR/EIS

Application to CALFED: CALFED actions may change flow and export levels in the estuary. This methodology translates flow and export levels into an index of proportion of flow that passes into the Delta that is exported.

Description: An index of the proportion of Delta Cross Channel and Georgianna Slough net flow exported from the Delta is estimated using a flow dispersion/entrainment model. An example output for a model run that uses historical flows and exports for the baseline 70-year period is depicted in the chart below.



Reference: Delta Wetlands Draft EIR/EIS

Input Data and Tools: Flow and export data; Delta Move Model - a water transport and mixing model.

Modifications Necessary for CALFED Use: None.

Species/Life Stage: Striped Bass / Larval and Juvenile (YOY) Rearing (Delta Habitat)

Assessment Variable: Delta Rearing Habitat Availability

Assessment Method: Shallow Water Habitat Description

Application to CALFED: CALFED alternatives may include actions that would alter the amount of shallow water habitat in the estuary. Such changes could affect distribution, abundance, and survival rates of juvenile striped bass.

Description: The hypothesis is that benefit the distribution, survival, and production of larvae and juvenile striped bass in the estuary.

Levees are a common feature along estuarine habitats in the Delta and the lower reaches of major riverine habitats. Riparian loss in these areas is primarily a result of levee construction and bank protection projects. Significant impacts to fisheries habitat have occurred from these projects, which typically require removing nearshore riparian vegetation and complex habitats, grading the bank slope, and placing rock revetment over the graded slope. Replacement of naturally eroding banks with rock revetment has been shown to locally reduce densities of juvenile chinook salmon. Levees and other flood control structures also have drastically reduced the occurrence and extent of temporarily flooded terrestrial habitat that historically provided thousands of acres of potential spawning and rearing habitats for numerous fish species.

A greater amount of shallow water habitat would improve food production, feeding habitat for juvenile bass, and predator refuge habitat. NOAA and DWR bathymetry data for the estuary could be used to map available shallow waters. Opportunities to create additional shallow waters can be input as completed. Comparison between existing and planned shallow water habitat can be made on a an area basis with some additional value expressed in terms of location.

GIS and other available information will be used to determine the areal extent of shallow waters within the river basin from available GIS and other bathymetric sources. Other attributes to the depth of water that could be added include salinity, turbidity, vegetation, and food supply.

Reference:

Input Data: Area by habitat type, defined by factors including water depth, vegetation type, and substrate type.

Modifications necessary for CALFED use:

Species/Life Stage: Striped Bass / Juvenile and Adult Rearing (Delta, Estuarine, and Ocean Habitats)

Assessment Variable: Pollutant Mortality Relationship

Assessment Method: Tissue Toxin Levels

Application to CALFED: CALFED alternatives may include may include measures that would reduce sources of toxins or decrease or increase dilution levels of toxins in river, Delta, and Bay waters. Such changes could affect the levels of toxins in the tissues of adult striped bass and thus the long-term survival and reproductive potential of adult striped bass.

Description: The hypothesis is that the amount and concentrations of toxins in the rivers, estuary, and nearby ocean waters adversely affects the survival and reproductive capacity of adult striped bass. Data on tissue toxin levels and water or substrate concentration of toxins will be reviewed along with expected changes in these levels from CALFED actions to qualitatively assess potential changes to the striped bass population.

Reference: Reports from San Francisco Estuary Institute, Department of Water Resources, Department of Fish and Game, and National Marine Fisheries Service.

Input Data: Tissue toxin levels; pollutant concentrations in the water and in bottom substrates.

Modifications necessary for CALFED use:

SACRAMENTO SPLITTAIL

C-000417

Fisheries Assessment Variables by Life Stage:

Sacramento Splittail

I. Adult Migration and Spawning (Riverine and Delta Habitat)

A. Temperature Survival Relationship for Spawning Success

B. Flow Relationship for Adult Migration

C. Flow Habitat Relationship for Spawning Success (**see Methods**)

D. Spawning Habitat Availability

E. Pollutant Mortality Relationship

F. Sport Fishing Mortality

G. Stock Recruitment Relationships

II. Incubation (Riverine and Delta Habitats)

A. Temperature Survival Relationship

B. Flow Survival Relationships (e.g., dewatering)

C. Pollutant Mortality Relationship

D. Predation and Disease Relationships to Survival

III. Larval and Juvenile (YOY) Rearing (Riverine and Delta Habitats)

A. Temperature Survival Relationship

B. Flow Transport Relationship for Rearing Success

C. Flow Survival Relationships (e.g., stranding)

D. Pathway and Barrier Survival Relationships (e.g., DCC and Old River)

E. Diversion Mortality Relationship

F. Rearing Habitat Availability

G. Predation, Competition, and Disease Relationships to Survival

H. Pollutant Mortality Relationships

IV. Juvenile (1 to 3 years old) and Adult Rearing (Delta and Estuarine Habitats)

A. Diversion Mortality Relationship

C-000418

B. Delta Rearing Habitat Availability

C. Suisun Bay Rearing Habitat Availability

D. Predation, Competition, and Disease Relationships to Survival

E. Pollutant Mortality Relationships

G. Fishing Mortality

What life stages would you include or delete? Why?

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Can you recommend any additional assessment variables for this species? If so, what are they?

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Are there any proposed assessment variables that you would recommend CALFED not use for this species? Why?

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Species/Life Stage: Sacramento Splittail/Adult Migration and Spawning (may also reflect Incubation and Larval and Juvenile Rearing life stage success)

Assessment Variable: Flow-Habitat Relationship for Spawning Success (encompasses to an unknown extent several other flow-driven relationships, including adult migration, spawning habitat availability, flow survival, temperature survival, flow transport, diversion mortality, rearing habitat availability, and pollutant mortality)

Assessment Method: Regression of Fall Mid-water Trawl Index on Average Proportion of Flood Bypass Inundation during February through June

Application to CALFED: CALFED actions may affect Sacramento splittail survival through changes to river flow and flood bypass operations. The index could be used to compare abundance of young-of-year Sacramento splittail among alternatives with variable extent of bypass flooding.

Description: The model uses analytical relationships developed from DFG fall mid-water trawl indices for variable flood bypass inundation. The specific factor controlling abundance cannot be identified because flow level may be correlated with habitat availability, pollutant concentration, diversion effects, transport, and other factors in the rivers, flood bypasses, and the Delta.

Reference: Outflow data and DFG historical data on the fall mid-water trawl index for Sacramento splittail

Input Data: Flood bypass inundation as a proportion of total bypass area

Modifications Necessary for CALFED Use: Although modifications to the model are not required with the existing facilities and operations, changes in specific flood bypass operation and area and to conditions outside of February-June may affect model usefulness.

Species/Life Stage: Sacramento Splittail/Adult Migration and Spawning (may also reflect Incubation and Larval and Juvenile Rearing life stage success)

Assessment Variable: Flow Habitat Relationship for Spawning Success (encompasses to an unknown extent several other flow-driven relationships, including adult migration, spawning habitat availability, flow survival, temperature survival, flow transport, diversion mortality, rearing habitat availability, and pollutant mortality)

Assessment Method: Regression of Fall Mid-Water Trawl Index on Average March-May Delta Outflow

Application to CALFED: CALFED actions may affect Sacramento splittail survival through changes to river flow, diversions, and water temperature. The abundance index could be used to compare abundance of young-of-year Sacramento splittail among alternatives with variable flow and diversion patterns.

Description: The model uses analytical relationships developed from DFG fall mid-water trawl indices for variable Delta outflow levels. Although the relationship is based on March-May Delta outflow, the effect of flow during other months may also be important but is not apparent because flow during preceding and following months may be correlated with flow during March, April, and May. Also, the specific factor controlling abundance cannot be identified because flow level may be correlated with habitat availability, pollutant concentration, diversion effects, transport, and other factors in the rivers, flood bypasses, and the Delta. The equation representing the relationship is:

$$\text{Abundance Index} = (58.46 * \text{Log}_{10}\ \text{Delta Outflow}) - 210$$

where the abundance index represents the estimated fall mid-water trawl index for Sacramento splittail and Delta outflow is the average outflow for March, April, and May in cubic feet per second.

Reference: Outflow data and DFG historical data on the fall mid-water trawl index for Sacramento splittail.

SPLITTAIL: I.C.2

Input Data: Delta outflow.

Modifications Necessary for CALFED Use: Although modifications to the model are not required with the existing facilities and operations, changes in specific watersheds (e.g., San Joaquin River and flood bypasses) and to conditions outside of March, April, and May could affect model usefulness.

DELTA SMELT

Fisheries Assessment Variables by Life Stage:
Delta Smelt

I. Adult Migration and Spawning (Delta and Suisun Bay Habitat)
   A. Temperature Survival Relationship for Spawning Success
   B. Flow Relationship for Adult Migration
   C. Flow Habitat Relationship for Spawning Success
   D. Spawning Habitat Availability
   E. Ocean Salinity Effects on Spawning Success
   F. San Joaquin River Salinity Effects on Spawning Success
   G. Pollutant Mortality Relationship
   H. Stock Recruitment Relationships

II. Incubation (Delta and Suisun Bay Habitats)
   A. Temperature-Survival Relationship
   B. Pollutant Mortality Relationship
   C. Predation and Disease Relationships to Survival

III. Larval and Juvenile Rearing (Delta and Suisun Bay Habitats)
   A. Temperature-Survival Relationship
   B. Flow-Transport Relationship for Rearing Success (**see Methods**)
   C. Pathway and Barrier Survival Relationships (e.g., DCC and Old River)
   D. Diversion Mortality Relationship (**see Methods**)
   E. Delta Rearing Habitat Availability (**see Methods**)
   F. Suisun Bay Rearing Habitat Availability (**see Methods**)
   G. Predation, Competition, and Disease Relationships to Survival
   H. Pollutant Mortality Relationships

IV. Juvenile and Adult Rearing (Delta and Suisun Bay Habitats)
   A. Diversion Mortality Relationship
   B. Delta Rearing Habitat Availability
   C. Suisun Bay Rearing Habitat Availability
   D. Predation, Competition, and Disease Relationships to Survival
   E. Pollutant Mortality Relationships

What life stages would you include or delete? Why?

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Can you recommend any additional assessment variables for this species? If so, what are they?

Are there any proposed assessment variables that you would recommend CALFED not use for this species? Why?

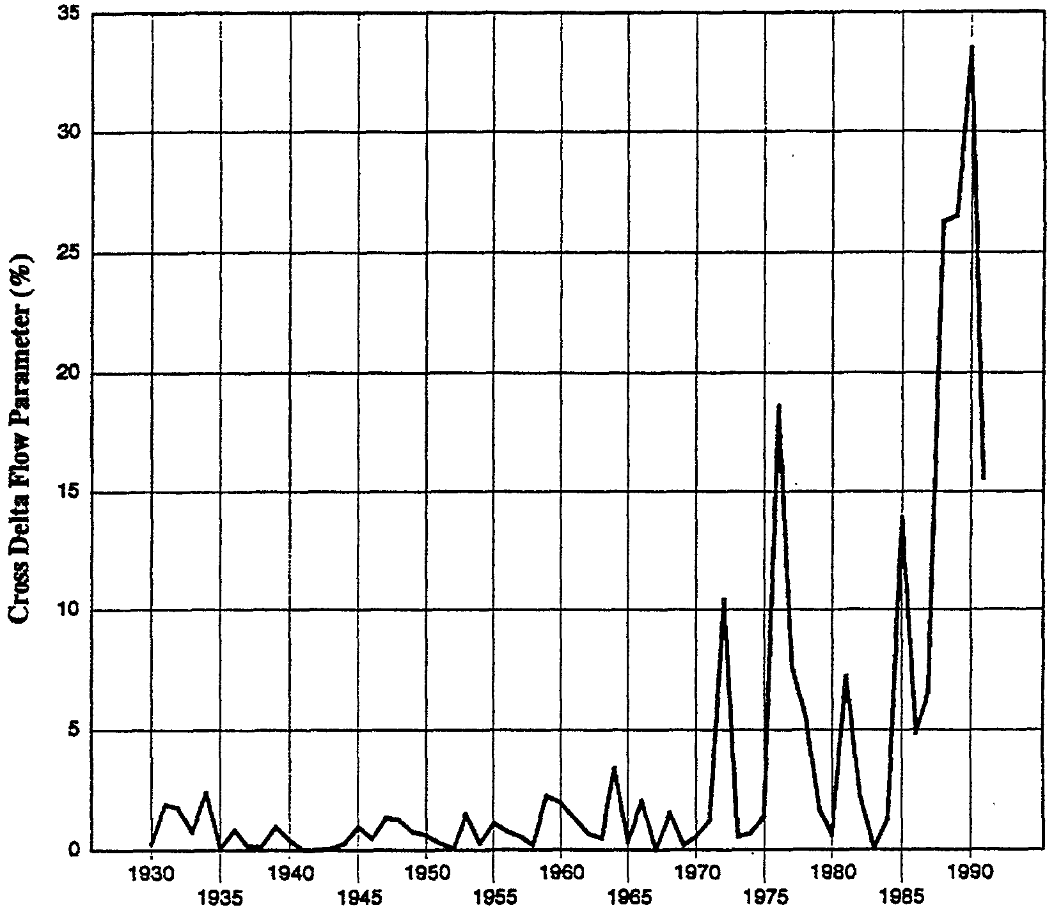
Species/Life Stage: Delta Smelt/Larval and Juvenile Rearing

Assessment Variable: Flow-Transport Relationship for Rearing Success (and Diversion Mortality Relationship)

Assessment Method: Larval and Early Juvenile Entrainment Index Developed for the Delta Wetlands EIR/EIS.

Application to CALFED: CALFED actions may change Delta inflow, Delta channel flow (e.g., barriers, conveyance facilities), and Delta diversions.

Description: The methodology translates Delta water movement, based on an initial distribution, into an index of the proportion of flow that is diverted from the Delta. If net flow in Delta channels is assumed to affect the movement and entrainment of delta smelt, the proportion of flow diverted (weighted for fish distribution) indicates potential transport and entrainment rates. An estimate of the proportion of Delta Cross Channel and Georgianna Slough net flow diverted from the Delta (i.e., Cross Delta Flow Parameter) is shown in the chart below for the historic 64-year period. Entrainment may also reflect effects of flow on habitat availability, pollutant concentrations, and prey availability.



Reference: Delta Wetlands Draft EIR/EIS

Input Data and Tools: Delta inflow, channel flow, and diversion data; DeltaMOVE Model - a water transport and mixing model.

Modifications Necessary for CALFED Use: Delta channel flow relationships would need to reflect changes to channel morphology and barrier implementation that could be implemented under the Programmatic EIR/EIS alternatives.

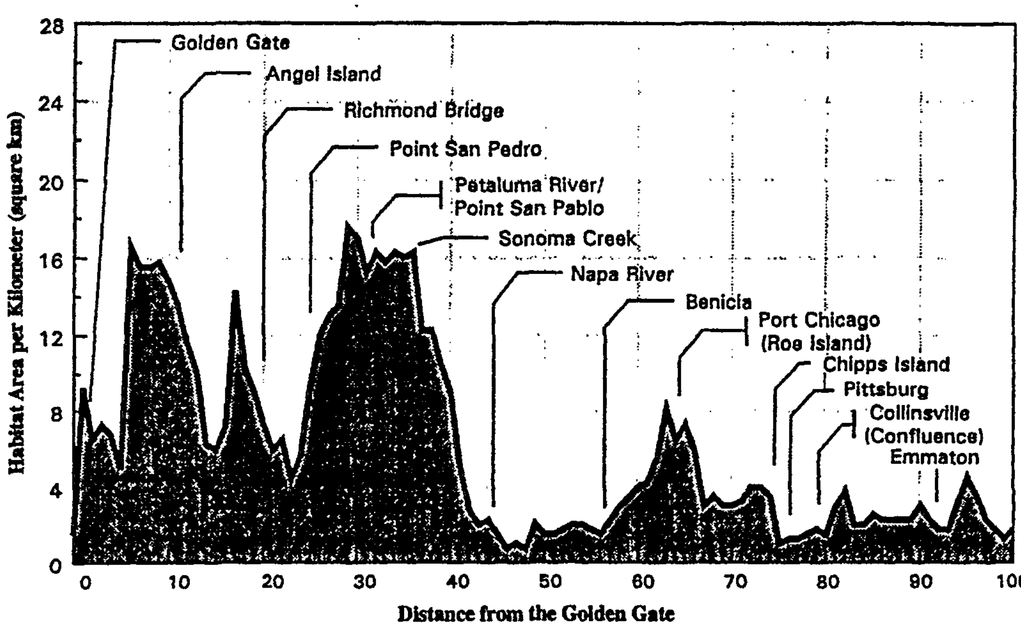
Species/Life Stage: Delta Smelt/Larval and Juvenile Rearing

Assessment Variable: Delta and Suisun Bay Rearing Habitat Availability

Assessment Method: Larval and Early Juvenile Estuarine Habitat Index Developed for CVPIA PEIS

Application to CALFED: CALFED actions may change habitat area, Delta outflow, and salinity distribution in the estuary.

Description: This tool directly translates flow into an index of habitat area so that area of habitat produced can be compared among implementation levels of actions and alternative action packages. Given flow, salinity distribution can be determined, and the area within the optimal range for delta smelt juveniles can be calculated from the relationship depicted in the chart below. Habitat area may also reflect effects of flow on larval transport and entrainment, pollutant concentrations, and prey availability.



DSMELT: III.E&F.1

Reference: CVPIA PEIS (preliminary administrative draft)

Input Data and Tools: Delta outflow, flow-salinity distribution relationship, and salinity-area relationship.

Modifications Necessary for CALFED Use: Possible need to modify salinity-area relationship to reflect changes in estuary morphology attributable to habitat restoration. Effects of flow patterns on habitat value may also need to be considered (i.e., entrainment and transport effects).

Species/Life Stage: Delta Smelt/Larval and Juvenile Rearing

Assessment Variable: Delta and Suisun Bay Rearing Habitat Availability

Assessment Method: Larval and Early Juvenile Survival Index Based on Delta Outflow and X2 Parameter Locations.

Application to CALFED: CALFED actions may alter Delta outflow levels.

Description: This tool uses the regression of the fall mid-water trawl index for Delta smelt on the number of days that X2 is in Suisun Bay during February-June. The hypothesis is that delta smelt survival is affected by Delta outflow and its effect on X2 position in the estuary. Survival of larvae to juvenile is assumed to be higher at higher flows for a variety of reasons, including better transport of larvae to Suisun Bay, more food production in the estuary, and reduced loss of larvae and juveniles to export.

Reference: Herbold 1994

Input Data and Tools: Delta outflow and the relationship between outflow and X2 location.

Modifications Necessary for CALFED Use: None under present Delta plumbing; but limited usefulness with major changes to habitat, fish protection measures, and plumbing in Delta.

LONGFIN SMELT

C-000431

Fisheries Assessment Variables by Life Stage:
Longfin Smelt

I. Adult Migration and Spawning (Delta and Suisun Bay Habitat)
   A. Temperature Survival Relationship for Spawning Success
   B. Flow Relationship for Adult Migration
   C. Flow Habitat Relationship for Spawning Success
   D. Spawning Habitat Availability
   E. Ocean Salinity Effects on Spawning Success
   F. San Joaquin River Salinity Effects on Spawning Success
   G. Pollutant Mortality Relationship
   H. Stock Recruitment Relationships

II. Incubation (Delta and Suisun Bay Habitats)
   A. Temperature Survival Relationship
   B. Pollutant Mortality Relationship
   C. Predation and Disease Relationships to Survival

III. Larval and Juvenile Rearing (Estuarine Habitat)
   A. Temperature Survival Relationship
   B. Flow Transport Relationship for Rearing Success (**see Methods**)
   C. Pathway and Barrier Survival Relationships (e.g., DCC and Old River)
   D. Diversion Mortality Relationship (**see Methods**)
   E. Rearing Habitat Availability (**see Methods**)
   F. Predation, Competition, and Disease Relationships to Survival
   G. Pollutant Mortality Relationships

IV. Juvenile and Adult Rearing (Estuarine Habitat)
   A. Diversion Mortality Relationship
   B. Rearing Habitat Availability
   C. Predation, Competition, and Disease Relationships to Survival
   D. Pollutant Mortality Relationships

What life stages would you include or delete? Why?

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Can you recommend any additional assessment variables for this species? If so, what are they?

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C-000432

Are there any proposed assessment variables that you would recommend CALFED not use for this species? Why?

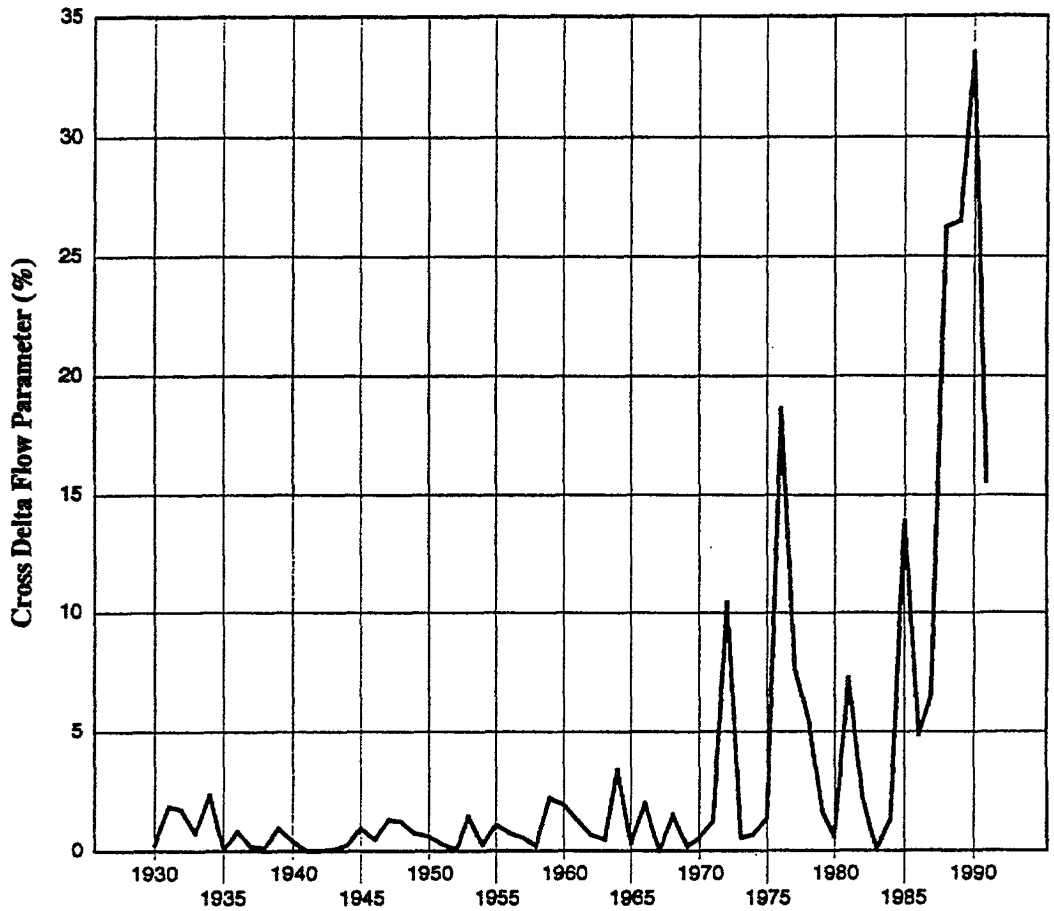
Species/Life Stage: Longfin Smelt/Larval and Juvenile Rearing

Assessment Variable: Flow Transport Relationship for Rearing Success (and Diversion Mortality Relationship)

Assessment Method: Larval and Early Juvenile Entrainment Index Developed for the Delta Wetlands EIR/EIS.

Application to CALFED: CALFED actions may change Delta inflow, Delta channel flow (e.g., barriers, conveyance facilities), and Delta diversions.

Description: The methodology translates Delta water movement, based on an initial distribution, into an index of the proportion of flow that is diverted from the Delta. If net flow in Delta channels is assumed to affect the movement and entrainment of longfin smelt, the proportion of flow diverted (weighted for fish distribution) indicates potential transport and entrainment rates. An estimate of the proportion of Delta Cross Channel and Georgiana Slough net flow diverted from the Delta (i.e., Cross Delta Flow Parameter) is shown in the chart below for the historic 64-year period. Entrainment may also reflect effects of flow on habitat availability, pollutant concentrations, and prey availability.



Reference: Delta Wetlands Draft EIR/EIS

Input Data and Tools: Delta inflow, channel flow, and diversion data; DeltaMOVE Model - a water transport and mixing model.

Modifications Necessary for CALFED Use: Delta channel flow relationships would need to reflect changes to channel morphology and barrier implementation that could be implemented under the Programmatic EIR/EIS alternatives.

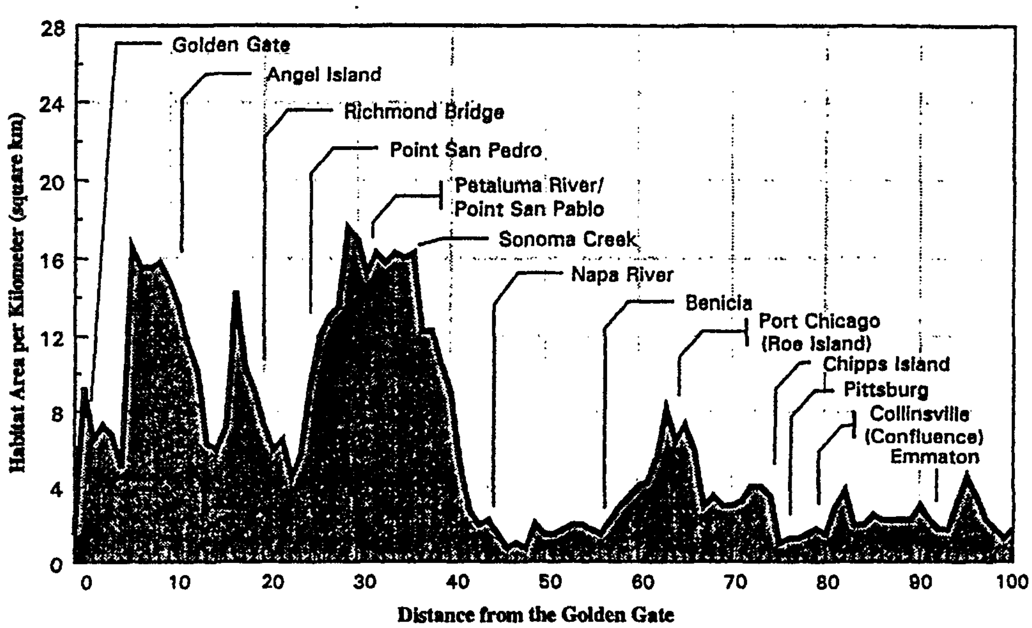
Species/Life Stage: Longfin Smelt/Larval and Juvenile Rearing

Assessment Variable: Rearing Habitat Availability

Assessment Method: Larval and Early Juvenile Estuarine Habitat Index Developed for CVPIA PEIS

Application to CALFED: CALFED actions may change habitat area, Delta outflow, and salinity distribution in the estuary.

Description: This tool directly translates flow into an index of habitat area so that area of habitat produced can be compared among implementation levels of actions and alternative action packages. Given flow, salinity distribution can be determined and the area within the optimal range for longfin smelt juveniles can be determined from the relationship depicted in the chart below. Habitat area may also reflect effects of flow on larval transport and entrainment, pollutant concentrations, and prey availability.



Reference: CVPIA PEIS (preliminary administrative draft)

Input Data and Tools: Delta outflow, flow-salinity distribution relationship, and salinity-area relationship.

Modifications Necessary for CALFED Use: Possible need to modify salinity-area relationship to reflect changes in estuary morphology attributable to habitat restoration. Effects of flow patterns on habitat value may also need to be considered (i.e., entrainment and transport effects).

C-000436

Species/Life Stage: Longfin Smelt/Larval and Juvenile Rearing

Assessment Variable: Rearing Habitat Availability

Assessment Method: Larval and Early Juvenile Survival Index Based on Delta Outflow and X2 Parameter Locations.

Application to CALFED: CALFED actions may alter Delta outflow levels.

Description: This tool uses the regression of the fall mid-water trawl index for longfin smelt on X2 during February-June. The hypothesis is that delta smelt survival is affected by Delta outflow and its effect on X2 position in the estuary. Survival of larvae to juvenile is assumed to be higher at higher flows for a variety of reasons, including better transport of larvae to Suisun and San Pablo Bays, greater food production in the estuary, and reduced loss of larvae and juveniles to export.

Reference: Jassby et al. 1993

Input Data and Tools: Delta outflow and the relationship between outflow and X2 location.

Modifications Necessary for CALFED Use: None under present Delta plumbing, but limited usefulness with major changes to habitat, fish protection measures, and plumbing in Delta.

C-000437

FOOD-PREY PRODUCTION

C-000438

Fisheries Assessment Variables by Life Stage:
Food-Prey Production

I. Primary Production
   A. Riverine Flow Autochthonous Production Relationship
   B. Riverine Allochthonous
   C. Delta and Estuarine Autochonous
   D. Delta and Estuarine Allochthonous

II. Secondary Production
   A. Temperature-Survival Relationship
   B. Pollutant Mortality Relationship
   C. Predation and Disease Relationships to Survival

III. Larval and Juvenile Rearing (Estuarine Habitat)
   A. Temperature-Survival Relationship
   B. Flow-Transport Relationship for Rearing Success
   C. Pathway and Barrier Survival Relationships (e.g., DCC and Old River)
   D. Diversion Mortality Relationship
   E. Rearing Habitat Availability
   F. Predation, Competition, and Disease Relationships to Survival
   G. Pollutant Mortality Relationships

IV. Juvenile and Adult Rearing (Estuarine Habitat)
   A. Diversion Mortality Relationship
   B. Rearing Habitat Availability
   C. Predation, Competition, and Disease Relationships to Survival
   D. Pollutant Mortality Relationships

What life stages would you include or delete? Why?

Can you recommend any additional assessment variables for this species? If so, what are they?

Are there any proposed assessment variables that you would recommend CALFED not use for this species? Why?

Fisheries Assessment Variables by Area:
Food-Prey Production

I. Riverine Habitat
   A. Temperature Relationship to In-River Primary Production
   B. Flow Relationship to In-River Primary Production
   C. Flow Relationship to Allochthonous Production (Primary and Secondary)
   D. Flow Relationship to Prey Availability (e.g., drift, invertebrate production)
   E. Riparian Habitat Relationship to Allochthonous Production

II. Delta and Estuarine Habitat
   A. Flow Relationship to Primary Production in the Delta and Suisun Bay
   B. Flow Relationship to Allochthonous Production (Primary and Secondary)(**see Methods**)
   C. Flow Relationship to Prey Availability (e.g., net flow, entrapment zone, tidal flow)(**see Methods**)
   D. Shallow Water Habitat Area Relationship to Primary Production
   E. Deep Water Habitat Area Relationship to Primary Production
   F. Riparian Habitat Relationship to Allochthonous Production

Can you recommend any additional assessment variables for this catagory? If so, what are they?

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Are there any proposed assesment variables which you would recommend CALFED not use for this catagory? Why?

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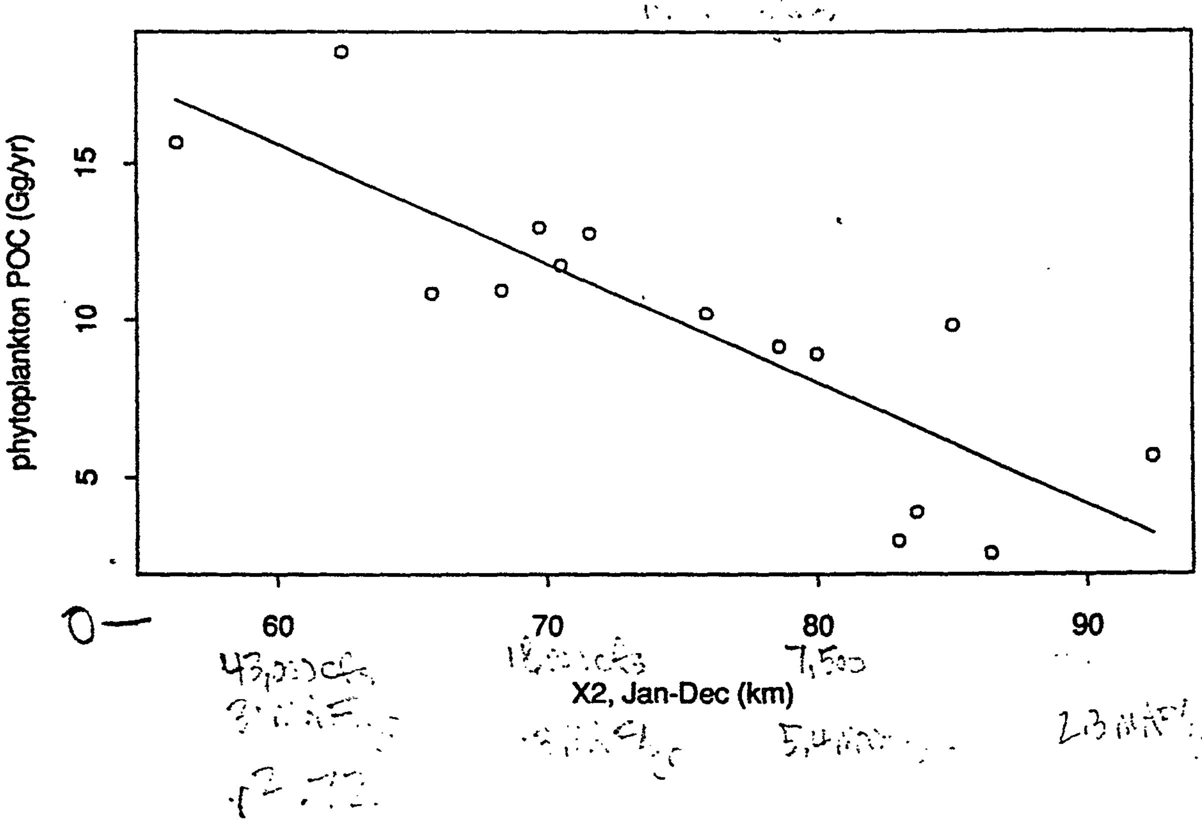
FIGURE LEGEND

Figure 1. Supply of particulate organic carbon (POC) to Suisun Bay from phytoplankton production and riverine loading of algal-derived particulate matter, compared to annual average X2.



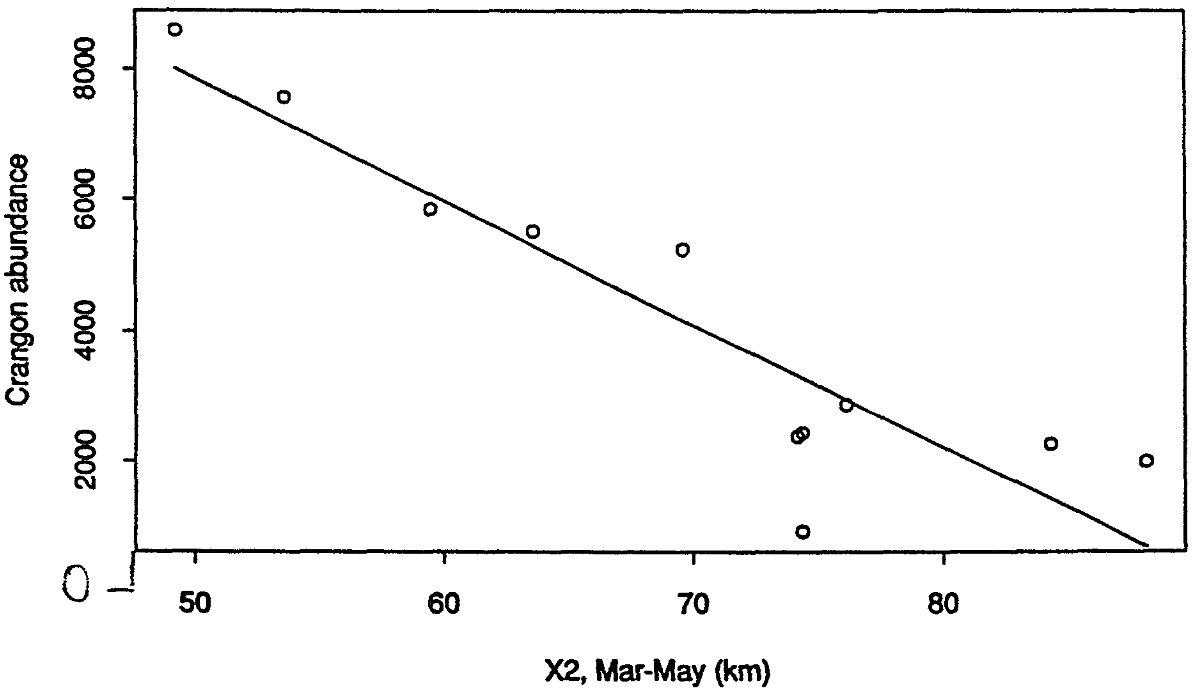
Food - Prey Production / Delta and Estuarine Habitat

Flow Relationship to Allochthonous Production

Jassby et al, 1993

FOOD: II. C.1

Figure 3. Annual abundance index of Crangon franciscorum *in the San Francisco estuary.*



Food- Prey Production/Delta and Estuarine Habitat

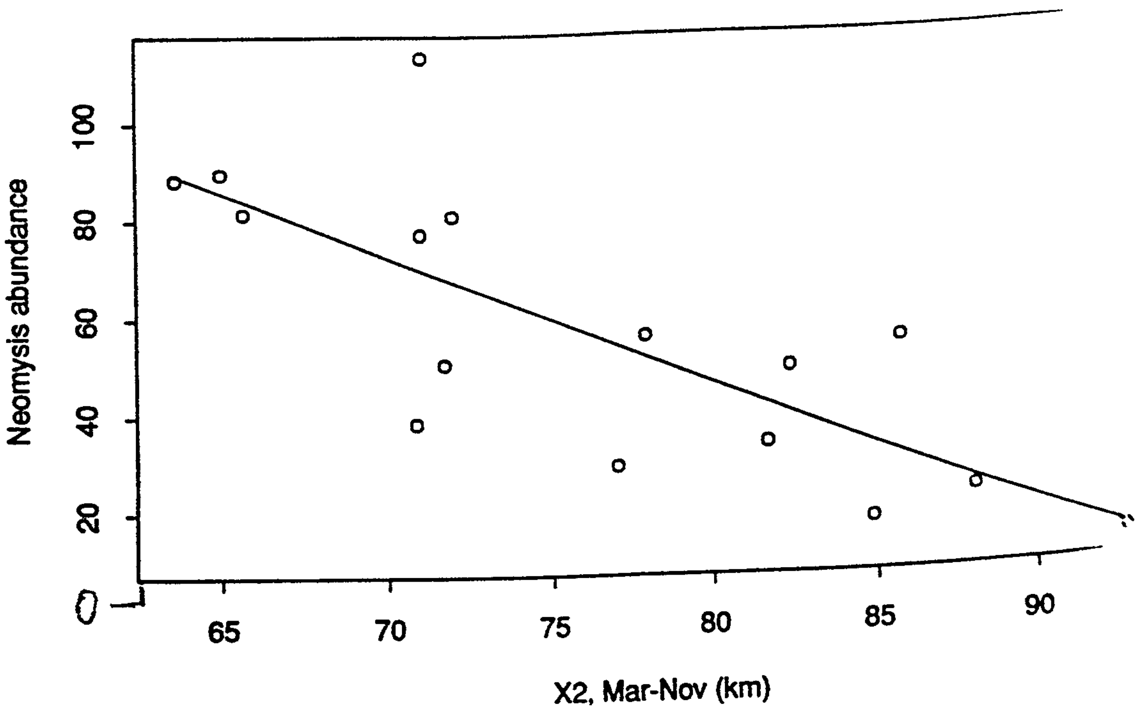
Flow Relationship to Prey Availability

Jassby et al., 1993

FOOD: II. C. 2

salinity

Figure 2. March-November abundance index of Neomysis mercedis.



Food-Prey Production / Delta and Estuarine Habitat

Flow Relationship to Prey Availability

Jassby et al., 1993