CALFED BAY-DELTA PROGRAM

SELECTION OF METHODS FOR AQUATIC ECOSYSTEM ASSESSMENT

CALFED
BAY-DELTA
PROGRAM

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SELECTION OF METHODS FOR AQUATIC ECOSYSTEM ASSESSMENT

OVERVIEW AND OBJECTIVES

The major ecosystem quality objectives of the CALFED Bay-Delta Program (CALFED) are to improve and increase aquatic and terrestrial habitats and to improve ecological functions in the San Francisco Bay/Sacramento-San Joaquin River Delta (Bay-Delta) to support sustainable populations of diverse and valuable plant and animal species. Alternatives included in the Programmatic Environmental Impact Report/Environmental Impact Statement (EIR/EIS) are structured to meet this and other objectives relating to water quality, water supply reliability, and system vulnerability. The different alternatives will have varying effects on the aquatic ecosystem, and the impact assessment must identify potential changes in the aquatic ecosystem, both beneficial and adverse, under each alternative relative to the No-Action Alternative and existing conditions (baseline).

This report consolidates information from several documents:

- the Fish Assessment Process Working Document (dated August 22, 1996), which provides a framework for identifying assessment methods by species and life stage;
- Species and Assessment Variable Selection for the Fish Assessment Process for the CALFED Bay-Delta Program Programmatic EIR/EIS (dated September 6, 1996), which identifies species and assessment variables that will be included in the impact assessment for the Programmatic EIR/EIS; and
- Proposed Aquatic Ecosystem Assessment Methods (dated October 8, 1996), which presents a process for selecting methods for the impact assessment.

Information provided by participants in meetings and in writing has substantially influenced the process for selecting methods. The most important and consistently restated concern is that an evaluation of differences between alternatives should be based on known and defensible relationships that are important with regard to ecosystem function and structure. This report reflects efforts to address this concern.

The initial focus of the work teams was on fish species. Responding to suggestions by some participants in the assessment process, the overall methodology for impact assessment has been modified to focus on the aquatic ecosystem as a whole. During the CALFED Fish Assessment Process Working Meeting on October 17, 1996, several participants stressed the importance of understanding the connection between ecosystem functions, assessment variables, and specific

assessment methods. This report identifies and defines key ecosystem functions, provides a revised list of assessment variables and their definitions, lists representative species and information supporting their selection, describes the process for selecting impact assessment methods, and provides example applications of the methods selection process.

AQUATIC COMMUNITIES

The aquatic ecosystem is divided into five communities based on occurrence of fish and invertebrate species and on habitat conditions that could be affected by CALFED actions:

- **The reservoir community** includes habitat within Central Valley reservoirs. The impact assessment will focus on the major downstream reservoirs on Central Valley rivers (e.g., Shasta and Folsom Lakes and Lake Oroville). The potential effects on reservoirs further upstream (and the associated stream reaches between reservoirs) will be acknowledged, but will not be evaluated in detail. Upstream reservoir operations are unlikely to be described in the Programmatic EIR/EIS, and site-specific environmental documentation of potential effects on specific upstream reservoirs may be required during implementation of specific CALFED actions.

- **The coldwater riverine community** encompasses the stream and river reaches below the downstream reservoirs, and provides spawning habitat for chinook salmon (i.e., habitat that is currently accessible to chinook salmon and meets the species' habitat needs, as defined by velocity, depth, substrate size, and adequate water temperature for spawning and incubation). The coldwater riverine community includes small tributary streams (e.g., Mill, Battle, and Clear Creeks) and portions of major rivers (e.g., the Feather, Yuba, Sacramento, and Tuolumne Rivers).

- **The warmwater riverine community** is located in the river reaches downstream of the coldwater riverine community and extends to the upstream edge of the Delta. In general, the warmwater riverine community includes portions of major rivers (e.g., the Feather, Yuba, Sacramento, and Tuolumne Rivers).

- **The estuarine community** extends from the downstream edge of the warmwater riverine community to the upstream edge of the marine community and includes tidally influenced habitat ranging in salinity from 0 to 10 parts per thousand (ppt). The estuarine community includes the Delta and usually includes most of Suisun Bay and Suisun Marsh.

- **The marine community** extends from the downstream edge of the estuarine community to the Golden Gate Bridge, in tidally influenced habitat with salinity exceeding 10 ppt. The marine community includes San Francisco Bay and usually includes San Pablo Bay.

With the exception of the reservoir community, the geographic boundaries between these aquatic communities are not clearly defined. Under varying hydrologic and meteorological conditions, the boundaries shift upstream and downstream. During wet years, the downstream boundaries of all communities (except the reservoir community) shift toward San Francisco Bay. During dry years, the downstream boundaries shift upstream toward dams or headwaters.

ECOSYSTEM FUNCTIONS AND ASSESSMENT VARIABLES

The function of ecosystems includes complex patterns of transfer, change, use, and accumulation of inorganic and organic materials (i.e., the flow of energy, nutrients, and species). Inorganic nutrients, organic foods, and other chemical agents are transferred between organisms and the environment to give ecosystems their functional unity. These substances may be transferred between and within local ecosystems.

For the purpose of assessing impacts of the CALFED Program on the aquatic ecosystem, ecosystem functions are divided into two broad categories: biomass production and biomass loss. Biomass production includes those functions related to capacity of the ecosystem to produce biomass through growth, reproduction, and external increases (e.g., migration and artificial production). Functions supporting biomass production include providing habitat, foodweb support, access, and artificial production. Biomass loss includes those functions related to mortality and removal (e.g., death or permanent dislocation of individuals). Functions resulting in biomass loss include loss to adverse water temperature condition, diversion, change in water surface level, adverse toxicant concentration, fishing, and predation. General definitions of ecosystem functions are provided below.

Change in assessment variables (i.e., change in ecosystem structure) drives ecosystem function. The effect of change in assessment variables on ecosystem function varies depending on specific indicators (e.g., communities, species groups, species, and life stage). For example, the effect of change in flow on provision of habitat for delta smelt would be different than the effect for juvenile chinook salmon. Tables 1 through 5 describe the relationships between ecosystem functions and assessment variables for each aquatic community (i.e., reservoir, coldwater riverine, warmwater riverine, estuarine, and marine).

Assessment variables likely to change under CALFED actions are identified in Tables 6 through 10. The potential CALFED actions, a brief description of the effect of the CALFED action, and the affected assessment variable are listed for each aquatic community. In general, CALFED conveyance and storage components and the water use efficiency program have potential to affect primarily flow and flow-related assessment variables (e.g., reservoir elevation and temperature). The conveyance component, however, may also substantially affect physical habitat in the estuarine community. Water quality improvements could also affect flow and flow-related assessment variables. Actions under the ecosystem restoration program could affect nearly all assessment variables, and actions under the levee system integrity program would affect primarily physical habitat in the estuarine community. Identification of assessment variables that change under

CALFED will be finalized when the alternatives to be included in the Programmatic EIR/EIS are clearly described.

DEFINITIONS OF ECOSYSTEM FUNCTIONS

PROVISION OF HABITAT

Provision of habitat includes providing physical, chemical, and biological conditions that support essential organism activities including spawning, feeding, respiration, assimilation, predator avoidance, and resting. Assessment variables that affect provision of habitat include flow, reservoir elevation, temperature, substrate, physical habitat, water quality, and species interactions.

PROVISION OF FOODWEB SUPPORT

The foodweb is essential to maintenance of species diversity, abundance, and distribution within an aquatic community. Provision of foodweb support includes factors affecting nutrient availability, production of food, and availability of food. Assessment variables that affect provision of foodweb support include flow, reservoir elevation, temperature, substrate, physical habitat, water quality, and species interactions.

PROVISION OF ACCESS

Provision of access includes physical, chemical, and biological conditions that support the essential movement (active or passive) of organisms to meet their specific needs (e.g., spawning, feeding, rearing, metabolic efficiency, and avoidance of predation). Provision of access may include conveyance, pathways, and environmental cues. Assessment variables that affect provision of access include flow, reservoir elevation, temperature, physical habitat, barriers, water quality, and species interactions.

PROVISION OF ARTIFICIAL PRODUCTION

Provision of artificial production (i.e., human introduction of organisms into an ecosystem) is identified as a separate ecosystem function because it is a fully or partially independent extension of the ecosystem. Provision of artificial production maintains population abundance of species that provide some human value (e.g., commercial and sport fishing, prevention of extinction). The existing ecosystem cannot adequately (as defined by human value) provide habitat, foodweb support, or access for all life stages of a target species.

Loss to Adverse Water Temperature Condition

Adverse water temperature, relative to the needs of specific indicators (e.g., species or life stage), causes indirect or direct mortality of organisms. Indirect mortality may result from reduced growth rates or reduced reproductive success. Assessment variables that affect loss to adverse temperature include flow, reservoir elevation, temperature, barriers, water quality, and species interactions.

Loss to Diversion

Diversions cause mortality of specific indicators through entrainment (removal from the ecosystem), impingement on fish screens or other structures associated with the diversion facility, abrasion, handling stress, and increased predation. Assessment variables that affect loss to diversions include flow, physical habitat, diversions (including diversion volume, location, and facility components [e.g., fish screens] and design), and species interactions.

Loss to Change in Water Surface Level

Change in water surface level may cause mortality through exposure of nests, stranding of individuals, loss of cover, and other factors. Assessment variables that affect loss from change in water surface level include flow, reservoir elevation, substrate, physical habitat, and species interactions.

Loss to Adverse Toxicant Concentration

Adverse toxicant concentrations cause indirect or direct mortality of organisms. Indirect mortality may result from reduced growth rates or reduced reproductive success. Assessment variables that affect loss to adverse toxicant concentrations include flow, reservoir elevation, water quality, and species interactions.

Loss to Fishing

Fishing causes mortality through removal from the ecosystem or through stress-related factors (e.g., vulnerability to predation or disease upon release of individual organisms). The primary assessment variables that affect loss to fishing are fishing (including timing, location, method, and rate of fishing) and species interactions.

Loss to Predation

Loss to predation is a natural ecosystem function. Predation losses may increase to levels that adversely affect specific indicators, however, through changes in ecosystem structure that increase prey vulnerability or increase predator feeding efficiency. Assessment variables that affect

predation loss include physical habitat, barriers, artificial production, and species interactions. Increased predation loss also occurs through increased vulnerability of prey organisms associated with the ecosystem functions discussed previously (i.e., loss to adverse water temperature conditions, loss to diversion, loss to change in water surface elevation, loss to adverse toxicant concentration, and loss to fishing).

DEFINITIONS OF ASSESSMENT VARIABLES

Assessment variables represent structural components of the aquatic ecosystem, including physical, chemical, and biological features. Ecosystem structure is reflected in the interrelation and organization of the assessment variables. Change in the assessment variables affects ecosystem functions and species populations within the aquatic ecosystem. Assessment variables identified for the aquatic ecosystem include flow, reservoir elevation, temperature, substrate, diversions, barriers, physical habitat, water quality, fishing, artificial production, and species interactions.

FLOW

Flow includes several parameters directly related to water movement in rivers, streams, and the Bay-Delta estuary. The parameters include instream flow, net channel flow, tidal flow, and estuarine salinity.

INSTREAM FLOW. Instream flow is the rate of water movement past a specific point in rivers and streams. Instream flow is affected by weather, reservoir operations, diversions, tributary inflow, groundwater accretion and percolation, and drainage water accretion (i.e., discharge and nonpoint-source runoff from municipal, industrial, and agricultural sources).

NET CHANNEL FLOW. Net channel flow is the rate of water movement past a specific point in the Bay-Delta Estuary, not including tidal flow. Net flow in a Delta channel is affected by weather; tides; tributary inflow, including effects of upstream reservoir operations; diversions; groundwater accretion; flow division to Delta channels, including the effects of barriers and channel morphology; drainage water accretion (i.e., discharge and nonpoint- source runoff from municipal, industrial, and agricultural sources); and potential discharge from future in-Delta water storage facilities. Commonly calculated net flows include Delta inflow, San Joaquin River flow past Jersey Point, and Delta outflow.

TIDAL FLOW. Tidal flow is the average channel flow attributable to ebb or flood tides not including net flow. Variables related to tidal flow include water surface elevation, tidal excursion (i.e., movement of a mass upstream and downstream with the flood and ebb tides), and tidal prism (i.e., the volume of water that moves past a location as the result of a change in tidal stage). Local factors affecting tidal flow include morphology of the tidal basin, weather, and Delta inflow.

ESTUARINE SALINITY. Estuarine salinity is presented as concentrations, electrical conductivity units, and geographical location. Estuarine salinity is a function of the mixing of ocean salinity with

freshwater inflow and does not include land-derived salinity, which is discussed under "Water Quality". Delta outflow, tidal flow, and estuary morphology affect the distribution of salinity in the estuary.

RESERVOIR ELEVATION

Reservoir elevation refers to water surface elevation at a specific time. Reservoir elevation is a function of reservoir inflow (including factors affecting instream flow), outflow (affected by reservoir operations, groundwater percolation, evaporation), and reservoir morphology.

TEMPERATURE

Water temperature refers specifically to the temperature of water in stream channels, including water released from storage reservoirs. Temperature does not include discharge of cooling water from electrical generation plants or other facilities (discussed under "Water Quality"). Water temperature is affected by weather, reservoir operations (including operation of multi-level release structures), flow, tributary inflow, groundwater accretion, and physical habitat (including shading by riparian vegetation).

SUBSTRATE

Substrate is defined by physical composition (including particle size and shape), chemical composition, density, erodibility, permeability, organic content (including benthic organisms [e.g., Asian clams]), and stability. Substrate is affected by erosion, deposition, and transport processes, including the effects of flow (e.g., scour, deposition), physical habitat, barriers to movement of material (e.g. dams), biological activity (e.g., burrowing organisms), source materials, and human actions (e.g., gravel cleaning, gravel addition, dredging).

DIVERSIONS

Diversion is the volume of water removed from a water body by pumps, siphons, and gravitational flow. Diversions have structural components related to channel morphology, intake design and size, fish screens, debris screens, pilings, and other structures associated with protecting the diversion and facilitating operations. Diversions reduce instream flow and net flow. The effects of diversions on biomass loss are determined for specific indicators (e.g., species, life stages); and are determined by flow, diversion volume, facility design (including fish screens), facility location, channel morphology, water quality (i.e., transparency), and species interactions (i.e., predation).

BARRIERS

Barriers are any structures that direct or influence the movement of organic and inorganic material along specific pathways. Barriers include dams, temporary physical obstructions of rock and other materials, gated structures, acoustical barriers, electrical barriers, air-bubble barriers, and louvered barriers. Barriers may affect movement of organisms without affecting flow of other material. Barriers are sometimes associated with diversions and the effects of barriers and diversions may be difficult to separate. The effects of barriers are generally determined for specific indicators (e.g., species, life stages); and are determined by flow, ratio of the flow division, facility design, facility location, channel morphology, and species interactions (i.e., predation).

PHYSICAL HABITAT

Physical habitat represents the shape and form of the ecosystem, including surface contours, elevation, gradient, and surface features (e.g., trees, woody debris, rocks, boulders, bridge abutments). For reservoirs, physical habitat includes shoreline circumference, surface area, depth, depth contours, rock outcroppings, woody debris, and vegetation (submergent, emergent, shaded riverine aquatic, and riparian). For rivers and streams, physical habitat includes channel pattern (braided, meandering, or straight), width, depth, meander geometry, cross-sectional profiles, riffle-to-pool ratios, boulders and rock outcroppings, woody debris, and vegetation (submergent, emergent, shaded riverine aquatic, and riparian).

Physical habitat also includes inlets and outlets, channels, islands, fetch, and exposure. Human created features are also part of physical habitat (e.g., bridge abutments, riprap, gabions, pilings, piers, boat ramps, docks, and artificial reefs). Physical habitat is affected over the long term by weather, geology, and geologic events; and over the short term by weather, flow, biological processes, and human modification (e.g., dredging, levees, bank protection).

WATER QUALITY

Water quality is a broad category of chemical, physical, and biological characteristics of water that may be attributable to natural and human induced conditions. Water quality is influenced by municipal and industrial discharge, agricultural and urban runoff, direct application of pesticides, and dredging or filling operations. Accretion of groundwater in river flow may also affect water quality by altering dissolved oxygen levels and water temperature, and introducing nutrients and toxicants. Other factors affecting water quality include flow, substrate, physical habitat, and other physical, chemical, and biological processes.

AGRICULTURAL SALINITY. Agricultural salinity originates from dissolved salts in agricultural runoff.

THERMAL POLLUTION. Electrical generation plants, sewage treatment plants and other facilities, and agricultural return flows discharge water at temperatures that may exceed the temperature of receiving water. Discharge from future in-Delta water storage facilities could also exceed the temperature of the receiving water.

DISSOLVED OXYGEN. Low dissolved oxygen levels may result from the discharge of organic material (e.g., treated sewage) to Delta channels. Changes in dissolved oxygen levels in rivers and streams may result from reservoir discharge drawn from anoxic reservoir strata, reservoir discharge that supersaturates oxygen levels, and accretion of groundwater.

NUTRIENT AVAILABILITY. Inorganic nutrients enter the aquatic ecosystem through agricultural runoff and sewage discharge. Nutrients can also enter the ecosystem through natural processes associated with physical (e.g., flood events that inundate terrestrial and wetlands habitats, natural runoff from storm events), chemical (e.g., dissolution of substrates), and biological (e.g., organic decomposition) processes.

TOXICANTS. Toxicants reduce the survival of fish and other aquatic organisms through acute and chronic effects. Toxicants include pesticides, metals, and other chemicals that enter the aquatic ecosystem through agricultural runoff, direct application (e.g., water weed control), industrial discharge, dredging, mine drainage, sewage discharge, and urban runoff.

TRANSPARENCY. Transparency is the ability of light to penetrate water (i.e., water clarity). Transparency is a function of the concentration and the chemical and physical properties of particulate (including inorganic and organic sediments, algae, and other organic particles) and dissolved materials. Natural (e.g., flow- and wind-driven mixing and erosion, decomposing vegetation, and algal populations) and human-induced processes (e.g., dredging, dredge disposal, sewage discharge, and boat wakes) affect transparency.

FISHING

Fishing includes commercial fishing, sport fishing, and illegal fishing activities that cause or contribute to the death of individuals in a species population.

ARTIFICIAL PRODUCTION

Artificial production is the human-aided production of a species in facilities isolated to some degree from the natural ecosystem (e.g., fish hatcheries, rearing pens). The produced individuals are released to supplement wild populations and provide fishing opportunities.

SPECIES INTERACTIONS

Species interactions are a broad range of biological factors. Species interactions may change substantially in response to other changes in the assessment variables discussed above.

PREDATION. Predation occurs naturally; however, fish and other aquatic organisms that are already stressed by other factors (e.g., elevated water temperature and turbulence created by barriers) may be more susceptible to predation, and the prey population may be sensitive to additional mortality. Predation may also increase with the introduction of exotic predators (e.g., striped bass and largemouth bass).

COMPETITION. Competition occurs when the use of a resource (e.g., food or habitat) by one individual reduces the availability of the same resource for another individual. Competition occurs within a species population and between species. As with predation, fish already stressed by other factors (e.g., elevated water temperature, reduced water velocity) may be less able to compete for limited resources, and species survival could decline. The introduction of exotic species with resource needs similar to native species may increase competition for limited resources.

DISEASE. Disease refers to fungi, bacteria, viruses, and other pathogens that may limit species population abundance. The pathogens may be natural or introduced, and the effects may vary depending on interactions with other assessment variables (e.g., water temperature, toxicant concentrations).

EXOTIC PLANTS. Introduction of exotic plants to aquatic habitats may affect species population abundance through modification of habitat (e.g., change in substrate, physical habitat, water circulation, and water quality) and through changes in species interactions (e.g., food availability, predation, and competition).

SELECTION OF REPRESENTATIVE SPECIES

Ecosystem functions are applicable to specific indicators (e.g., communities, species groups, species, and life stages). For example, provision of habitat for delta smelt may not meet the habitat needs of chinook salmon. Also, each community, species, and life stage responds differently to change in an assessment variable. A representative group of fish and other aquatic species was selected based on the importance of the species and their response to the assessment variables that could be affected by CALFED actions. A total of 25 species were selected for inclusion in the impact analysis, 18 species of fish and seven species or groups of invertebrates (Table 11). Although chinook salmon is identified as a single species in Table 11, it will be treated as multiple species (fall, late fall, winter, and spring runs) based on migration timing and geographic isolation.

DETERMINING SPECIES IMPORTANCE

Species importance is the first factor considered in selection of representative species. A species may be considered important if it meets any one of the following criteria:

- supports a commercial fishery,

- supports a sport fishery,
- is listed under the federal Endangered Species Act (ESA) or the California Endangered Species Act (CESA), or
- has a significant ecological role.

Species support commercial and sport fisheries if they are currently part of the sport or commercial catch. Species listed under the ESA and CESA include species listed as threatened or endangered, species proposed for listing as threatened or endangered, and species of special concern.

A "significant ecological role" generally refers to those species that have substantial direct effects on other species or respond to change in an assessment variable not reflected by the response of other species in the aquatic community. Effects on other species can include importance in food-web support, effects on habitat availability, and effects on physical or chemical habitat conditions. For example, the Asian clam has a significant ecological role because of probable effects on phytoplankton and zooplankton abundance. Sacramento squawfish has a significant ecological role because of predation on juvenile chinook salmon.

The criteria are assigned values based on the relative importance of a species. The criteria is assigned a value of 2 if the species is very important, 1 if the species may be important or is less important, and 0 if the species is not important and a blank if species importance is unknown. If the sum of the values for all criteria is greater than 1, the species is considered for inclusion in the programmatic assessment. For example, winter-run chinook salmon and delta smelt are assigned a value of 2 for the ESA criterion because both are listed under the ESA (Table 12).

RESPONSE TO CHANGE IN ASSESSMENT VARIABLES

The second factor considered in selecting species to be included in the impact assessment is the expected level of species response to potential change in the assessment variables under the CALFED alternatives. The level of response is assigned a value based on the importance of the species-variable interaction. If the species response to a variable is critical to survival, or to the maintenance or increase of a species' population abundance and distribution, the variable is assigned a value of 2. If the variable may be important but further evaluation is needed, the variable is assigned a value of 1. A variable that has minimal effects on a species is assigned a value of 0. If information on a species-variable interaction is not available and the species' response to the variable is unknown, the value is left blank. If the sum of the values for all variables is greater than 1, the species was considered for inclusion in the programmatic assessment (Table 12).

SELECTION OF METHODS

This section describes the process for selection of impact assessment methods for fish and aquatic resources (Figure 1). Information provided above (i.e., aquatic communities, ecosystem functions, assessment variables, and representative species) provides the foundation for the selection process. Selection of assessment methods is an ongoing process that will move to the final stages when the alternatives to be included in the Programmatic EIR/EIS are clearly described.

Preliminary assessment methods selection process includes five major tasks:

- identify assessment variables likely to change under CALFED,
- identify potential assessment methods that measure a response to a change in the assessment variables,
- apply screening criteria to the known assessment methods for consideration in the programmatic assessment,
- identify additional assessment methodology needs including new, revised, or alternative methods and apply professional judgement to potential assessment methods, and
- develop a preliminary strategy for application and interpretation of assessment results.

The Fish Assessment Methods Team developed six standardized screening criteria for use in evaluating and selecting assessment methods for fish and aquatic resources. These criteria are:

1. Does the assessment method represent affected ecosystem functions?
2. Is the assessment method confirmed by current and historical data?
3. Are accuracy and precision sufficient so that the variability of the assessment method is less than the differences between the alternatives and the method is capable of distinguishing between the alternatives?
4. Can the assessment method be applied to all alternatives to provide a fair and consistent evaluation of the alternatives?
5. Is the assessment method consistent when extended beyond existing and historic conditions?
6. Is the assessment method appropriate for a programmatic level of analysis?

Any assessment method which successfully passes all of these screening criteria is suitable for use in the CALFED programmatic analysis. Many known assessment methods may be able to

meet some but not all of these screening criteria. In these cases, particularly where there is no alternative method for the particular ecosystem function represented, assessment methods may require further evaluation to determine if they can be modified or the relationship expressed by the method used as the basis for a qualitative discussion.

A list of potential assessment methods has been identified in previous documents (Fish Assessment Process Working Document; August 22, 1996 and Proposed Aquatic Ecosystem Assessment Methods; October 8, 1996) and by participants in the process for development of the impact analysis. The following examples are intended to illustrate the assessment methods selection process.

EXAMPLE 1

Method Description: Length of river meeting temperature needs of eggs and larvae of juvenile chinook salmon (i.e., water temperature less than 56°F)

Community/Species/Life Stage: Coldwater riverine/chinook salmon/eggs and larvae

Assessment Variables: Temperature

Programmatic Analysis: This method may be appropriate for a programmatic level of analysis. The method requires water temperature simulation. Water project operations are simulated on a monthly time step. Monthly water temperature models are available for the Sacramento, Feather, American, and Stanislaus Rivers. Information on other rivers may allow development of water temperature relationships to reservoir storage and flow.

Represented Ecosystem Functions: Although water temperature is a factor in several ecosystem functions (i.e., provide habitat, provide foodweb support, provide access, and loss to adverse water temperature conditions), the method gives information only on provision of habitat.

Confirmed by Data: Laboratory data support temperature effects on survival of individuals. Population-level effects are obscured by synergistic or compound effects with flow, physical habitat, and water quality.

Accuracy and Precision: The accuracy and precision of monthly simulation and estimated habitat length are insufficient to permit estimation of population numbers. Consistent change in habitat availability, however, could be expected to alter production of chinook salmon juveniles. Application of the method should include consideration of variability in the temperature simulation and variability of individual response to temperature conditions.

Application to All Alternatives: The key variable is length of river meeting specific temperature needs for chinook salmon. The length of river would be equally important under all alternatives.

Extension to Future Conditions: The method is based on individual response to temperature conditions, not historic population trends, and should be applicable to future conditions.

Potential for Use: The method could be considered for use in the impact analysis as a measure of habitat availability. Use will be determined by availability, precision, and accuracy of simulated water temperature data.

EXAMPLE 2

Method Description: The relationship between instream flow and habitat area available for spawning based on instream flow studies

Community/Species/Life Stage: Coldwater riverine/chinook salmon/spawning

Assessment Variables: Flow

Programmatic Analysis: This method may be appropriate for a programmatic level of analysis. The method requires flow simulation. Water project operations are simulated on a monthly time step for Central Valley rivers with major reservoirs.

Represented Ecosystem Functions: The method provides information on provision of habitat for spawning chinook salmon.

Confirmed by Data: Population effects of spawning habitat limitations are assumed, but not supported by available data. Effects are obscured by synergistic or compound effects with temperature, substrate, physical habitat, and water quality.

Accuracy and Precision: For selected rivers, the relationship between flow and habitat availability (based on depth, velocity, and substrate use or preference) may be acceptable relative to accuracy and precision. Relationships for other rivers have been identified as inadequate. Application of the method should include consideration of flow variability (i.e., daily or weekly) and the variability of monthly flow simulation.

Application to All Alternatives: The ecosystem restoration program may include creation of additional spawning habitat. The restoration program will be common to all alternatives; therefore, application of this method could provide an estimate of habitat availability in response to flow.

Extension to Future Conditions: The method is a measure of habitat availability under conditions present when the instream flow study was completed. Changes in physical habitat and substrate may alter the relationship.

Potential for Use: The method could be considered for use in estimating habitat availability relative to flow. Method use is limited by several unknowns, including the absence of confirmed population response to spawning habitat availability and unknown accuracy relative to future habitat conditions.

EXAMPLE 3

Method Description: A model estimates mortality of chinook salmon juveniles during outmigration down the Sacramento River and through the Delta. Three regression equations were developed from release and recapture of hatchery produced fall-run chinook salmon. The first equation is applicable to the Sacramento River from Freeport to the Delta Cross Channel (DCC). The second equation is applicable to the Sacramento River from the DCC to Chipps Island, and the third equation is applicable to the Delta channels beginning at the DCC and Georgiana Slough and ending at Chipps Island (i.e., Mokelumne and San Joaquin River portions of the Delta).

Community/Species/Life Stage: Estuarine/chinook salmon/outmigrant juveniles

Assessment Variables: Temperature, flow and barriers (relative to the flow division into the DCC and Georgiana Slough), and exports (Delta diversions by the Central Valley Project at Tracy and the State Water Project at Banks)

Programmatic Analysis: This method may be appropriate for a programmatic level of analysis. The method requires simulation of water temperature and Delta flow. Monthly water temperature and flow simulation may be available for the Delta.

Represented Ecosystem Functions: Although loss to adverse water temperature conditions and loss to diversion are clearly represented, other ecosystem functions may also be affecting the relationship (e.g., loss to adverse toxicant concentrations, loss to predation, and provision of access).

Confirmed by Data: Although the model was developed from field experiments, temperature-mortality relationships for the field data are inconsistent with findings of laboratory studies, possibly because of complicating factors related to other ecosystem functions (e.g., loss to predation). Losses to export are not confirmed by recoveries at the export facilities, again possibly because of complicating factors related to other ecosystem functions.

Accuracy and Precision: The accuracy and precision of the model are insufficient for estimating population loss; however, consistent differences between alternative conditions may indicate the direction of change.

Application to All Alternatives: The model is developed from field studies under existing conditions. The model may not be applicable to conditions with altered Delta channel conveyance.

Extension to Future Conditions: Current studies also indicate that migration-survival relationships are changing in the Delta. Applicability to future conditions is questionable.

Potential for Use: The method is not suitable for use in the impact assessment. The information from the field studies, however, may be applicable for development of alternative methods.

ADDITIONAL ASSESSMENT NEEDS

After the alternatives to be considered in the Programmatic EIR/EIS have been clearly described and the affected assessment variables identified, assessment needs not addressed by existing methods will be determined. Additional assessment needs will be based on:

- the magnitude and occurrence (i.e., frequency and timing) of change in the assessment variable,
- the geographical extent of potential effects,
- the sensitivity of ecosystem functions to change in the assessment variable, and
- the potential response of specific indicators (e.g., communities, species, and life stages) to change in the assessment variable.

Methods will be identified to address the assessment needs. When methods are not available and cannot be developed within the time frame of the programmatic analysis, however, assessment of change in the assessment variables will incorporate professional judgment.

STRATEGY FOR APPLICATION AND INTERPRETATION OF RESULTS

Development of a strategy for applying and interpreting the results of the evaluation is ongoing and will be described in a future document.

Figure 1. Selection of Methods for the Aquatic Ecosystem Impact Analysis

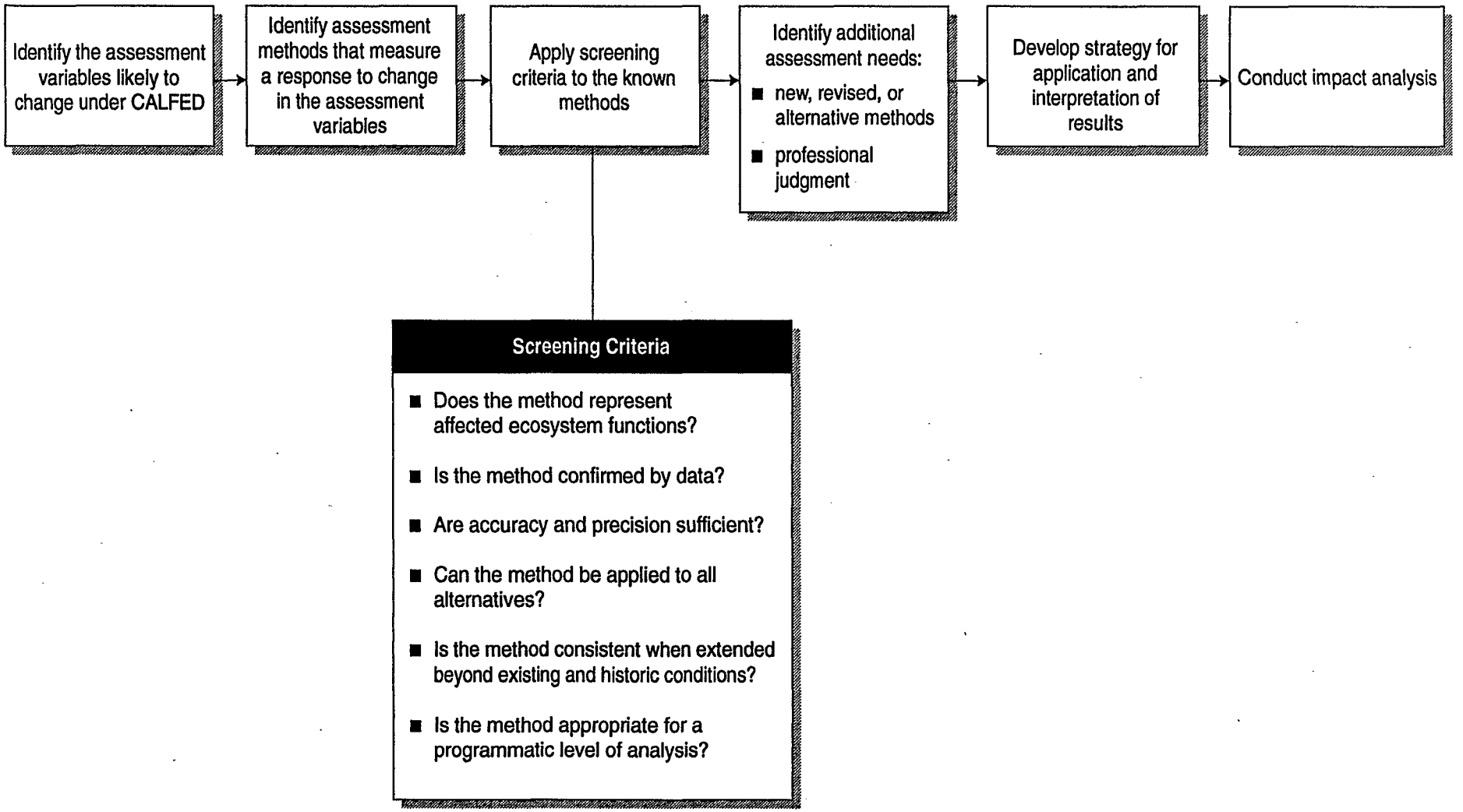

Table 1. Ecosystem Functions and Assessment Variables Related to Biomass Production and Loss in the Reservoir Community

Ecosystem Function	Assessment Variables	Primary Affect of Changes in the Assessment Variable on Ecosystem Functions
Provide habitat	Reservoir elevation	Determines habitat area or volume with usable depth conditions
	Temperature	Determines habitat area or volume with water temperature conducive to growth, survival, and reproductive success
	Substrate	Determines habitat area with appropriate physical properties to support reproduction and rearing activities
	Physical habitat	Determines habitat area or volume with usable depth and cover
	Species interactions: competition	For specific indicator species, species with overlapping habitat needs may affect habitat availability (may include competition with species originating from artificial production and species introduction)
	Water quality: dissolved oxygen	Determines habitat area or volume with dissolved oxygen levels conducive to growth, survival, and reproductive success
Provide foodweb support	Reservoir elevation	Determines habitat area or volume with usable depth conditions for food organisms
	Temperature	Determines habitat area or volume with water temperatures conducive to growth, survival, and reproductive success of food organisms
	Substrate	Determines habitat area with appropriate physical conditions to support reproduction and rearing activities of food organisms
	Physical habitat	Determines habitat area with usable depth and cover to support food organisms; affects food availability from terrestrial, riparian, shaded riverine aquatic, and wetland habitats (i.e., allochthonous input)

Table 1. Continued

Ecosystem Function	Assessment Variables	Primary Affect of Changes in the Assessment Variable on Ecosystem Functions
Provide foodweb support (continued)	Species interactions: competition	Species with overlapping habitat or dietary needs may affect habitat availability for food organisms or availability of food (may include competition with species originating from artificial production and species introduction)
	Water quality: dissolved oxygen	Determines habitat area with dissolved oxygen levels conducive to growth, survival, and reproductive success of food organisms
Provide access	Barriers	Directs or prevents movement to tributary streams that may provide spawning and rearing habitat
	Reservoir elevation	Enables or prevents movement to reservoir habitat or tributary streams that may provide spawning or rearing habitat
Provide artificial production	Artificial production	Adds individuals to a species population; may provide food web support; may affect competition for limited resources; may affect genetic integrity and the ability of the species to adapt to changes in the assessment variables
Loss to adverse water temperature conditions	Temperature	Water temperature may exceed species' metabolic tolerance and result in direct and indirect mortality
Loss to diversion	Diversion	Removes fish from the ecosystem; mortality may result from abrasion and handling
Loss to change in water surface level	Reservoir elevation	May expose nests or strand juvenile fish
Loss to adverse toxicant concentration	Reservoir elevation	Determines concentration levels of toxins in water that may interfere with normal physiological functions and result in direct and indirect mortality

C-000044

Table 1. Continued

Ecosystem Function	Assessment Variables	Primary Affect of Changes in the Assessment Variable on Ecosystem Functions
Loss to adverse toxicant concentration (continued)	Water quality	May interfere with normal physiological functions and result in direct and indirect mortality
Loss to fishing	Fishing	Removes organisms from the ecosystem; may increase mortality through injury of released organisms
Loss to predation	Reservoir elevation	May disorient or concentrate organisms and increase vulnerability to predation
	Artificial production	Fish introduced to the ecosystem prey on other organisms
	Species interactions: introduced species	Organisms introduced to the ecosystem prey on other organisms

C-000045

Table 2. Ecosystem Functions and Structures Related to Biomass Production and Loss in the Coldwater Riverine Community

Ecosystem Function	Assessment Variables	Primary Affect of Change in the Assessment Variable on Ecosystem Functions
Provide habitat	Flow	Determines habitat area with usable depth and velocity conditions
	Temperature	Determines habitat area with water temperatures conducive to growth, survival, and reproductive success
	Substrate	Determines habitat area with appropriate physical properties to support spawning and rearing activities
	Physical habitat	Determines habitat area with usable depth , velocity, and cover
Provide foodweb support	Flow	Determines habitat area with usable depth and velocity conditions for food organisms; determines opportunity for consumption (e.g., drift)
	Substrate	Determines habitat with appropriate physical conditions to support spawning and rearing activities of food organisms
	Physical habitat	Determines habitat area with usable depth and cover to support food organisms; affects food availability from terrestrial, riparian, shaded riverine aquatic, and wetland habitats (i.e., allochthonous input)
Provide access	Flow	Affects depth and velocity needed for upstream and downstream (both passive and active) movement to usable habitat; provides migration cues for movement to usable or preferred habitat
	Barriers	Directs or prevents movement to usable habitat
Provide artificial production	Artificial production	Adds individuals to a species population; may provide food web support; may affect competition for limited resources
Loss to adverse water temperature conditions	Temperature	Adverse water temperature may affect metabolic processes and cause direct and indirect mortality
	Barriers	Limit movement out of habitat with adverse water temperature conditions

Table 2. Continued

Ecosystem Function	Assessment Variables	Primary Affect of Change in the Assessment Variable on Ecosystem Functions
Loss to diversion	Diversion	Removes organisms from the ecosystem; mortality may result from impingement, abrasion, and handling
Loss to change in water surface level	Flow	May expose nests or strand juveniles
Loss to adverse toxicant concentration	Flow	Affects toxicant concentrations and duration of exposure; toxins may affect metabolic processes and cause direct and indirect mortality
	Water quality: toxicant concentration	Toxins may affect metabolic process and cause direct and indirect mortality
Loss to fishing	Fishing	Removes organisms from the ecosystem; may increase mortality through injury of released organisms
Loss to predation	Physical habitat	May alter cover and improve predator feeding efficiency
	Diversions	May disorient or concentrate organisms and increase vulnerability to predation
	Barriers	May disorient organisms or alter migration pathway and increase vulnerability to predation
	Artificial production	Fish introduced to the ecosystem prey on other organisms
	Species interactions: introduced species	Organisms introduced to the ecosystem prey on other organisms

Table 3. Ecosystem Functions and Structures Related to Biomass Production and Loss in the Warmwater Riverine Community

Ecosystem Function	Assessment Variables	Primary Affect of Changes in the Assessment Variable on Ecosystem Functions
Provide habitat	Flow	Determines habitat area with usable depth and velocity conditions
	Temperature	Determines habitat area with water temperature conducive to growth, survival, and reproductive success
	Substrate	Determines habitat area with appropriate physical properties to support spawning and rearing activities
	Physical habitat	Determines habitat area with usable depth, velocity and cover
	Species interactions: competition	Species with overlapping habitat needs may affect habitat availability (may include competition with species originating from artificial production and species introductions)
	Water quality: agricultural salinity	Determines habitat area having salinity conducive to growth, survival, and reproductive success
Provide foodweb support	Flow	Determines habitat area with usable depth and velocity conditions for food organisms; determines opportunity for consumption (e.g., drift)
	Substrate	Determines habitat with appropriate physical conditions to support reproduction and rearing activities of food organisms
	Physical habitat	Determines habitat area with usable depth and cover to support food organisms; affects food availability from terrestrial, riparian, shaded riverine aquatic, and wetland habitats (i.e., allochthonous input)
	Species interactions: competition	Species with overlapping habitat or food needs may affect habitat availability for food organisms or food availability (may include competition with species originating from artificial production and species introductions)

Table 3. Continued

Ecosystem Function	Assessment Variables	Primary Affect of Changes in the Assessment Variable on Ecosystem Functions
Provide foodweb support (continued)	Water quality: nutrient availability	Affects nutrient input to support primary productivity (i.e., autochthonous input)
	Water quality: transparency	Determines light penetration and affects primary productivity (i.e., autochthonous input); determines opportunity for consumption by sight feeders
Provide access	Flow	Affects depth and velocity needed for upstream and downstream (both passive and active) movement to usable habitat; provides migration cues for movement to usable or preferred habitat
	Barriers	Direct or prevent movement to usable habitat
Provide artificial production	Artificial production	Adds individuals to a species population; may provide foodweb support; may affect competition for limited resources
Loss to adverse water temperature conditions	Temperature	Water temperature may affect metabolic processes and cause direct and indirect mortality
	Barriers	Limit movement out of habitat with adverse water temperature conditions
Loss to diversion	Diversion	Removes organisms from the ecosystem; mortality may result from impingement, abrasion, and handling
Loss to adverse toxicant concentration	Flow	Affects toxin concentrations and duration of exposure; toxins may affect metabolic processes and cause direct and indirect mortality
	Water quality: toxicant concentration	Toxins may affect metabolic process and cause direct and indirect mortality
Loss to fishing	Fishing	Removes organisms from the ecosystem; may increase mortality through injury of returned organisms

C-000049

Table 3. Continued

Ecosystem Function	Assessment Variables	Primary Affect of Changes in the Assessment Variable on Ecosystem Functions
Loss to predation	Physical habitat	May alter cover and improve predator feeding efficiency
	Barriers	May disorient organisms or alter migration pathway and increase vulnerability to predation
	Diversions	May disorient or concentrate organisms and increase vulnerability to predation
	Artificial production	Fish introduced to the ecosystem prey on other organisms
	Species interactions: introduced species	Organisms introduced to the ecosystem may prey on other organisms

C—000050

Table 4. Ecosystem Functions and Structures Related to Biomass Production and Loss in the Estuarine Community

Ecosystem Function	Assessment Variables	Primary Affect of Changes in the Assessment Variable on Ecosystem Functions
Provide habitat	Flow	Determines habitat area with usable velocity (i.e., transport channels versus nontransport channels) and salinity conditions
	Substrate	Determines habitat area with appropriate physical properties to support spawning and rearing activities
	Physical habitat	Determines habitat area with usable depth, velocity, and cover
	Barriers	Determine habitat area with usable velocity (i.e., transport channels versus nontransport channels) and salinity conditions
	Species interactions: competition	Species with overlapping habitat needs may affect habitat availability (may include competition with species originating from artificial production and species introductions)
	Species interactions: exotic plants	Affects habitat area through changes in physical habitat, substrate, water circulation, and water quality
	Water quality: agricultural salinity	Determines habitat area having salinity conducive to growth, survival, and reproductive success
Provide foodweb support	Flow	Determines habitat area with usable velocity and salinity conditions for food organisms; determines opportunity for consumption (e.g., drift)
	Substrate	Determines habitat with appropriate physical conditions to support reproduction and rearing activities of food organisms
	Physical habitat	Determines habitat area with usable depth and cover to support food organisms; affects food availability from terrestrial, riparian, shaded riverine aquatic, and wetland habitats (i.e., allochthonous input)

Table 4. Continued

Ecosystem Function	Assessment Variables	Primary Affect of Changes in the Assessment Variable on Ecosystem Functions
Provide foodweb support (continued)	Species interactions: competition	Species with overlapping habitat or food needs may affect habitat availability for food organisms or food availability (may include competition with species originating from artificial production and species introduction)
	Species interactions: exotic plants	Affects habitat area for food organisms through changes in physical habitat, substrates, water circulation, and water quality; determines opportunity for consumption
	Water quality: nutrient availability	Affects nutrient input to support primary productivity (i.e., autochthonous input)
	Water quality: transparency	Determines light penetration and affects primary productivity (i.e., autochthonous input); determines opportunity for consumption by sight feeders
Provide access	Flow	Affects velocity needed for upstream and downstream (both passive and active) movement to usable habitat; provides migration cues for movement to usable or preferred habitat
	Barriers	Direct or prevent movement to usable habitat
	Water quality: dissolved oxygen	Enables or prevents movement to spawning and rearing habitat
	Species interactions: exotic plants	Enables or prevents movement to spawning and rearing habitat
Provide artificial production	Artificial production	Adds individuals to a species population; may provide foodweb support; may affect competition for limited resources
Loss to adverse water temperature Conditions	Temperature	Water temperature may affect metabolic processes and cause direct and indirect mortality

C-000052

Table 4. Continued

Ecosystem Function	Assessment Variables	Primary Affect of Changes in the Assessment Variable on Ecosystem Functions
Loss to diversion	Diversion	Removes organisms from the ecosystem; mortality may result from impingement, abrasion, and handling
Loss to adverse toxicant concentration	Flow	Affects toxin concentration and duration of exposure; toxins may affect metabolic processes and cause direct and indirect mortality
	Water quality: toxicant concentration	Toxins may affect metabolic processes and cause direct and indirect mortality
Loss to fishing	Fishing	Removes organisms from the ecosystem; may increase mortality through injury of released organisms
Loss to predation	Physical habitat	May alter cover and improve predator feeding efficiency
	Diversions	May disorient or concentrate organisms and increase vulnerability to predation
	Barriers	May disorient organisms or alter migration pathway and increase vulnerability to predation
	Artificial production	Fish introduced to the ecosystem prey on other organisms
	Species interactions: introduced species	Organisms introduced to the ecosystem prey on other organisms

C-000053

Table 5. Ecosystem Functions and Structures Related to Biomass Production and Loss in the Marine Community

Ecosystem Function	Assessment Variables	Primary Affect of Changes in the Assessment Variable on Ecosystem Functions
Provide habitat	Flow	Determines habitat area with usable salinity conditions
	Physical habitat	Determines habitat area with usable depth, velocity and cover
	Species interactions: competition	Species with overlapping habitat or food needs may affect habitat availability for food organisms or food availability (may include competition with species originating from artificial production and species introduction)
Provide foodweb support	Flow	Determines habitat area with usable salinity conditions for food organisms; determines opportunity for consumption (e.g., drift)
	Physical habitat	Determines habitat area with usable depth and cover to support food organisms; affects food availability from wetland habitats (i.e., allochthonous input)
	Species interactions: competition	Species with overlapping habitat needs may affect habitat availability for food organisms (may include competition with species originating from artificial production and species introductions)
	Water quality: nutrient availability	Affects nutrient input to support primary productivity (i.e., autochthonous input)
Provide access	Barriers	Direct or prevent movement to usable habitat
Provide artificial production	Artificial production	Adds individuals to a species population; may provide food web support; may affect competition for limited resources
Loss to adverse toxicant concentration	Flow	Affects toxin concentration and duration of exposure; toxins may affect metabolic processes and cause direct and indirect mortality
	Water quality: toxicant concentration	Affects toxin concentration and duration of exposure; toxins may affect metabolic processes and cause direct and indirect mortality

Table 5. Continued

Ecosystem Function	Assessment Variables	Primary Affect of Changes in the Assessment Variable on Ecosystem Functions
Loss to fishing	Fishing	Removes organisms from the ecosystem; may increase mortality through injury of released organisms
Loss to predation	Artificial production	Fish introduced to the ecosystem prey on other organisms
	Species interactions: introduced species	Fish introduced to the ecosystem prey on other organisms

C-000055

Table 6. Assessment Variables Affected by Potential CALFED Bay-Delta Program Actions: Reservoir Community

CALFED Programs and Components	Effect of CALFED Actions	Affected Assessment Variable
Conveyance	Change in reservoir operations due to changes in Delta diversion timing and volume	Reservoir elevation
	Change in coldwater pool, in addition to changes in reservoir operations due to changes in Delta diversion timing and volume	Temperature
Storage	Change in reservoir operations due to changes in available storage volume and locations	Reservoir elevation
	Change in coldwater pool, in addition to changes in reservoir operations due to changes in available storage volume and locations	Temperature
Water use efficiency	Change in reservoir operations due to changes in urban and agricultural water demand	Reservoir elevation
	Change in coldwater pool, in addition to changes in reservoir operations due to changes in urban and agricultural demand	Temperature
Water quality improvements	Change in reservoir operations to provide water to dilute pollutant concentrations	Reservoir elevation
	Change in coldwater pool, in addition to changes in reservoir operations to provide water to dilute pollutant concentrations	Temperature
	Reduction of discharges upstream of reservoirs of water quality constituents that are of concern to aquatic habitats and water users, in addition to changes in reservoir operations to provide water to dilute pollutant concentrations	Water quality
Ecosystem restoration	Change in reservoir operations to provide environmental water	Reservoir elevation

Table 6. Continued

CALFED Programs and Components	Effect of CALFED Actions	Affected Assessment Variable
Ecosystem restoration (continued)	Riparian habitat restoration that may provide shade, in addition to changes in coldwater pool and change in reservoir operations to provide environmental water	Temperature
	Protection, enhancement, and restoration of physical habitat	Physical habitat
	See "Water Quality Improvements"	Water quality
	Improvement of data management for fish harvest regulation	Fishing
	Management of fish hatchery production	Artificial production
	Control of introduced species	Species interactions
Levee system integrity	Not relevant to this aquatic community	--

Note: -- = not relevant.

C-000057

Table 7. Assessment Variables Affected by Potential CALFED Bay-Delta Program Actions: Coldwater Riverine Community.

CALFED Programs and Components	Effect of CALFED Actions	Affected Assessment Variable
Conveyance	Change in reservoir operations due to changes in Delta diversion timing and volume	Instream flow
	Change in coldwater releases, in addition to change in reservoir operations due to changes in Delta diversion timing and volume	Temperature
Storage	Change in reservoir operations due to changes in available storage volume and locations	Instream flow
	Change in coldwater releases, in addition to changes in available storage volume and locations	Temperature
Water use efficiency	Change in reservoir operations due to changes in urban and agricultural water demand	Instream flow
	Change in coldwater releases, in addition to changes in urban and agricultural demand	Temperature
Water quality improvements	Change in reservoir operations to provide water to dilute pollutant concentrations	Instream flow
	Change in coldwater releases, in addition to change in reservoir operations to provide water to dilute pollutant concentrations	Temperature
	Reduction of discharges of water quality constituents that are of concern to aquatic habitats and water users, in addition to change in reservoir operations to provide water to dilute pollutant concentrations	Water quality
Ecosystem restoration	Change in reservoir operations to provide water for the environment	Instream flow

Table 7. Continued

CALFED Programs and Components	Effect of CALFED Actions	Affected Assessment Variable
Ecosystem restoration (continued)	Riparian habitat restoration that may provide shade, in addition to change in coldwater releases and change in reservoir operations to provide water for the environment	Temperature
	Construction and restoration of habitat	Substrate
	Improvement or installation of fish screens at water diversion facilities, in addition to change in reservoir operations to provide water for the environment	Diversions
	Modification of barriers that restrict fish passage and migration	Barriers
	Protection, enhancement, and restoration of physical habitat	Physical habitat
	See "Water quality improvements"	Water quality
	Improvement of data management for fish harvest regulation	Fishing
	Management of fish hatchery production	Artificial production
	Control of introduced species	Species interaction
Levee system integrity	Not relevant to this aquatic community	--

Note: -- = not relevant.

Table 8. Assessment Variables Affected by Potential CALFED Bay-Delta Program Actions: Warmwater Riverine Community

CALFED Programs and Components	Effect of CALFED Actions	Affected Assessment Variable
Conveyance	Change in reservoir operations due to changes in Delta diversion timing and volume	Instream flow
	Change in coldwater releases, in addition to change in reservoir operations due to changes in Delta diversion timing and volume	Temperature
Storage	Change in reservoir operations due to changes in available storage volume and locations	Instream flow
	Change in coldwater releases, in addition to change in reservoir operations due to changes in available storage volume and locations	Temperature
	New diversion location	Diversions
Water use efficiency	Change in reservoir operations due to changes in urban and agricultural water demand	Instream flow
	Change in coldwater releases, in addition to change in reservoir operations due to changes in urban and agricultural water demand	Temperature
Water quality improvements	Change in reservoir operations to provide water to dilute pollutant concentrations	Instream flow
	Change in coldwater releases, in addition to change in reservoir operations to provide water to dilute pollutant concentrations	Temperature

Table 8. Continued

CALFED Programs and Components	Effect of CALFED Actions	Affected Assessment Variable
Water quality improvements (continued)	Reduction of discharges of water quality constituents of concern to aquatic habitats and water users, in addition to change in reservoir operations to provide water to dilute pollutant concentrations	Water quality
Ecosystem restoration	Change in reservoir operations to provide water for the environment	Instream flow
	Riparian habitat restoration that may provide shade, in addition to change in coldwater releases and change in reservoir operations to provide water for the environment	Temperature
	Construction and restoration of habitat	Substrate
	Improvement or installation of fish screens at water diversion facilities, in addition to change in reservoir operations to provide water for the environment	Diversions
	Modification of barriers that restrict fish passage and migration	Barriers
	Protection, enhancement, and restoration of physical habitat	Physical habitat
	See "Water quality improvements"	Water quality
	Improvement of data management for fish harvest regulation	Fishing
	Management of fish hatchery production	Artificial production
Ecosystem restoration (continued)	Control of introduced species	Species interaction

Table 8. Continued

CALFED Programs and Components	Effect of CALFED Actions	Affected Assessment Variable
Levee system integrity	Not relevant to this aquatic community	--

Note: -- = not relevant.

C-000062

Table 9. Assessment Variables Affected by Potential CALFED Bay-Delta Program Actions: Estuarine Community

CALFED Programs and Components	Effect of CALFED Actions	Affected Assessment Variable
Conveyance	Change in channel flow due to change in point of diversion and change in reservoir operations due to changes in Delta diversion timing and volume	Delta flow
	Change in diversion location, timing, and volume	Diversions
Storage	Change in reservoir operations due to changes in available storage volume and locations and change in channel flow due to changes in points of storage diversion or discharge (e.g., in-Delta storage)	Delta flow
Water use efficiency	Change in reservoir operations due to changes in urban and agricultural water demand	Delta flow
Water quality improvements	Change in reservoir operations to provide water to dilute pollutant concentrations	Delta flow
	Reduction of discharges of water quality constituents of concern to aquatic habitats and water users, in addition to change in reservoir operations to provide water to dilute pollutant concentrations	Water quality
Ecosystem restoration	Change in reservoir operations to provide water for the environment	Delta flow
	Riparian habitat restoration that may provide shade, in addition to change in reservoir operations to provide water for the environment	Temperature
	Construction and restoration of habitat	Substrate

Table 9. Continued

CALFED Programs and Components	Effect of CALFED Actions	Affected Assessment Variable
Ecosystem restoration (continued)	Improvement or installation of fish screens at water diversion facilities, in addition to change in reservoir operations to provide water for the environment	Diversions
	Modification of barriers that restrict fish passage and migration	Barriers
	Protection, enhancement, and restoration of physical habitat	Physical habitat
	See "Water quality improvements"	Water quality
	Improvement of data management for fish harvest regulation	Fishing
	Management of fish hatchery production	Artificial production
	Control of introduced species	Species interaction
Levee system integrity	Implementation and development of the Delta Long-Term Levee Protection Plan, including levee maintenance and improvements	Substrate
	Incorporation of aquatic habitat restoration and enhancement in levee maintenance and improvement plans	Physical habitat

Note: -- = not relevant.

C-000064

Table 10. Assessment Variables Affected by Potential CALFED Bay-Delta Program Actions: Marine Community

CALFED Programs and Components	Effect of CALFED Actions	Affected Assessment Variable
Conveyance	Change in reservoir operations due to changes in Delta diversion timing and volume	Delta flow
Storage	Change in reservoir operations due to changes in available storage volume and locations	Delta flow
Water use efficiency	Change in reservoir operations due to changes in urban and agricultural water demand	Delta flow
Water quality improvements	Change in reservoir operations to provide water to dilute pollutant concentrations	Delta flow
	Reduction of discharges of water quality constituents of concern to aquatic habitats and water users	Water quality
Ecosystem restoration	Change in reservoir operations to provide water for the environment	Delta flow
	Protection, enhancement, and restoration of physical habitat	Physical habitat
	See "Water quality improvements"	Water quality
	Improvement of data management for fish harvest regulation	Fishing
	Management of fish hatchery production	Artificial production
	Control of introduced species	Species interaction

Table 10. Continued

CALFED Programs and Components	Effect of CALFED Actions	Affected Assessment Variable
Levee system integrity	Not relevant to this aquatic community	--

Note: -- = not relevant.

Table 11. Species Selected for Inclusion in the Fish Impact Assessment

Species (Common/Scientific Name)		Aquatic Community				
		Reservoir	Cold Water	Warm Water	Estuarine	Marine
Fish						
Rainbow trout	*Oncorhynchus mykiss*	X				
Largemouth bass	*Micropterus salmoides*	X			X	
White sturgeon	*Acipenser transmontanus*		X	X	X	X
Chinook salmon	*Oncorhynchus tshawytscha*		X	X	X	X
Steelhead trout	*Oncorhynchus mykiss*		X	X	X	
Sacramento squawfish	*Ptychocheilus grandis*		X	X		
American shad	*Alosa sapidissima*			X	X	
Sacramento blackfish	*Orthodon microlepidotus*			X	X	
Sacramento splittail	*Pogonichthys macrolepidotus*			X	X	
Striped bass	*Morone saxatilis*			X	X	X
Smallmouth bass	*Micropterus dolomieui*			X		
Tule perch	*Hysterocarpus traskii*			X	X	
Delta smelt	*Hypomesus transpacificus*				X	
Longfin smelt	*Spirinchus thaleichthys*				X	X
White catfish	*Ictalurus catus*				X	
Inland silverside	*Menidia audens*				X	
Pacific herring	*Clupea harengeus pallasii*					X
Starry flounder	*Platichthys stellatus*					X
Invertebrate						
Terrestrial invertebrates			X	X	X	
Other aquatic invertebrates			X	X		
Rotifers	Rotifera				X	
Native mysid shrimp	*Neomysis mercedis*				X	
Crayfish	*Pacifastacus leniusculus*			X	X	
Asian clam	*Potamocorbula amurensis*				X	X
Bay shrimp	*Crangon franciscorum*					X

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Table 12. Factors Considered for Selection of Species to Include in the Impact Assessment

Aquatic Communities and Species	Species Importance					Response to Change in Assessment Variables											
	Commercial fishery	Sport fishery	ESA or CESA	Ecological role	Sum	Flow	Reservoir elevation	Temperature	Substrate	Physical habitat	Diversions	Barriers	Water quality	Fishing	Artificial production	Species interaction	Sum
Reservoir Community																	
Rainbow trout	0	2	0		2	0	1	1		1		1	1	2	2	1	10
Largemouth bass	0	2	0		2	0	2		2	2		0	1	2		1	10
Coldwater Riverine Community																	
White sturgeon	0	2	0	1	3	2	0	1	1	1	0	1		0	0		6
Chinook salmon	2	2	2	1	7	2	0	2	1	2	2	1	1	1	2	1	15
Steelhead trout	0	2	2	1	5	2	0	2	1	2	1	1	1	1	2	1	14
Sacramento squawfish	0	1	0	2	3		0		1	2	1	2	1	0	0		7
Terrestrial invertebrates	0	0	0	2	2	0	0	0	0	2	0	0	0	0	0	2	4
Other aquatic invertebrates	0	0	0	2	2	2	0	1	2	2	0	0	1	0	0		8
Warmwater Riverine Community																	
White sturgeon	0	2	0	1	3	2	0	1	1	1	0	0	1	0	0	1	7
Chinook salmon	2	2	2	1	7	1	0	2	1	2	1	0	1	1	1	1	11
Steelhead trout	0	2	2	1	5	1	0	1	1	2	1	0	1	1	1	1	10
Sacramento squawfish	0	1	0	2	3		0	0	1	2	1	0	1	0	0	2	7
American shad	0	2	0	1	3	2	0	1		1	1	0	1	1	0	1	8
Sacramento blackfish	1	0	0	1	2		0	0	1	1		0	1	1	0	1	5
Sacramento splittail	0	2	2	1	5	2	0	1	2	2	0	0	1	1	0	1	10
Striped bass	0	2	0	2	4	2	0	1		1	1	0	2	1	1	1	10
Smallmouth bass	0	2	0	1	3		0	0	1	2	0	0	1	1	0	1	6
Tule perch	0	0	0	2	2		0	0	1	2	0	0	1	0	0	1	5
Terrestrial invertebrates	0	0	0	2	2	1	0	0	0	2	0	0	0	0	0	2	5
Other aquatic invertebrates	0	0	0	2	2	1	0	0	2	2	0	0	1	0	0	2	8
Crayfish	2	2	0	2	6	1	0	0			0	0	1	1	0		3
Estuarine Community																	
Largemouth bass	0	2	0	1	3	1	0	0	1	2	0	1	1	1	0	1	8
White sturgeon	0	2	0	1	3	1	0	0		1	0	1	1	2	0		6
Chinook salmon	2	2	2	1	7	1	0	1		2	2	2	1	1	1	1	12
Steelhead trout	0	2	2		4	1	0			1	1	2	1	0	1	1	8
American shad	0	2	0	1	3	1	0	0		1	2	1	1	1	0	1	8
Sacramento blackfish	1	0	0	1	2		0	0	1	2	0		1	0	0		4
Sacramento splittail	0	1	2	1	4	2	0	0	1	2	1	1	1	0	0	1	9
Striped bass	0	2	0	2	4	2	0	0		1	2	2	1	2	2	2	14
Tule perch	0	0	0	2	2		0	0	2	2	1		1	0	0	1	7
Delta smelt	0	0	2	1	3	2	0	0	1	2	2	2	1	0	0	2	12
Longfin smelt	0	0	1	1	2	2	0	0	1	1	2	1	1	0	0	1	9
White catfish	0	2	0	1	3	1	0	0	1	2	2		1	1	0	2	10
Inland silverside	0	0	0	2	2		0	0	1	2	1	0	1	0	0	2	7
Terrestrial invertebrates	0	0	0	2	2	1	0	0	0	2	0	0	0	0	0	2	5
Rotifers	0	0	0	2	2	1	0	0					1	0	0	2	4
Native mysid shrimp	0	0	0	2	2	2	0	0					1	0	0	2	5
Crayfish	2	1	0	2	5	1	0	0	1	2	0	0	1	2	0	2	9
Asian clam	0	0	0	2	2	1	0	0	1	1	0	0		0	0	2	5

11/12/96

Table 12. Continued.

Aquatic Communities and Species	Species Importance					Response to Change in Assessment Variables											
	Commercial fishery	Sport fishery	ESA or CESA	Ecological role	Sum	Flow	Reservoir elevation	Temperature	Substrate	Physical habitat	Diversions	Barriers	Water quality	Fishing	Artificial production	Species interaction	Sum
Marine Community																	
White sturgeon	0	2	0	1	3		0	0	1	1	0	0	1	2	0		5
Chinook salmon	2	2	2	1	7		0	0			0	0	1	2	2		5
Striped bass	0	2	0	2	4		0	0			0	0	1	2	2	1	6
Longfin smelt	0	0	1	1	2	2	0	0			0	0	1	0	0	1	4
Pacific herring	2	0	0	1	3	1	0	0	1	1	0	0	1	2	0		6
Starry flounder	1	1	0		2	1	0	0	1	1	0	0	1	1	0		5
Bay shrimp	1	1	0	1	3	2	0	0	1	1	0	0	1	0	0	1	6
Asian clam	0	0	0	2	2	1	0	0	1	1	0	0		0	0	2	5

Notes:

Species Importance:
2 = very important
1 = may be important
0 = not important
"blank" = unknown importance

Response to Change in Assessment Variables:
2 = critical to species abundance
1 = may be critical to species abundance
0 = minimal effects on species abundance
"blank" = species response is unknown

11/12/96