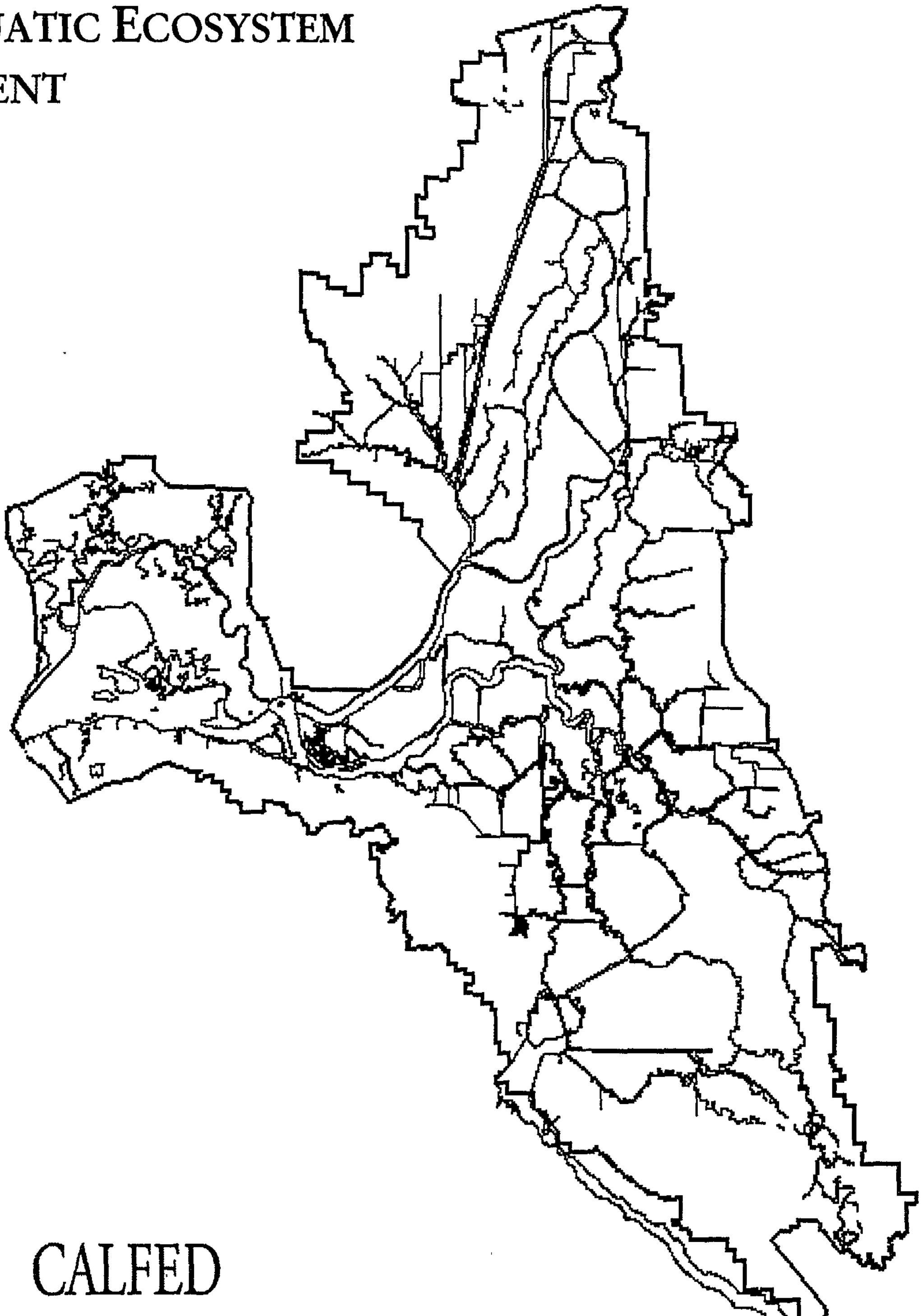
CALFED BAY-DELTA PROGRAM

DRAFT SELECTION OF METHODS FOR AQUATIC ECOSYSTEM ASSESSMENT



CALFED
BAY-DELTA
PROGRAM

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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 these 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 and from participants in work-team meetings. They are the

- Fish Assessment Process Working Document (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 (September 6, 1996), which identifies species and assessment variables that will be included in the impact assessment for the Programmatic EIR/EIS;
- Proposed Aquatic Ecosystem Assessment Methods (October 8, 1996), which presents a process for selecting methods for the impact assessment; and
- Draft Selection of Methods for Aquatic Ecosystem Assessment (November 12, 1996).

Information provided by participants during both work-team meetings and by written comments 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-team meetings was on specific relationships for selected fish species. Responding to suggestions by some participants in the assessment process, the overall methodology for impact assessment has been modified to focus on an expanded array of aquatic ecosystem structures and functions. 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, and describes the process for selecting impact assessment methods.

The Programmatic EIR/EIS will include alternative suites of actions intended to meet CALFED objectives. The pathway for linking actions to impacts and benefits is shown in Figure 1. Actions affect assessment variables that, in turn, affect ecosystem functions that have direct relevance to the impacts and benefits of implementing the CALFED alternatives.

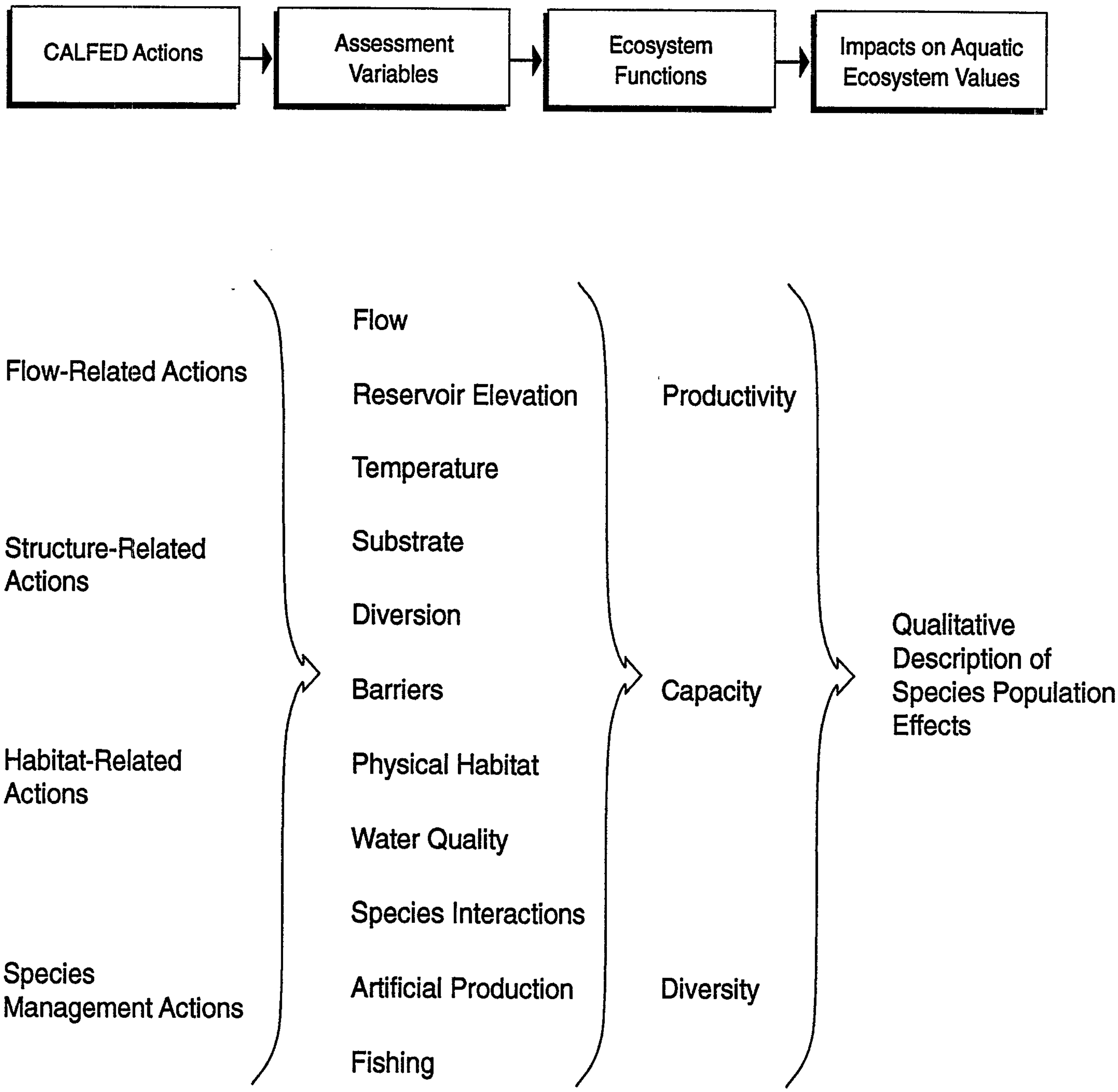
CALFED alternatives will implement interrelated actions to restore and improve ecosystem function and structure. Flow-related actions include reservoir operations and diversions. Structure-related actions include relocation and consolidation of diversions, construction and operation of barriers, fish screen construction and improvements, and operation of multilevel release structures to provide for water temperature needs. Habitat-related actions will include improved water quality (e.g., programs to address wastewater discharge and urban and agricultural runoff) and habitat restoration (e.g., watershed management programs, restoration of riparian zones, meander belts, and spawning and rearing habitat). Species management actions include fishing regulation, hatchery production, removal of predators, and restrictions on introduction of non-native species.

Assessment variables (i.e., ecosystem structure) reflect the interrelation and organization of physical, chemical, and biological features. Assessment variables identified for the aquatic ecosystem include flow, reservoir elevation, temperature, substrate, diversions, barriers, physical habitat, water quality, species interactions, artificial production (i.e., human-aided production of organisms released into an ecosystem), and fishing (Figure 1). Change in assessment variables in response to CALFED actions drives ecosystem functions and affects species populations within the aquatic ecosystem.

Ecosystem functions include complex patterns of transfer, change, use, and accumulation of inorganic and organic materials (i.e., the flow of energy, nutrients, and species). Ecosystem function (i.e., represented by the species' response) is characterized by three interrelated categories: productivity, capacity, and diversity (Figure 1). Ecosystem functions include loss to adverse water temperature conditions, loss to diversion, provision of habitat, provision of foodweb support, and others.

For the purpose of the Programmatic EIR/EIS, dividing the aquatic ecosystem into aquatic communities and representative species provides a way of coping with ecosystem complexity. Division of the ecosystem into aquatic communities enables analysis based on distinctive characteristics of component parts, while recognizing the importance of connectivity in maintaining

Figure 1. Pathway for Linking CALFED Actions to Impacts and Benefits



ecosystem values as a whole. Representative species populations provide an important cross-section of aquatic ecosystem values potentially affected by CALFED actions.

AQUATIC COMMUNITIES

The environmental consequences of implementing CALFED actions are assessed for the aquatic ecosystem encompassed by the Sacramento-San Joaquin River basins, including the Sacramento-San Joaquin Delta estuary. Aquatic communities are divisions of the aquatic ecosystem that consist of the connected sequences of water bodies through which aquatic species pass as they complete their life cycles. 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 farther 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).

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

- **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 Sacramento-San Joaquin 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 meteorologic conditions, the upstream and downstream boundaries shift. 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. Additional division of the aquatic communities (e.g., specific rivers and streams) may be required to address specific actions included in the CALFED alternatives.

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. Twenty-five species were selected for inclusion in the impact analysis, 18 species of fish and seven species or groups of invertebrates (Table 1). Although chinook salmon is identified as a single species in Table 1, 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 selecting 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.

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Table 1. Species Selected for Inclusion in the Fish Impact Assessment

Species (Common/Scientific Name)		Aquatic Community				
		Reservoir	Coldwater	Warmwater	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

Species support commercial and sport fisheries if they are currently part of the sport or commercial catch. Species listed under 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 foodweb 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 its probable effects on phytoplankton and zooplankton abundance. Sacramento squawfish has a significant ecological role because of its predation on juvenile chinook salmon.

The criteria are assigned values based on the relative importance of a species. The criterion is assigned a value of 2 if the species is very important, 1 if the species may be important or is less important, 0 if the species is not important, and is left 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 ESA (Table 2).

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 the 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 response is assigned a value of 2. If the species-variable interaction may be important but further evaluation is needed, the response is assigned a value of 1. A response to 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 responses is greater than 1, the species is considered for inclusion in the programmatic assessment (Table 2).

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 (i.e., toxicants) are transferred between organisms and the environment to give ecosystems their functional unity. These substances may be

Table 2. 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	[redacted]	Flow	Reservoir elevation	Temperature	Substrate	Physical habitat	Diversions	Barriers	Water quality	Fishing	Artificial production	Species interactions	[redacted]
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

Table 2. Continued.

Aquatic Communities and Species	Species Importance					Response to Change in Assessment Variables											
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

transferred between and within local ecosystems. 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 water flow on habitat for delta smelt would be different from the effect of change in water flow on habitat for juvenile chinook salmon.

DEFINITIONS OF ECOSYSTEM FUNCTIONS

PRODUCTIVITY

Productivity is the density-independent reproductive rate that represents a life history pattern over an entire life cycle. Productivity includes functions related to reproductive potential (i.e., the number of viable eggs produced by the spawning population) and density-independent mortality. For a given species, productivity determines the rate of loss that can be sustained by a population. The mortality component of productivity is primarily dependent on habitat quality and reflects loss and removal attributable to adverse water temperature, diversion, change in water surface level, increased toxicant concentration, predation, and other factors.

LOSS TO ADVERSE WATER TEMPERATURE. Adverse water temperature, relative to the needs of specific indicators (e.g., species or life stage), exceeds metabolic tolerances and causes mortality of organisms. Water temperature is a primary assessment variable; however, there are interrelated assessment variables that affect water temperature including water flow, reservoir water elevation, barriers, water quality, and physical habitat. Each of these must be considered in the evaluation of the effects caused by changes in water temperature. In the Sacramento-San Joaquin basin, water temperature is primarily a concern for coldwater species (e.g., chinook salmon and steelhead trout).

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, stress from handling, and increased predation. The variables considered in the assessment of loss to diversions are diversion volume, fish screen design, handling procedures, source-flow volume, estuarine salinity, barriers, physical habitat, and species interactions (i.e., predation).

LOSS TO CHANGE IN WATER SURFACE LEVEL. Change in water surface level may cause mortality by exposing nests, stranding individuals, reducing or eliminating cover, and other factors. Effects of change in water surface level is assessed for streams, rivers, and reservoirs. The assessment variables considered in the assessment of loss to change in water surface level for streams and rivers are flow, substrate, physical habitat, and species interactions. The assessment variables for reservoirs are reservoir water elevation, substrate, physical habitat, and species interactions.

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LOSS TO INCREASED TOXICANT CONCENTRATION. Toxicants are poisonous substances that cause the death of organisms. The assessment variables considered in the assessment of loss to increased toxicant concentration are flow, reservoir water elevation, and water quality. Increased flow reduces the concentration of toxicants by diluting them. Reduced application of potential toxicants (e.g., by reducing agricultural acreage) and actions to clean up point and non-point sources reduce input to rivers and streams, reducing the concentration of toxicants affecting aquatic organisms.

LOSS TO FISHING. Fishing causes mortality by removing organisms from the ecosystem or by increasing stress on organisms, increasing stress-related mortality (e.g., vulnerability to predation or disease upon release of weakened or wounded individuals). 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; however, loss may increase to levels that adversely affect specific indicators through changes in ecosystem structure that increase prey vulnerability or increase predator feeding efficiency. Assessment variables considered in the assessment of loss to predation include artificial production (e.g., human-aided production of predatory species) and species interactions (e.g., introduction of new predatory species).

Loss to predation also increases through increased vulnerability of prey organisms that is associated with the ecosystem functions discussed previously (i.e., adverse water temperature conditions, diversion, change in water surface level, increased toxicant concentration, and fishing).

LOSS TO INADEQUATE TRANSPORT. Losses include those from inadequate transport of planktonic eggs (e.g., flows insufficient to prevent eggs from settling) and transport of larval and juvenile fish in adverse habitats (e.g., movement of juvenile chinook salmon from the Sacramento River along the Delta Cross Channel and Georgiana Slough pathways). Assessment variables that increase or decrease transport in adverse habitats include flow, diversions, barriers, and physical habitat.

LOSS TO ATTRACTION TO NONSALMONID HABITAT. The attraction of adult salmon into adverse habitat (e.g., migration up the San Joaquin River past the mouth of the Merced River, migration into the Colusa Basin drain) increases mortality. Assessment variables that affect attraction during migration are flow and water quality (e.g., determined by increases in agricultural return flows).

CAPACITY

Ecosystem capacity includes density-dependent functions related to habitat quantity, including density-dependent mortality. Habitat quantity (i.e., amount of space, food, and other needed resources) sets an upper limit to the number of organisms that the ecosystem can support and becomes increasingly important as population numbers increase. Functions related to capacity include provision of habitat, foodweb support, and access to connected habitats. For a species, habitat quantity relates to that component of total habitat that is available and strongly preferred or needed during a specific life stage at a specific time.

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 water elevation, temperature, substrate, barriers, physical habitat, water quality, and species interactions.

FOODWEB SUPPORT. The foodweb is essential to maintaining species diversity, abundance, and distribution within an aquatic community. Foodweb support depends on factors affecting nutrient availability, production of food, and availability of food. Assessment variables that affect these factors include flow, reservoir water elevation, temperature, substrate, diversion, barriers, physical habitat, water quality, species interactions, and artificial production.

ACCESS TO CONNECTED HABITATS. Access to connected habitats includes physical, chemical, and biological conditions that support the essential movement (passive or active) of organisms to meet their specific needs (e.g., spawning, feeding, rearing, metabolic efficiency, and avoidance of predators). Access to connected habitats may depend on conveyance, pathways, and environmental cues. Assessment variables that affect these factors include flow, reservoir water elevation, temperature, barriers, physical habitat, water quality, and species interactions.

DIVERSITY

SUPPORT OF LIFE-HISTORY DIVERSITY. Ecosystem diversity represents the multitude of pathways for the flow of energy, nutrients, and species through the ecosystem. In this document, the definition is restricted to species life-history diversity and includes pathways through space and time available to and used by a species in completing its life cycle. Greater life-history diversity enables species to survive and maintain productivity during natural and human-caused changes in environmental conditions (i.e., population resilience). Life-history diversity is dependent on functions identified above under productivity and capacity.

Artificial production is a human-aided life-history pathway and a component of species life-history diversity. Artificial production maintains population abundance of species that provide some human value (e.g., commercial and sport fishing, prevention of extinction). Artificial production is usually initiated when the existing ecosystem cannot adequately (as defined by human value) maintain the species' population and provide habitat, foodweb support, or access to connected habitats for all life stages of a target species. Artificial production may have adverse effects on the genetic diversity of the produced species and may increase predation on and competition with these and other species.

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 these components. 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 water elevation, water temperature, substrate, diversions, barriers, physical habitat, water quality, fishing, artificial production, and species interactions.

FLOW

Flow includes several parameters directly related to flow volume 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 Water Elevation

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

Water 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 electricity-generating plants or other facilities (discussed under "Water Quality"). Water temperature is affected by weather, reservoir operations (including operation of multilevel 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 that are a function 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 reduce instream and net flows. Diversion facilities have structural components related to channel morphology, intake design and size, fish screens, debris screens, pilings, and other structures associated with protecting the diversion facility and facilitating operations. The effects of diversions and diversion facilities on biomass loss are assessed 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 diversion facilities and the effects of barriers and diversions may be difficult to separate. The effects of barriers are generally assessed 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 that includes 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. Electricity-generating plants, sewage treatment plants and other facilities, and agricultural return flows discharge water at temperatures that may exceed the temperature of the 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 have acute and chronic effects and therefore reduce the survival of fish and other aquatic organisms. 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 depend on 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 therefore to additional mortality. Predation may also increase with the introduction of non-native 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 and other aquatic organisms 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 non-native species with resource needs similar to those of 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).

NON-NATIVE PLANTS. Introduction of non-native plants to aquatic habitats may affect species population abundance by modifying habitat (e.g., changing substrate, physical habitat, water circulation, and water quality) and changing species interactions (e.g., food availability, predation, and competition).

SELECTION OF ASSESSMENT METHODS

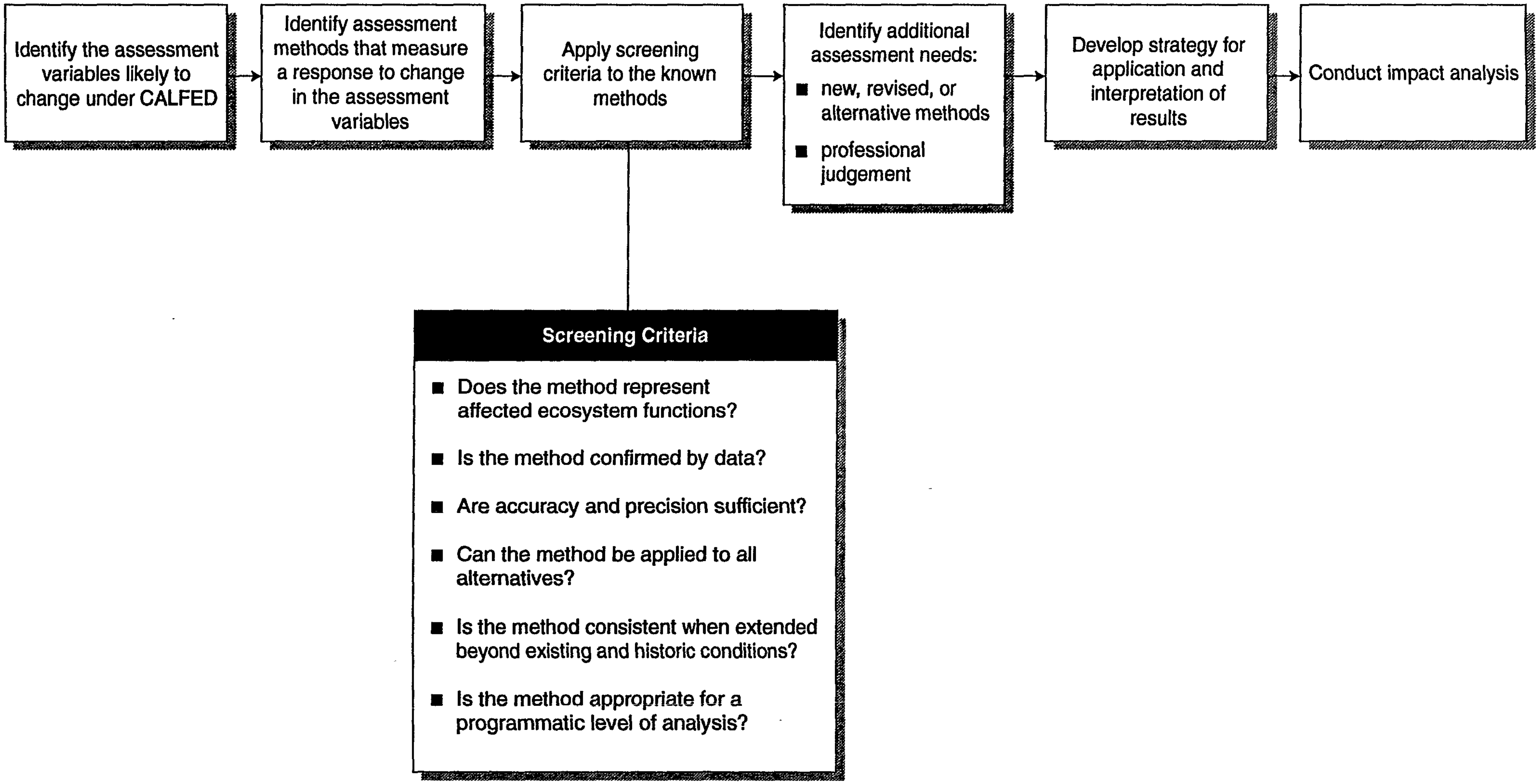
This section describes the process for selection of impact assessment methods for fish and aquatic resources (Figure 2). Information provided above (i.e., aquatic communities, representative species, ecosystem functions, and assessment variables) provides the foundation for the selection process. Selection 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.

Key agency and stakeholder representatives and fishery experts are being asked to participate in the selection of assessment methods for the CALFED Programmatic EIR/EIS. To facilitate the

Figure 2. Selection of Methods for the Aquatic Ecosystem Impact Analysis



process, CALFED has made a preliminary selection of applicable assessment methods. The assessment methods and the process for selection are describe below.

PRELIMINARY ASSESSMENT METHODS

Ecosystem functions, the assessment variables that drive the ecosystem functions, and the assessment methods are listed for each of the selected species by life stage (Attachments 1 though 12). Ecosystem functions and the assessment variables are defined in preceding sections. Ecosystem functions are not applicable to all life stages of all species.

The assessment method is a statement or set of statements that describe specific relationships representing specific ecosystem functions. For example, the assessment method representing the ecosystem function "loss to adverse water temperature" for the adult migration/holding life stage of chinook salmon is: temperatures that exceed the optimal temperature for survival and growth cause mortality. Mortality is calculated from existing temperature-mortality relationships.

The measured indicators represent response to change in the assessment variables and will be used to describe the differences between the CALFED alternatives. The measured indicators identified for each assessment method depend on the supporting data. If data supporting the assessment method is sufficiently detailed, the measured indicator may represent the response of individuals (e.g., the measured indicator for response of chinook salmon to change in water temperature is mortality rate). If supporting data is meager, the measured indicator would be less precise and change in assessment variables could be used to describe differences between alternatives (e.g., change in water temperature could describe the difference between alternatives for the ecosystem function "loss to adverse water temperature").

PROCESS FOR SELECTION OF ASSESSMENT METHODS

Prior to the workshops for selection of assessment methods (beginning February 18, 1997), team participants are asked to review the preliminary assessment methods and be prepared to identify missing relationships, errors in concept, and alternative methods. If the preliminary assessment method identified by CALFED is acceptable to all participants, the method will be applied to identify differences between alternatives.

If the assessment method requires additional consideration, screening criteria will be applied to the preliminary method and to any suggested alternative methods. During the last meeting (October 17, 1996), 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 as follows:

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 that successfully passes all of these screening criteria is suitable for use in the CALFED programmatic analysis and may be included in the tools applied to describe differences between alternatives in the Programmatic EIR/EIS.

ATTACHMENTS

Evaluation Tools for Chinook Salmon and Steelhead Trout

I. Adult Migration/Holding	
A. **Ecosystem Function:** Loss to Adverse Water Temperature **Assessment variables:** • water temperature (as affected by flow, facility operations, and reservoir storage) • physical habitat **Assessment methods:** 1) temperature that exceeds the optimal temperature for survival and fertility increases mortality *Measured indicators:* mortality (calculated from existing mortality relationships) 2) riparian habitat reduces elevated water temperature *Measured indicators:* length of restored habitat	
B. **Ecosystem Function:** Loss to Attraction to Non-salmonid Habitat **Assessment variables:** • flow • water quality **Assessment methods:** 1) flow attracts salmon to non-salmonid habitat *Measured indicators:* number of migration barriers constructed; flow volume (e.g., San Joaquin River above the Merced and agricultural return flows)	

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