Appendix A

ESSENTIAL ECOSYSTEM-LEVEL ATTRIBUTES OF THE SAN FRANCISCO BAY-DELTA WATERSHED

Draft January 1998 (with minor revisions August 1998)

I. Rationale

Planning efforts directed towards restoration and protection of complex ecosystems requires a basic understanding of the natural structure, function and organization of the systems to be restored. Such understanding enables managers to assess, during planning phases of a program, the degree to which prospective restoration sites diverge from a "healthy" or "natural" condition, as well as to evaluate, after actions have been undertaken, project progress and effectiveness. In a management context, perhaps the most practical means of summarizing the most relevant existing information on ecosystems is to develop, over an appropriate hierarchy of spatial and ecological scales, a list of key system attributes - those fundamental natural ecological characteristics that together define and distinguish these systems, their status, and/or their interrelationships. Such lists of attributes may serve as a convenient and necessary "check list" of environmental factors that might be addressed in an ecological restoration/rehabilitation context. At sites for which comprehensive restoration is the goal, a full suite of applicable attributes would presumably be addressed. More commonly, at sites where partial restoration (rehabilitation) is the goal, actions and efforts would be focused upon an appropriate subset of attributes.

Some individual system attributes - such as water temperature - may be evaluated directly. Others, such as "habitat continuity", are more nebulous, and must be evaluated by developing appropriate "indicators" - measurable parameters that provide a means to objectively (preferably quantifiably) evaluate individual attributes that in themselves are not readily measured. The term indicators is also used in a broader context to refer to a *subset* of system attributes (or their measurable parameters) that are derived and used *as a group* to provide a convenient way to evaluate *overall* system status. Thus, the term "indicator" is commonly used in two somewhat different ecosystem management/restoration contexts, representing two differing scales of resolution: that of *individual* attributes, or alternately, that of *groups* of attributes. In either case, "indicators" are simply a convenient way of measuring or evaluating that which is of primary concern - system attributes. An additional, and most useful tool in understanding and describing fundamental characteristics of complex systems is the use of conceptual models that integrate and diagrammatically represent the three basic *kinds* of system components: elements (attributes), their states, and the relationships that affect attribute states (see Herbold write-up).

This document develops a provisional list of natural ecological attributes of the ecosystems of this watershed for use in the contexts summarized above.

E-036354

E-036354

II. Methods

Attributes for each of the watershed's ecosystem-types were generated by reviewing, analyzing, and summarizing available information on (1) the historical state of these systems, (2) "pristine" remnant sites within this watershed, and (3) similar types of systems at other locations. They represent our best current evaluation of the condition of the system in its natural or pristine state, which may differ from a desired (or attainable) "target state" of a restoration program. "Stressors" attached to the attribute groupings represent those anthropogenic factors believed most influential in altering attribute states over the last few centuries. The attributes presented are most applicable to the broader, ecosystem level of restoration/rehabilitation planning. They represent common, fundamental ecological features of these types of systems. It is emphasized that application of these attributes (and their indicators) at particular sites will require refinement by experts familiar with the unique properties and environmental conditions found at those sites, as well as the specific goals and objectives of the particular restoration project.

For practical reasons, ecosystem attributes were organized into five broad categories, each of which reflects essential aspects of ecosystem structure/function:

A. **GENERAL HYDROLOGIC ATTRIBUTES** - *Rationale: The integrity of natural hydrologic attributes is essential for the protection and/or restoration of native habitats and biological communities, and the maintenance of natural ecological processes (including sediment and nutrient dynamics, trophic dynamics, and salinity patterns). In rivers and streams for example, minimal flow levels are necessary to assure viability of all life stages of all native aquatic organisms, and to maintain adequate groundwater levels in support of riparian vegetation; sufficient seasonal shifts in stream level are essential to flushing, groundwater and other river-riparian exchange processes; seasonal velocity ranges and timing must be compatible with viability of all life stages of aquatic organisms, and the maintenance of sediment delivery/deposition processes, periodic flooding is necessary to maintain diversity and succession within riparian zone, and for the exchange of materials between riverine and riparian habitats.*

B. **GENERAL GEOMORPHIC ATTRIBUTES** - *Rationale: The integrity of natural geomorphic attributes is essential for the protection and/or restoration of native habitats and biological communities, and the maintenance of natural ecological processes. For example, altered local topography may cause habitat fragmentation; physical barriers may prevent or inhibit natural water, sediment and/or animal movement, and/or prevent reestablishment of riparian zone even if hydrologic restoration is successful; in-stream structure, sinuosity of channel, and cross-sectional profile interact with flow to determine sediment deposition and distribution and therefore substrate composition, a key determinant in the structuring of aquatic communities in shallow streams.*

E-036355

E-036355

C. **NATURAL HABITATS: TYPES/ATTRIBUTES** - *Rationale: Within the larger framework of ecosystem hydrology and geomorphology, component habitat-type have more specialized attributes* ***(within-habitat)*** *that distinguish them as ecologically different (but highly interactive) types of areas. In a larger context, the ecosystem as a whole has attributes* ***(among-habitat)*** *related to such things as spatial distribution and arrangement of component habitat-types, and water quality. For example, the disconnection of nearby habitats (through construction of barriers or alteration of natural topography) may prevent full community development and/or restrict the distribution and viability of some populations. Both within and among habitat attributes are essential to the support of native biological communities and natural ecological processes in these ecosystems.*

D. **NATIVE BIOLOGICAL COMMUNITY ATTRIBUTES** - *Rationale: Restoration of natural community attributes is an essential aspect of restoring and protecting ecosystem integrity. The five defined ecosystem-types of the watershed each harbor distinctive biological communities, distributed within and among their component habitat-types. The maintenance of overall biodiversity and fundamental aspects of community structure are not only the primary goal of most restoration/management programs, but are also in themselves essential to habitat structure and many fundamental ecosystem processes, including primary production, nutrient cycling and exchange.*

E. **COMMUNITY ENERGETICS/NUTRIENT CYCLING ATTRIBUTES** - *Rationale: The acquisition, cycling and fate of energy and nutrients are critical aspects of ecosystem function, and essential to the support of native biological communities. Ecosystem attributes related to energy/nutrient movement are a combination of both abiological (e.g., water movement and circulation) and biological (trophic dynamics) factors.*

Attribute lists in each of these five categories were developed separately for each of four ecosystem-types deemed most relevant to the CALFED program: (1) upland and (2) lowland river-floodplain systems (defined respectively as those river-floodplain areas either above or within the alluvial deposits of the Central valley floor), (3) the legal Delta, and (4) greater San Francisco Bay (including Suisun Bay). The overall structural framework ("typology") used is summarized in Table 1, which is based upon systematic differences in large-scale hydrological, geomorphic, and biological features of the landscape. This has been developed through several years of discussion and refinement by a wide variety of knowledgeable individuals.

TABLE 1. A PRACTICAL BAY-DELTA WATERSHED ECOLOGICAL TYPOLOGY

<u>Ecosystem-Type/Habitat-types</u>

1. **Upland (Mountain) river-floodplain**
   a. river
      * water column
      *channel and bank
   b. floodplain
      * riparian zone
      * mountain meadows

** Associated and interactive nearby major habitat-types include: **upslope conifer forests**, and **oak woodlands** at some lower elevations)*

2. **Alluvial river-floodplain**
   a. river
      * water column
      * channel and bank
      * mid-channel islets
   b. floodplain
      * riparian forest
      * marsh
      * other (valley oak woodlands, grasslands, chapparal, wildflower fields, and vernal pools

(At elevations above the floodplain, these grade into a mixture of **valley oak woodlands, native grasslands, chapparal, wildflower fields**, and **vernal pools***

3. **Delta**
   a. intertidal wetlands
   b. subtidal waterways
      * river channels
      * large distributary sloughs
   c. supratidal landforms/riparian (mainly natural levees)
   d. non-tidal marsh

(Associated and interactive nearby major habitat-types include: **valley oak woodlands, native grasslands, chapparal, wildflower fields**, and **vernal pools***

4. **Greater San Francisco Bay**
   a. open water (pelagic)
   b. subtidal benthic
   c. tidal marsh
   d. intertidal mudflats
   e. rocky intertidal
   f. small tributary streams

(Associated and interactive nearby major habitat-types include: **valley oak woodlands, native grasslands, chapparal, wildflower fields, riparian forest** and **vernal pools***

UPLAND RIVER-FLOODPLAIN SYSTEMS
(Includes Sacramento River above Red Bluff)

I. Introduction

Upland river-riparian systems are defined as those rivers, streams and associated riparian zones that occur above the alluvial deposits comprising the Central Valley floor, which are found near the 300 ft. elevation contour. The rivers and streams included in the upland system (as defined herein) are distributed over a vast area, extending from southern Oregon southward to the Tehachapi Range at the southern end of the Central Valley, and occupying the western slopes of the Sierra Nevada and Cascade Ranges, and the eastern slopes of the Coast and Klamath ranges. These areas vary predictably and substantially in terms of annual mean temperature and total precipitation, as well as in the proportionate amounts of precipitation delivered as rain or snow. The bulk of upland waterways are located along the Sierra Nevada and Cascade ranges, at elevations ranging from about 300 - 12,000 ft. Together, these two ranges account for about 80% of total Central Valley runoff (Kattelman 1996).

As they descend from their headwaters towards the valley floor, smaller streams eventually join with others to form ever-larger tributary rivers that finally enter alluvial deposits of the valley floor. The upland portion of the watershed consists of a series of adjacent drainage basins whose streams, rivers and riparian zones share many fundamental ecological characteristics. Different workers have treated much of the region as a single "ecosystem" (e.g., SNEP 1996), or alternately a series of considerably smaller management units (i.e., ecosystems) representing particular subregions or drainages (e.g., Battle Creek, Cosumnes River, etc.). All such schemes are arbitrary; within the practical context of developing management and/or restoration programs for this region, it is probably most appropriate to rely on operational delineations of such boundaries most relevant to the scope and goals of particular programs.

River-floodplain ecosystems of the upland watershed, as defined here, are characterized by two major structural elements - the river itself, and an associated floodplain - that define primary habitat-types. The submerged portion of the channel, and the flowing waters contained therein, comprise *riverine habitat.* The adjacent lands naturally subject to river bank overflow constitutes the floodplain, an area of increased soil moisture, occupied by distinctive plant assemblages, including most notably a riparian zone and areas of marsh. These features are maintained through periodic flooding which transports water laterally across the floodplain, as well as through elevated groundwater levels. In combination, these processes result in moisture levels in surrounding soils well above those that would accrue from precipitation alone, leading to the establishment and successional development of characteristic and specialized plant assemblages that would not otherwise survive there.

In their natural states, the riverine systems of higher elevations were essentially continuous, both within this zone and with waterways of lower portions of the watershed. While flows at any given site might be altered somewhat by the formation and/or dissolution of sand or

E-036358

E-036358

gravel bars, or by accumulations of large organic debris, these represented localized, temporary, and partial obstructions. Even when landslides suddenly and completely obstructed a channel, streams eventually eroded a new channel, thereby re-establishing connectivity with lower reaches of the watershed. Thus, no physical barriers existed that were capable of completely or largely interfering, on a sustained basis, with the drainage of water (along with its loads of sediments, organic nutrients, and passively drifting organisms), or the active movement of fishes.

II. Attributes

The following represents a list of fundamental attributes that generally characterize these types of ecosystems in this geographic region. Upland river-riparian systems are distributed and extend over large geographic areas, and display considerable localized and geographic variability in many of the attributes listed below.

A. General Hydrologic Attributes

1. **Surface water present** in channels, at least seasonally

2. Variable **stream levels** (within-bank flow variability) over a variety of time scales (e.g., interannual, seasonal, weekly, daily).

3. **Periodic flooding** (occasional overbank flows), displaying high inter-annual variability

4. **Adequate groundwater exchange**, sufficient to support characteristic riparian assemblages in a corridor of natural width for this region
   Stressors: dams and other in-stream barriers, diversions, water management operations, altered bank topography

B. General Geomporphic Attributes

1. **Continuous channels** - Lack of permanent and/or complete channel obstacles or barriers to fish movement

2. **Bedrock controlled channels** predominate, with occasional reaches of localized alluvial deposits

3. **Balanced sediment budget**

4. **Dynamic channel substrates and sediment deposits** (frequent mobilization of substrates and temporally shifting gravel bars, riffles, etc.)

5. **Steep, confining topography: narrow floodplain/riparian zone** (except in localized alluvial deposits)
   Stressors: dams and other in-stream barriers, destabilized upslope topsoils, water management operations, hydraulic mining

C. Natural Habitat Attributes

Among-habitat:

1. **Natural landscape mosaic.** Sufficient habitat diversity, distribution, proportionate areal extent, and connectivity to ensure full support of native biodiversity and essential ecosystem processes

2. **"Healthy" water/sediment quality.** Range and variability of nutrients, water column dissolved oxygen, sediment DO and redox, salinity, temperature, water clarity/light penetration, turbidity and water quality (lack of biotoxicity) sufficient to support all native species and essential ecological processes

Within-Habitat:

1. **Rivers** - channels, banks and the waters contained therein
   a. **Boulder/cobble/sand** substrates
   b. **Cold water** temperatures (<14°C)
   c. **Low turbidity**
   d. **Low nutrient** (nitrate, phosphate) **levels**
   e. **High dissolved oxygen**
   f. **High hydrodynamic complexity** (many pools, riffles, cataracts)
   g. **Abundant large woody debris** in channels

2. **Floodplain** - distinctive plant assemblages supported by increased moisture levels due to proximity of streams
   a. **minimal lateral extent**, increasing in localized alluvial deposits
   b. riparian forest **composition** is mixture of high-disturbance adapted species (willows, cottonwoods) and conifers typical of upslope forests but in higher density
   c. **All successional stages present**, from saplings to old-growth conifers
   d. **Continuous riparian corridor,** extending over large stretches
   e. **Mountain meadows** - formed in localized alluvial deposits

<u>Associated/Interactive Habitats</u>

a. **Upslope forest** - forest areas beyond riparian zone
b. **Oak woodlands** (lower elevations only)

Stressors: land management practices (timber, mining agriculture), road building, urbanization, dams and diversions

D. Native Biological Community Attributes (Community Structure)

1. Natural abundance/distribution patterns of:

Major Components	Dominant group(s)/comments
Riverine Habitat	
a. plants	phytoplankton rare; benthic algae low, but increasing in lower reaches
b. invertebrates	crustaceans (isopods, amphipods) and aquatic insects abundant and diverse
c. fishes	general species composition variable with elevation, gradient, and water temperature. Three fish "zones" recognized; presence of anadromous salmonids (some streams)
d. amphibians	frogs, salamanders dominate fishless areas, mainly at higher altitudes (>6,000 ft.)
Floodplain Habitat	
a. plants	mixture of high-disturbance (willow, cottonwood) and low-disturbance (forest conifers) adapted trees, shrubs, and herbaceous species
b. insects	high diversity/abundance relative to upslope forest areas; high abundance of aquatic-dependent species
c. birds	high diversity relative to upslope forest areas; high use by neotropical migrants
d. amphibians	high diversity relative to upslope forest areas, may constitute high proportion of vertebrate biomass in some areas
e. reptiles	poorly known; difficult to assess
f. mammals	high diversity relative to upslope forest areas

E. Community Energetics/Nutrient Cycling Attributes

1. Most of system biomass derived from primary production within riparian zone

2. Most decomposition occurs within riparian zone

3. **Low in-stream primary productivity**; riverine habitat highly dependent upon regular transfer of energy from riparian zone

4. Large seasonal influx of nutrients to riverine habitat in the form of salmon carcasses (some streams), and flushing of riparian zone by flood events

E —0 3 6 3 6 2

E-036362

LOWLAND RIVER-FLOODPLAIN SYSTEMS
(Includes Sacramento River below Red Bluff)

I. Introduction

The Sacramento and San Joaquin Rivers, along with the portions of their tributaries that traverse the alluvial valley floor, were naturally flanked by extensive floodplains that supported extensive riparian forests and wetlands. These elements - rivers, riparian forests, and wetlands constitute the major habitat-types of the Sacramento and San Joaquin Valley river-floodplain ecosystems. Riparian forest is naturally most common immediately adjacent to the rivers, and also along natural levees. Wetlands dominated low-lying areas - primarily backwater areas extending laterally from the main channels, and the floodbasins. Together, these two habitat-types encompass the vast majority of frequently inundated areas of the floodplain.

Extending upland from the outer margins of the forests and wetlands, or occurring sporadically in drier "pockets" within these habitats, were two more mesic plant associations - valley oak woodlands and native grasslands. These terrestrial ecosystems interacted with river-floodplain systems in several particularly notable ways. First, they provided essential habitat support to enormous populations of large, wide-ranging mammals - antelope, elk, etc. - that regularly visited the river-riparian systems, thereby forming an ecological connection among aquatic and terrestrial systems of the Central Valley through which energy and nutrients were regularly transferred. Secondly, because they immediately adjoined more frequently inundated habitats but were somewhat higher, they undoubtedly served as critical refuges for many ground nesting animals (reptiles, mammals, and birds) during flood events that temporarily submerged marshplains and forest floors. Interspersed within these major features of the landscape were a number of somewhat more restricted habitat features such as chaparral, wildflower fields, and vernal pools, each occupied by somewhat distinctive biological assemblages.

Lowland rivers are distributed across a vast area covering thousands of square miles of the Central Valley. This does *not* include the Redding Basin, which is considered part of the "upland" system described above.

The Sacramento Valley is drained by the Sacramento River, which enters the alluvial lowlands of the Valley near Red Bluff. Above Red Bluff, the Sacramento River collects water from the east side of the Klamath Ranges as well as drainage from the Cascade Range and the Modoc Plateau, a spring-fed area of volcanic rock east of the Cascades. From Red Bluff to its mouth near Collinsville, the lowland portion of the Sacramento River traverses about 245 miles of the Central Valley. The largest tributaries to this portion of the Sacramento are the Feather River (which is joined by the Yuba and Bear Rivers in the lowlands) and the American River, both of which mainly originate in the Sierras (except for two streams that collect water from the southern Cascades). A number of smaller

E-036363

E-036363

tributaries draining the Cascades (e.g., Butte, Deer, Mill, and Antelope Creeks) enter the Sacramento River north of its confluence with the Feather River. Tributaries draining the Northern Coast Ranges (e.g., Elder, Cache, Putah Creeks) contribute a relatively minor (about 8% of the average annual inflow) portion of the total inflow to the Sacramento River.

On the southern (San Joaquin) side of the Valley, the San Joaquin Basin is drained by the San Joaquin River. This river originates in the Sierras and enters the Central Valley in the vicinity of Fresno. From here, the river flows 267 miles to its mouth in the Delta, where its outflow joins that of the Sacramento River. The major tributaries to the San Joaquin — the Merced, Tuolumne, and Stanislaus Rivers — also originate in the Sierra Nevada. The Mokelumne, Cosumnes and Calaveras Rivers (or "eastside tributaries") may also be considered part of the San Joaquin Basin drainage because they flow into branches of the San Joaquin River in the Delta, *before* its junction with the Sacramento. Several small streams drain the Coast Ranges to the west of the San Joaquin Basin, but these are intermittent and generally do not discharge into the main channel of the San Joaquin River.

In the southern third of the San Joaquin Valley, Tulare Basin runoff was historically collected in terminal lakes on the basin floor. The Kings, Kaweah, and Tule Rivers historically flowed into Tulare Lake. The Kern River flowed into Kern and Buena Vista Lakes, which often discharged to Tulare Lake. During high water stages, Fresno Slough temporarily connected the two basins by establishing a hydrologic link between the San Joaquin River and Tulare Lake. The Kings River flows atop the alluvial fan that separates the San Joaquin and Tulare Basins.

The lowland rivers of the Central Valley change in character as they emerge from the foothills of the surrounding mountain ranges and approach the main axis of the valley floor. As they first enter the lowlands, the tributaries to the Sacramento and San Joaquin rivers, along with more upstream portions of those major rivers themselves, traverse a transitional zone between the bedrock-dominated "*erosional zone*" of the upland systems and the comparatively flat "*depositional zone*" that characterizes floodplains of the valley floor. Because of its intermediate position, this region is sometimes referred to as a "*zone of transport*".

In general, the zone of transport is characterized by rivers that run swifter and deeper, and are more turbulent and complex than further downstream in depositional zone. Distinctive hydrologic and geomorphic characteristics of waterways in this zone lead to some ecologically distinctive attributes. In this intermediate region, where vertical gradients are relatively high (1-2%), river channels migrate back and forth in a sinuous pattern across their floodplains in a process called "active meandering." This results in comparatively high structural diversity, with "oxbow cutoffs" and backwater areas branching off from the main channel (Figure II-4). The latter encompasses side channels, distributary channels, sloughs, and other backwater areas of the main river channel. Side channels are small channels branching off the main stem. They are typically abandoned river channels or overflow channels on the floodplain or on low terraces near the main stem. Distributary channels are channels that branch off the main stem and flow into the estuary as separate channels.

Sloughs are side channels or distributary channels characterized by minimal flows. They therefore generally maintain pool or pond-like characteristics, although relatively high velocities may occur during large floods (Beechie et al. 1994).

As the rivers approach the base of the valley floor, slopes become more gentle (<1 %) and a depositional zone (low-gradient floodplain) results. Rivers here have higher natural channel sinuosity, but lower rates of meander migration than those found further upstream (Fischer 1994). Here also, the main river channel beds gradually shift from mainly gravel to mostly sand, and river banks naturally take the form of laterally extensive depositional levees. As they flow downstream, lowland rivers become increasingly warmer, more turbid, lower in oxygen and richer in nutrients. In the lowest reaches, as the great rivers approach their mouths in the Delta, benthic substrates incorporate increasingly finer sediments - muds and silts - that settle out of suspension only after the river slows. In the depositional zone, only accumulations of large woody debris (LWD) provide the physical structure needed to create topographic and hydrodynamic complexity, and vary the otherwise (except during floods) slow, uniform flow. In the comparatively wide channels characteristic of this region, LWD may cause local scour and channel migration, as well as trapping sediments (Somers et al. 1991).

In some locations the lowland rivers were entirely contained within a single channel, while in other places the flow was split into networks of secondary or overflow channels, or distributary sloughs. The presence and complexity of these ancillary channel networks was largely dependent on the gradient and depositional processes of a particular reach. Areas with particularly complex channel networks included the tributaries where they emerged from the Sierran foothills, the San Joaquin between Firebaugh and the Merced River, the Sacramento "zone of transport", and the mouths of the Sacramento and San Joaquin Rivers.

In their natural states, the riverine systems of the Central Valley channels formed vast, interconnected networks of main and side (including marshplain) channels. While flows might be altered by natural obstructions such as shoals, bars, or accumulations of organic debris, these represented highly localized, partial, and in most cases temporary obstructions. No physical barriers existed that were capable of largely or completely blocking the drainage of water (along with its loads of sediments, organic nutrients, and passively drifting organisms), or inhibiting the natural movements of fishes.

II. Attributes

The following represents a list of generally applicable attributes that characterize these ecosystems. However, these systems extend over a very large geographic area, within which the attributes listed below display considerable localized and geographic variability.

A. General Hydrologic Attributes

1. **Some surface water *always* present** in channels

2. Pronounced **seasonal shifts in river levels** and flow magnitude/velocity (within-bank flow variability) over a variety of time scales (e.g., interannual, seasonal, weekly, daily).

3. **Periodic flooding** (occasional overbank flows), with high interannual variability. Occasional inundation of riparian zone of sufficient extent and duration to support full successional development and all life stages of native plants and animals.

4. **Hydrodynamic complexity** (pools, riffles, etc.) higher in meander zone, decreasing towards Delta. Depositional zone characterized by slow, uniform flows

5. **Adequate groundwater exchange**, sufficient to provide natural riverine warer temperature regime and to support riparian zone of natural width for this region

6. **Floodbasin storage and release** (Sacramento Valley only) provides "buffering" of peak flows
   Stressors: dams and other in-stream barriers, altered bank topography (unnatural levees), diversions, water management operations

B. General Geomorphic Attributes

1. **Continuous channels** - Lack of permanent and/or complete channel obstructions or barriers to fish movement

2. **Active channel migration and floodplain construction.** Rates should be consistent with natural, but vary considerably with vertical gradient. Unrestricted corridor available for meandering and floodplain deposition.

3. **Occasional "backwater" areas** (sloughs, side-channels, ox-bow lakes, etc.) present and connected to main river channels

4. **Floodplain/Floodbasin connectivity with channel.** Lack of unnatural barriers to floodplain inundation during "normal" overbank flow events (flood basin Sacramento side only)

5. **Balanced sediment budget.** Over long term, river reaches should accrue no net loss or gain of sediment

6. **Dynamic channel substrates and sediment deposits** (frequent mobilization of substrates and temporally shifting gravel bars, riffles, etc.)

7. **Flat, non-confining topography: wide floodplain/riparian zone**

E-036366

E-036366

8. **Seasonally Variable Turbidity:** seasonal flow-related increases in turbidity of appropriate magnitude, timing and duration to provide migratory cues and protection to anadromous fishes
Stressors: land-use practices (particularly agriculture), channelization of rivers, unnatural levees, dams and diversions, water management operations

C. Natural Habitat Attributes

Among-habitat:

1. **Natural landscape mosaic.** Sufficient habitat diversity, distribution, proportionate areal extent, and connectivity to ensure full support of native biodiversity and essential ecosystem processes

2. **"Healthy" water/sediment quality.** Range and variability of nutrients, water column dissolved oxygen, sediment DO and redox, temperature, water clarity/light penetration, turbidity and water quality (lack of biotoxicity) sufficient to support all native species and essential ecological processes

Within-Habitat:

1. **River** - channels, banks and the water contained therein. Includes "littoral zone" (used in this context to refer to the within-bank area alternately submerged and exposed by shifting stream levels), and small point bars and mid-channel islets, sometimes supporting high-disturbance riparian plant assemblages

   a. **"Zone of transport"** located in upstream, higher gradient reaches characterized by comparatively lower temperatures, turbidity, nutrient concentrations, gravel/sand substrates
   b. **"Depositional zone"** located in lower gradient reaches (towards Delta) characterized by increased water temperatures, turbidity, nutrient (nitrate, phosphate) levels, and sand/mud substrates
   c. **Large woody debris** common in channels
   d. **Natural levees** formed in some sections
   e. **Variable benthic topography**, on both local and regional scales. Sufficient to provide depth, flow, and photic variability necessary to all life stages of native species
   f. **Islets and point bars** formed by mobilized sediments present
   g. **Occasional backwater sloughs**, associated subhabitats present and connected to main river channels

2. **Floodplain** - specialized plant assemblages flanking the river (dependent upon increased moisture levels due to proximity to river/overbank flows). Riparian zone dominates low terraces adjacent to river and natural levees. Marsh (tules and other emergent vegetation) dominating low-lying areas adjacent to levees, backwater areas and/or floodbasins.

a. Riparian forest/woodlands.

* **Vertical terracing** of nearby floodplain, corresponding to 1-year (low terrace) and 2-5 year (high terrace) floodplains. Two distinct assemblages commonly present: (1) low-terrace cottonwood willow bordering channel, and (2) high-terrace oak-dominated assemblage extending further from channel

* **Multi-layered forest structure**, with well-developed canopy, high tree density. Highly variable in width (averaging 2-4 miles in many areas), composition, and tree density.

b Wetlands (Marsh):

* high density of emergent vegetation
* complex of drainage channels and other marshplain subhabitat features present
* water movement slow, benthic macrophytes/duckweed present

c. Other floodplain habitats (chaparral, wildflower fields, vernal pools, valley oak woodloands, grasslands)

Stressors: Land-use practices, river channelization, levee building, urbanization, dams and diversions, water management operations, pollution

D. Native Biological Community Attributes (Community Structure)

Major Components	*Dominant group(s)/comments*
Riverine Habitat	
1. plants	gradual downstream shift in dominants from benthic algae to phytoplankton (diatoms)
2. invertebrates	aquatic insects (pelagic); mollusks, crustaceans, worms (benthic)
3. fishes	combination of freshwater and anadromous forms. different assemblages characterize backwater and main channels
Riparian Habitat	
1. plants	distinctive assemblages of trees shrubs grasses and vines, with high tree density and canopy formation. Low terraces dominated by specialists (willow, cottonwood); high terraces dominated by generalists (mainly oak)
2. insects	high diversity relative to upslope habitats
3. birds	high diversity relative to upslope habitats

4. amphibians and reptiles	high diversity relative to upslope habitats
5. mammals	high diversity of small resident species and frequent visits by large, wide-ranging species

Wetland Habitat

1. plants	tules, wet prairies (grasses and forbs)
2. birds	rich, particularly wintering waterfowl
3. others	variety of insects, fishes, amphibians, reptiles and mammals

Stressors: Land-use practices, river channelization, levee building, urbanization, dams and diversions, water management operations, pollution

E. Community Energetics/Nutrient Cycling Attributes

1. Most of ecosystem production occurs within riparian and wetland habitat

2. Most decomposition occurs within riparian and wetland habitat, particularly in floodplain groundwater

3. In-stream primary productivity higher than upland rivers; still highly dependent upon regular transfer of energy from riparian zone. Seasonal phytoplankton "blooms" common in more downstream reaches

4. Large seasonal influx of nutrients to riverine habitat from flushing of riparian zone by flood events

Stressors: clearing of riparian forest, grazing, pollution, dams and diversions, water management operations, urbanization

THE DELTA

I. Introduction

The Delta is the easternmost (upstream) portion of the estuary, and today is clearly delimited by a legal boundary that includes areas that historically were intertidal, along with supra-tidal portions of the floodplains of the Sacramento and San Joaquin Rivers. It is a flat, roughly triangular area extending to the northeast and southeast from Chipps Island (the legal western boundary of the Delta - about 4 miles west of the confluence of these rivers). Today's legal Delta extends between the upper extent of the tidewater (near the city of Sacramento on the Sacramento River and Mossdale on the San Joaquin River) and Chipps Island to the west, and encompasses the lower portions of the Sacramento and San Joaquin river- floodplain systems as well as those of some lesser tributaries (Mokelume, Calveras Rivers). The Sacramento and San Joaquin Rivers enter the Delta from the north and south respectively, where they join and together discharge their contents near the western margin of the Delta.

For most of its geologic history, the Delta was an unusually dynamic environment. The attributes described here refer to structural and functional characteristics of the region as it appeared around 1850, the earliest historic period for which sufficient information is available to provide such a description. At the time of the early European explorers, the Delta was largely a vast, sea-level swamp, composed mostly of large tracts of intertidal wetlands transected by a complex network of waterways of varying size (Thompson 1957). Three major "depositional environments" of the historic (circa 1850) Delta also define the system's major habitat-types: intertidal wetlands, subtidal waterways, and elevated (supratidal) landforms (mainly levees) which typically supported riparian vegetation (Atwater and Belknap 1980). Around the historic Delta's intertidal perimeter, tidal wetlands merged gradually into non-tidal wetlands, and further upland into oak woodlands and grasslands dotted with vernal pools.

The natural connectivity among Delta habitats was maintained by water movement, and the movement and activities of organisms. Although somewhat isolated by high natural levees, the larger river channels were nonetheless intermittently connected to nearby intertidal wetlands by a series of distributary channels that occasionally joined the river channels. Water also periodically overflowed the levees, creating an additional hydrological link with the surrounding wetlands. Much of the abundant wildlife of the area moved among habitats, feeding in one area and resting (or being preyed upon) in others. These processes promoted the regular exchange of nutrients and energy among major habitat-types of the Delta. With the exception of some of the elevated landforms (e.g., sand mounds, alluvial ridges, point bars) and their riparian vegetation, the intertidal wetlands existed as comparatively large, continuous areas, with few natural barriers to the movement of water, sediment or organisms.

E —0 3 6 3 7 0

E-036370

II. Attributes

A. General Hydrologic Attributes

1. **Water levels variable daily and seasonally**, determined generally by interactions of freshwater inflow and tides, and locally by the interactions of these factors with topography. Typically high during winter/spring and low during summer/fall. During flood events, most of the delta could be covered by 10-15 feet of water. Seasonal inundation of wetland vegetation of sufficient extent and duration to provide spawning, rearing and refuge habitat for native fish species (e.g., Delta smelt, splittail)

2. **Complex water circulation/movement patterns** determined by interactions of "natural" patterns of river discharge, tides and local topography. Net movement of water generally "downstream" (towards Bay), temporarily and regularly interrupted by incoming tide.

3. **Salinity gradient seasonally variable**, due to seasonal differences in river discharge and local precipitation. Water generally fresh throughout "wet" season (December-June), with regular seasonal incursion of slightly brackish (~1-2ppt) water into western Delta during "dry" season (August-October). Greater incursion of brackish water could occur during severe drought or extremely dry years.

Stressors: Diversions, impoundments (dams and levees), unnatural barriers, channelization of rivers, rock rip-rap and other water management actions.

B. General Geomorphic Attributes

1. **Extremely flat topography**, with few places exceeding level of wetland plain by more than ten feet.

2. **Highly channelized topography,** with network of waterways of varying dimension branching throughout

3. **Riverine channels geomorphically/hydrologically connected to wetlands,** continuously by distributary channel system, and intermittently by levees low enough to be regularly topped during flood events.

4. Natural sediment production and acquisition resulting in **net soil accretion at a rate comparable to sea level rise** rate, resulting in negligible net change in sea level. Sediment delivery from external sources occurs mainly during large flood discharges from the Sacramento River.

Stressors: diversions, impoundments (dams and levees), unnatural barriers, channelization of rivers, rock rip-rap, recreational boating, and land use changes such as conversion to agriculture and urban development.

E—036371

E-036371

C. Natural Habitat Attributes

Among-habitat:

1. **Natural landscape mosaic.** Sufficient habitat diversity, distribution, proportionate areal extent, and connectivity to ensure full support of native biodiversity and essential ecosystem processes

2. **"Healthy" water/sediment quality.** Range and variability of nutrients, water column dissolved oxygen, sediment DO and redox, salinity, temperature, water clarity/light penetration, turbidity and water quality (lack of biotoxicity) sufficient to support all native species and essential ecological processes

3. Because the Delta is transitional between freshwater and brackish/marine systems, it contained an **unusually high concentration of biodiversity apparent in many taxa**

Within-Habitat (I): Tidally Influenced Area

1. **Intertidal Wetlands** - complex, swamp-like mosaic of sub-habitats, including areas dominated by emergent vegetation, smaller tidal drainage channels, shallow lakes, ponds and pools, and mudflats

   a. Minimal topographic relief

   b. high overall plant diversity (over 40 native species), with tule marsh dominant in many areas

   c. Substantial seasonal variability in average level of inundation

   d. fresh water conditions generally prevail, but seasonal incursions of slightly brackish water not unusual

   e. Sediment composition mainly organic (peat) with minor but necessary (for stabilization) inorganic contribution

2. **Subtidal Waterways** - includes two major types (riverine channels and distributary sloughs), each composed of three general sub-habitats: water column, benthic, and littoral zone (within-bank area alternately submerged and exposed by changing water levels)

   a. Riverine channels: Net one-way, downstream water movement controlled primarily by river discharge. Comparatively high velocity, low residence time, minimal benthic vegetation, low plankton concentrations

E-036372

E-036372

b. Distributary Sloughs: Bidirectional water movement controlled mainly by tides. Comparatively low velocity, high residence time, well-developed benthic vegetation, higher plankton concentrations

3. **Riparian/other elevated (supratidal) landforms within subtidal/intertidal areas**
   a. occupied by plant and animal assemblages generally typical of Central valley river riparian zones

   b. frequently topped by floods, resulting in a high-disturbance, successional habitat

Within-Habitat (I): Tidally Influenced Area

1. **Riverine Channels** - see description: Lowland (Alluvial) River-Floodplain Systems (Section II; above)

2. **Non-tidal Wetlands** - see description: Lowland (Alluvial) River-Floodplain Systems (Section II; above)

3. **Riparian Zone** - see description: Lowland (Alluvial) River-Floodplain Systems (Section II; above)

Associated/Interactive Habitats (Delta Uplands)

1. native (largely perennial) grasslands
2. oak woodlands
3. chaparral
4. vernal pools
5. wildflower fields
6. dune scrub

Stressors: dams and diversions, unnatural levees, unnatural barriers, dredge-fill activities, and urban/suburban and agricultural land use modifications. Water quality is affected by toxic contaminants from agriculture, urban runoff, recreational boating

D. Native Biological Community Attributes (Community Structure)

(Note: Because most larger animals (many insects, fishes, birds, reptiles, amphibians, mammals) commonly used several or all major habitat-types, biological assemblages are described here for the ecosystem as a whole rather than by habitat-type as has been done for other ecosystem-types)

1. **Natural abundance/distribution patterns of:**

E—036373

E-036373

Major Components	Dominant group(s)/comments
a. plants	**Wetlands:** tule (*Scirpus actus*), common reed (*Phragmites australis*) and cattail most common emergent plants; **Riparian zone**: species typical of Central Valley river riparian areas, including coarse bunch grasses, willows, oak, sycamore, alder, walnut and cottonwood, blackberry and rose thickets; **Major waterways:** duckweed and benthic macrophytes common in areas of low water movement; phytoplankton likely dominated by diatoms
b. invertebrates	Mosquitos abundant and ubiquitous, other insects, benthic invertebrates; zooplankton dominated by ciliate protozoans, rotifers, copepods, and cladocerans
c. fishes	mixture of native resident estuarine (e.g., Delta smelt) and freshwater forms, and anadromous species
d. birds	extremely rich waterfowl assemblage, many others
e. mammals	diverse assemblage of small and large mammals, including tule elk, grizzly bear, beaver, river otter, bobcat, raccoon, mink, skunk. Many more species around drier periphery of swamps

Stressors: Exotic species, diversions, impoundments (dams and levees), unnatural barriers, channelization of rivers, rock rip-rap, recreational activities (boating, fishing, hunting), land-use practices (agriculture, road building), and urban development.

E. Community Energetics/Nutrient Cycling Attributes

1. **Most** of ecosystem **primary production is within wetland** habitats
2. **Most decomposition occurs within tidal and non-tidal wetland** habitats
3. **Detrital chain dominates** Delta energy cycling and transfer
4. Large amounts of **detritus exported** to San Francisco Bay

Stressors: Exotic species, land-use practices (agriculture) and urban development pollution; modification of natural topography (levees, subsided marshplains)

GREATER SAN FRANCISCO BAY

I. Introduction

Greater San Francisco Bay, as defined herein, is that part of the estuary lying between Chipps Island and the Golden Gate. This includes four major embayments - Suisun Bay, San Pablo Bay, Central Bay and South Bay.

The general structure of San Francisco Bay is that of a series of embayments, each containing a central expanse of open water overlying subtidal sediments, and ringed by intertidal wetlands, mudflats, and/or rocky shores. These different kinds of areas constitute the major distinctive habitat-types of the ecosystem. Hydrologically, the Bay may be divided into two broad subdivisions with differing ecological characteristics: a *southern reach* consisting of South Bay, and a *northern reach* composed of Central, San Pablo, and Suisun Bays (Cohen 1991). The southern reach receives little freshwater discharge, leading to high salinity and poor circulation (high residence time). It also has more extreme tides. The northern reach, which directly receives Delta outflow, is characterized by less extreme tides and a pronounced horizontal salinity gradient, ranging from near full marine conditions in Central Bay to near fresh water conditions in Suisun Bay. Central and Suisun Bays contain sizeable islands, features not present in San Pablo and South Bays.

The extent (surface area) of open water circa 1850 was estimated by Atwater et al. (1979) to cover about 1100 km2. Suisun, San Pablo, and South Bays have an average depth of 3-4 m, but are incised by deep, narrow channels (typically 10-20 m depth) maintained by river and tidal scouring (Nichols & Pamatmat 1988; Conomos et al. 1985). Central Bay, located near the City of San Francisco, is a comparatively deep basin immediately adjacent to the ocean, with an average depth of about 11 m, about three times that of the other embayments. Because of its greater depth, Central Bay also contains the largest water volume, even though its surface area is less than half that of South Bay.

Each of the four embayments that constitute San Francisco Bay historically consisted largely of the same basic habitat elements - a central expanse of open water bordered by intertidal mudflats and marshes. However, each also represents a structural subdivision with somewhat different ecological properties from the others in terms of such factors as depth and salinity characteristics, tide levels, mixing processes, distribution and extent of habitats, etc. The deepest area of the entire estuary is the heavily scoured channel that traverses the Golden Gate; depths here exceed 100 m.

The water column in the Bay's northern reach is naturally characterized by complex salinity and density characteristics. The fresh waters discharged into the estuary from the watershed's major rivers are lighter (less dense) than ocean water carried in on the tides. At the interface where the two water masses meet (called the *mixing zone*) they do not readily or completely mix. Rather, the fresh water tends to form a surface layer that overrides the heavier sea water, resulting in a vertical salinity gradient that is more pronounced at times of

E—036375

E-036375

greater river discharge. The location of the mixing zone is determined by the relative magnitude of river discharge and tidal influence; thus, it moves back and forth twice a day a distance of about 2-6 miles with the advance and retreat of the semi-diurnal tide. Except during extreme high or low river discharge periods, the mixing zone was naturally located in Suisun Bay, a shallow area characterized by numerous islands and extensive wetlands along its northern shore.

On the other side of Carquinez Straits, San Pablo Bay formed an expanse of shallow open water with extensive mudflats and marshes extending along its northern borders. Due to its depth, structural characteristics, and proximity to the ocean, Central Bay maintains the most marine-like environement of the four embayments, and is largely inhabited by species common to marine coastal areas of Central California. Historically, Central Bay was bordered by mudflats and marshes along its southeastern and western boundaries. It is the only one of the four embayments to contain substantial reef-like outcroppings of bedrock below the surface. These areas support comparatively (in relation to areas of the Bay floor covered by unconsolidated sediment) diverse assemblages of fishes, seaweeds, and intertidal invertebrates (Ricketts and Calvin 1956).

The southern reach (South Bay) receives far less fresh water runoff, and thus, except under conditions of unusually high river discharge, does not generally exhibit the type of estuarine circulation described above for the northern reach. Salinity here is characteristically high, often close to that of the nearshore ocean, and seldom displays vertical gradients. South Bay is also characterized by much higher residence time of water, and on average is flushed at about one-fourth the rate of the northern reach. Most of this exchange is naturally concentrated during the "wet" season of high river discharges.

II. Attributes

A. General Hydrologic Attributes

1. **Variable freshwater inflow (seasonally and interannually)** in terms of both quantity and timing. Predominate source (~90%) is from Delta; some inflow also provided by smaller, peripheral streams (e.g. , Napa River, Petaluma River, etc.). Generally highest in winter/spring; lowest late summer/early fall.

2. **Complex and highly variable water circulation/movement/mixing patterns,** determined by complex interactions of "natural" patterns of river discharge, wind, tides, local topography, tidal prism, and water mass characteristics. Net movement of water, dissolved substances, and suspended particulates generally "downstream" (towards Golden Gate), with instantaneous direction of movement reversible with tides. Large tidal range relative to average water depths. Complex geomorphology creates local variation in tide elevation and range. South Bay characterized by considerably less stratification and higher residence time. Seasonally variable low-salinity "plume" (surface layer) extending to Farallon Islands during flood events

3. **Horizontal salinity gradient seasonally variable**, due to seasonal differences in river discharge and local precipitation. Mixing zone generally found in Suisun Bay, but also sometimes found upstream (Delta) or downstream (San Pablo Bay) under particularly dry or wet conditions. Marine-like conditions (less variability) generally prevail in South and Central Bays.

Stressors: Upstream dams and diversions, unnatural levees and other barriers, unnatural channelization of waterways, water management actions, dredging and filling activities.

B. General Geomorphic Attributes

1. Embayments generally characterized by **broad shallows (≤ 3 m deep) incised by narrow channels** typically 10-20 m deep. Average depth 6 m at mean low water. Topography variable by embayment: Suisun Bay is shallowest, Central Bay deepest.

2. **Sediment accretion rate comparable to sea level rise rate, so that there is minimal net change in sea level.** Main source is Delta; some sediments obtained from smaller local watersheds. Delivery occurs mainly during large flood discharges from the Sacramento River. Sufficient accretion rate to maintain intertidal wetland and mudflat habitats. Sediments comprised mainly of silt and clay, except in deep channels and deeper parts of Central Bay (sand substrates).

Stressors: upstream land-use practices, urbanization of Bay margins, all water management actions affecting freshwater inflow and sediment delivery

C. Natural Habitat Attributes

Among-habitat:

1. **Natural landscape mosaic.** Sufficient habitat diversity, distribution, proportionate areal extent, connectivity and range of successional states to ensure full support of native biodiversity and essential ecosystem processes

2. **"Healthy" water/sediment quality.** Range and variability of nutrients, water column dissolved oxygen, sediment DO and redox, salinity, temperature, water clarity/light penetration, turbidity and water quality (lack of biotoxicity) sufficient to support all native species and essential ecological processes

Within-Habitat:

1. **Open Water (Pelagic)** - water column overlying all subtidal areas. Deep and shallow areas distinguished.
   a. Depth, salinity, tidal range, other characteristics variable with embayment.
   b. Generally shallow photic zone
2. **Subtidal Benthic** - all substrates submerged even at lowest of tides.
   a. Most areas are shallow, unvegetated mud (silt/clay)
   b. Other minor subhabitats include: deeper channels, seagrass/macroalgae (vegetated unconsolidated substrate)), and rock outcropppings (Central Bay) providing some overall habitat complexity

3. **Intertidal Wetlands** (Marsh) - complex mosaic of marsh sub-habitats within tidal range
   a. Dominant emergent vegetation assemblage composition and diversity variable with salinity
   b. Density of emergent vegetation stands highly variable, ranging in height from 0-6 ft.
   c. Pronounced vertical zonation present (see Josslyn 1983; Atwater 1980)
   d. complex marshplain structure, with drainage channels, small mud flats, ponds and pools

4. **Intertidal Mudflats** - unvegetated unconsolidated sediments within tidal range
   a. minimal vertical relief
   b. mainly silt/clay composition (~80% typical), mixed with sand, organic debris and shell fragments
   c. generally devoid of macroscopic plants

5. **Rocky Intertidal** - consolidated substrates within tidal range (low areal extent, but very high biodiversity)
   a. complex micro-topography
   b. stabilized substrate provides attachment sites for plants and invertebrate animals not found on unconsolidated substrates
   c. very high concentrations of biodiversity

6. **Seasonal (Non-tidal) Wetlands** - mosaic of sub-habitats found in low-lying areas around the margins of the Bay, including emergent vegetation, smaller freshwater drainage channels, and shallow water (temporary pools and ponds) above the reach of highest tides. Sustained by groundwater, proximity to streams, and/or seasonal precipitation. Structure and vegetative assemblages highly variable.

Associated/Interactive Habitats (Bay Uplands)

1. native (largely perennial) grasslands
2. oak woodlands
3. chaparral
4. vernal pools
5. wildflower fields
6. riparian

Stressors: exotic organisms, wildlife and fish harvest, water diversions, other water management actions affecting river discharge patterns, unnatural barriers, dredge-fill activities, urbanization, agricultural land use modifications. Water quality is degraded by agricultural and urban runoff, pollutants in Delta discharge, and offshore pollution.

D. Native Biological Community Attributes (Community Structure):

1. Natural abundance/distribution patterns of:

Major Components	Dominant group(s)/comments
Open Water Habitat	
a. Phytoplankton	dominated by diatoms; seasonal "blooms"
b. Zooplankton	dominated by copepods, other crustaceans, rotifers
c. Fishes	diverse mixture of marine, estuarine and freshwater forms present; some are full-time residents, others part-time visitors. Shallow and deeper water assemblages differ.
d. Birds	diverse and abundant seabirds and waterfowl
e. Marine Mammals	sea otters, harbor seals, porpoises common
Subtidal Benthic Habitat	
a. plants	Benthic microalgae/blue-green algae assemblage: diatom dominated. Some seagrass (eelgrass) and macroalge present at localized sites.
b. invertebrates	bivalve mollusks (clams, oysters, mussels) and crustaceans (crabs, shrimp, crayfish) abundant; diversity of small filter and detrital feeders also present
c. fishes	benthic/demersal fish assemblages varied with embayment: Central and South Bays dominated by marine species; Suisun Bay by freshwater and estuarine fishes; San Pablo by a mixture of these types
Intertidal Mudflats	
a. plants	Edaphic microalgae assemblage dominated by diatoms, blue-green algae, flagellates.
b. Invertebrates	Deposit feeding invertebrates dominate, including amphipods, isopods, gastropods, worms, crabs. Some filter-feeding invertebrates present
c. Foraging birds/fish	Heavily used as foraging area by shorebirds (avocets, plovers, sandpipers, dowitchers, etc.) and some benthic/demersal fishes at high tide

Tidal Marsh

a. plants	diverse and variable assemblages of emergent vegetation, mainly grasses, sedges, rushes, succulents. Species diversity inversely correlated with salinity, decreasing from Delta to Bay.
b. invertebrates	three major groups: epifauna (crabs, amphipods, gastropods), infauna (worms, etc.), arthropods on vegetation (insects and spiders).
c. fishes	variable with salinity; Estuarine/freshwater and marine assemblages recognized
d. birds	waterfowl (many wintering), wading birds, shorebirds. Most are migratory.

Rocky Intertidal

a. plants	diversity of red, brown, green macroal;gae (seaweeds)
b. invertebrates	high diversity of characteristic species (see Ricketts and Calvin 1956)
c. fishes	habitat for rock-reef fishes

Stressors: exotic organisms, wildlife and fish harvest, water diversions, other water management actions affecting river discharge patterns, unnatural barriers, dredge-fill activities, urbanization, agricultural land use modifications. Water quality is degraded by agricultural and urban runoff, pollutants in Delta discharge, and offshore pollution.

E. Community Energetics/Nutrient Cycling Attributes

1. Organic and inorganic nutrient transport into the Bay ecosystem primarily from the Delta.

2. Net transport of organic carbon from marshes to mudflat, benthic, and pelagic habitats.

3. Primarily detrital based food chain in benthic, marsh, and mudflat habitat; secondarily filter feeding web in unvegetated benthic and mudflat.

4. Primarily grazing food chain in pelagic (water column) habitat.

Stressors: Exotic species, nutrient runoff from nearby agriculture and urban discharges, pollution; harvest, conversion of most of Delta from wetlands to agriculture, increased turbidity