

Suisun Marsh Tidal Marsh and Aquatic Habitats Conceptual Model

Chapter 4: Species

**FINAL REVIEW DRAFT
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Suisun Marsh Habitat Management, Restoration and Preservation Plan

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4 Species

This chapter presents a series of brief conceptual models for several target species and guilds of tidal marsh and aquatic open water habitats in Suisun Marsh. Species selected for these conceptual models are those identified as species of concern or of management interest. This chapter describes how the key physical and ecological processes discussed in the previous chapters influence each species at one or more points in their life histories. It describes the ecological functions that tidal marsh restoration provides at each stage along the evolutionary trajectory from when restoration begins to years in the future; for many species, those functions change with stage of development. This model makes the assumption that a geographic matrix of multiple restoration areas implemented at different times and each evolving at different rates according largely to their location will result over the longer term in the broadest number of species supported, each at relatively high population abundances.

4.1 Species of Concern for Suisun Marsh Tidal Marshes and Aquatic Open Water Environments

Table 4-1 below lists all species of concern for tidal marshes and open water environments to be restored within Suisun Marsh.

Table 4-1. Conservation Status and Habitat Functions, Suisun Marsh Species

| | Species | | Conc Model | Listing Status | | Tidal Aquatic | | | | Tidal Marsh | | | | |
|----------------------|--|------------------------------------|------------|----------------|-------|-------------------------|------------------------------|---------------------|--------------------------|----------------|-----------|-----------|------------|-------------------|
| | Common Name | Species Name | | Federal | State | Bays | Montezuma and Suisun Sloughs | Minor Sloughs | Sloughs w/in Tidal Marsh | Low Intertidal | Low Marsh | Mid Marsh | High Marsh | Upland Transition |
| INVERTEBRATES | | | | | | | | | | | | | | |
| | Corophium Amphipods | <i>Corophium</i> spp. | | | | RFB | RFB | RFB | RFB | | | | | |
| | Asian Clam* | <i>Corbicula fluminea</i> | | | | | | RFB | | | | | | |
| | California Bay Shrimp | <i>Cranqon franciscorum</i> | | | | RFB | RFB | RFB | RFB | | | | | |
| | Dungeness Crab | <i>Cancer magister</i> | | | | J/F | J/F | | | | | | | |
| | Oposum Shrimp | <i>Neomysis mercedis</i> | | | | RFB | RFB | RFB | RFB | | | | | |
| | Oriental Shrimp* | <i>Palaemon macrodactylus</i> | | | | | | RFB | | | | | | |
| | Overbite Clam* | <i>Corbula amurensis</i> | | | | RFB | RFB | | | | | | | |
| FISH | | | | | | | | | | | | | | |
| Salmonids | Central Valley steelhead | <i>Oncorhynchus mykiss</i> | Y | T | | A/M, A/F, J/M, J/F | A/M, A/F, J/M, J/F | J/M, J/F, J/R | J/F, J/R | J/F, J/R | J/F, J/R | J/F, J/R | J/F, J/R | |
| | Central California Coast steelhead | <i>Oncorhynchus mykiss</i> | | T | | A/M, A/F, J/M, J/F | A/M, A/F, J/M, J/F | J/M, J/F, J/R | J/F, J/R | J/F, J/R | J/F, J/R | J/F, J/R | J/F, J/R | |
| | Central Valley spring-run chinook salmon | <i>Oncorhynchus tshawytscha</i> | Y | T, X | T | A/M, J/M, J/F | A/M, J/M, J/F | J/M, J/F | J/F | J/F | J/F | J/F | J/F | |
| | Winter-run chinook salmon, Sacramento River | <i>Oncorhynchus tshawytscha</i> | Y | E, X | E | A/M, J/M, J/F | A/M, J/M, J/F | J/M, J/F | J/F | J/F | J/F | J/F | J/F | |
| | Central Valley fall/late fall run chinook salmon | <i>Oncorhynchus tshawytscha</i> | Y | C | SC | A/M, J/M, J/F | A/M, J/M, J/F | J/M, J/F | J/F | J/F | J/F | J/F | J/F | |
| Pelagic | Delta Smelt | <i>Hypomesus transpacificus</i> | Y | T, X | | A/F, J/F, L | A/F, A/B, J/F, L, E | A/F, A/B, J/F, L, E | A/B, L, E | | | | | |
| | Longfin Smelt | <i>Spirinchus thaleichthys</i> | Y | P | | A/F, J/F, L | A/F, A/B, J/F, L, E | A/F, A/B, J/F, L, E | A/B, E, L | | | | | |
| | Northern Anchovy | <i>Engraulis mordax</i> | | | | A/F, J/F, J/R | A/F, J/F | A/F, J/F | A/F, J/F | | | | | |
| | Splittail | <i>Pogonichthys macrolepidotus</i> | Y | | | A/F, J/F | A/B, A/F, J/F, L, E | A/B, A/F, J/F, L, E | A/B, A/F, J/F, L, E | | | | | |
| | Striped Bass* | <i>Morone saxatilis</i> | Y | | | A/M, A/F, J/F, L, E | A/M, A/F, J/F, L, E | A/F, J/F, L | | | | | | |
| | Tule Perch | <i>Hysterothorax traski</i> | | | | | A/B, A/F, J/F | A/B, A/F, J/F | A/B, A/F, J/F | | | | | |
| | Sacramento splittail | <i>Pogonichthys macrolepidotus</i> | | | SC | | | | | | | | | |
| Benthic | Prickly Sculpin | <i>Cottus asper</i> | | | | L | A/F, J/F, L, E | A/B, A/F, J/F, L, E | A/B, A/F, J/F, L, E | | | | | |
| | Starry Flounder | <i>Platichthys stellatus</i> | | | | A/F, J/F, J/R | A/F, J/F | A/F, J/F | A/F, J/F | A/F, J/F | A/F, J/F | A/F, J/F | A/F, J/F | |
| | Green sturgeon | <i>Acipenser medirostris</i> | Y | T, PX | | A/M, A/F, J/M, J/F, J/R | A/M, A/F, J/M, J/F, J/R | A/F, J/M, J/F, J/R | J/F, J/R | J/F, J/R | J/F, J/R | J/F, J/R | J/F, J/R | |
| | Yellowfin Goby* | <i>Acanthogobius flavimanus</i> | | | | A/F, J/F, L | A/F, J/F, L | A/F, J/F, L | A/F, J/F, L | | | | | |

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| | Common Name | Species Name | | Federal | State | Bays | Montezuma and Suisun Sloughs | Minor Sloughs | Sloughs w/in Tidal Marsh | Low Intertidal | Low Marsh | Mid Marsh | High Marsh | Upland Transition |
| | White Sturgeon | <i>Acipenser transmontanus</i> | Y | | | A/M, A/F, J/M, J/F, J/R | A/M, A/F, J/M, J/F, J/R | A/F, J/M, J/F, J/R | J/F, J/R | J/F, J/R | J/F, J/R | J/F, J/R | J/F, J/R | |
| BIRDS | | | | | | | | | | | | | | |
| Diving Ducks and Allies | Bufflehead | <i>Bucephala albeola</i> | | | | F | F | F | | | | | | |
| | Common Goldeneye | <i>Bucephala clangula</i> | | | | F | F | | | | | | | |
| | Barrow's Goldeneye | <i>Bucephala islandica</i> | | | SC | F | F | | | | | | | |
| | Canvasback | <i>Aythya valisineria</i> | | | SC | F | F | F | | | | | | |
| | Ring-Necked duck | <i>Aythya collaris</i> | | | | F | F | | | | | | | |
| | Greater Scaup | <i>Aythya marila</i> | | | | F | F | | | | | | | |
| | Lesser Scaup | <i>Aythya affinis</i> | | | | F | F | | | | | | | |
| | Redhead | <i>Aythya americana</i> | | | SC | F | F | | | | | | | |
| | Ruddy Duck | <i>Oxyura jamaicensis</i> | | | | F | F | | | | | | | |
| | Surf Scoter | <i>Melanitta perspicillata</i> | | | | F | F | | | | | | | |
| | Double-Crested Cormorant | <i>Phalacrocorax auritus</i> | | | WL | F | F | | | | | | | |
| | Eared Grebe | <i>Podiceps nigricollis</i> | | | | F | F | F | F | F | F | F | | |
| | Pied-Billed Grebe | <i>Podilymbus podiceps</i> | | | | F | F | F | F | F | F | F | | |
| | Western Grebe | <i>Aechmophorus occidentalis</i> | | | | F | F | | | | | | | |
| | Clark's Grebe | <i>Aechmophorus clarkii</i> | | | | F | F | | | | | | | |
| | Common Merganser | <i>Mergus merganser</i> | | | | F | F | | | | | | | |
| | Red-breasted Merganser | <i>Mergus serrator</i> | | | | F | F | | | | | | | |
| Common Loon | <i>Gavia immer</i> | | | SC | F | F | | | | | | | | |
| American Coot | <i>Fulica americana</i> | | | | F | F | F | F | | | | | | |
| California brown pelican | <i>Pelecanus occidentalis californicus</i> | | | E | E | F | F | | | | | | | |
| American white pelican | <i>Pelecanus erythrorhynchos</i> | | | SC | F | F | | | | | | | | |
| Dabbling Ducks and Allies | Mallard | <i>Anas platyrhynchos</i> | | | | | | F | F | F | F | F | F | F, B |
| | American Wigeon | <i>Anas americana</i> | | | | | | F | F | F | F | F | F | F |
| | Green-winged Teal | <i>Anas crecca</i> | | | | | | F | F | F | F | F | F | F |
| | Northern Pintail | <i>Anas acuta</i> | | | | | | F | F | F | F | F | F | F |
| | Northern Shoveler | <i>Anas clypeata</i> | | | | | | F | F | F | F | F | F | F |
| Tule Greater White-Fronted Goose | <i>Anser albifrons elgasi</i> | | | SSC | F | F | F | F | F | F | F | F | F | |
| Hérons, Egrets, and Bitterns | Great Blue Heron | <i>Ardea herodias</i> | | | S | | | F | F | F | F | F | F | F |
| | Black-crowned Night Heron | <i>Nycticorax nycticorax</i> | | | S | | | F | F | F | F | F | F | F |
| | Snowy Egret | <i>Egretta thula</i> | | | | | | F | F | F | F | F | F | F |
| | Great Egret | <i>Ardea alba</i> | | | S | | | F | F | F | F | F | F | F |
| | Least Bittern | <i>Ixobrychus exilis</i> | | | SC | | | F | F | F | F | F | F | F |
| Gulls and Terns | California Gull | <i>Larus californicus</i> | | | | F, Lo | F, Lo | | | | | | | |
| | Ring-Billed Gull | <i>Larus delawarensis</i> | | | | F, Lo | F, Lo | | | | | | | |
| | Elegant Tern | <i>Sterna elegans</i> | | | SC | F | F | | | | | | | |
| | California Least Tern | <i>Sterna antillarum browni</i> | | | E | E | A/F, J/F | A/F, J/F | A/F, J/F | | | | R | R |

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| | Common Name | Species Name | | Federal | State | Bays | Montezuma and Suisun Sloughs | Minor Sloughs | Sloughs w/in Tidal Marsh | Low Intertidal | Low Marsh | Mid Marsh | High Marsh | Upland Transition |
| Passerines | Salt Marsh Common Yellowthroat | <i>Geothlypis trichas sinuosa</i> | Y | | SC | | | | | | A/F,J/F | A/F,J/F | A/F,J/F | A/F,J/F |
| | Suisun Song Sparrow | <i>Melospiza melodia maxillaries</i> | Y | | SC | | | | | A/F,J/F | A/F,J/F | A/F,J/F, R | A/F,J/F, R | |
| | Tricolored blackbird | <i>Agelaius tricolor</i> | | | SC | | | | | | | | | |
| Raptors | Bald Eagle | <i>Haliaeetus leucocephalus</i> | | | E, S, FP | F | F | | | | | | | |
| | White-tailed Kite | <i>Elanus leucurus</i> | | | FP | | | | | | | | F | F |
| | Osprey | <i>Pandion haliaetus</i> | | | S | F | F | | | | | | | |
| | Northern Harrier | <i>Circus cyaneus</i> | | | SC | | | | | | | F | F | F |
| | Swainson's Hawk | <i>Buteo swainsoni</i> | | | T | | | | | | | | F | F |
| | American Peregrine Falcon | <i>Falco peregrinus anatum</i> | | | E, S, FP | | | | | | | | F | F |
| | Burrowing Owl | <i>Athene cunicularia</i> | | | SC | | | | | | | | | F, B |
| Short-eared Owl | <i>Asio flammeus</i> | | | SC | | | | | | | F | F | F | |
| Rails | California black rail | <i>Laterallus jamaicensis coturniculus</i> | Y | SC | T | | | | | A/F,J/F | A/F,J/F | A/F,J/F | A/F,J/F, R | A/F,J/F,R |
| | California clapper rail | <i>Rallus longirostris obsoletus</i> | Y | E | E | | | | | A/F,J/F | A/F,J/F | A/F,J/F | A/F,J/F | A/F,J/F |
| Shorebirds | Long-billed Curlew | <i>Numenius americanus</i> | | | WL | F | F | F | F | F | F | Lo | Lo | |
| | Western Sandpiper | <i>Calidris mauri</i> | | | | F | F | F | | F | F | Lo | Lo | |
| | Least Sandpiper | <i>Calidris minutilla</i> | | | | F | F | F | | F | F | Lo | Lo | |
| | Long-Billed Dowitcher | <i>Limnodromus scolopaceus</i> | | | | F | F | F | F | F | F | Lo | Lo | |
| | Short-Billed Dowitcher | <i>Limnodromus griseus</i> | | | | F | F | F | F | F | F | Lo | Lo | |
| | Marbled Godwit | <i>Limosa fedoa</i> | | | | F | F | F | | F | F | Lo | Lo | |
| | Willet | <i>Tringa (= Catoptrophorus) semipalmata</i> | | | | F | F | F | | F | F | Lo | Lo | |
| MAMMALS | | | | | | | | | | | | | | |
| | American beaver | <i>Castor canadensis</i> | | | | | F | F | F | | | | | |
| | California sea lion | <i>Zalophus californianus</i> | | | | F | F | | | | | | | |
| | Harbor seal | <i>Phoca vitulina</i> | | | | F | F | | | | | | | |
| | Muskrat | <i>Ondatra zibethicus</i> | | | | | F | F | F | | | | | |
| | North American river otter | <i>Lutra canadensis</i> | | | | | F | F | F | | | | | |
| | Salt marsh harvest mouse | <i>Reithrodontomys raviventris</i> | Y | E | E | | | | | | | A/F,J/F, R | A/F,J/F, R | A/F,J/F |
| | Suisun shrew | <i>Sorex ornatus sinuosus</i> | Y | | SC | | | | | | | A/F,J/F, R | A/F,J/F, R | |
| | Tule Elk | <i>Cervus elaphus nannodes</i> | | | | | | | | | | | | A/F,J/F, R |
| REPTILES and AMPHIBIANS | | | | | | | | | | | | | | |
| | Northwestern pond turtle | <i>Clemmys marmorata marmorata</i> | | | SC | | A/F,J/F, R | A/F,J/F, R | | | | | | R,B |
| PLANTS | | | | | | | | | | | | | | |
| | Soft bird's-beak | <i>Cordylanthus mollis</i> ssp. <i>mollis</i> | | E, X | R | | | | | | | | | |
| | Suisun thistle | <i>Cirsium hydrophilum</i> var. <i>hydrophilum</i> | | E, X | | | | | | | | | | |

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|--|--------------------|---|------------|----------------|-------|---------------|------------------------------|---------------|--------------------------|----------------|-----------|-----------|------------|-------------------|
| | Common Name | Species Name | | Federal | State | Bays | Montezuma and Suisun Sloughs | Minor Sloughs | Sloughs w/in Tidal Marsh | Low Intertidal | Low Marsh | Mid Marsh | High Marsh | Upland Transition |
| | Suisun Marsh aster | <i>Aster lentus</i> | | SC | | | | | | | | | | |
| | Delta tule pea | <i>Lathyrus jepsonii</i> ssp. <i>jepsonii</i> | | SC | | | | | | | | | | |
| | Mason's lilaepsis | <i>Lilaepsis masonii</i> | | | R | | | | | | | | | |

(DFG 2005, Goals Project 1999, K. Hieb DFG pers.comm. 2006, Liguori 1995, M. Nobriga DWR Pers. Comm. 2006, Moyle et al. In Review, Orsi 1999, Stevens 1977, SEW 2001, and USFWS 1996)

Life Stage:

(A) = Adult, (J) = Juvenile, (L) = Larval, (E) = Egg

Habitat Function:

(B) = Breeding, (R) = Rearing, (F) = Foraging, (M) = Migrating, (Lo) = Loafing

Listing Status

(P) = Species proposed, (PX) = Species listed, critical habitat proposed, (X) = Critical habitat listed, (E) = Listed as Endangered under Endangered Species Act, (Rare) = Limited in distribution, declining throughout their range, or with vulnerable life history stage, (SC) = Species of Special Concern, (T) = Listed as Threatened under Endangered Species Act, (S) = Sensitive (CDFG and USBLM). (WL) = Watch List (CDFG). (FP) = Fully Protected (CDFG)

* = **Non-native species**

4.2 Sensitive Species

An enormous, diverse assemblage of fish, amphibians, reptiles, birds, and mammals uses the habitats within Suisun Marsh at one or more points during their various life stages. Many of these species are listed sensitive and/or special-status species. This section contains brief conceptual models of habitat usage for 15 of these sensitive species, representing multiple guilds and types of habitat dependencies. Appendix 4-A contains a complete list of all species that use Suisun Marsh, and the general habitats in which they are found.

4.2.1 California Clapper Rail (*Rallus longirostris obsoletus*) (FWS)

Species Description

The California clapper rail is a secretive, hen-like waterbird, indigenous to estuarine marshlands in the San Francisco Bay (Goals Project 2000). California clapper rails occur almost exclusively in tidal salt and brackish marshes with unrestricted daily tidal flows, adequate invertebrate prey food supply, well developed tidal channel networks, and suitable nesting and escape cover during extreme high tides. They once occupied coastal California tidal marshes from Humboldt Bay southward to Morrow Bay, and estuarine marshes of San Francisco Bay and San Pablo Bay to the Carquinez Strait (SEW 2000). Resident populations are currently limited to San Francisco Bay, San Pablo Bay, Suisun Bay, and associated tidal marshes.

Conceptual Model of California Clapper Rail Use of Tidal Marshes in Suisun Marsh

The conceptual model for California clapper rail is displayed in Figure 4-1. Primary drivers for the California clapper rail are the inundation regime, the invertebrate community, access to high ground refugia and channels (marsh geomorphology), salinity, and the marsh plain vegetation communities. Size of the marsh, location relative to other marshes and buffer areas between the marsh and upland should be considered when selecting sites for California clapper rail habitat restoration.

Habitat that has direct tidal circulation is preferred and is characterized by predominant coverage by pickleweed (*Salicornia virginica*) with extensive stands of Pacific cordgrass (*Spartina foliosa*), and, in the North Bay, *Scirpus robustus*, abundant high marsh cover, and an intricate network of tidal sloughs which provide abundant invertebrate populations (Grinnell et al. 1918, DeGroot 1927, Harvey 1988, Collins et al. 1994) as well as escape routes from predators (Zembal and Massey 1983, Foerster et al. 1990). Research suggests that rail density is positively correlated to channel density. Local populations of breeding California clapper rails are most dense where patches of historical and youthful marshlands are together in at least 100 ha in size. Such patches typically comprise some historical and youthful marshlands together (Collins and Evens 1992, Collins et al. 1994).

The primary diet of clapper rails consists of various invertebrate species, including mussels, clams, crabs, snails, amphipods, worms, spiders, insects, and fish (Williams 1929, Applegarth 1938, Moffitt 1941). Most

foraging occurs when food is more available during low tide when mudflats and tidal sloughs are exposed (Applegarth 1938, Foerster and Takekawa 1991).

Non-native mammalian predators represent the most severe short- and long-term threat to the species. Non-native species, such as the red fox (*Vulpes fulva*) and feral cats (*Felis domestica*), pose a serious threat to adult clapper rails (USFWS and USN 1990, Foerster et al. 1990, Foerster and Takekawa 1991, Zembal 1992, Albertson 1995). Norway rats (*Rattus norvegicus*) and raccoons (*Procyon lotor*) also pose serious threats to clapper rail eggs (DeGroot 1927, Applegarth 1938, Harvey 1988, Foerster et al. 1990). No studies have been conducted to confirm these threats in Suisun Marsh.

Lack of extensive blocks of tidal marsh with suitable structure is the ultimate limiting factor for the species' recovery; vulnerability to predation is exacerbated by reduction of clapper rail habitat to narrow and fragmented patches close to urban edge areas that diminish habitat quality. Dikes provide artificial access to terrestrial predators, and displace optimal cover by high marsh vegetation. Non-native plant species management is also essential to protect from invasives such as smooth cordgrass (*Spartina alterniflora*) and pepperweed (*Lepidium* spp.). The rapid invasion of San Francisco Bay by exotic *Spartina alterniflora* (smooth cordgrass) also threatens to cause major long-term structural changes in tidal salt marsh creek beds and banks, creek density, and marsh plains, and could impair future habitat for California clapper rails.

Contaminants, particularly mercury, selenium, and polychlorinated biphenyls (PCBs) are significant factors affecting viability of California clapper rail eggs (Schwarzbach et al. 2001, 2002, 2006, Novak et al. 2005). Restoration in heavily subsided areas could benefit from the addition of dredge material, but this could potentially introduce contaminants (Foin et al. 1997).

Restoration of the high marsh should include a buffer zone between the high marsh and the upland ecotone. There is some evidence that rails will abandon their habitat if frequently disturbed, so the buffer zone should have limited access. The creation of channels would also provide secure escape routes for rail movement back and forth with the tides (Foin et al. 1997).

Expected Restoration Effects at Each Trajectory Stage

California clapper rails utilize the low intertidal, low marsh, mid marsh, high marsh, and upland transitional zones. Rail foraging and refugia habitat encompasses the lower, middle, and high marsh zones, as well as the adjacent transitional zone. Lower and middle marsh zones provide foraging habitat at low tide. Higher marsh areas (high marsh and transitional zones) with dense vegetation are used for high-tide refugia (DeGroot 1927; Harvey 1988; Foerster et al. 1990; Evens and Collins 1992; Collins et al. 1994). California clapper rails typically nest in the upper-middle tidal marsh plain or high tidal marsh zones, not upland habitat transition zones bordering tidal marsh.

Historically, the California clapper rail has been restricted to the western, more saline portions of Suisun Marsh, however more recent surveys have documented California clapper rails primarily in the northcentral portion of Suisun. Therefore, it is anticipated that restoration sites in the western or northcentral portion of the marsh are more likely to provide habitat for the California clapper rail. Low intertidal sites may provide marginal foraging habitat for the California clapper rail. Sites at the low marsh stage may be used for foraging and refugial habitat. Mid marsh sites may provide foraging and refugial habitat, and marginal nesting habitat along the fringing higher elevation areas. High marsh sites would be optimal for the California clapper rail and may provide foraging, refugial and nesting habitat. Sites with upland transition may be used for foraging and refuge, but are not likely to be used for nesting.

4.2.2 California Black Rail (*Laterallus jamaicensis coturniculus*) (DFG)

Species Description

California black rails occur almost exclusively in tidal marsh habitat (Evens et al. 1991, Manolis 1978, Nur et al. 1997). The majority of the species population is currently found in the historical marshes of San Pablo Bay, Suisun Bay, and the Carquinez Strait (Evens et al. 1991). The highest concentrations are in marshes associated with large rivers and sloughs (Petaluma River Marsh, Black John Slough, Coon Island, Fagan Slough, Napa River) (Evens et al. 1991, Nur and Spatz 2002); thus freshwater input to tidal marshes appears to correlate positively with black rail abundance. Manolis (1978) found black rails only in the upper elevations of marshes, near the limit of tidal inundation. Black rails prefer saturated substrates; therefore, marshes with muted tidal influence are more likely to provide habitat in years when there is above average precipitation. Thelander (1994) describes marsh habitat preferred by black rails as those characterized by stable water levels that seldom flood, dense stands of low-growing, semiaquatic plants, as well as areas of open water and dry upland habitat. The authors note that these are characteristics of well-developed marshes and that newly restored marshes have not been found to support black rails.

Black rails are nearly absent from South San Francisco Bay marshes which may be a function of lower marsh elevations there as compared to the North Bay (Manolis 1977, Evens et al. 1989). Other factors that may explain higher black rail numbers in the North Bay are a greater abundance of emergent marsh vegetation and lower rates of subsidence relative to mean tide. These are likely proximate factors influencing the ultimate factors that define habitat suitability, such as high food abundance, nest site availability, and access to high tide refugial habitat (Evens et al. 1989).

Marsh size appears to increase the potential that black rails will be present; however, marsh size has not been found to significantly correlate with black rail density (Nur et al. 1997). Marshes which support black rails also tend to be far from urbanization and close to other large marshes (Nur and Spatz 2002).

Black rails may suffer from predation pressure by great egrets, northern harriers, as well as other birds and mammals if they move into areas without cover during high tides. Therefore, a transitional zone of peripheral halophytes, between the marsh and uplands, is an essential component of suitable habitat for this species because it provides high tide refuge (Evens et al. 1991). Marshes associated with minor

sloughs and creeks (Napa Slough, Sonoma Slough, Tolay creek, South Slough) are generally linear and narrow (<100 m wide) and are often bordered by man-made levees or ditches and therefore lack this type of peripheral halophyte zone (Evens et al. 1991). Pedestrian access close to marshes with black rails can also be detrimental effect if black rails are inhibited from moving into upper elevations during high tides (Trulio and Evens 2000).

Black rails nest from March into early July with the greatest nesting activity occurring from early April to May (Spautz and Nur 2002). During the breeding season, birds are most often found in marsh areas dominated by *Salicornia* and *Scirpus* spp. (Manolis 1977, Spautz and Nur 2002). Breeding birds seem to prefer marshes with a high abundance of *Scirpus* spp. (Spautz and Nur 2002, Trulio and Evens 2000). In San Pablo Bay, most nests have been found in *Salicornia*, or a combination of *Salicornia* and *Scirpus maritimus* or *Distichlis spicata*. Those nests were also associated with a high density of plant stems or leaves within 10 cm of the ground. They were also near to water and far from urbanization (Nur and Spautz 2002). In the Suisun Marsh, black rail occurrences are highly correlated with pickleweed, alkali heath, and *Schoenoplectus americanus* (DWR 1994). Nests are usually concealed in dense vegetation near the limit of tidal flooding (SEW 2001). A study conducted in non-tidal habitats of Southwestern Arizona found nests placed consistently over shallow water, elevated above the mud substrate, and in clumps of vegetation (Flores and Eddleman 1993). Nests may be rebuilt if they are disturbed by high tides (Wilbur 1974). Black rails are not known to nest in diked marshes which may be a function of low food densities in these habitats (Post and Enders 1969 in Maonolis 1978).

Black rails may use newer, younger marshes with *Spartina* in the non-breeding season. Additionally, seasonal wetlands with high vegetative cover and muted tidal flow may be used during the non-breeding season if they are adjacent to fully tidal marshes (Trulio and Evens 2000). Research on the foraging behavior and diet of black rails is limited. They have been observed foraging on the ground, consuming terrestrial insects, aquatic invertebrates, arthropods, and seeds (Trulio and Evens 2000, Huey 1916).

Contaminants may impact rails. Although there is no literature on the subject, contaminants have been found to affect the viability of California clapper rail eggs (Schwarzbach et al. 2001, 2002, 2006, Novak et al. 2005) which share similar habitats.

Conceptual Model of the Use of Tidal Marshes by California Black Rail

The conceptual model for California black rail is displayed in Figure 4-2. The main landscape drivers of habitat suitability for the California black rail are marsh geomorphology, freshwater input, and connectivity between open water and marsh habitat. Higher elevation marshes and marshes with variable topography may be less prone to flooding and provide more refugial and nesting habitat for black rails. The ability to avoid predation is an important factor affecting the suitability of marshes to support black rails. Full tidal inundation and freshwater influence benefit rails by increasing invertebrate prey communities and may provide other unknown benefits.

Use of Evolutionary Trajectory Stages

California black rails are associated with habitat features representative of mature, well-developed marshes. Newly restored marshes have not been found to support black rails (Thelander 1994). However, most studies of black rails have been conducted to detect breeding activity; therefore, while we would not expect black rails to breed in newly established marshes, they may use these areas for dispersal or foraging, especially once vegetation becomes somewhat dense. The length of time it takes for marsh to mature enough to support black rails will likely depend upon the following factors: beginning site elevation, availability of sediment to create high marsh habitat, tidal influence, proximity to existing sites in use by black rails, freshwater influence, and distance from urbanization. High marsh transitional zones that offer cover from predators, or the potential for these areas to develop, is an important restoration consideration. Where upland transitions or levees are planned, site characteristics which prevent easy access to the marsh zone by mammalian predators should be included in restoration designs. Partial restoration of tidal flows or managed wetland enhancements that result in muted tidal flows are not likely to benefit black rails as much as full tidal restoration. Black rails are most often found in larger marshes and in close proximity to other large marshes; therefore, marsh size should be considered when selecting sites for California black rail habitat restoration.

4.2.3 Suisun Song Sparrow (*Melospiza melodia maxillaris*) (DFG)

Species Description

The Suisun song sparrow is currently a federal species of concern. The Suisun song sparrow is a distinct subspecies of song sparrows completely endemic to Suisun Bay. Previous literature suggested that these birds are confined to undiked tidal marshes. However, field surveys by DFG and DWR have observed Suisun song sparrows along distribution ditches, permanent ponds, and other areas in diked wetlands of Suisun Marsh where required plant assemblages and brackish water conditions exist (Collins et al. 1994). Marshall (1948) and Cogswell (2000), point out that song sparrows use freshwater marsh, riparian vegetation along stream courses, coastal scrub, brackish marsh and salt marsh. Non-tidal seasonal wetlands may be used for foraging, but much less than fully tidal marsh.

Suisun song sparrows are distributed over most of their original range, occurring in marshes from Martinez (Contra Costa County) eastward along the south bayshore of Suisun Bay to Pittsburg (Contra Costa County), then north of Suisun Bay throughout the extensive Suisun marshlands (Solano County). The reproductive success of the Suisun song sparrow was monitored at Rush Ranch and calculated to be approximately 27 percent. The density of Suisun song sparrows was estimated to be 11 birds per acre, with a total population estimated to be 22,000 to 53,000 (Nur *et al.* 1997).

Intermixed stands of bulrush (*Schoenoplectus* spp.), cattail (*Typha* spp.), and other emergent vegetation provide suitable habitat. Suisun song sparrows use the tallest, centermost *Schoenoplectus acutus* patch for song and calling perches and find concealment in the piles of dead stems below. Individuals seldom move more than 9 meters (30 feet) from cover and, once a territory is established, adults occupy it for their

lifetime, seldom moving more than 100 meters (328 feet) away (Johnston 1956). Juvenile dispersal is the main means by which individuals transfer between salt marsh song sparrow populations.

Suisun song sparrow nests are strung along edges of sloughs and bays in linear fashion, at 48 to 70 yard intervals. As the fringe marsh widens, distances between adjacent nests increase. Open marsh more than ten yards from the winding tidal channels is avoided. Each territory must have enough area for nesting and foraging (Walton 1975).

Suisun song sparrows forage on the bare surface of tidally exposed mud among the tules and along slough margins in the brackish marshes of Suisun Bay during low tides. They feed mostly on *Schoenoplectus* (bulrush) seeds from the ground, once they fall from flower heads above. They also feed on the insects (mostly mosquito larvae and flies) and other invertebrates exposed during low tides (Marshall 1948).

Conceptual Model of Suisun Song Sparrow Use of Tidal Marshes in Suisun Marsh

The conceptual model for Suisun song sparrow is displayed in Figure 4-3. Nest sites are selected for protection from inundation at high tides, but the predation threat is increased if nests are placed high enough that cover from taller plants is no longer effective. High rates of predation by birds of prey during high tides pose a serious threat to the survival of individuals. Mortality rates for Suisun song sparrows are 80 percent during the first year of life, and 43 percent per year for adults (Larsen 1989).

Diking, channelization, development, and a substantial decrease in freshwater outflow from the Sacramento- San Joaquin Delta have greatly reduced the habitat that supports this subspecies. The remaining habitat is highly fragmented, existing in thin strips along the inside edges of tidal sloughs.

Suisun song sparrows are very sedentary, never making long flights over unfamiliar habitat. This behavior coupled with the severe fragmentation of brackish tidal marsh habitat predisposes the Suisun song sparrow to the threat of local extinction.

Habitat areas must be in tidal marsh with sufficient food and water or moisture availability (Marshall 1948a). They are obligate ground foraging birds (Larsen 1989).

Use of Evolutionary Trajectory Stages

Given their need for dense and tall stands of cover, Suisun song sparrow populations will likely depend upon well developed mid- and high-marsh vegetation for their nesting, rearing and refuge needs. Under ideal conditions, *Schoenoplectus* and *Typha* species have been observed to establish quickly following restoration of full tidal connectivity to some sites such as Carl's Marsh on the Petaluma River, which was fully vegetated within 3 years of breaching. The time period required for the development of established marsh and subsequent use by Suisun song sparrows in Suisun Marsh will depend upon beginning site elevation, availability of sediment, proximity to existing sites in use by the sparrow and other factors.

Studies to date indicate that the Suisun song sparrow needs all its functional requirements integrated into a relatively small area. Because the Suisun song sparrow is an obligate tidal flat feeder, high topographic variability is an important component in restoration planning for this species. Its feeding behavior could be accommodated by initial stages of low marsh restoration, provided these sites are exposed during low tides and sufficiently near enough to cover and nesting sites.

For either managed wetland or full tidal restoration sites, channel banks and other upland transitions must be sloped in order provide tidal flats for grazing by song sparrows. Evidence of Suisun song sparrow presence in diked wetlands suggests that the species may be able to use managed wetlands if conditions are established which provide the needed cover, topographic variability, and tidal exchange.

4.2.4 Salt Marsh Common Yellowthroat (*Geothlypis trichas sinuosa*) (FWS)

Species Description

Salt marsh common yellowthroats are winter residents of tidal marshes, but occur in other habitats (often wetland ecotones) such as riparian thickets, freshwater marshes, marshy coastal forb vegetation, and brush or scrub near wetlands (Terrill 2000). Most breeding (60 percent in the San Francisco Bay region) occurs in brackish marsh, about 5 percent in salt marsh, and the remainder in other wetland or peripheral wetland habitats. Salt marsh common yellowthroats nest in a variety of habitats around San Francisco Bay wetlands and adjacent uplands; moisture appears to be the factor common to all types of breeding habitat. Nesting occurs in areas in or next to wet ground and dense vegetation (Bent 1953; Hobson et al. 1986).

Survey data determined that yellowthroats are associated with large amounts of brackish marsh vegetation, notably bulrush (*Bolboschoenus maritimus*) and common cattail (*Typha latifolia*), and non-native perennial pepperweed (*Lepidium latifolium*). Although pickleweed (*Sarcocornia pacifica*) is often the dominant plant in tidal marshland, the more *Sarcocornia* present, the fewer yellowthroats (Nur et al. 1997).

Salt marsh common yellowthroat nesting territories were observed in five habitat types: brackish marsh, salt marsh, riparian woodland or swamp, freshwater marsh, and upland/or grassland (Hobson et al. 1986). Yellowthroats frequently use borders between various plant communities, and territories often straddle the interface of riparian corridors or the ecotones between freshwater or tidal marsh and upland vegetation (Shuford 1993). Outside of the breeding season, some populations of salt marsh common yellowthroat shift habitat use from brackish or freshwater marshes to more saline marshes dominated by *Sarcocornia* or *Spartina*. Female yellowthroats construct the nest, which is typically placed no higher than 60 centimeters (23.6 inches) above the ground, close to water, and well concealed in dense vegetation. Nests are constructed of grasses and sedges held firmly to the surrounding vegetation and covered by loosely woven materials (Bent 1953; Erlich et al. 1988). Yellowthroats are primarily insectivorous, and glean insects on or near the ground (to about 1.5 meters [5 feet] above the ground or water) from low herbaceous vegetation, bushes, and small trees, or from the surface of mud (Shufford 1993).

Conceptual Model of Salt Marsh Common Yellowthroat Use of Tidal Marshes in Suisun Marsh

The conceptual model for salt marsh common yellowthroat is displayed in Figure 4-4. Primary drivers for the salt marsh common yellowthroat are the marsh geomorphology, the marsh plain vegetation communities, and the invertebrate community. Research from the San Francisco Bay indicates that salt marsh common yellowthroats rely on natural and artificial channels in marshes, and that the abundance of yellowthroats was significantly greater in marshes with more channels (Nur *et al.* 1997).

Common yellowthroats, as a whole, are known to be hosts to the parasitic brown-headed cowbird. Brown-headed cowbirds are brood parasites that lay eggs in the nests of other species, directly affecting their hosts by reducing nest success (Whitfield 1994; Mayfield 1977; Brittingham and Temple 1983). Stewart (1953), as cited by Foster (1977), found parasitism by cowbirds to be a significant cause of mortality among yellowthroats in Michigan. It is still unknown whether salt marsh common yellowthroats are impacted as heavily by cowbirds.

Salt marsh common yellowthroats may be susceptible to high rates of predation. Reduction of cover, especially in drought years or as a result of human disruption, can increase the incidence of predation. Predators that typically affect passerines include domestic cats, racoons, opossums, red foxes, rats, crows and ravens, scrub jays, snakes, and raptors.

Expected Restoration Effects at Each Trajectory Stage

If there is enough cover, salt marsh common yellowthroat can occur in low marsh, mid marsh, high marsh, and upland transition.

4.2.5 Salt Marsh Harvest Mouse (*Reithrodontomys raviventris*) (FWS)**Species Description**

Salt marsh harvest mice are small, native rodents endemic to the salt marshes and adjacent diked wetlands of the San Francisco Bay (Goals Project 2000). They are generally restricted to saline or subsaline marsh habitats around the San Francisco Bay estuary and mixed saline/brackish areas in the Suisun Bay area. The distribution of salt marsh harvest mice in Suisun is closely correlated with the abundance of mixed wetland vegetation (including native and non-native species such as fat hen, saltgrass, Baltic rush, Olney's three-square bulrush, and pickleweed) and pickleweed dominated vegetation (Suistatia *et al.* 2004). The salt marsh harvest mouse has been found throughout the Marsh in a variety of habitats. Current studies show that pickleweed is not necessarily the most "preferred" habitat as defined by the USFWS Draft Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California (USFWS 2010 DFG, DWR unpublished data) and their distribution is not restricted to pickleweed habitat. Ongoing genetic studies of the salt marsh harvest mouse in the Marsh show that the population is genetically diverse (S. Brown, 2003). The Suisun Marsh has been extensively surveyed for salt marsh harvest mice since 1997 by DFG and DWR. Five tidal marsh areas (Peytonia Slough, Rush Ranch, Hill Slough, Joice Island, Lower Joice Island) in Suisun have averaged a capture efficiency of which is much

higher than any other surveys conducted in the salt marsh harvest mouse's range. Salt marsh harvest mice have also been found in high numbers in areas dominated by *Schoenoplectus americanus* in Suisun (Barthman-Thompson pers. comm.).

Conceptual Model of Salt Marsh Harvest Mouse Use of Tidal Marshes in Suisun Marsh

The conceptual model for salt marsh harvest mouse is displayed in Figure 4-5. Primary drivers of salt marsh harvest mouse tidal marsh use are the marsh plain vegetation community and access to high ground refugia or tall vegetation that is not submerged during high tides. Viable populations of salt marsh harvest mice also appear to be limited by the distribution of high tide cover and escape habitat (tidal refugia).

Predation on the salt marsh harvest mouse in Suisun is unknown. Recurrent but shallow flooding by tidal restoration or brackish water is probably needed to maintain habitat that favors the salt marsh harvest mouse over sympatric rodents such as voles and house mice. Interactions between various rodent species (*Mus*, *Microtus*, *Rattus*) and the salt marsh harvest mouse do not appear to negatively impact the salt marsh harvest mouse (Suistatia et al. in prep). The impacts of non-native plant species, such as perennial pepperweed (*Lepidium latifolium*), need to be researched, as does the degree to which chemical contaminants, such as heavy metals, organochlorines, and PCBs affect the quality of the salt marsh harvest mouse habitat.

Expected Restoration Effects at Each Trajectory Stage

Salt marsh harvest mice occur in the tidal middle, high marsh zones and adjacent uplands. The basic habitat of the salt marsh harvest mouse is pickleweed-dominated vegetation (Dixon 1908; Fisler 1965), however in Suisun they have been found in mixed wetlands not dominated by pickleweed. Other highly important habitat considerations include high tide/flood refugia (both at the upper edge of the marsh and within mature marshes as areas of emergent gumplant or *Schoenoplectus americanus* even at the highest high tides), seasonal use of terrestrial grassland, exploitation of suboptimal habitats, and habitat selection in brackish marsh vegetation where pickleweed is a relatively minor component, as often is the case in Suisun Bay marshes.

Salt marsh harvest mice are dependent on the thick, perennial cover of salt marshes and move in the adjacent grasslands only in the spring and summer when the grasslands provide maximum cover (Fisler 1965). Restoration of managed marsh may temporarily result in the loss of salt marsh harvest mouse habitat due to initial flooding, but over time will create viable long-term habitat. When selecting sites for tidal marsh restoration, sites containing an area of high marsh and upland transition are necessary for the salt marsh harvest mouse. Sea-level rise makes this upland transition component even more important.

4.2.6 Suisun Shrew (*Sorex ornatus sinuosus*) (DFG)

Species Description

The Suisun shrew is a small mammalian insectivore with a total length of 95 to 105 mm and total weight of between 4.5 to 6.8 grams (Jameson and Peeters 1988). Historically, the Suisun Bay was lined with natural

salt brackish marshes. Since diked marshes are not capable of supporting enough invertebrates, these shrews prefer tidal over diked marshes (WESCO 1986). Natural tidal marsh within the range of the Suisun shrew has decreased by approximately 88,000 acres (WESCO 1986). The current distribution of the Suisun shrew appears to be limited to the isolated tidal salt and brackish marshes in San Pablo Bay and Suisun Marsh. Its range is bounded on the west by Tubbs Island in Sonoma County and on the east by Collinsville in Solano County. Ornate shrews outside these boundaries are considered to be *Sorex ornatus californicus* (Brown and Rudd 1981; Williams 1983).

There is evidence indicating that shrews may have home ranges and defend territories for at least part of the year (Hawes 1977; Hays 1990; Moraleva and Telitzina 1994). These dynamic territories can range from 360 to 1,700 square meters in area (3,875 to 18,300 square feet), or from 11 to 100 meters (36 to 328 feet) in length (Moraleva and Telitzina 1994), depending on sex, age, and season. In Suisun Marsh, dense breeding subpopulations of Suisun shrew exist in the fall (Hays 1990).

Breeding occurs from April through October, with most breeding in early spring through May by individuals born the previous year (Newman and Rudd 1978; Owen and Hoffman 1983). Females give birth to 2-9 young following a three week gestation period and young remain fully dependent until 3 weeks prior to weaning. Survival rates of young range from 55-60% from birth to just after weaning (Johnston and Rudd 1957). Although rare, Suisun shrews can produce 2 litters in one breeding season and some first year shrews will breed in late summer (Owen and Hoffman 1983). In early March males reach sexual maturity and subdominant males will disperse into nearby suboptimal habitat and may compete with resident males in optimal habitat (Hays 1990). During dispersal individuals may pass through deep and diked tidal marsh, as well as upland habitats. After breeding Suisun shrews aggregate into small population units consisting of one dominant male, several breeding females, and several non-breeding females (Hays 1990).

All *Sorex* species die after the breeding season with 16 months being the average life span of most individuals (Owen and Hoffman 1983). Early spring populations consist of individuals born the previous year, whereas late summer populations consist mostly of individuals born in the current year (Owen and Hoffman 1983). By fall most of the population has died out and only the young of the year remain (Owen and Hoffman 1983).

Salt marsh shrews are intense feeders with high energetic needs (Newman 1970). Newman (1970) estimated an assimilation rate of 65% in reproductively active shrews and 42% in reproductively inactive shrews. The average metabolic rate is about 4.5 Kcal/day, and increases to 6.0 Kcal/day at 20°C (Owen and Hoffman 1983). Metabolic rates are so elevated that one hour without food may be sufficient enough to cause mortality (Orr 1949; Owen and Hoffman 1983). To compensate for their high activity level and extremely high metabolic rate, shrews must consume large quantities of food (Newman 1970). They can ingest, in a 24-hour period, an amount equal to or exceeding their own weight (Genoud and Vogel 1989). Suisun shrews will often undergo daily torpor to conserve energy (Newman and Rudd 1978).

Shrews generally are dietary opportunists that eat whatever invertebrates they encounter (Newman 1970). Salt marsh shrews feed primarily on crustaceans present in the middle elevation marsh zone and seem to prefer continuously moist soils near the mean high tide level where high densities of amphipods (hundreds per square meter) are present on the soil surface during all seasons (Newman 1970; WESCO 1986; Hays 1990).

Salt marsh shrews are susceptible to extreme tides and weather-induced stress and can die if their fur becomes wet or cold (Hays 1990). To avoid high tides, shrews will climb into dense foliage that is above the tidal level (Hays 1990). Nearby upland habitat 13.8 to 2.4 m above sea level provides critical refugia from flooding (Williams 1983).

Conceptual Model of Suisun Shrew Use of Tidal Marshes in Suisun Marsh

The conceptual model for Suisun shrew is displayed in Figure 4-6. The shrew seems to require areas of fairly constant soil moisture with dense, low-lying plant cover, and abundant invertebrates; and where driftwood and other litter are available above the mean high tide line for nesting and foraging (WESCO 1986; Williams 1983). Upland refugia are essential for escape from inundation. Hadaway and Newman (1971) captured shrews most often at the interface between pickleweed marsh and upland levees. Thus, tidal marshes with adjacent upland edges suitable for refugia and nesting are important for supporting shrews. More information on suitable edge types and the range of slopes that support shrews is needed.

The middle marsh appears to be optimum habitat for salt marsh shrews (Owen and Hoffman 1983). Generally, Suisun shrews inhabit tidal marshes characterized by cordgrass, pickleweed, and gum plant, and brackish marsh characterized by California bulrush and cattail (Rudd 1955). However, the physical structure of the habitat seems to be more important than the specific plant composition. Thick low lying cover provides critical foraging habitat where invertebrates are plentiful. In addition, complex litter structure, such as driftwood, planks, and blocks, above mean high tide can provide additional foraging and nesting sites (MacKay 2000). Suisun shrews may stay within its home range during tidal events and tall vegetation above the tide level within provides refuge from extreme high tides (Newman 1970; Hadaway and Newman 1971). Salt marsh shrews have not been trapped in either high tidal marsh or diked salt marsh (WESCO 1986; Hays 1990; Shellhammer 2000). High marsh, however, may provide refuge from tidal flooding, and drift-line debris may provide local microhabitats rich in invertebrate prey (Williams 1986; Mackay 2000).

Seasonality determines habitat use of the Suisun shrew. Hays (1990) found shrews in dense layers of matted plant material and under succulents during the fall when weather was hot and tides high, whereas during winter and early spring shrews were found foraging mostly among arrowgrass (*Maritime maritimum*) when weather was cooler and tides lower. Constructed burrow systems can be complex, averaging 8 cm in depth (Hays 1990). Suisun shrews were found to use burrows and runways of other sympatric species such and harvest mice (*Reithrodontomys*) and meadow mice (*Microtus*).

The greatest current threats are the consequences of past reduction in the extent, quality, and continuity of tidal marsh habitat and resident shrew populations. The remaining populations are vulnerable to extreme tidal flooding events and erosion along wave-exposed shorelines. The isolated populations render dispersal difficult, if not impossible, across large distances which may limit genetic variability within the Suisun marsh. Adequate connectivity between middle marsh, high marsh, and upland habitats is scarce within the Suisun marsh. In addition, current management within the marsh favors the establishment of bulrush and threatens to decrease habitat suitability for the remnant shrew populations.

The effect of contaminants in estuarine sediments may pose risks for recovery of tidal marsh shrews. Shrews have very high rates of metabolism and consume large quantities of invertebrates. Contaminants, such as PCBs, PNCs, heavy metals, and pesticides, may concentrate in the invertebrate species present in the marsh (WESCO 1986). These factors may make shrews more vulnerable to the effects of toxic substances in the estuarine environment. Diffuse, non-point sources of contaminants in the estuary may increase as urban development around the region intensifies. Pankakoski *et al.* (1994) demonstrated that heavy metal pollution could adversely affect the developmental stability of shrew populations. Sublethal effects of contaminants, such as reduced fecundity of adults or reduced viability of young, are probably the most significant potential population-level threats associated with estuarine contaminants. Specific studies relevant to the effects of contaminants on tidal marsh shrews are needed.

Several studies seem to indicate that shrews are seldom preyed upon (Pearson 1946; Crowcroft 1957). Predatory birds, such as owls and other raptors, are possible culprits to shrew predation, yet no shrew remains were found in pellets (Newman 1970). It is plausible that some mortality can be attributed to rats. More studies are needed on shrew predation.

The effects of non-native invasive plant or wildlife species has not been studied in regards to Suisun shrew habitat use/suitability and competition. However, it is likely that non-native species have some deleterious effects on shrews. Non-native invasive plants are known to out-compete native species and result in an altered vegetation community and structure, thereby possibly altering invertebrate communities shrews depend on. Non-native wildlife species may increase predation risk and competition for suitable foraging and nesting sites.

Expected Restoration Effects at Each Trajectory Stage

Suisun shrews use the middle and high marsh. Restoration that improves the structure of both remnant and restored tidal marshes at the appropriate mid and high marsh elevations will likely benefit tidal marsh shrews. It is important to restore areas to the appropriate vegetation structure over species composition, as structure seems to play an important role in habitat suitability. Variations in vegetation density and height will allow for appropriate foraging and nesting sites, as well as provide refugia from high tidal events. Connections between marsh and upland habitat are essential as uplands also provide refugia and nesting habitat. The construction or evolution of shallow sloping banks and extensive high marsh edges of well-vegetated tidal marsh plains is most likely to provide habitat that will be used by shrews. Natural tidal

regimes provide higher prey availability than diked wetlands, so all efforts should be made to maximize natural tidal marsh restoration. Restoring marsh complexity by adding driftwood, wood planks, and other litter can further augment foraging and nesting sites.

The ability of tidal marsh restoration projects to compensate for past habitat loss is limited by the rate at which restored tidal marshes mature and form marsh plains near the elevation of mean high water. Earlier stages of marsh succession appear unlikely to benefit recovery of the shrew. The rate at which the marsh becomes fully functional for Suisun marsh will depend on several factors including tidal action, sedimentation rate, and contaminants.

4.2.7 Delta Smelt (*Hypomesus transpacificus*) (DFG)

Species Description

Delta smelt are an estuarine resident species that spawns in tidal freshwater (Moyle et al. 1992; Hobbs et al. 2007). They can briefly tolerate salinities as high as 19 psu (Swanson et al. 2000), but most individuals have been collected at salinities less than 2 psu as larvae (Dege and Brown 2004) and less than 5-6 psu as juveniles (Feyrer et al. 2007; Nobriga et al. in press). They select waters that are well oxygenated and have relatively cool temperatures, usually less than 20-22 degrees Celsius (68-72 degrees Fahrenheit) in summer. Delta smelt are endemic to the upper San Francisco Estuary, and occur principally in the Delta and Suisun Bay (Moyle 2002). They are found seasonally throughout Suisun Marsh in small numbers (Matern et al. 2002). During high flow years they can spawn in the Napa River and be washed into San Pablo bay, but do not establish permanent populations there. In all but high outflow years, the population has typically been centered in the northwest Delta in the Sacramento River during summer and fall. When not spawning, delta smelt tend to be concentrated near the zone where incoming salt water and out flowing freshwater mix (mixing zone). This area historically had the highest primary productivity in the Estuary and was where zooplankton populations (on which delta smelt feed) are usually most dense (Knutson and Orsi 1983; Orsi and Mecum 1986). Zooplankton population abundances changed significantly following the introduction of the overbite clam *Corbula amurensis* (Kimmerer and Orsi 1996).

Delta smelt primarily live one year and have relatively low fecundity. A small portion of delta smelt live two years; these individuals have higher fecundity (Bennett 2005). Spawning can occur from late February to June, but most occurs March to May. Wang (1986) reported spawning taking place in fresh water at temperatures of about 7-15 degrees Celsius (44-59 degrees Fahrenheit). However, ripe delta smelt and recently hatched larvae have been collected in recent years at temperatures of 15-22 degrees Celsius (59-72 degrees Fahrenheit), so some spawning may take place over the entire 7-22 degrees Celsius (44-72 degrees Fahrenheit) range. Recent laboratory hatching data suggest spawning is most successful at temperatures of about 15-20 degrees Celsius (Bennett 2005).

Delta smelt is currently State and federally listed as threatened. In the past few years, delta smelt populations have shown marked declines. The abundance indices for 2002-05 include record lows for delta smelt (Sommer et al. 2007).

Conceptual Model of Delta Smelt Use of Tidal Marshes in Suisun Marsh

The conceptual model for Delta smelt is displayed in Figure 4-7. Since delta smelt are deriving indirect productivity benefits from tidal marshes within Suisun Marsh, connectivity between the tidal marshes and the tidal sloughs and access of delta smelt into the tidal sloughs from the southern bays are likely the most important drivers of that tidal marsh function. Delta smelt is primarily a pelagic species, so it is unlikely they require the structural complexity provided by the marsh. However, they may benefit from prey production exported from the marsh. The SMSCG and other water control structures are physical barriers to connectivity between Suisun Marsh and the open-water system of Suisun Bay and the western Delta. The SMSCG can be operated from October through May and the expected operational frequency is 10 to 20 days per year (USFWS 2008). When operating, the SMSCG temporarily limits access to and from the eastern end of Montezuma Slough.

Expected Restoration Effects at Each Trajectory Stage

Delta smelt use of tidal marshes in Suisun Marsh may be largely limited to a secondary function – consumption of productivity exported from the marshes. Thus, connectivity of the tidal marshes to the tidal aquatic environment is the key process linking delta smelt to tidal marsh productivity.

Exported production function: Since the primary ecological function of Suisun tidal marshes is consumption of productivity exported, then the linkage to evolutionary stage is that of relative differences in magnitude of exported production as a function of evolutionary stage. Few studies exist on this topic. Since delta smelt feed on pelagic secondary production (zooplankton), then it is reasonable to conclude that earlier stage restoration sites may provide greater exported production as the lower elevations of these sites would provide greater inundation duration and thus more aquatic habitat to support primary and secondary production.

Direct access to early stages: Delta smelt may also physically enter restoration sites that are of relatively low elevation (early stage of evolution), as such sites are essentially shallow tidal aquatic environments during higher tide stages. The subtidal and low intertidal stages are most likely to provide such habitat.

4.2.8 Longfin Smelt (*Spirinchus thaleichthys*) (DFG)

Species Description

Longfin smelt is an anadromous fish species that inhabits open waters of estuaries along the Pacific coast of North America. For juveniles through pre-spawning adults, optimum salinity ranges are typically 15 to 30 psu (Moyle 2002; Baxter *et al.* 1999), whereas during their spawning migration they prefer fresher water habitats where salinities are 0-2 parts per thousand. Spawning generally occurs from November until June, with the peak spawning period being from February through April, in areas that provide an adequate amount of rocks and/or submergent vegetation for eggs to adhere to. According to data from U.C. Davis monitoring, longfin smelt can occur in the Marsh year-round, but is mostly used during the larval stage when they use the brackish waters as nurseries. Longfin smelt abundance in the Marsh declined sharply in

the early 1980s and has remained low since then (Matern *et al.* 2002). Annual mean catches between 1980 and 1985 were about 1 smelt per trawl, with a peak of 7 per trawl in 1980. Since 1985, values have always been < 2 smelt per trawl (DWR 1999). There has historically been a strong positive correlation between winter and spring Delta outflow and longfin smelt abundance during the subsequent fall (Jassby *et al.* 1995; Kimmerer 2002). High freshwater outflows increase the volume of low-salinity water rearing habitat required by larval and juvenile smelt. Historically, high freshwater flows also increased prey production for longfin smelt, but this changed after the introduction of the overbite clam (Kimmerer 2002).

Longfin smelt are currently listed as a Species of Special Concern by CDFG. On August 8, 2007, The Bay Institute along with the Natural Resource Defense Council submitted a petition to have longfin smelt listed as endangered under the Endangered Species Act due to its persistent decline in numbers in the San Francisco Estuary in the last 20 years.

As with delta smelt, use of tidal marshes in Suisun Marsh may be largely limited to a secondary function – consumption of productivity exported from the marshes. Thus, connectivity of the tidal marshes to the tidal aquatic environment is the key process linking longfin smelt to tidal marsh productivity.

Conceptual Model for Use of Suisun Marsh

The conceptual model for longfin smelt is displayed in Figure 4-8. Since longfin smelt are deriving indirect productivity benefits from tidal marshes with Suisun Marsh, connectivity between the tidal marshes and the tidal sloughs and access of longfin smelt into the tidal sloughs from the southern bays are likely the most important drivers of that tidal marsh function. Salinity appears to have the greatest influence on larval distribution, and there is a strong relationship with X2 (Kimmerer 2004). The center of larval distribution is correlated with X2, which is often centered in Suisun Bay (R. Baxter unpublished data). Juvenile and sub-adult longfin smelt are found in higher salinities (15-30 psu) and their distribution in Suisun may be less influenced by salinity. The SMSCG and other water control structures are physical barriers to connectivity between Suisun Marsh and the open-water system of Suisun Bay and the western Delta. The SMSCG can be operated from October through May and the expected operational frequency is 10 to 20 days per year (USFWS 2008). When operating, the SMSCG temporarily limits access to and from the eastern end of Montezuma Slough.

Expected Restoration Effects at Each Trajectory Stage

Longfin Smelt is primarily a pelagic species so it is unlikely they require the structural complexity provided by the marsh. Juvenile and sub-adults have been found to be more abundant at sampling locations over deep water (Rosenfield and Baxter in press). However, they may benefit from prey production exported from the marsh. Thus, as with delta smelt, connectivity of the tidal marshes to the tidal aquatic environment is the key process linking delta smelt to tidal marsh productivity, and the exported production and direct access functions as described above for delta smelt apply to longfin smelt.

4.2.9 Sacramento Splittail (*Pogonichthys macrolepidotus*) (DFG)

Species description

The Splittail (*Pogonichthys macrolepidotus*) is a relatively large (>300mm in length) member of the minnow family. It is endemic to the San Francisco Estuary and watershed (Moyle et al. 2004). Juveniles and adults inhabit tidal fresh and brackish water in the Delta, Suisun Bay, Suisun Marsh, and lower portions of the Napa and Petaluma rivers and their marshes. They are abundant in moderately shallow (<4 m), narrow, turbid, sloughs lined with tules and other emergent vegetation (Feyrer et al. 2005; Moyle et al. 2004). In recent years, splittail have been most common in brackish tidal waters of Suisun Marsh and the Sacramento-San Joaquin Delta. The core of the distribution of adult splittail in summer lies between Suisun Bay and the west Delta. Juveniles and adults commonly inhabit salinities of 10-18 psu (Meng and Moyle 1995; Sommer et al. 1997), and adults can survive salinities up to 29 psu for brief periods of time (Young and Cech 1996). Splittail are found in waters with a broad range of temperatures from 5 to 24°C and can acclimate to temperatures up to 29-33°C for short periods. Splittail of all ages can tolerate low dissolved oxygen levels (<1 mg/L (Moyle et al. 2004).

Spawning occurs in shallow (<2 m) freshwater, inundated floodplain habitat with detectable water flow (Sommer et al. 1997; Sommer et al. 2001; Moyle et al. 2004). Evidence indicates that spawning may occur in Suisun Marsh in submerged vegetation, including submerged portions of emergent intertidal marsh vegetation (Meng and Matern 2001). Larvae remain in this habitat and then move into deeper open water as they mature. They are opportunistic benthic feeders, consuming crustaceans, detritus, insect larvae, and other invertebrates. Splittail forage in very shallow water (< 0.5 m) particularly during flood tides (Baxter unpublished data). Splittail, in turn, are a prey of striped bass, and have been used as bait for sport fishing (U.S. Fish and Wildlife Service 1996).

Splittail was listed as threatened by the USFWS in 1997. The listing was subsequently vacated in 2003, but remains a Species of Concern by USFWS and DFG.

Conceptual Model of Sacramento Splittail Use of Tidal Marshes in Suisun Marsh

The conceptual model for Sacramento splittail is displayed in Figure 4-9. Unlike delta and longfin smelt, splittail are relatively tolerant of a wide range of water quality conditions. In Suisun Marsh, splittail are abundant in late summer when salinities are typically 6 to 10 psu and temperatures are 15 to 23°C (Meng et al. 1994; Meng and Moyle 1995). Splittail of all sizes can survive in waters with dissolved oxygen levels <1 mg/L, allowing them to tolerate slow-moving sections of sloughs (Moyle and others 1982; Daniels and Moyle 1983). Therefore, suitable water quality, with respect to salinity, temperature, and dissolved oxygen, is not a primary driver of connectivity with the Marsh. There is some evidence that turbidity may be a moderately important driver as juveniles are most abundant in shallow (<2 m deep) turbid waters (Moyle et al. 2004). Hydrologic connection between spawning and rearing areas may be an important driver of Marsh use. It has been hypothesized that rapid passage of young-of-year splittail to rearing areas, such as Suisun Marsh, increases survival (Moyle et al. 2004). It is suggested that much of the water draining the Yolo

Bypass enters Suisun Marsh via Montezuma Slough so juvenile trends in the Marsh are likely heavily influenced by upstream production. This connectivity allows rapid passage to preferred rearing areas, hence increasing survival.

Marsh geomorphology, specifically channel depth, is likely an important driver of splittail use within the Marsh. Generally, non-reproductive splittail are most abundant in sloughs <4 m deep, while juveniles are most abundant in sloughs <2 m deep (Feyrer *et al.* 2005; Moyle *et al.* 2004). Sommer *et al.* (2002) found that early life stages of splittail were associated with shallow habitat near sources of flow and emergent vegetation, while larger fish used deeper water in open and vegetated areas. The SMSCG and other water control structures are physical barriers to connectivity between the marsh sloughs and the adjacent bays and floodplains. The SMSCG can be operated from October through May and the expected operational frequency is 10 to 20 days per year (USFWS 2008). When operating, the SMSCG temporarily limits access to and from the eastern end of Montezuma Slough. Other water control structures such as levees and gates prevent access to channels and marsh plains. The impacts of these barriers to marsh access and the entrainment of splittail into seasonally unsuitable habitat within the marsh are unknown.

The diet of splittail in Suisun is fairly well known. In Suisun Marsh in the early 1980's splittail foraged primarily on opossum shrimp (*Neomysis mercedis*), amphipods, *Corophium* spp., and harpacticoid copepods, though detritus accounted for more than half of the gut contents by volume (Moyle *et al.* 2004). Following the invasion of the overbite clam (*Corbula amurensis*), populations of *Neomysis mercedis* dropped significantly and were no longer important in the splittail diet. Splittail in the Marsh still eat mostly detritus and other items such as bivalves, amphipods, cladoerans, and harpacticoid copepods (Feyrer and others 2003). Detritus typically makes up 50-60% (by volume) of splittail gut contents (Feyrer and others 2003), and given the quantity, may have some nutritional value (Moyle *et al.* 2004). Invertebrate prey production in the Marsh is likely a fairly important driver of splittail use. Splittail tolerate a fairly wide range of water quality conditions, therefore, suitable water quality conditions exist many places throughout the Estuary. Additionally, many places throughout the Estuary have shallow water areas preferred by splittail. The fact that splittail primarily use Suisun Marsh for rearing indicates that conditions exist which allow it to outcompete competitors and minimize predation. Although these specific conditions are unknown, it can be speculated that food resources is a likely driver for marsh use.

Expected Restoration Effects at Each Trajectory Stage

Splittail are known to forage in shallow areas throughout the Marsh such as subtidal and intertidal mudflats, sloughs, and marsh plain. They are tolerant of a wide range of water quality conditions and can tolerate slow moving waters. Therefore, it is reasonable to conclude that splittail will directly utilize restoration stages from subtidal through mid-marsh. They are also likely to derive indirect benefits through increased export of primary and secondary pelagic production. Splittail are not expected to gain any direct benefit from high-marsh sites, but may benefit indirectly through increased production. The upland transition stage is unlikely to provide any direct or indirect benefits to splittail.

4.2.10 Chinook Salmon (*Oncorhynchus tshawytscha*) (NMFS)**Species description**

Chinook salmon follow the typical life cycle of Pacific salmon in that they hatch in freshwater, migrate to the ocean, and return to freshwater to spawn and die. Chinook salmon return to freshwater to spawn when they are three to eight years old (Healey 1991). Migration from the ocean to streams for spawning can be stimulated or inhibited by stream flow, atmospheric pressure, water turbidity, water temperature and dissolved oxygen (Allen & Hassler 1986).

Chinook salmon runs are designated on the basis of adult migration timing; however, distinct runs also differ in the degree of maturation at the time of river entry, thermal regime and flow characteristics of their spawning site, and actual time of spawning (Myers et al. 1998). The different runs have been identified as Evolutionarily Significant Units (ESU), and the runs that utilize Suisun Marsh are Central Valley fall and late-fall run, Sacramento River winter-run and Central Valley spring-run Chinook salmon.

Central Valley fall and late fall-run Chinook salmon generally enter freshwater at an advanced stage of maturity, move rapidly to their spawning areas on the mainstem or lower tributaries of rivers, and spawn within a few days or weeks of freshwater entry (Healey 1991). Spawning occurs in the lower reaches of most rivers and streams in the Central Valley (Meyers et al. 1998). Juvenile fall-run Chinook salmon emigrate as fry or smolt within a few months after hatching. Rearing occurs in estuaries and juveniles travel to the ocean within their first year of life (Allen & Hassler 1986). Late-fall-run spend longer rearing in freshwater reaches of mainstem rivers before traveling to the ocean within the first 7-13 months of life (Moyle 2002). Fry typically reside in estuaries until they increase in size and environmental conditions stimulate travel to the ocean (Allen & Hassler 1986). On April 15, 2004, NMFS classified Central Valley fall and late-fall Chinook a species of concern.

Central Valley spring-run Chinook salmon adults enter the Sacramento Delta beginning in January and enter natal streams from March to July (Myers et al. 1998). After entering freshwater, adults hold over summer, and spawn in the fall. Juveniles typically spend a year or more in freshwater before migrating toward the ocean. Adequate instream flows and cool water temperatures are more critical for the survival of Central Valley spring-run Chinook salmon due to over summering by adults and/or juveniles. On June 28, 2005, the National Marine Fisheries Service (NMFS) reconfirmed the threatened status of Central Valley spring-run Chinook salmon.

Sacramento River winter-run Chinook salmon generally enter San Francisco Bay from November through June (Hallock and Fisher 1985), and delay spawning until spring or early summer. Spawning occurs in the in the Sacramento River reach between Keswick Dam and the Red Bluff Diversion Dam. In the Sacramento River and other tributaries, juveniles may begin migrating downstream almost immediately following emergence from the gravel with emigration occurring from December through March (Moyle 2002). Fry and parr may spend time rearing within riverine and/or estuarine habitats including natal

tributaries, the Sacramento River, non-natal tributaries to the Sacramento River, and the delta. On June 28, 2005, The NMFS reconfirmed the endangered status of Sacramento River winter-run Chinook salmon.

Conceptual Model of Chinook Salmon Use of Tidal Marshes in Suisun Marsh

The conceptual models for Chinook salmon rearing and migration are displayed in Figure 4-10 and Figure 4-11, respectively. The Suisun Marsh Fish Monitoring (SMFM) program has documented the presence of juvenile Chinook salmon throughout the Marsh. However, methods used for sampling are not effective at capturing fish with strong swimming abilities such as salmonids. Therefore, the number of Chinook salmon sampled should not be considered an accurate population estimate for individuals that utilize the Marsh. Montezuma Slough, as well as Suisun and Grizzly Bay are located between Central Valley salmonid freshwater spawning and rearing habitat and the Pacific Ocean. Adult and juvenile Chinook salmon utilize Suisun Marsh, particularly Montezuma Slough, along with Suisun and Grizzly Bays as migration routes. Juveniles are believed to enter Suisun Marsh at a smolt stage, although fall-run smolts are generally smaller in size compared to listed Chinook salmon. Juveniles likely utilize the Marsh for foraging, migration and potentially minimal rearing. The primary drivers that likely influence Chinook salmon habitat connectivity throughout the Marsh are physical barriers and adverse water quality conditions, rendering the water column unsuitable for occupancy by this species.

The ability of Chinook salmon to access the majority of tidal marsh areas in Suisun is excluded by levees and gates. Marsh geomorphology such as edge habitat, channel networks of varying complexity and vegetated bank edges are known to be important habitat features for fish utilizing tidal marshes (Peterson and Turner 1994 and Visinainer et al. 2006). Juvenile Chinook salmon forage in shallow areas with protective cover, such as intertidal and subtidal mudflats, marshes, channels and sloughs (McDonald 1960, Dunford 1975). Levees obstruct hydraulic connectivity between tidal marshes and adjacent aquatic habitat and prevent the development of edge habitat.

Suitable water quality for Chinook salmon may include appropriate levels for water temperature, salinity, turbidity, and dissolved oxygen (DO). Water temperature strongly affects the growth and survival of juvenile Chinook salmon (Moyle 2002). Migrating adults require temperatures between 10.6-19.4° C (51.08-66.92 °F). If exposed to excessive high levels of turbidity such as can occur periodically in Suisun and Honker bays, Chinook salmon may suffer reduced feeding and foraging ability (Gregory 1988, Benfield and Minello 1996) and be prone to fish gill injury (Nightingale and Simenstad 2001). Higher turbidities are driven by wind resuspension from shallower reaches of the southern bays; winter has the least winds (California Climate Data Archive, 2010). Winter storms can also bring sediment from the Delta, raising Suisun turbidity. Combined factors, such as decreased temperature and increased turbidity, can interact to encourage the emigration of juveniles to the ocean (Moyle 2002). Salinity acclimation is important for the osmoregulation of juveniles with tolerance increasing as fish grow. Low DO levels are known to reduce growth, feeding, and swimming ability and increase susceptibility to disease, predation, and toxic contaminants (Allen & Hassler 1986). DO levels below 5 mg/l are known to be deleterious to fish and likely block migration corridors for anadromous fish such as Chinook salmon (Schroeter 2004). In Suisun Marsh, significant

depressions in DO concentrations (DO sags) that are associated with managed marsh pond discharge and flood up activities, have been reported since fall of 1999 (Schroeter 2004). In fall of 2003, 32 dead Chinook salmon adults were observed during a DO sag event in Suisun Slough (Schroeter 2004). Thus, areas of the Marsh with low DO concentrations are unlikely to be used, and could be fatal to Chinook salmon. One study is near completion examining contributions of diked, managed wetlands to slough low DO and elevated methyl mercury events. The *Suisun Marsh Low Dissolved Oxygen and Methyl Mercury Best Management Practices for Diked Wetlands* study is anticipated to release its project report later in 2010. See Chapter 1 for a description of this study. SRCD has been working with landowners over the last several years to implement changes to club operations, and this study supports those efforts. These efforts have helped to reduce the low DO events though they still occur including one and perhaps two noted events in 2009.

The availability of prey items will also influence the use of tidal marshes as foraging areas by Chinook salmon. In the Sacramento-San Joaquin Delta, juveniles primarily feed on terrestrial insects, although aquatic crustaceans are also eaten. In flooded areas during high tide, juveniles consume large amounts of zooplankton and small insect larvae (Moyle 2002). Emergent vegetation communities can provide protective cover and support invertebrate populations, which provide an important food source for juveniles (Moyle 2002). Keljson et al. (1981) reported that juvenile Chinook salmon demonstrated a diel migration pattern, orienting themselves to nearshore cover and structure during the day, but moving into more open, offshore waters at night.

Inundation regime may also influence the use of tidal marshes by Chinook salmon. Within estuarine habitat, juvenile Chinook salmon movements are generally dictated by tidal cycles, following the rising tide into shallow water habitats from the deeper main channels, and returning to the main channels when the tide recedes (Levy and Northcote 1982; Levings 1982; Healey 1991). As juvenile Chinook salmon increase in length, they tend to school in the surface waters of the main and secondary channels and sloughs, following the tides into shallow water habitats to feed (Allen and Hassler 1986).

Expected Restoration Effects at Each Trajectory Stage

Juvenile Chinook salmon are known to forage in shallow areas with protective cover such as intertidal and subtidal mudflats, marshes, channels and sloughs. If provided appropriate accessibility, water quality conditions and prey items, juveniles will likely directly utilize restoration stages, such as subtidal, low intertidal, low marsh, mid marsh and high marsh for foraging. These restoration stages may also provide benefits to Chinook salmon in adjacent aquatic habitats through an increased export in productivity.

4.2.11 Steelhead (*Oncorhynchus mykiss*) (NMFS)

Species Description

Steelhead generally follow the typical Pacific salmon lifecycle in that they hatch in freshwater, migrate to the ocean, and return to freshwater to spawn. However, steelhead are iteroparous, meaning they do not die after spawning and are capable of spawning more than once. Steelhead also exhibit greater variation than

most anadromous fish in the time spent at each life stage. The Distinct Population Segments (DPS) that utilize Suisun Marsh are Central California Coast and Central Valley steelhead.

Steelhead from the tributaries of San Francisco Bay typically enter freshwater to spawn between November and April, with peak numbers occurring in January and February. Central California Coast and Central Valley steelhead are at, or near, sexual maturity when they enter freshwater and spawning occurs shortly after.

Juveniles rear in freshwater for 1-4 years before migrating to the ocean as smolts. Emigration from natal streams occurs episodically during fall, winter, and spring high flows. Estuaries provide important transitional habitat for juvenile steelhead since they are used for rearing, foraging, freshwater to saltwater acclimation, and migration.

The DPS for Central California Coast steelhead pertinent to the Marsh includes all naturally spawned populations of steelhead in tributary streams to Suisun Marsh including Suisun Creek, Green Valley Creek, and an unnamed tributary to Cordelia Slough (commonly referred to as Red Top Creek). Suisun Marsh is the easternmost extent of their range. NMFS reconfirmed the threatened status of Central California Coast steelhead on January 5, 2006.

The DPS for Central Valley steelhead consists of naturally spawned populations in the Sacramento and San Joaquin Rivers and their tributaries. NMFS reconfirmed the threatened status of Central Valley steelhead on January 5, 2006.

Conceptual Model of Steelhead Use of Tidal Marshes in Suisun Marsh

Figure 4-12 and Figure 4-13 display conceptual models of, respectively, Central Valley and Central Coast steelhead rearing. Conceptual models of Central Valley and Central Coast steelhead migration are displayed respectively in Figure 4-14 and Figure 4-15. The Suisun Marsh Fish Monitoring (SMFM) program has documented the presence of juvenile steelhead in the Marsh (BDAT 2007). However, the methods used for sampling are not effective at capturing fish with strong swimming abilities such as salmonids. Therefore, the number of steelhead sampled should not be considered an accurate population estimate for the amount of individuals that utilize the Marsh. Montezuma slough, as well as Suisun and Grizzly Bay, are located between Central Valley salmonid freshwater spawning habitat and the Pacific Ocean. Adult Central Valley steelhead utilize Suisun Marsh, particularly Montezuma Slough, along with Suisun and Grizzly Bays as migration routes. Juvenile Central Valley steelhead enter the Suisun Marsh at a smolt stage and likely utilize the Marsh for foraging, rearing and migration. Suisun Slough is located between Central California Coast steelhead freshwater spawning habitat and the Pacific Ocean. Adult Central California Coast steelhead spawn and rear in Suisun and Green Valley creeks and utilize lower Suisun and Cordelia sloughs as migratory habitat. Electrofishing surveys conducted in 1999 and 2001 in Suisun and Green Valley Creeks (Sanford 1999, Sanford 2001) and habitat surveys conducted in Suisun Creek between 2000 and 2002 (Hanson Environmental Inc. 2002), have documented the presence of juvenile Central California

Coast steelhead in these watersheds. Juvenile Central California Coast steelhead may also utilize tidal sloughs, particularly those tributary to their migratory routes for foraging and rearing. The primary drivers that likely influence steelhead habitat connectivity throughout the Marsh are physical barriers and adverse water quality conditions, rendering the water column unsuitable for occupancy by this species.

The ability of steelhead to access the majority of tidal marsh areas in Suisun is excluded by levees and gates. Marsh geomorphology such as edge habitat, channel networks of varying complexity and vegetated bank edges are known to be important habitat features for fish utilizing tidal marshes (Peterson and Turner 1994 and Visinainer et al. 2006). Levees obstruct hydraulic connectivity between tidal marshes and adjacent aquatic habitat and prevent the development of edge habitat.

Suitable water quality for steelhead may include appropriate levels for water temperature, salinity, turbidity, and dissolved oxygen (DO). Adequate water temperatures for rearing juveniles are between 7 -14 ° C (45-48 ° F) with an upper lethal limit of 24 ° C (75 ° F) (Barnhart 1986, Bjornn and Reiser 1991). Adequate temperatures for upstream and downstream migrating adults are between 8 and 11 ° C (46-52 ° F). Successful outmigration of smolts to the ocean depends primarily on adequate flows and water quality. High concentrations of suspended solids can cause sublethal effects including physiological stress that reduces performance capacity (Redding and Schreck 1987). Low DO levels are known to reduce growth, feeding, and swimming ability and increase susceptibility to disease, predation, and toxic contaminants (Allen & Hassler 1986). In Suisun Marsh, significant depressions in DO concentrations (DO sags) that are associated with managed marsh pond discharge and flood up activities, have been reported since fall of 1999 (Schroeter 2004). DO levels below 5 mg/l are known to be deleterious to fish and likely block migration corridors for anadromous fish such as steelhead (Schroeter 2004). Thus, areas of the Marsh with low dissolved oxygen levels are unlikely to be used by steelhead. One study is near completion examining contributions of diked, managed wetlands to slough low DO and elevated methyl mercury events. The *Suisun Marsh Low Dissolved Oxygen and Methyl Mercury Best Management Practices for Diked Wetlands* study is anticipated to release its project report later in 2010. See Chapter 1 for a description of this study. SRCD has been working with landowners over the last several years to implement changes to club operations, and this study supports those efforts. These efforts have helped to reduce the low DO events though they still occur including one and perhaps two noted events in 2009.

The availability of prey items will also likely influence the use of tidal marshes by steelhead. Juvenile steelhead feed on a wide variety of drifting aquatic organisms and terrestrial insects, but as size increases fish become more important in their diet (Moyle 2002). Emergent vegetation communities support invertebrate populations and provide refuge from water currents and predation. Cover is an important habitat component for juvenile steelhead, both as a velocity refuge and as a means of avoiding predation (Shirvell 1990, Meehan and Bjornn 1991).

Expected Restoration Effects at Each Trajectory Stage

Juvenile steelhead are likely utilizing the Marsh for migration, foraging and rearing. If provided appropriate accessibility, water quality conditions and prey items, juveniles will likely directly utilize restoration stages, such as subtidal, low intertidal, low marsh, mid marsh and high marsh. These restoration stages may also provide benefits to steelhead in adjacent aquatic habitats through an increased export in productivity.

4.2.12 Green Sturgeon (*Acipenser medirostris*) (NMFS)

Species Description

Sturgeon are an anadromous, iteroparous and long-lived fish species. The largest fish have been aged at 42 years, but the maximum age is probably closer to 60-70 years (Moyle 2002). Sexual maturity is reached for male green sturgeon at 15 years and for females at 17 years. The Southern Distinct Population Segment (DPS) of North American green sturgeon consists of coastal and Central Valley populations south of the Eel River. Current spawning habitat for Southern DPS green sturgeon has been reduced to a limited area of the deep turbulent sections of the upper reaches of the Sacramento River (Moyle 2002). On April 7, 2006, NMFS listed the Southern DPS green sturgeon as threatened. In September 2008, NMFS proposed critical habitat for the Southern DPS that includes Suisun Marsh.

Adult Southern DPS green sturgeon return to freshwater to spawn every two to five years, and generally show fidelity to their upper Sacramento River spawning sites. Adults typically migrate into fresh water beginning in late February, spawning occurs from March to July, with peak activity from April to June. Juvenile green sturgeon move from freshwater rivers within their first year to estuaries, where they spend approximately 3 years before migrating to the ocean (Kelly et al. 2006). Juveniles use estuarine waters year-round. The distribution and physical parameters that may influence movement in the estuary are not well known (Moyle 2002). After out-migration, green sturgeon disperse widely in the ocean. Tagged fish from the Sacramento River have been captured to the north in coastal and estuarine waters, such as the mouth of the Columbia River in Oregon (Adams et al. 2002).

Conceptual Model of Green Surgeon Use of Tidal Marshes in Suisun Marsh

The conceptual models for green sturgeon rearing and migration are displayed in Figure 4-16 and Figure 4-17, respectively.

The Suisun Marsh Fish Monitoring (SMFM) program has documented the presence of juvenile green sturgeon in the Marsh (BDAT 2007). However, the methods used for sampling are not effective at capturing fish with strong swimming abilities. Therefore, the number of green sturgeon sampled should not be considered an accurate population estimate for individuals that utilize the Marsh. Essentially no information exists regarding green sturgeon use of the Marsh. Montezuma Slough, as well as Suisun and Grizzly Bay, are located between Central Valley freshwater spawning habitat and the Pacific Ocean. Adult and juvenile green sturgeon likely utilize these areas as a migratory corridor, although it is unclear what portion of the population utilize these routes. Based on the known life history of the species, it is assumed that juvenile green sturgeon could be present in all regions of the Marsh throughout the year. The primary drivers that

likely influence green sturgeon habitat connectivity throughout the Marsh are physical barriers and adverse water quality conditions, rendering the water column unsuitable for occupancy by this species.

The ability of green sturgeon to access the majority of tidal marsh habitat in Suisun is excluded by levees and gates. Levees prevent the development of edge habitat and obstruct hydraulic connectivity between tidal marshes and adjacent aquatic habitat. Since no scientific data currently exists relating to green sturgeon use of the tidal marsh habitat, it is unknown what features of marsh geomorphology would provide the most valuable habitat.

Suitable water quality for green sturgeon may include appropriate levels for water temperature, salinity, turbidity, and dissolved oxygen (DO). Studies on the effects of temperature to juvenile green sturgeon found that optimal bioenergetic performance occurred between 15-19 ° C (59-66.2 °F) (Mayfield et al. 2004). Studies on the energetic cost of different salinities for juvenile green sturgeon found that any age/body size may be found in fresh or brackish water, but adaptations to salt water require a minimum age of 1.5 years (Allen and Cech 2006). Green sturgeon can tolerate elevated levels of turbidity, although thresholds have not been well studied, especially for juveniles. In Suisun Marsh, significant depressions in DO concentrations (DO sags) that are associated with managed marsh pond discharge and flood up activities, have been reported by since fall of 1999 (Schroeter 2004). DO levels below 5 mg/l are known to be deleterious to fish and likely block migration corridors for anadromous fish such as sturgeon (Schroeter 2004). Thus, areas of the Marsh with low dissolved oxygen levels are unlikely to be used by green sturgeon.

Although it is uncertain if and for what functions green sturgeon would utilize tidal marsh habitat in Suisun, the availability of prey items could influence potential site use for foraging. Sturgeon are highly adapted to prey upon benthic species, with primary diet items made up of bottom dwelling estuarine invertebrates. Juveniles in the San Francisco Estuary feed on opossum shrimp and amphipods (Moyle 2002). Adults captured in the Sacramento-San Joaquin Delta feed on invertebrates, including shrimp, mollusks, amphipods, and even small fish (Adams et al. 2002). Colonization of invasive benthic invertebrates is widespread throughout the Bay-Delta and it is currently unknown how green sturgeon are responding to invasive species as a source of prey. Green sturgeon may be feeding on the exotic overbite clam (*Corbula amurensis*) that is common in white sturgeon diet (Moyle 2002). Invasive overbite clams are known to effectively bioaccumulate toxic levels of the trace element selenium, which is known to have deleterious health effects to fish (Deng et al. 2007, Higashi et al. 2005).

Expected Restoration Effects at Each Trajectory Stage

Green sturgeon are likely utilizing the Marsh for migration, foraging and rearing. Although it is unknown if juvenile green sturgeon would utilize any restoration stages of tidal marsh habitat, appropriate accessibility, water quality conditions and prey items could increase the likelihood of providing suitable habitat for direct use. Restoration stages such as subtidal, low intertidal, low marsh, mid marsh and high marsh could

provide indirect benefits to green sturgeon in adjacent aquatic habitats through an increased export in productivity.

4.2.13 Soft bird's beak (*Cordylanthus mollis* ssp. *mollis*) (FWS)

Species Description

Soft bird's beak occurs in the high salt and brackish tidal marsh of northern San Pablo Bay and the Suisun Marsh area, and in some diked brackish marshes with limited tidal circulation. It has an affinity for the higher, well-drained portions of the marsh and the edges of salt pans. It occurs primarily in portions of the middle marsh and high marsh zones where the dominant vegetation includes gaps and areas of sparse vegetative canopy cover, often in association with *Sarcocornia pacifica* and *Distichlis spicata* (saltgrass). It is negatively associated with dense, tall, grass-like vegetation and dense, or tall, nonnative brackish marsh vegetation. Its potential for dispersal to suitable habitat is limited due to isolation of populations by dikes and non-tidal managed marsh. The remaining low populations exist in severely reduced habitat areas with reduced habitat quality. Invasion by non-native tidal marsh vegetation and hydrologic alterations to tidal sloughs are significant potential threats to remaining habitat.

Conceptual Model of Use of Tidal Marshes in Suisun Marsh

Figure 4-18 illustrates the conceptual model applicable to these plant species. Primary drivers for the soft bird's beak are the geomorphology, salinity, and the inundation regime. Sparse vegetation patches, which are preferred by soft bird's beak, may be caused by driftlines (smothering by tidal litter deposits; Chapman 1964, Hartman *et al.* 1983, Parsons and Zedler 1997), by parasitism by *Cuscuta salina* var. *major* (salt marsh dodder; Grewell *et al.* 2003, Grewell 2004), low rainfall, and salinity stress (Allison 1992, Callaway 1994). Variation in soil conditions along upland salt marsh edges also appears to influence species distribution, and the density and cover of tidal marsh vegetation (Baye *et al.* 1999).

The invasion of the middle and upper brackish tidal marsh zones by non-native *Lepidium latifolium* is potentially detrimental to *Cordylanthus mollis* ssp. *mollis* populations. *Lepidium latifolium* generally excludes *Cordylanthus mollis* ssp. *mollis* by establishing dense stands. The invasion of brackish tidal marshes by *Lepidium latifolium* has proceeded rapidly in the last two decades. It currently threatens at least portions of *Cordylanthus mollis* ssp. *mollis* populations at Rush Ranch in Suisun Marsh where it has spread rapidly in the last decade, particularly in high rainfall years (B. Grewell, P. Baye pers. observ. 1991-1999).

Another potential threat to *Cordylanthus mollis* ssp. *mollis* is the large-scale alteration of salinity regimes. In recent decades, water quality standards for salinity in Suisun Marsh emphasized conditions specifically favorable for waterfowl habitat (State Water Resources Control Board 1999). Artificially stabilizing salinities at low levels during the summer and fall subdues the climate-driven pattern of vegetation fluctuations. Water quality standards for salinity have been modified in western Suisun Marsh to allow greater climate-driven fluctuation, but the low salinity range is still enforced in eastern Suisun Marsh.

In a 2004 survey at Rush Ranch, direct destruction of *Cordylanthus mollis* ssp. *mollis* habitat by feral hogs was frequently encountered (Grewell 2004). Feral hogs were observed rooting and overturning vegetation in former *Cordylanthus mollis* ssp. *mollis* population sites.

Other potential threats to *Cordylanthus mollis* ssp. *mollis* include spills of crude oil or refined petroleum products. Crude oil spills tend to deposit near the high tide line where the species is most abundant.

Public access and recreation trails (e.g., jogging trails, bike trails) are often placed along the edges of tidal marshes. Initial disturbance may harm *Cordylanthus mollis* ssp. *mollis*, but may also reduce density and cover of closed marsh vegetation and create favorable semi-open conditions suitable for expansion into unoccupied habitat. Chronic or increasing trampling, or progressive expansion of marsh footpath networks, however, could cause decline or local extinction of *Cordylanthus mollis* ssp. *mollis*.

Sea level rise may impose significant long-term threats to conservation of *Cordylanthus mollis* ssp. *mollis*. Conservation of high marsh zones requires landward transgression (displacement) of the marsh profile on broad sloping plains. Many areas adjacent to the estuary are bordered by steep levees or are already converted to agriculture, residential, or commercial development. As sea level rise increases, conflicting needs for flood protection, agriculture, and marsh transgression could effectively compress tidal marsh zones to a point at which they could not support *Cordylanthus mollis* ssp. *mollis* habitat.

Expected Restoration Effects at Each Trajectory Stage

Soft bird's beak is rarely found in non-tidal conditions (a single collection is known: L.R. Heckard 4665, JEPS76417). *Cordylanthus mollis* ssp. *mollis* abundance is often greatest in or near the upper marsh-upland ecotone (Chuang and Heckard 1973, Ruygt 1994). The principal cause of the species' current rarity and decline is extensive loss of its narrow habitat caused by diking of large tracts of tidal marshes. Diking for agricultural destroyed most of the original tidal marshes in the northern part of the San Francisco Bay Estuary. Tidal marsh acreage has been reduced to approximately 15 percent of its historical area (Goals Project 1999). Most of this residual tidal marsh was formed by recent sedimentation, with very little of the pre-historic marsh area actually remaining (Dedrick 1989). Most populations of *Cordylanthus mollis* ssp. *mollis* are associated with areas of relict old tidal marshes.

Tidal marsh restoration may have temporary adverse impacts on *Cordylanthus mollis* ssp. *mollis* populations. Care should be taken during tidal marsh restoration to prevent "drowning" of *Cordylanthus mollis* ssp. *mollis* populations. When managed marshes with limited tidal range are restored to full or increased tidal action, a rapid increase in tidal range could submerge populations. Marsh succession in restored marshes is likely to result in additional habitat for *Cordylanthus mollis* ssp. *Mollis* in the long term.

Most uncommon to rare plants have rather weak colonizing and dispersal ability, and thus are overwhelmed by native or non-native dominant tidal marsh pioneer plants (Baye 2007). Establishment of

rare plant species at restoration sites will most likely require active multi-year reintroduction programs which include exotic species control.

4.2.14 Delta tule pea (*Lathyrus jepsonii* var. *jepsonii*) (FWS)

Species Description

Delta tule pea typically grows along relatively well-drained creek banks and natural levees (occasionally artificial dikes). This large climbing perennial herb grows over tall bulrushes and tules, as well as other vegetation. It is not found in seasonal wetlands with dry or saline soil in summer. *Lathyrus jepsonii* var. *jepsonii* abundance appears to vary with salinity. During seasons of relatively high salinity, it may be highly inconspicuous, with reduced vegetative growth, failure to flower, or even failure to emerge from perennating roots. In wet, low-salinity years, plants may reappear with robust growth, prolific bloom, and seed production at the same location.

Conceptual Model of Use of Tidal Marshes in Suisun Marsh

Figure 4-18 illustrates the conceptual model applicable to these plant species. The primary driver for the Delta tule pea seems to be salinity. It is not known how long it can persist through years of high salinity conditions. It is uncommon or locally common in Suisun Marsh, but is not particularly rare during high rainfall years

Expected Restoration Effects at Each Trajectory Stage

Delta tule pea abundance in Suisun Marsh has declined because of the elimination of all but the largest tidal creeks due to levee creation. Restoration of the tidal marsh that also includes tidal creeks would create habitat for this rare species.

4.2.15 Suisun thistle (*Cirsium hydrophilum* var. *hydrophilum*) (FWS)

Species Description

Suisun thistle grows in the upper middle marsh plain and high marsh, usually associated with small tidal creek banks that locally drain the marsh peat surface. It is influenced by soil salinity and drainage and restricted to freshwater-influenced brackish marshes. Its extreme historical decline was due to diking and reclamation of nearly all the tidal marshes in Suisun Marsh for either agriculture or waterfowl production. It is likely that the elimination of habitat caused by extensive dike construction between the 1870s and 1930s in Suisun Marsh (Thompson and Dutra 1983) caused a major decline in species abundance and distribution. Immediate threats include precariously low numbers, confined dispersal of its seeds in limited habitat, introduced non-native insect seed predators, and interference with its regeneration caused by nonnative invasive marsh vegetation. Other threats include invasion by non-native *Lepidium latifolium*, disturbance, salinity changes, and genetic assimilation by non-native thistle species.

Conceptual Model of Use of Tidal Marshes in Suisun Marsh

Figure 4-18 illustrates the conceptual model applicable to these plant species. Primary drivers for the Suisun thistle are the geomorphology, the marsh substrate, salinity, and the inundation regime.

Operation of the salinity control gates lowers the salinity of the marsh upstream, and incidentally raises tidal elevations on the order of centimeters (Suisun Ecological Workgroup 2001). Preliminary evidence suggests that the altered salinity and tidal regime may subtly, but significantly, threaten long-term survival of *Cirsium hydrophilum* var. *hydrophilum*.

Non-natives also pose threats to Suisun thistle. Dense, tall stands of *Lepidium latifolium* appear to inhibit survival and growth of juvenile thistles as well. Colonies of *Cirsium hydrophilum* var. *hydrophilum* have not been observed to persist in colonies of this invasive brackish marsh species (B. Grewell and P. Baye pers. observ. 2000). Feral hogs also pose a significant threat to this rare species (B. Grewell and P. Baye pers. observ. 2000). The introduced thistle weevil (*Rhinocyllus conicus*) has been documented in the Rush Ranch population of *Cirsium hydrophilum* var. *hydrophilum* and may be negatively affecting seed production. Larvae of the Mylitta crescent butterfly (*Phyciodes mylitta*) were also found to damage vegetative plants of *C. hydrophilum* (California Department of Water Resources in litt. 1996).

There is a risk that either competitive displacement, interspecific hybridization and assimilation, or both, could corrupt the genetic integrity or population viability of *Cirsium hydrophilum* var. *hydrophilum* due to the reduced modern populations and relatively larger surrounding populations of non-native *Cirsium vulgare*. Some preliminary morphological evidence of hybridization between *Cirsium hydrophilum* and *Cirsium vulgare* has been reported (J. Horenstein in litt. 1987, California Natural Diversity Database 1997), but has not been confirmed by recent field observations (B. Grewell and P. Baye 2000).

Expected Restoration Effects at Each Trajectory Stage

The fundamental cause of the decline of *Cirsium hydrophilum* var. *hydrophilum* was the historical diking of almost all of Suisun Marsh and the conversion of extensive tidal brackish marsh to non-tidal wetlands (Atwater *et al.* 1979, Dedrick 1989). Tidal marsh area in Suisun Marsh was reduced from 29,000 hectares (71,100 acres; ca. 1850) to less than 4,000 hectares (9,500 acres; Dedrick 1989). Tidal marsh restoration will create more high marsh habitat for this species.

4.3 Suisun Marsh Species and Guilds of Management Interest

The following section provides descriptions of wildlife guilds and species of management interest within Suisun Marsh.

4.3.1 Waterfowl (SRCD)

Waterfowl encompass ducks, geese, swans, and whistling ducks. They are holarctic in distribution. In the Nearctic, they are characterized by breeding in the northern interior wetlands of North America and into the prairie pothole regions of the United States and Canada and on into Alaska. In the fall, they migrate south to the interior or coastal states. Some migrate as far south as Central America (Belrose 1980). Nest site selection generally requires the proximity of nest sites in upland grasses and shrubs to water. The

exceptions are the hole nesting species. Specific requirements vary from species to species. Adequate nesting cover requires avoidance of conflict with conspecifics (if nesting densities are high) and of predator detection which means that vertical height and foliage density are important (McLandress et al. 1996). Following breeding, waterfowl, particularly ducks, migrate to areas where they can safely molt. During this post-breeding molt, they lose their breeding plumage and primary flight feathers, rendering them flightless (Belrose 1980; Yarris et al. 1994). When weather conditions force them from their breeding areas and molting areas, they migrate to their wintering areas along four Flyways (Pacific, Inter-mountain, Great Plains and Atlantic). Site fidelity to breeding and wintering areas is strong. There are some species of ducks and geese that are resident, i.e., remaining in one small region rather than make trans-continental excursions. Here in California, mallard, pintail, teal and Canada geese are among the resident waterfowl species. Resident mallards contribute 70% to the wintering population in California (McLandress et al. 1996).

Suisun Marsh provides important waterfowl habitat in California because it is one of the largest contiguous areas of remaining wetland habitat in California. "The Marsh represents approximately 13% of California's remaining wetlands and has historically wintered up to 28% of the wintering waterfowl in California."(SEW 2001) The Marsh is used as a permanent wintering area, as a resting area prior to completing migration, and depending upon regional habitat availability, opportunistically (Miller 1987). As more wintering habitat is lost, Suisun managed wetlands will become increasingly valuable to migratory waterfowl.

The first available water for most wintering California waterfowl, south of the Siskiyou Mountains, is provided by the Marsh. Wetland habitat in the Central Valley and elsewhere is limited when waterfowl populations peak in October and early November. With peak population numbers and limited water, Suisun Marsh and its available water is critical to arriving waterfowl. During droughts, water in the Central Valley is limited throughout the wintering period. Suisun becomes especially important at these times. Marsh water supplies remain very stable during droughts while Central Valley water supplies are reduced. As a result, many areas within the Central Valley may not be flooded during a drought, thereby reducing available Central Valley waterfowl habitat. Waterfowl crowded onto remaining wetlands make them more susceptible to diseases such as avian cholera and botulism.

Taxonomically, migratory waterfowl using Suisun managed wetlands for wintering habitat are, dabbling ducks, diving ducks (or bay ducks), sea ducks, whistling ducks, stiff-tailed ducks, geese, and swans. The Marsh provides important foraging habitat for dabbling ducks (Euliss and Harris 1987; Miller 1987) such as: mallard (*Anas platyrhynchos*), gadwall (*A. strepera*), northern pintail (*A. acuta*), northern shoveler (*A. clypeata*), American wigeon (*A. americana*), Eurasian wigeon (*A. penelope*), cinnamon teal (*A. cyanoptera*), green-winged teal (*A. crecca*), and blue-winged teal (*A. discors*). Additional species that feed by dabbling include: wood duck (*Aix sponsa*), fulvous whistling duck (*Dendrocygna bicolor*) and tundra swan (*Cygnus columbianus*). Diving ducks using the Marsh in the fall, winter and spring include: canvasback (*Aythya valisineria*), redhead (*A. americana*), ring-necked duck (*A. collaris*), greater scaup (*A. marila*), and lesser scaup (*A. affinis*). Sea ducks (which also feed by diving) using managed wetlands in the Marsh include:

common goldeneye (*Bucephala clangula*), Barrow's goldeneye (*B. islandica*), bufflehead (*B. albeola*), black scoter (*Melanitta nigra*), white-winged scoter (*M. fusca*), and surf scoter (*M. perspiculatus*). The following are taxonomically diving ducks, but are piscivores: common merganser (*Mergus merganser*), red-breasted merganser (*M. serrator*) and hooded merganser (*Lophodytes cucullatus*), Stiff-tailed ducks (which also feed by diving) using the Marsh include ruddy ducks (*Oxyura jamaicensis*). Three geese species also use these managed wetlands including: Canada geese (*Branta canadensis*), tule greater white-fronted geese (*Anser albifrons*), and snow geese (*Chen caerulescens*). Geese graze on grains and foliage in the winter. The Suisun Marsh provides a variety of food items such as invertebrates, seeds, and other plant material for these waterfowl. The division of these species into these Guilds is based on (Takekawa et al. 2001).

Suisun's breeding waterfowl include: mallard, green-winged teal, cinnamon teal, gadwall, northern shoveler, northern pintail, wood ducks, ruddy ducks and Canada geese (SRCD pers. comm.) Following breeding, these ducks migrate to inland wetlands to molt their alternate (or breeding) plumage (Yarris et al. 1994). During this period, they are flightless and the return to basic plumage which provides them with less conspicuous plumage (Belrose 1980).

4.3.1.1 Diving Benthivores

The conceptual model for diving benthivores is presented in Figure 4-19. Diving benthivores include the taxonomic categories: sea ducks, diving ducks and stiff-tailed ducks. In winter in the San Francisco Bay estuary, the diving benthivores feed on benthic epifauna and benthic infauna. For example, greater and lesser scaup feed largely on Asian clams (*Potamocorbula amurensis*) and to a lesser extent on native clams (*Macoma balthica*) (Poulton et al. 2002). Asian clams are an introduced species which has overtaken the native populations of clams throughout the estuary. They are an epifaunal and infaunal species on the surface of the sediments and in the upper stratum of the benthos (97% in top 5cm of sediment), whereas the native species is more infaunal. Poulton et al. (2002) found that 48% of the native *Macoma* clam occurred in the top 5cm of sediment with 34% occurring in the 5-10 cm profile and 18% in the 10-20cm level. *Macoma* clams are generally larger, averaging 16.5 mm whereas Asian clams average 8mm. *Macoma* clams increase in size the deeper they are in the sediment. In San Pablo Bay, greater and lesser scaup feed principally on Asian clams in the fall and early winter. Densities of Asian clams were higher than the native *Macoma balthica* in the fall and early winter, and lower than *Macoma* clams in the spring (Poulton et al. 2002). Asian clam densities decline dramatically in the spring. It appears that scaup impact the local densities of Asian clams within their feeding areas. They feed in subtidal and intertidal areas and feed around the clock, unlike dabbling ducks (Custer et al. 1996). The subtidal areas used by scaup in San Pablo Bay are < 2m deep. When feeding in intertidal areas, scaup resort to "dabbling" for clams like dabbling ducks. Clams used by *Aythya* spp occur in soft sediments in relatively shallow waters (< 2m). These ducks appear to remain in the same location to feed and loaf (rest) (Poulton et al. 2004).

Historically, i.e., before major anthropogenic changes and introduced species, canvasbacks (and probably redheads) fed on submerged aquatic vegetation (SAV) in the brackish marshes where the rivers met the bays. In Chesapeake Bay, wild celery (*Valisineria americana*), sago pondweed (*Potamogeton* spp) and

widgeon grass (*Ruppia maritima*) were historically important foods of canvasbacks (Bayley et al. 1978; Perry and Uhler 1988). Today, Chesapeake canvasbacks feed on clams (Perry and Uhler 1988). Changes in the Chesapeake area parallel changes in the San Francisco Bay estuary. Canvasbacks will feed on SAV in California when it is available. Although the causes of loss of SAV beds in San Francisco Bay – Delta estuary are not well understood, the causes for the decline SAV within the brackish marshes of Chesapeake Bay were determined by to be related to several interrelated environmental factors including storms, turbidity, salinity and disease (Bayley et al. 1978). Although no food habits studies of canvasbacks and redheads have been done in Suisun, it is probable that those feeding in the Suisun bays and sloughs feed on native clams or the more abundant Asian clam, whereas those in the managed wetlands feed on appropriate SAV until late winter when they switch to clams or other invertebrates. Canvasbacks also feed on the tubers of aquatic vegetation (Tome and Wrubleski 1988). Historically, canvasback was one of the most widely hunted species in Suisun (Arnold 1996). *Aythya* species feed on the bottom at 90 degrees from horizontal. The loss of tidal SAV for feeding canvasbacks and redheads has shifted their diet to clams making them less desirable as a hunted species. The dietary changes wrought by changes in the estuary have changed the distribution of canvasbacks and redheads (Perry and Uhler 1988).

Ruddy ducks (the only Stiff-tailed duck found in North America) feed in wetland ponds of various salinities from alkali to brackish to saline wetlands, although hypersaline salt ponds can adversely affect the waterproofing of ducks (Takekawa et al. 2000). They have been found feeding in ponds averaging 60-80cm in depth (Euliss et al. 1991). Unlike *Aythya* species, ruddy ducks feed on the bottom by furrowing through the mud with their bill open and their bodies approximately 45 degrees from horizontal. They also will feed on invertebrates at the surface of wetlands if in sufficient abundance; these include waterboatmen and emerging midges (Euliss et al. 1991). Ruddy ducks are opportunistic feeders, but are mostly predators of chironomid midges. They also feed on oligochaetes in the winter (Tome and Wrubleski 1988). Ruddy ducks are the only diving benthivore that nests in Suisun Marsh. They also breed on inland lakes and ponds of North America that are freshwater (Manitoba, Canada), brackish (Suisun Marsh) or alkaline (Tule Lake, CA). Males undergo pre-alternate molt before pair formation, usually in late March in California (Gray 1980). Nests are sited in well concealed, dense emergent vegetation such as cattails (*Typha* spp.) and bulrush (*Scirpus* spp.). The egg of the Ruddy duck has the largest egg size to body ratio of any of the ducks (Lack 1968). The breeding diet of adult males and females is “varied, but almost exclusively invertebrates” (Gray 1980). In California, they feed on chironomid midge larvae and leeches (Gray 1980).

Sea ducks include the scoters. All three species of scoters (*Melanitta* spp.) use the bays and large sloughs of Suisun Marsh. White-winged scoters eat marine mollusks (especially bivalves) and crustaceans during the winter (Brown and Fredrickson 1997). Animal foods comprise 94% of their diet of which 75% is mollusks such as oysters and scallops (Brown and Fredrickson 1997). This species of sea duck uses larger food items than its congeners, the black and surf scoters. White-winged scoters also use deeper waters further from shore than the other two species. These species are also separated by preferred foraging substrate which presumably relates to types of prey species. Along the coast, white-winged scoters prefer sandy or gravelly substrates. Black scoters are significantly less numerous than white-winged scoters

(Belrose 1980). While wintering, they feed almost exclusively on mollusks, especially bivalves (Bordage and Savard 1995). Along the coast, though, they also consume mussels averaging 6.2mm in size. They forage in waters < 10m. Preferred substrates include cobble and bedrock ledges (at least along the east coast), although they are known to use waters with sandy substrates in Puget Sound. This is a relatively little known species. No data is available on foraging activities in San Francisco Bay estuary. They may seek refuge in Suisun Marsh and the rest of the estuary during Pacific storm events. Until recently, surf scoter habits were virtually unknown (Belrose 1980; Savard et al. 1998). Even now, wintering activities are not well known (Savard et al. 1998). Adults feed on mollusks when wintering, principally mussels and clams. Clams comprise 64% by volume of diet in winter. *Macoma balthica* is a principal component of their diet. There is some indication that this species is able to detect the breathing hole of Baltic *Macoma* clams. Mussels used are the same size as those used by black scoters but smaller than those eaten by white-winged scoters. Daily consumption averages approximately 196 g/day. They congregate in winter in conspecific flocks (Savard et al. 1998).

Buffleheads and the two goldeneye species use the Marsh. Bufflehead use ponds, lakes, impoundments and bays during winter. This species principally eats crustaceans and mollusks (Gauthier 1993). Plant foods become important in winter and include emergent vegetation seeds of *Scirpus/Schonoeplectus* spp. and *Potamogeton* spp. (Erskine 1972). Along the Pacific coast areas, buffleheads will join other species feeding on herring eggs. Their use of Suisun managed wetlands provides access to emergent vegetation seeds. Common goldeneyes winter along the Pacific coast in shallow bays and estuaries. This species forages in waters < 4m deep over mud, sandy, gravelly, rocky or boulder substrates. Their diet consists of small fish, crabs, amphipods, mussels, snails, and fish spawn (Eadie et al. 1995). Their use of Suisun Marsh is probably limited to loafing and occasional feeding. Barrow's goldeneyes exhibit intra- and interspecific aggression on its wintering grounds. They are particularly aggressive toward congeners, but include other diving and dabbling ducks (Savard and Smith 1987). Molluscs make up the majority of the winter diet, but their diet also includes small amounts of vegetation, e.g., algae. Barrow's goldeneyes are very selective in their diet and do not feed in proportion to the abundance of their prey. Winter habitat is predominantly over mussel beds along the Pacific coast in water deeper than conspecifics or white-winged scoters use (Eadie et al. 2000). They will group together near freshwater which may explain its presence in Suisun Bay. Like scoters, this species make seek refuge in Suisun and Honker bays during Pacific storms.

Use of Evolutionary Trajectory Stages:

Diving benthivores are expected to use subtidal areas for foraging at all stages of the trajectory while the site contains sufficiently deep waters and supports the appropriate benthic infauna and epifauna. Diving Benthivores are expected to move into the sites during high tides if the sediments support their food resources. During the initial Low Marsh stage, provided clams and other invertebrates invade the restored site, diving benthivores would be expected to use the restoration site. As the site matures, through middle marsh and high marsh with the accumulation of sediment and organic debris, their use of the site will depend upon the water depths and available invertebrates. Diving benthivores will be displaced to adjacent subtidal habitats. Benefits to some diving benthivores, particularly canvasback and redheads would be

provided if wild celery could be propagated within these new marsh sites where SAV vegetation would thrive. Canvasback ducks would benefit from the development of high marsh plains with ponds in the latter stages of tidal marsh development.

4.3.1.2 Diving Piscivores

The conceptual model for diving piscivores is presented in Figure 4-20. Diving piscivores includes only one subgroup of ducks, the mergansers. Taxonomically, mergansers belong to the sea ducks. There are three species in this group: red-breasted merganser, common merganser, and the hooded merganser.

Red-breasted merganser, like all mergansers, is an excellent foot-propelled diver. They have four feeding strategies while wintering along the coasts of North America and Mexico: 1) cooperative feeding where they join with conspecifics forming a line to “herd” or drive fish into shallow areas where they are more easily captured. 2) As a visual predator, they swim with only their heads submerged looking for fish, and then they grasp or dive to catch the prey. 3) shallow diving (< 2m); usually in turbid waters. They often dive in unison with other red-breasted mergansers in these circumstances. 4) deep diving (~ 5m) (Titman 1999). The diet of red-breasted merganser consists of small fish (10 – 15 cm) and crustaceans. They also consume worms, insects and amphibians. Salmon smolts are a preferred prey item. Along the Pacific coast, it also eats sticklebacks (*Gasterosteus* spp.), sculpin (*Cottus* spp.), herring (*Clupea* spp.), shrimp and crab (Munro and Clemens 1939). Increases in capture rates are positively correlated with increases in prey density. In winter, they favor salt marsh estuaries, often over shallow mudflats at high tide (depth sometimes < 0.3m). They can be found in near shore habitats (Titman 1999).

Common mergansers forage by diving or swimming on the surface with their heads submerged (Mallory and Metz 1999). Like red-breasted mergansers, salmonid smolts are a favored food item. Fish girth (165mm – 198mm), rather than length, determines the acceptability of fishes. Over 50 species of fish have been recorded in the diet of common mergansers in North America. Their principal prey include: salmonids (*Salmo* spp. and *Oncorhynchus* spp.), trout (*Salvelinus* spp.), sculpin (*Cottus* spp.), shad (*Dorosoma* spp.), sticklebacks (*Gasterosteus* spp. and *Pungitius* spp.), chub (*Semotilus* spp. and *Couesius* spp.) and minnows (*Notropis* spp. and *Notemigonus* spp.). In addition, they will consume insects, mollusks, crustaceans, worms and frogs. The proportion of large fish (10cm – 30cm) they consume is greater than their availability, indicating definite size selection. In winter, although they will inhabit coastal bays and estuaries, generally feeding in areas with water < 4m deep, they generally prefer freshwater wetlands. They will, however forage in deeper water when schooling fish are available. Overall, they tend to winter wherever suitable fish populations are found (Mallory and Metz 1999).

Hooded mergansers are the smallest of the mergansers and limited to North America, wintering in brackish estuaries and tidal creeks. Their diet is more diverse than the other two merganser species. Nationwide sampling of winter food habits revealed the following: 44% fish (species unknown), 22% crayfish (*Cambarus* spp.), 13% aquatic insects, 10% other crustaceans, 6% amphibians (mostly *Rana* spp.), 4% vegetation, and < 1% mollusks (Dugger et al. 1994). In winter, this merganser, unlike the other two North

American mergansers, prefers shallow, freshwater and brackish bays, estuaries, and tidal creeks and ponds.

Use of Evolutionary Trajectory Stages

Waterfowl piscivores are more varied in their diet than the guild name implies, although fish remain the most important component of all of their prey items. Use of developing wetlands would be expected to extend from the initial subtidal stages through low intertidal, low marsh and mid marsh, provided depths are such and prey items are available on the site and vegetation density does not preclude the ability of these birds to propel themselves through the water in pursuit of fish and other prey items. The only area they would be excluded from would be high marsh and upland transition. They can use the habitat opportunistically at the tides and water depths that are favorable to their hunting techniques and supportive of the species they pursue. Water depth as in diving benthivores is the critical factor along with food availability. As vegetation becomes thicker, diving birds may find it difficult to impossible to penetrate into low or mid marsh areas.

4.3.1.3 Dabbling Omnivores

The conceptual model for dabbling omnivores is presented in Figure 4-21. The dabbling guild includes dabbling ducks (*Anas* spp.), wood ducks (*Aix* spp.), whistling ducks (*Dendrocygnus* spp.) and swans (*Cygnus* spp.). Dabbling consists of "tipping up" so the body is perpendicular to the surface of the water. In this way, they feed on items on the bottom of wetlands. The exception is of the shoveler which is a filter feeder with very fine and closely spaced lamellae on its bill. Dabbling will also pick up seeds and invertebrates from the surface of a wetland when available. Dabbling ducks fall into several dietary categories. The teal, mallard and pintail are primarily granivores, but are omnivores in the early fall right after returning from the molting areas and again in late winter and early spring prior to spring migration; whereas, the American wigeon and gadwall are primarily herbivores .

Anas duck food habits studies show that granivorous/omnivorous dabblers favor invertebrates in the early fall and again in the late winter (Burns et al. 2003; Euliss et al. 1991). For pintail in Euliss et al's study (1991) late winter diet consisted of 60-100% invertebrates, principally chironomid larvae. Foods during the most of the non-breeding season consists primarily of seeds of such plant as swamp timothy (*Heleochoa schoenoides*), bulrush (*Schonoeplectus maritimus*), watergrass (*Echinochlon crusgalli*), sea purslane (*Sesuvium verucosum*), fat hen (*Atriplex triangularis*), brass buttons (*Cotula coronopifolia*) and pickleweed (*Sarcocornia pacifica*). In the case of pickleweed additional value is provided by gleaning its multi-branching stems of invertebrates (de Szalay and Resh 2000).

Food preference by the various species of *Anas* is dependent upon size, specifically length of neck, body size and foot length of the bird (Bolduc and Afton 2003). Isola et al. (2000) found that small dabblers such as teal prefer to feed in water depths of 10-15cm, whereas those of the larger *Anas* species used waters greater than 20cm deep. According to Euliss and Harris (1987), Miller (1987) and others, dabblers feed

mostly at night within vegetated areas. During the day, open water is sought (Burns et al. 2003) as a refuge particularly from raptors (Euliss and Harris 1987).

Burns et al. (2003) did an exhaustive study of food habits of N. pintail, mallard and green-winged teal in Suisun Marsh. They concluded that for alkali bulrush seeds that green-winged teal avoided them, and that the other two species ate them in proportion to their availability. Management of seasonal wetlands is well suited to its seed production, but it occurs along the tidal channels of San Pablo and Suisun bays. Bulrush supports the subdominants fat hen and brass buttons. Green-winged teal had foraging to availability ratios greater than 1.0 for brass button, rabbit's foot grass, purslane and swamp timothy, but none of them was significant. Teal also ate watergrass and pickleweed seeds in proportion to their availability.

For pintails, Burns et al. (2003) found that they use diurnal feeding sites with highest percentage of purslane (55.1%); they also included bulrush (15.6%), watergrass (10.8%) and pickleweed (10.7%). Pintail showed a positive foraging ratio for purslane, rabbits-foot grass, and fat hen. Only purslane seed was consumed significantly higher than its availability. They also consumed watergrass and bulrush in proportion to its availability. They significantly avoided brass buttons, dock and pickleweed.

Mallards (the most abundant species in North America (Drilling et al. 2002)) studied by Burns et al. (2003) fed at sites with the highest percentage of purslane (35.6%), bulrush (25.7%), pickleweed (15.2%) and watergrass (11.8%). However, they were neutral toward purslane in dietary composition, meaning they ate in proportion to its availability. The only significance preference shown by mallards was for watergrass. Bulrush, rabbits-foot grass, swamp timothy and dock were eaten in quantities relative to their availability. Mallards also nest in Suisun Marsh (SEW 2001). Average nesting densities for mallards in California is 111 nests per square kilometer. Nest success is approximately 32%. Nesting is initiated from February to June, with a peak in April. Average clutch size for California mallards starts at approximate 10 and drops to approximately 7 by the first of June. Brood size averages 6 approximately. Unlike other areas of California, hens in Suisun tend to be more than one year old. Older birds are the norm (McLandress et al. 1996).

Northern shovelers are a common holarctic duck having a spatulate bill with narrowly spaced lamellae to assist it in filter feeding for invertebrates in the bottom muds and water column (DuBowy 1996). "In saltwater wetlands, ostracods (24%), foraminifera (16%), gastropods (15%), copepods (7%), fish (7%), and *Ruppia maritima* vegetation (wigeongrass) and seeds (5% each)" (DuBowy 1996). The winter diet also includes nektonic invertebrates and seeds (DuBowy 1996). They may tip-up or dive or swim with their heads underwater to secure their prey. As filter feeders and a larger bodied *Anas* species, their preferred water depth for foraging is 4.9cm (Euliss et al. 1991) although they are not limited to it. Euliss et al. (1991) found in fresh to alkaline waters that shovelers prefer waterboatmen, rotifers and copepods during most months. They provide 70-90% of their diet for each month. However, waterboatmen use diminished in January through March. At this time, rotifers become dominant during the months of January and February, whereas copepods become more important in March. Batzer et al. (1993) found that wetlands flooded in

September yielded higher populations of amphipods and water scavenger beetles in the winter as compared to those flooded in late October.

Shovelers also nest in Suisun Marsh. On average, they prefer to nest within 2.7 – 45m of water. The nest is a scrape in the ground or in grass lined with down. Clutch size averages 10.1. Length of incubation is approximately 25 days at least in the more northern latitudes. Females are the only ones to incubate (DuBowy 1996). Precocious young leave the nest shortly after hatching and move to water. They feed on invertebrates smaller than those used by sympatric species because of the more narrow lamellae characteristic of their species.

Use of Evolutionary Trajectory Stages

Mallard, pintail and teal will likely use the restored sites for loafing and some foraging. Given the subsidence of most of the diked wetlands, 30.5cm to 122cm, Siegel (2004) precludes them from foraging in the early stages of development except at the fringe of the new wetland and provided the necessary seeds are available, principally purslane, bulrush, and watergrass. During the intermediate stages of development, low marsh, mid marsh and high marsh will see differences in the use of the habitat. As high marsh develops pannes and ponds, these dabblers would resume their use of these wetlands for foraging and loafing.

4.3.1.4 Dabbling Herbivores

The conceptual model for dabbling herbivores is presented in Figure 4-22. Two *Anas* species, American wigeon and gadwall, are primarily herbivores with some use of invertebrates. The wigeon bill morphology and physiology facilitates its grazing diet. Its diet consists largely of plant matter with significant percentage of animal matter used only by females prior to breeding. Both sexes eat the stems and leafy parts of aquatic vegetation and the leafy parts of upland grasses (*Poaceae*) and clovers (*Trifolium* spp.), and the leafy parts and seeds of various agricultural crops (Mowbray 1999).

Wigeon are found in tidal brackish wetlands, mudflats, freshwater wetlands and slow moving rivers. They feed on submerged vegetation from the surface to 20cm in depth; they graze on vegetative parts, seeds and fruits of emergent and agricultural plants. The three components of the bill which suit this species to grazing are: 1) bill length, 2) bill width at the commisure, and 3) bill height at the commisure. These traits increase the strength of the bill for plucking. Like most *Anas* spp they have limited efficiency as filter feeders. This is due to their short bill length, narrowing of the bill from base to tip and few lamellae/cm on the upper mandible. It feeds by tipping—up like other *Anas* species. Mowbray (1999) reports that they feed almost exclusively in the intertidal area below mean water. It also feeds more extensively along estuarine foreshore and deltas during low tide than at high tide.

Mowbray (1999) also reports that wigeon feed mostly at night especially following the onset of storms. They are known to forage in mixed flocks with mallard, pintail and green-winged teal. In California, this species feeds extensively on agricultural crops including lettuce, alfalfa, pasture, grasses, barley and clover.

Wigeon diet varies with locations, season and reproductive status. Its diet consists of 97-100% plant material and only 0-3% animal matter. Among plant material they are known to consume *Potamogeton*, *Ruppia maritimus*, *Zostera marina*, *Lemna minor*, bushy pondweed, *Valisineria americana*, *Elodea*, *Myriophyllum exabescens*, turf grass; leaves and seeds of *Panicum* spp., *Zinania aquatica*, clover, cultivated rice, wheat, barley, *Eleocharis* spp., *Carex* and *Fimbristylis*; as well as benthic and planktonic algae, *Chara*, *Ulva*, and *Cladophora*.

During migration and winter, dominant foods are those most available. In Northern California that is almost exclusively plant matter (99.7%) (Yocum and Keller 1961). Their diet consisted of eelgrass (81%), clover (6%), spike-rush (3.5%) and water milfoil (1.2%). According to Yocum and Keller (1961) winter habitat includes estuaries and salt water bays with primary focus in these two habitats in intertidal areas with abundant submerged vegetation and emergent vegetation.

The other herbivorous *Anas* species is the gadwall. Leschack et al. (1997) assembled the available information for this species for the Cornell Ornithological Labs compilation of birds species life histories. The information presented here is from that effort. It is a medium sized duck that resides in the area year long. They principally feed on submerged aquatic vegetation (SAV), as well as seeds and aquatic invertebrates. They feed from the surface to 30cm below the water surface over SAV beds. They also tend to forage in deeper water than other *Anas* spp. Although they feed diurnally and nocturnally, they consume the majority of their food during the nocturnal hours. During the winter they will spend > 60% of their day foraging and 11-20% swimming. Certain researchers discovered that feeding rates (dips/min) and foraging speeds (m/min) significantly increased as the temperature drops. They would also switch to the more energy rich source found in invertebrates under these same conditions.

Gadwall food habits consist of eating leafy portions of *Potamogeton* spp (pondweed), wigeon grass (*Ruppia* spp.), water milfoil (*Myriophyllum* spp) and naiads (*Najas* spp.) During the winter gadwall consume plants at a rate of approximately 95-97%, whereas during the breeding season, the plant material diminishes to only 42-54% of their diet. They also eat seeds, specifically *Potamogeton* spp., smartweed (*Polygonum* spp.), burush (*Schonoeplectus* spp.) and spike rush (*Eleocharis* spp.) Invertebrates are believed to be an insignificant portion (3-5%). However, invertebrates become important as the breeding season progresses comprising 23-46% of adult breeding diet. The invertebrates important to gadwall include crustaceans, *Anostraca*, *Cladocera* and *Chironomid* larvae. Nesting occurs in preferred grass areas such as salt grass (*Distichlis* spp.) and *Bromus* spp. Nest site selection is based on availability of vegetation of sufficient density and vegetation height to shield the hen and eggs from predators. Proximity to water is also important.

The remaining waterfowl that feed by dabbling are the wood duck and tundra swan. Wood ducks breed and winter in Suisun Marsh (SEW 2001). They are hole-nesting birds often nesting in holes drilled by woodpeckers, or in Wood duck boxes distributed around the marsh. During the breeding season they need

abundant plant and invertebrate food bases interspersed among shrubs, water tolerant trees, and small areas of open water with 50-70% cover. Winter habitat is very similar. Their food habits are omnivorous. Seeds, fruits, aquatic and terrestrial invertebrates occur within 18-40cm foraging depth. Major food habits include mast from oak etc., watershield (*Brasenia schreberi*), smartweed (*Polygonum* spp.), blackberry (*Rubus* spp.), wild cherry (*Prunus serotina*), duckweed (*Lemna* sp. & *Spirodela* spp), pondweed (*Potamogeton* spp.). Major invertebrates include *Coleoptera* (*Hydrophilidae* and *Dystiscidae*), *Diptera* (*Chironomid*, *Tilulipidae*, and *Tabanidae*), also *Lepidoptera*, *Hemiptera*, *Isopoda* and *Decapoda*, *Gastropoda*, *Trichoptera*, *Hymenoptera*, *Odonata*, and *Hemiptera*.

The tundra swan (*Cygnus columbianus*), which is limited to the North America, is less well studied than *C. c. bewickii* of the European continent. However, Limpert and Earnst (1994), citing Cramp (1977.) and Dirksen *et al* (1991), show that at least for the European subspecies, foraging is by dabbling in waters up to 1m in depth; limited by the length of the neck. They feed on "plants, primarily seeds, stems, roots and tubers of submerged and emergent vegetation." They feed by tipping up and extending their long necks into the water, feeding along the bottom and around the perimeter of ponds, pools and channels. These are the more natural food habits of Tundra swans, whereas today, the landscape has changed and they will exhaust the native wetlands vegetation and then move into winter cereal grain crops (wheat, rye, barley, rice and soybeans) (Earnst 1992) to feed. In the winter, they will also feed on waste grain e.g., corn from agricultural seed production and actively growing grains, such as rice in shallow water. In the Central Valley of California, clearly winter rice crops are important to swans, but within Suisun Marsh, native habitats still exist and provide high quality foods for adults and young recuperating from fall migration and for building fat reserves for the breeding migration and nesting (Belrose 1980).

Tundra swans winter on both coasts of North America. They are found in freshwater and estuarine environments where plenty of submerged and aquatic vegetation is found; otherwise they depend upon the winter cereal grains grown in and around estuaries. According to Limpert and Earnst (1994) habitat preferences for wintering Tundra swans consist of "shallow estuarine tidal areas, freshwater lakes, ponds, and rivers." Today, because of the significant loss of submerged and emergent aquatic vegetation "agricultural fields are used extensively for foraging" (Limpert and Earnst 1994).

Use of Evolutionary Trajectory Stages

Herbivorous Ducks: These herbivorous ducks seems more closely associated with tidal wetlands than their conspecifics (Yocum and Keller 1961). Thus, provided newly breached sites include SAV for these two species they are likely to utilize the new tidal area. So they should occur for subtidal habitat if SAV is available at all. The same holds true for Low Intertidal. Then in Low Marsh where the depths are coming up closer to their natural feeding depths use should increase significantly. As Mid marsh and High marsh develop the presence of SAV and the accompanying water depths will determine whether these two species use these restored wetland sites. But given both species proclivity to use intertidal habitat, their presence and utilization of these evolutionary stages is to be expected.

Wood Ducks: It seems clear that wood ducks are restricted to fresh or at least oligohaline or mesohaline waters found in Suisun Marsh. Wood ducks would likely be precluded from any type of intertidal wetland given their preference for fresh to low salinity water.

Tundra Swans: During the subtidal stage of evolution of breached sites, use by swans will depend upon the depth and slope of the edges of the site, and the presence of submerged and/or emergent aquatic plants, seeds, stems, roots and tubers; and probably how active the tidal or water currents are at the site. If the current is too rapid, individuals will be unable to remain in one position while foraging. Waterfowl bioenergetics suggests that swans will select the energetically most effective means of foraging and foraging source (Belrose 1980). During the low intertidal phase, there will probably remain some habitat for swans, but foraging habitat will diminish if either submerged or emergent plants diminish significantly. Again feeding in these areas will largely depend upon the tidal and river current at the fringes of the open water areas. By the time of development of low marsh, if submerged and aquatic vegetation remain and ponds exist or channels exist that are not too dynamic in current and tidal cycle, may still be used by swans. By the time middle marsh develops, the presence of appropriate species of submerged and emergent vegetation will be sufficiently low to preclude use by swans. The same remains true for the remaining evolutionary stages unless, open water areas exist that support *Scirpus*, *Typha* and other important plants of swan diets.

4.3.2 Shorebirds (SRCD)

The conceptual model for shorebirds is presented in Figure 4-23. Taxonomically, shorebirds are divided into various groups primarily based on morphology and physiology. In Suisun Marsh include the families *Haematopodidae* (Oystercatchers), *Recurvirostridae* (Avocets and Stilts), *Charadriidae* (Plovers), *Scolopacidae* (Sandpipers) Sandpipers include Godwits, Curlews, Whimbrels, Willets, Yellowlegs, true Sandpipers, Tattlers, Phalaropes, Dowitchers, Snipe, Turnstones, Knots, Dunlin, and Sanderling. True to their name, these species with the exception of the Killdeer are found along the shores of coasts, bays, estuaries, marshes and freshwater wetlands. Baker and Baker (1973) were among the earliest to recognize that bill morphology and tarsus lengths among shorebirds provided means by which species sharing the same feeding area could avoid competition. Baker (1979) identified 8 feeding methods that segregated the species of shorebirds he was studying. The foraging methods also affected the rate at which prey items were captured. He based his classification on pecking vs. probing occurring in singular or multiples attempts and locomotion method: steady or halting. He also found that there is a distinct difference in the selectivity of prey items by shorebirds on summer and wintering grounds. He found that summer microhabitats were more abundant allowing for less overlap between species than on wintering grounds. Birds with longer bills had more diverse microhabitats than those with short bills. Longer billed birds fed higher in vegetative structures than small billed birds because their reach exceeded smaller competitors, and they foraged to greater depths than short billed shorebirds. In addition, he confirmed that birds with longer bills and longer tarsus length could move further into water and exploit a greater portion of habitat than its small billed counterpart. Isola et al. (2000) concluded that water depth explained 86% of the difference among shorebird taxa on wintering grounds. Isola et al. (2000) found that small shorebirds used

water generally less than 5cm deep, whereas large shorebirds use water between 5-11cm. Elphick and Oring (1998) and Warnock et al. (2002) concluded shorebirds do not feed in water much > 10-15cm, and most prefer 4cm (Isola et al. 2000). Robinson (Robinson et al. 1997) found that American avocet use habitat \leq 15-20cm, and occasionally swimming in 25cm deep water and forage with their heads in the water, dabbling much like dabbling ducks. Because water depth is not controlled in many shorebird habitats, Safran et al. (1997) concluded that water depth constrained the habitat available to shorebirds, depending upon the slope of the foraging surface. Safran et al. (1997) further concluded water level mediates invertebrate availability. Safran et al. sampled water depth and benthic invertebrates at foraging and random sites. They found there is a significant difference in density of prey species at foraging sites and random locations. Therefore, they concluded that habitat selection by shorebirds is directly related to benthic invertebrate density. They, also, found the same difference between the water depth of selected sites vs. random sites, i.e., prey were more available at foraging depths than at randomly chosen sites. Therefore, foraging depth is correlated with habitat selection for shorebirds.

Skagen and Oman (1996) reviewed 75 papers on diets of 43 shorebird species. They found that shorebirds consume a variety of taxa, specifically: 12 phyla, 22 classes, 72 orders, 238 families and 404 genera. The most widely represented classes were: *Insecta*, *Malacostraca*, *Gastropoda*, *Polychaeta* and *Bivalvia*. Further, they found that 15 invertebrate families are common to seven of the 10 most studied species of shorebirds. They reveal there is little dietary overlap between regions, especially between tidal areas vs. inland areas. However, similarities in diet of co-existing species within a given region were high. They felt that management efforts should maintain hydrologic regimes and ecosystem processes that promote growth and maintenance of invertebrate populations.

Stenzel et al. (2002) surveyed the distribution and abundance of shorebirds within San Francisco and San Pablo Bay. The San Francisco Bay estuary supports more than 60% of the shorebirds on the conterminous Pacific Coast. The Bay is critically important to the survival of shorebirds in the Western Hemisphere. Harrington and Perry (1995) (cited by Stenzel) concluded that San Francisco Bay estuary and associated wetlands are of Hemispheric importance to wintering and migratory shorebirds. The need for this classification arises from the study by Page and Gill (1994) which concluded that there has been a 70% cumulative decline in shorebird populations worldwide since the 1970's. Most of this is contributed to loss of habitat. Stenzel et al.'s study of shorebird populations throughout most of the estuary mudflats contributes greatly to our knowledge of which areas within the estuary are important to shorebirds. There is also recognition that the areas previously supporting tidal marsh but converted to salt ponds and then abandoned such as in the marshes north of San Pablo Bay are very important to shorebirds and other waterbirds.

Takekawa et al. (2000) closely studied seven of the abandoned salt ponds in the Napa marsh area north of San Pablo Bay in the San Pablo Bay State Wildlife Area. The study examined numerous physical and biotic factors related to the distribution and abundance of waterbirds (shorebirds, waterfowl, gulls, and grebes). Takekawa et al. (2000) noted that, "The salt ponds currently support large and diverse communities of

migratory birds." Because of this, ". . . the Napa Marshes in the North Bay were designated as a 'Globally Important Bird Area' by the American Bird Conservancy because a large proportion of the shorebirds and waterfowl in the entire estuary are found in the salt pond habitats of that region." Takekawa et al. (2002b) noted the San Francisco Bay estuary is a migratory and wintering area for more than 1.5 million waterbirds on the west coast of North America. Because of this, the 70% cumulative decline in shorebirds and the loss of more than 90% of the historic San Francisco bay wetlands since the mid-1800's (Josselyn 1983), Takekawa et al. (2002b) and others, caution that the effects of tidal restoration of diked wetlands for endangered species is largely unknown and therefore should proceed cautiously. They also point out that waterbirds show strong site fidelity to San Francisco Bay estuary subregions, and, therefore, mitigation for impacts in one subregion should not take place in another subregion.

Takekawa et al. (2002a) studied the pre- and post-breach effects on the Tolay Creek wetland. Prior to the breach, the pH ranged from 3.6-7.9 in 1998, post-breach it stabilized to 8.9-9.2. Flow increased causing an increase in the tidal amplitude within the marsh while decreasing the tidal lag. Sediment height changes went in both directions. In the Lower Lagoon, 6.1cm of sediment was added, whereas 1.2cm was lost in the Upper Lagoon. Vegetation at the site also changed dramatically. Pickleweed density increased from 33% (in fall 1998) to 92% (in spring of 2002), but its height decreased. Coyote bush increased, whereas the height of pepperweed diminished, as did exotics (38% to 2%). Pre-breach, 43 bird species were found, post breach, the number nearly doubled to 83.

Granadeiro et al. (2006) found that the density of shorebirds which are "tide followers" are present in up to 5X more that those of "non-followers". They found that rates of biomass acquisition much higher in the lower flats, but insufficient to counter the rate of exposure of upper flats, therefore, most shorebird needs are met on the upper flats; i.e., the longer exposure time. Safran et al. (1997) found that water depth mediates invertebrate availability, and also affects the accessibility of foods to small shorebirds. Further, high benthic invertebrate productivity correlates with organic material originating from salt marsh plains (Warwick and Price 1975) or adjacent upland detritus and refugia.

In Takekawa et al.'s (2000) study of the abandoned San Pablo Bay salt ponds they divided the shorebirds into 3 foraging groups: shallow probers, deep probers and surface feeders. Shallow probers include: black-bellied plovers (*Pluvialis squatarola*), dunlin (*Calidris alpina*), killdeer (*Charadrius vociferous*), red knot (*Calidris canutus*), semipalmated plover (*Charadrius semipalmatus*), snowy plover (*Charadrius alexandrinus* and *Charadrius alexandrinus nivosus*), spotted sandpiper (*Actitis macularis*), least sandpiper (*Calidris minutilla*), and western sandpiper (*Calidris mauri*). Additional shallow probers found in Suisun Marsh are: American golden-plover (*Pluvialis dominica*), Pacific golden-plover (*Pluvialis fulva*), mountain plover (*Charadrius montanus*), ruddy turnstone (*Arenaria interpres*), black turnstone (*Arenaria melanocephalus*), surfbird (*Aphriza virgata*), sanderling (*Calidris pusilla*), Baird's sandpiper (*Calidris bairdii*), pectoral sandpiper (*Calidris melanotos*), rock sandpiper (*Calidris ptilocnemis*).

Deep probers include lesser yellowlegs (*Tringa flavipes*), greater yellowlegs (*Tringa melanoleuca*), long-billed curlew (*Numenius americanus*), long-billed dowitcher (*Limnodromus scolopaceus*), short-billed dowitcher (*Limnodromus griseus*), marbled godwit (*Limosa fedoa*), whimbrel (*Numenius phaeopus*), and willet (*Cataporphorus semipalmatus*). Surface Feeders include American avocet (*Recurvirostra americana*), black-necked stilt (*Himantopus mexicanus*), red-necked phalarope (*Phalaropus lobatus*), Wilson's phalarope (*Phalaropus tricolor*), and in Suisun Marsh the red phalarope (*Phalaropus fulicarius*).

Suisun Marsh supports 38 species of shorebirds during fall and spring migrations and over the winter (SRCD, per. comm.). A few species nest in Suisun Marsh, e.g., American avocet. Shorebirds counts for Suisun Marsh were not available for this effort. Some species such as dunlins use the marsh all winter with periodic infusions of dunlins from Tomales Bay and other small estuaries along the coast in response to winter storms (Kelly 2001). This is true of other species as well, such as the dowitchers (Takekawa et al. 2002b). Baker (1979) found that few microhabitats are available to shorebirds in the winter and therefore they share much of the same habitat with the exceptions related to morphology and the ease with which substrates can be probed. Because there is a high degree of overlap or similarities in the diet of co-existing species within a region (Skagen and Oman 1996, Baker 1979), only two species from each guild will be explored. They are assumed to represent the general requirements of conspecifics and other guild members unless specified otherwise.

4.3.2.1 Shallow Probers

Western sandpipers are the most numerous shorebird species in the San Francisco Bay estuary, particularly in the fall, early winter and spring (Stenzel et al. 2002). They are also very numerous in the salt ponds of San Pablo Bay and South San Francisco Bay (Warnock and Takekawa 1995, Stenzel et al. 2002) and are found in Suisun diked marshes.

Western sandpipers, like most shorebirds, have a more flexible foraging strategy on its wintering grounds as opposed to its breeding grounds (Burger et al. 1977) and (Recher 1966). In fact, Recher (1966) found a positive correlation between the density of western sandpipers and the density of its major prey, *Corophium*. These data suggest western sandpipers have the ability to detect fine differences in the density of their prey. Recher's (1966) data for Palo Alto region (south San Francisco Bay), showed western sandpiper diet consisted of 8.6% amphipods, 8.6% *Gemma gemma* (bivalve), 8.6% *Nereis succinea* (polychaete), 62.8% ostracods and 11.4% *Ilyanassa obsoleta* (gastropod).

Western sandpipers have a distinct preference for foraging in wet, fine sand or muddy substrates (Wilson 1994). They will preferentially select mud substrates over others. Burger et al. (1977) in New Jersey found that the western sandpiper restricted its use to the interior mudflat region instead of the interior or exterior sand sites. Within the mud substrate they preferentially used the wet sand area with large, visible concentrations of periwinkles (*Littorina littorea*), averaging 324/m². They also used an area with drier mud, but which was mixed with small blades of sea lettuce (*Ulva lactuca*). This particular mudflat took an average of 3.5 hours to become entirely exposed, but only 2.5 hours to cover again. Burger et al. (1977)

also explored temporal segregation of mixed species flocks. The data suggest that feeding is a function of tide time not diel time. The species using the mudflats, like those using outer sand beaches showed a bimodal abundance pattern correlating with low tides. Burger et al. (1977) concluded "Niche specialization is occurring in mixed species aggregates of shorebirds in New Jersey with respect to habitats, microhabitats, and temporal responses to tidal fluctuations.

Warnock and Takekawa (1995) described the use of habitats by western sandpiper in San Francisco Bay estuary. They identified salt-pond levees, drained salt-ponds, tidal salt-ponds (restored to tidal action), seasonal wetlands, mudflats, tidal sloughs and salt marsh plains. Mudflats are best if they have shallow areas during high tides (consistent with the water depth limitations of western sandpipers) and exposed areas at low tides. Mudflats also exist in tidal sloughs. Salt-marsh plains are characterized by tidal wetlands that are thickly vegetated with pickleweed (*Salicornia virginica*) and cord grass (*Spartina foliosa*). At low tide in winter, western sandpipers prefer tidal sloughs and mudflats, followed by salt marsh plains and tidal salt ponds. At high tide, they were found mostly on salt-pond levees, followed by drained salt ponds. Warnock and Takekawa (1995) concluded that "the extent to which modifications of wetlands may change the distribution and abundance of shorebirds in the estuary is unknown."

Quammen (1982) experimented with the use of mudflats by adding sand to an area actively used for foraging by western sandpipers and three other shorebirds. The data showed all four species significantly decreased their feeding time in these experimental sand areas. Quammen (1982) postulated that substrate texture was a determinant of the types and abundance of benthic infauna, i.e., deposit-feeders are associated with mud, whereas suspension feeders are associated with sand. Goss-Custard (1970) suggested that exceptions to density-dependent predation are correlated with a bird's response to the sediment substrate. Quammen (1982) used his own in preparation data to suggest that sand interferes with feeding success. Quammen noted that Myers et al. (1980) concluded that substrate penetration among other things can reduce prey availability for sanderlings (another small, shallow prober on mudflats).

The availability of adequate populations of invertebrates to support the shorebirds found on Suisun Marsh diked wetlands is likely because of the management strategy used on the sites. de Szalay and Resh (2000) found that mowing salt grass (*Distichlis spicata*) especially and then leaving the area unflooded until at least late September (the later the better), yielded greater invertebrate population. Basically, the greater the time between mowing and flooding yields higher plant cover and greater invertebrate diversity.

Bolduc and Afton (2003) found that the biomass of medium *Ostracoda* are greatest in impounded marsh. It will also supports medium sized *Nematoda*, *Copepoda*, and *Ostracoda* as well as small *Nematoda* and *Copepoda*. They concluded that invertebrate communities are related to the sediments and hydrologic character of the wetlands which is affected by the structural marsh management (levees, water control structures and impoundments) and salinity. Given western sandpipers affinity for consuming nematodes, the consequences of impounded marsh may provide abundant food resources for this species.

Dunlin are also small, shallow probers, although slightly larger than western sandpipers. As many as 9 races breed in the subarctic and arctic on the tundra of the holarctic. They are among the most cosmopolitan and well studied shorebirds. During winter most occur on large estuaries along the Pacific and Atlantic coasts of the U.S. and Mexico (Warnock and Gill 1996).

From a generic point of view, clams, worms, insect larvae and amphipods are prominent in their diet reflecting their tie to the coastal and intertidal areas throughout most of its annual cycle. The Pacific coast population is substantially larger than any of the others in North America. The population is approximately one-half million individuals. Despite their widespread distribution and large numbers, like other shorebird species they experienced declines (Page and Gill 1994) and (Warnock and Gill 1996).

Microhabitats for foraging. Warnock and Gill (Warnock and Gill 1996) note that microhabitats and prey vary by season. In the winter, along estuaries dominated by mudflats, such as Bolinas Lagoon, CA. Bolinas Lagoon has mudflats composed of well to moderately sorted fine sand. During the northward migration and at other times, dunlin are tide-followers. Granadeiro et al. (2006) noted that tide-follower species are comprised of mixed flocks that are 5X the size of non-follower flocks.

Dunlin are tactile feeders; probing, pecking and jabbing at the substrate open with an open bill. It is believed this may permit access to taste buds. Like western sandpipers, least sandpipers and red-necked phalaropes they may be able to evaluate "surface-tension" as a indication of presence of prey. Taste and visual cues are used. They rarely probe deeper than 3.5mm (Warnock and Gill 1996).

Diet of dunlin on staging areas is dominated by bivalves and amphipods. During winter and migration Arthropods, especially the orders *Tanaidacea* and *Amphipoda* predominate. Stenzel et al. (1983) in their studies of Bolinas Lagoon found arthropods (*Corophium* and *Grandiderella* spp.) in 70% of the stomachs, polychaetes (primarily *Lumbrineris*) > 20%. Amphipods, bivalves and gastropods, alga-dwellers, were also found in significant amounts. Decapods, small crustaceans, foraminifera, insects and oligochaetes were found in trace amounts. Within San Francisco Bay, Recher (1966) found 76% (of 46 stomachs) contained *Neanthes succinea*. He also found bivalves, especially *Gemma*, *Macoma*, *Mya*, *Mytilis* and *Transsennella* spp. to be important in San Francisco Bay. Stenzel et al. (1983) found winter and spring diets to be similar.

Non-breeding habitats are commonly on coastal estuaries, bays, interior seasonal wetlands, flooded fields and other agricultural lands. Mudflats, as with western sandpiper remain an important habitat type. At Bolinas, radio tracking revealed that tagged individuals remained on the mudflats 94% of the time. The remaining 6% of the time was spent on an outer coastal reef (Stenzel et al. 1983). Colwell (1993) found a different situation on the more hydrodynamically active Mad River estuary on the California coast. He observed 85% of the population in water, 14% on sand, 0.4% on cobble and 0.1% on mud.

Researchers in the United Kingdom have discovered a negative correlation between dunlin population size and the expansion of *Spartina* spp. (Warnock and Gill 1996).

Granadeiro et al.'s (2006) study which examined tide-followers and non-followers also examined how the shorebirds used the mudflats with the receding and rising tide. Generally, the rate of biomass acquisition is much higher in the lower flats, but the exposure time is insufficient to counter the rate of exposure of the upper flats. They concluded that most of the dietary needs of the tidal species are met on these higher flats. They also suggested that because of the importance of these upper tidal flats, that they should be protected from disturbance and reclamation.

Kelly (2001) examined the hydrographic correlates of winter dunlin abundance and distribution in Tomales Bay. First he discovered in the period of his study, 1989 to 1999, there was a reduction in the total numbers of dunlins in the bay. His data suggest this occurred because of increased rainfall and storm activity during this period. He does not address the fact that the early part of study period was during the 5 year drought. He studied two distinct populations of dunlin. One population was at the mouth of the bay and the other was at the head of the bay where tributaries contribute fresh water. He examined the role of the hydrographic regime on these two populations and their prey populations. The data reveal temperate estuaries are governed by the hydrographic regime, including the amount of freshwater inflow, circulation and water residence time. The magnitude of these effects is unique to each system. He found that rainfall and storm events in particular caused the tributary streams to freshen the head of the bay. This freshening cause dunlin to move to more saline regions, usually to join the population at the mouth of the bay. Additionally, the decreased salinity caused a decrease in the density of benthic invertebrates (including those used by dunlin) based on the work of Nordby and Zedler (1991) as cited in his paper.

Baker and Baker (1973) identified 8 foraging methods based on bill use and mode of locomotion. They hypothesized that for the 6 species they studied that food density was higher in summer and foraging more selective. In winter, dunlin and other shorebirds utilize these foraging methods since each statistically significant different in food resources. Winter was associated with low behavioral and microhabitat diversity and low resource overlap between species which yielded small niche breadth. They felt that the data support the supposition that shorebird populations are regulated through competitive processes occurring in winter habitats. They found that temperature, the number of conspecifics within 25 ft, and the total number of birds within 25 ft were independent factors determining foraging strategy. (Baker and Baker 1973)

Safran et al. (1997) sampled water depth and benthic invertebrates at inland ponds. They found a significant difference in benthic invertebrate densities between foraging sites and random site. Thus, they concluded habitat selection in ponds (and probably elsewhere as occurs with western sandpipers) is correlated with benthic invertebrate density. They also found a significant difference between water depths at foraging sites and random sites. They concluded that foraging depth is correlated with habitat selection. This fits with Isola et al. (2000) finding that small shorebirds used water < 5cm deep, and large sandpipers used water depths in the 5-11cm range. In conclusion shorebirds are strongly influenced by water depth which mediates the availability of benthic invertebrates.

Burger et al. (1997) studied the importance of beach, mudflat and marsh habitats to migratory shorebirds on Delaware Bay. The study included dunlin among the seven most commonly observed species. The data show that 68% of all shorebirds prefer mudflats to beach or marsh habitats. The remainder of the populations were even distributed between these other habitats. The percent found feeding ranged from 45% on the Bay beach to 68% at the West Creek tidal mudflats.

Use of Evolutionary Trajectory Stages

The foraging strategies of western sandpiper and dunlin are very similar; in fact they probably compete for some resources, but avoid too much overlap by using different feeding strategies according to the circumstances (Baker 1979). Meeting their energy needs during the non-breeding season and prior to breeding migration is the most important function provided by their habitats.

The ability of these two species to make use of restoration sites in the earliest subtidal stage is going to be dependent upon the design of the site. If levees are sloped to provide broad expanses of exposed mudflats at low tide, then these species will be able to use the site from the earliest stages. If that slope is maintained throughout the evolution of the site, western sandpipers and dunlins will be able to use the site even when mature tidal marsh is achieved. This assumes that the original slope remains along with development of dendritic tidal channels with mud substrates and tidal ponds which flood only at the highest tide and have either optimum depths or at least provide shallow areas for foraging. The Burger et al. (1997) study clearly showed that these two shallow probers prefer estuarine mudflats even when presented with mature tidal marsh or estuarine sand beaches. Baker (1979), Burger et al. and Takekawa et al. (2000) have clearly shown that water depth and substrate type are the critical factors in habitat selection.

There is one potential conflicting circumstance. Kelly's (2001) data clearly demonstrate that salinity is also an important factor for dunlin. The site might not be preferred by dunlin if sufficient fresh water flows lower the salinity level in the Marsh to a point that interferes with habitat selection by dunlin by interfering with its preferred prey items. Unfortunately, Kelly did not quantify the salinity changes caused by storm events that initiated movement by the dunlin population at the head of Tomales Bay to retreat to and join the population at the mouth of the Bay.

4.3.2.2 Deep Probers

Dowitchers (Long-billed and Short-billed). Takekawa et al. (2000), the source for the foraging guilds used in this model, considers both long-billed and short-billed dowitchers to be Deep Probers. Therefore, they were going to be lumped together for the purposes of this discussion. Part of the problem with using one or the other of these species is that there is a dearth of data on Short-billed dowitcher with the exception on some studies of the Atlantic subspecies (Burger et al. 1977) and work of Baker and Baker (1973). The Long-billed dowitcher is more of a freshwater species (Takekawa and Warnock 2000) than the Short-billed version. Many authors do not clearly distinguish between the two species. Taxonomic confusion about these species has existed for over a hundred years. Pitelka (1950) (cited in (Takekawa and Warnock 2000)) examined 2,900 collected Long-billed and Short-billed dowitchers. He concluded that

Long-billed dowitcher were a separate race and that Short-billed dowitchers consisted of three subspecies. Mayr and Short (1970) (cited by (Takekawa and Warnock 2000)) considered them superspecies. Takekawa and Warnock (2000) noted that examination of mitochondrial DNA demonstrated that there is a wider disparity in the genetic code of these two congeneric than normally found in other congenics citing Avise and Zink (1988). Avise and Zink (1988) concluded that the species separated as much as 4 million years ago. Despite the taxonomic distinction between these two, a comparison of Takekawa and Warnock (2000) and Jehl et al. (2001) indicates they use similar habitat in a similar manner and forage by similar or the same methods which strengthens the argument that they both belong to this Guild..

Another trait distinguishes these two congenics. Long-billed dowitchers seldom feed or are active at night except during fall migration (Dodd and Colwell 1996) cited by Takekawa and Warnock (2000). Short-billed dowitchers by comparison have a high ratio of rods to cones which gives it better night vision and it uses it to forage at night. Rojas de Azuaje et al. (1993) cited by Takekawa and Warnock (2000) and Jehl et al. (2001) in the descriptions of the ecology of Long-billed dowitcher and Short-billed dowitcher, respectively.

Both species jab (or peck in Baker's (1979) terminology) and probe. Both species use a "sewing machine" or stitching technique in probing the substrate. Probes are deeper, last longer and include a "quivering" motion (Jehl et al. 2001). Baker (1979) noted that changes in locomotion in addition to pecking vs. probing helped diminish competition between congenics and other shorebirds. Locomotion was characterized as either steady or halting. The halting method when use by Short-billed dowitchers has been noted to include rotating in a circle and then moving on or back to a "fruitful" site. Both species forage with the tip of the bill open allowing the Herbst corpuscles or receptors in the bill to differentiate and locate prey. Quammen (1982) found that both species are prone to probe deeper than the length of their bills. Both species also will submerge their heads while foraging for prey items.

Shallow water and mud substrates are preferred by both species for foraging according to Takekawa and Warnock (2000) and Jehl et al. (2001). Most dietary information for short-billed dowitchers comes from the eastern subspecies, e.g. (Burger et al. 1997), whereas data for long-billed dowitchers, strictly a western species, are more plentiful. Long-billed dowitchers will feed in shallow water with sand substrates but foraging success is diminished by the resistance to penetration provided by sand substrates as discovered by Quammen (1982). Short-billed dowitchers will, in the fall, frequent zones of soft mud with some standing water, or covered with large blades of marine algae (sea lettuce, *Ulva lactuca*). They are markedly less common in areas of drier sand with some periwinkles (*Littorina littorea*) (Burger et al. 1977). Burger et al. (1977) also found that they avoid sandy ocean beaches. Colwell and Dodd 1995 (cited by Takekawa and Warnock (2000) researched food habits of long-billed dowitchers in coastal pastures of California. They found that foraging success was adversely impacted by increasing vegetation height. Water depth was important in determining where long-billed dowitchers and short-billed dowitchers will feed. Elphick and Oring (1998) found that long-billed dowitchers favor use of rice fields with water 2-8 cm deep. This is consistent with the work done by Isola et al. (2000) which identified small shorebirds using water depths < 5 cm and larger shorebirds using 5-11cm deep water. Clearly, a lower limit is not really needed since habitat

in shallower depth zones are also available to larger shorebirds. As medium sized shorebirds, their water depth requirements are fully consistent with Isola et al.'s (2000) data. Since both species will submerge their heads to feed, this upper limit may not hold for them. Both will probe deeper than the length of their bills (Quammen 1982).

The diet of long-billed dowitchers in Bolinas Lagoon, CA consists of sedentary polychaetes, particularly *Capitella* spp. and tube-dwelling amphipods (most *Corophium* spp.) were common in fecal samples. Stenzel et al. (1983) commonly observed polychaetes, ostracods, copepods, bivalves and oligochaetes. In 99 species of long-billed and short-billed dowitchers collected larval insects were found to commonly include *Diptera* spp. (58%), *Coleoptera* (11%), others (2%); other prey included crustaceans (8%), mollusks (4%), and marine worms (3%). Quammen (1984) collected both species in Newport, CA. He found *Streblospio*, polydorids, capitellids, oligochaetes, followed by mollusks (*Utriculostris*, *Tryonia*, *Asssiminia*), bivalves, crustaceans (*Pontogenea*, *Corophium*, *Rudilemboides*). Burger et al. (1977) found that mudflats support the greatest number of individuals regardless of species. In general, Burger et al. concluded that collectively, most data suggest that shorebirds species overlap broadly in their diets and feeding habits. In estuarine environments, dowitchers preferred areas of soft mud, some standing water and extensive cover with sea lettuce (marine algae). The average maximum number of shorebirds found on exposed mudflats equals 84 species during each exposure period (Burger et al. 1997).

Mudflats are not the only thing preferred by dowitchers in the form of habitat. They also prefer relatively shallow water (5-8cm deep). Safran et al. (1997) found that selection of foraging habitat by smaller bodied shorebirds (including long-billed dowitchers, dunlin, western sandpiper and least sandpiper) is strongly influenced by water depth which mediates the availability of benthic invertebrates. Davis and Smith (1998) suggest that habitat selection by American avocets, long-billed dowitchers, least sandpipers and western sandpipers is based up < 25% vegetative cover, 10-15% mudflats, 10-20% shallow water (< 4cm deep) and higher invertebrate populations in inland lakes and ponds in the Playa Lakes Region (PLR) of Texas. They also found that these species ate more plants in fall than in spring. The important PLR fall invertebrates are chironomids, hydrophilids, leeches, planorbids, corixids, conchostracans and hydracarinae. In these circumstances all four species are opportunistic feeders. (Many authors consider wintering shorebirds to be opportunistic feeders. Further, they found that shorebirds actually impact invertebrate populations in the spring prior to breeding migration. Presumably this is the result of the winter resident populations being supplemented by large numbers of individuals migrating into these stop-over areas on their way to the breeding grounds

Jehl et al. (2001) describes the diet of eastern short-billed dowitchers. The diet of eastern short-billed dowitchers migrant (n=191) consists of 88% animal material and 12% plants. Animals mainly include insects (29%: mainly *Diptera* [flies 18%], and *Coleoptera* [9%]), marine polychaetes (27%: *Nephtys caeca*, *Scoloplos robustus*), mollusks (21%), crustaceans (6%: fiddler crab (*Unca* spp.), shrimps (*Crago* spp.), fresh-water isopods (*Cyathura carinata*), and horseshoe crabs (*Limulus polyphemus*) eggs (3%). Plant food, chiefly seeds, mainly sedges, bayberry (*Myrica* spp.), pondweeds (*Potamogeton* spp.), wigeongrass

(*Ruppia maritima*), and bog bean (*Menyanthes* spp.) are cited by Jehl et al. (2001) from Sperry (1940) and Mallory and Schneider (1979). The data is also from Skagen and Oman (1996).

Short billed dowitchers typically forage in cohesive non-agnostic individuals that move together across the mudflat (Mallory and Schneider 1979) cited in (Jehl et al. 2001), using probe-multiple halting and probe-single halting methods (see (Baker and Baker 1973)) Individuals pivot, often returning to certain successful spots.

Both species use two feeding modes and two locomotion methods (Baker and Baker 1973). Jabbing or pecking as Baker and Baker (1973) term it consists of rapid shallow pokes at the sediment submerging only up to half the bill and done quickly. Probes consist of deeper penetrations (sometimes beyond the length of the bill (Quammen 1982) which can last longer and include quivering (at least in short-billed dowitchers) (Jehl et al. 2001). Both species are known to use what is referred to as a "sewing machine" or "stitching" pattern of probers where successive probes are quickly executed in one direction and at roughly equally spaced intervals (Jehl et al. 2001). The modes of locomotion are "steady" and "halting" (see (Baker and Baker 1973)) for a more complete discussion of how these modes of foraging and locomotion contribute to avoiding foraging competition between similarly adapted shorebirds.).

Takekawa et al. (2002b) found in San Francisco Bay that long-billed dowitchers "prefer open water habitats such as the muted tidal marsh during high tide, but the majority (78.5%) remained in these wetlands during low tide rather than feeding at nearby mudflats." This atypical avoidance of mudflats contrasts sharply with the small probers discussed above, but was similar to black-necked stilts. The radio tracking data from this study, yielded 7 of 32 individuals who migrated inland to the Central Valley. Unlike dunlin responding to rain and changes in the hydrographic conditions, long-billed dowitchers were speculated to be moving because of a marked drop in barometric pressure, indicative of rainfall and flooding of Central Valley agricultural fields. The 25 remaining radio-tagged individuals showed strong site fidelity to the subregions of San Francisco Bay, similar to western sandpiper, black-necked stilt, greater scaup and lesser scaup. "A general picture is emerging that indicates wintering waterbirds rarely move among subregions in the estuary in the winter, but remain in a single bay or local area." (Takekawa et al. 2002b).

Use of Evolutionary Trajectory Stages

Many of the evolutionary discussion points made about shallow prober species apply to deep probers. As with shallow probers, if existing or newly built levees are built with slopes adequate to provide habitat for deep probers, then these species will probably colonize these sites as soon as the prey base is sufficient. It seems a fair assumption that since both these species already use Suisun Marsh for wintering and migratory habitat that the appropriate food species are present in sufficient numbers to support existing populations. If these food species do not presently inhabit the bays and sloughs of the Marsh, then presumably the breaching of diked wetlands and use of existing levee soils to form shallow gradient intertidal zones will create colonization habitat for appropriate food species.

It is unknown which species, long-billed or short-billed dowitchers, dominates the diked marshes of Suisun Marsh. Long-billed dowitchers are known to use inland freshwater habitats. So changes in salinity and associated changes in the prey base probably will not affect long-billed dowitchers. However, short-billed dowitchers are considered tied to salt-water environments (Jehl et al. 2001). Therefore, the effects of changes in the salinity regime on the prey base of short-billed dowitchers may be adverse to the forage base of short-billed dowitchers. Only research or time will answer this question.

Takekawa et al. (2002b) found that long-billed dowitchers “prefer open habitats such as muted tidal marshes during high tide, but the majority (78.5%) remained in these wetlands during low tides rather than feeding at nearby mudflats.” Clearly, the openness of the new tidal marsh and size of the open shallow water areas (like that found in muted tidal wetlands) will determine the usefulness of the new tidal marsh to long-billed dowitchers.

Like shallow probers, deep probers will be able to use the developing tidal marsh through all stages of its evolution provided the mudflat area is maintained free of vegetation. If development of the tidal marsh eliminates the mudflat area, but mud substrates line the dendritic channels of the tidal marsh, dowitchers may continue to use the area, but given a choice between mud substrate in tidal channels and mudflats, short-billed dowitchers clearly prefer mudflats (Burger et al. 1977).

4.3.2.3 Shallow Feeders

American Avocet. The American avocet is distributed in North and Central America. Eastern U.S. populations were extirpated by the early 20th century. They are now restricted in the east to winter populations along the coast of Florida. They are found in wetlands that range from freshwater to alkaline to hypersaline. In California, they are found around the San Francisco Bay estuary into the Central Valley, and into the Sierras and Siskiyou mountains. During the winter they migrate to some southern California estuaries. In San Francisco Bay estuary they use artificial and abandon salt ponds in addition to mudflats and diked wetlands and are found year round (Robinson et al. 1997).

Research on this species has focused on behavior and population ecology and the ecotoxicological effects of agricultural drain water throughout the arid west. Behavioral research has examined its foraging habits (Recher 1966, Hamilton 1975, Quammen 1982, Burger and Gochfeld 1986, Boettcher et al. 1994 and others).

Avocet foraging is typically characterized by “scything”, i.e., moving the bill, slightly open, through the water as it stands or walks forward. Evans (1988) and Evans and Harris (1994) describe the avocets’ use of Humboldt Bay, CA in the winter. They use mudflats when the tide is less than 1.4m MLLW. They forage in water depths that cover the feet to belly deep. At tide less than 0.5m MLLW, their feeding is concentrated along the edges of tidal channels. Recher (1966) cited in Robinson (1997) described them as feeding at low tide, where “61% fed in water > 30.5cm from waters’ edge, 36% fed below the water line and beyond the contour line of 30.5cm and parallel to water edge, 3% fed in areas above water edge that retained a film

of water at its surface." Basically, they will feed from the area above the tide line with water surface film, to belly deep depending on the circumstances. Boettcher et al. (1994) described their wintering foraging activities in South Carolina in relationship to the tibiotarsus and belly. He found that less than 1% feed on wet mud, 17% in water below the tibiotarsus, 49% above the tibiotarsus, 33% belly deep and less than 1% beyond belly deep. In San Francisco Bay, avocets feed on mudflats during low tide, and feed high tide and low tide in the shallow waters of diked baylands, be they active or inactive salt ponds, brackish wetlands, as well as at tidal wetlands. They will use salt ponds if the water depth is appropriate for their foraging needs. Davis and Smith (1998) found wintering avocets using playa lakes in winter and during migration stop-overs. There, 100% of them foraged in 4-16cm deep water.

Avocets are both visual and tactile foragers. They use 3 different visual foraging strategies: Pecking, Plunging (described as jabbing by other authors), and Snatching. They also have six tactile strategies: Bill pursuit, Filtering, Scraping, Single Scything, Multiple Scything, and Dabble Scything. These different foraging behaviors are used to deal with different circumstances, as well as probably reducing conflict with its congeners, black-necked stilts. Pecking is a quick jab at prey on the mud or near the surface of the water. Plunging consists of submerging the head and breast to capture prey in the water column. Snatching is simply "snatching" prey, such as brine flies, e.g., *Lipochaeta slossonae* and *Ephydra* spp. out of the air. Bill Pursuit is rare, but involves moving along the surface of a shallow area opening and closing the bill rapidly. Filtering is similar to Bill Pursuit in the motion of the bill, but the movement is through the mud instead of the water. When engage in this method, the bird will pause to swallow. Scraping involves extending the neck 5-20cm forward through the mud, followed by swallowing. In Single Scything, the bill open slightly, and as the bird moves across the surface, it sweeps its bill from side to side. The bird make one swipe per step, with the swipe moving toward the leading foot. Multiple Scything is the same thing except there is more than one sweep per step. Dabble Scything resembles the action of dabbling ducks. The avocet tips up while swimming or wading in deep water and puts its bill in contact with the substrate as it moves forward. Hamilton (1975) defined and described these terms.

Granadeiro et al. (2006) described shorebirds species in terms of being "tide followers" or "non-followers". American avocets fall into the "tide follower" category. Burger and Gochfeld (1986) measured foraging efficiency of adult and hatch year young in the marshes near Palo Alto along the southern part of San Francisco Bay. They found that they feed faster on mudflats than in tidal channels. Based on the time it took to capture 10 prey items, they found that Pecking is a more efficient means of foraging than Scything. Adults were faster than young at acquiring 10 prey items, which Burger and Gochfeld (1986) hypothesize as the reason for delayed breeding in this species.

Habitat selection in avocets seems similar to other shorebirds, specifically water depth is an important parameter. Takekawa et al. (2000) that avian species diversity and community distribution in a series of abandoned salt ponds that graded from a muted tidal wetland through increasingly saline ponds, was more correlated with water depth more than salinity. Other taxa showed a distinct reduction in diversity with increasing salinity. The bird populations were ordered in decreasing abundance as follows: diving

benthivores, shallow probers, surface feeders, dabbling birds, deep probers and others. Takekawa et al. (2000) observations on the importance of water depth to the distribution of waterbirds are consistent with those made by Isola et al. (2000). Isola et al. (2000) categorized shorebirds and waterfowl into 4 water depth groups. Small shorebirds used water < 5cm, large shorebirds used water in the 5-11cm range, whereas teal used 10-15cm deep water and larger waterfowl used water > 20cm.

Outside the breeding season, activity patterns are governed by food types and other factors (Hoetker 1999). But, there are other things which affect their activity budgets. Hoetker (1999) found that consumption of fish reduced foraging time, whereas consumption of Chironomid larvae prolonged it. Temperature also affected foraging. Decreasing temperatures yielded an increase in the time spent foraging. This is consistent with the idea that increasing thermoregulatory demands requires boosting the consumptions of fuel. Wind speed also affected foraging. When winds exceeded 10m/s (~22mph), foraging decreased. Although high winds may increase energy demands, it also can stir up sediments in shallow water areas making visual predation difficult. Tactile discrimination of prey may be confused by sediment particle size. Certainly Quammen (1982) postulated that as why avocets and other shorebirds avoid foraging on sandy substrates and when they did forage were less efficient than in mud substrates. Additionally, foraging was related to the darkness of the previous night. Moonless nights require compensatory foraging the following day.

Diets of avocets are mediated by the foraging method used. Boettcher et al. (1994) that South Carolina, based on 17,010 samples that Probing was used by wintering avocets 75% of the time, whereas Multi-Scything was used 24%, and Single-Scything 1% of the time. Probing yield polychaete worms from the sediment, whereas Multi-Scything in the water column often netted small fish. They postulated, based on nearest neighbor distance during Multi-Scything feeding, that avocets may be cooperating when feeding on fish. Robinson et al. (1997) reported that avocets feed on the seeds of marsh and aquatic plants, especially sago pondweed (*Potamogeton pectinatus*), salt grass (*Distichlis spicata*) and bulrushes. Davis and Smith (1998) found that shorebirds, including avocets, in the Playa Lakes Region of Texas consumed more plant material in the fall than in the spring. They also found that invertebrate densities and diversity was higher in the fall. Important fall invertebrates, in this region, included chironomids, hydrophylids, planorbids, leeches, and corixids. For marine tide lands, amphipods (*Gemma gemma* and *Neanthes succinea*) and ostracods (*Hyanassa obsoleta*) were important were reported by Recher (1966). A quantitative analysis done on avocets feeding in San Francisco Bay region consisted of 52% *Gemma gemma* (an amphipod), 24% *Hyanassa obsoleta* (an ostracod), 16% *Neanthes succinea* (an amphipod), 4% unidentified ostracods, 4% unidentified amphipods (Recher 1966). At this location, they took whatever they could by filter feeding. Prey size = 85% < 63mm, and 15% 63-126mm in length.

Black-necked Stilts. Black-necked stilts are not as well studied as American avocets. But there is sufficient data to assess habitat selection, foraging strategies and diets. Stilts use wetlands with more emergent vegetation than American avocets. They are also more territorial breeders contrasting with the semi-colonial nesting of avocets. In California, black-necked stilts are roughly distributed in the same areas

where avocets are found; largely the San Francisco Bay Delta and along the Central Valley (Robinson et al. 1999).

Hamilton (1975) described the foraging behaviors of black-necked stilts using many of the same terms and definitions used for avocets. Like avocets, stilts have 3 visual methods of foraging, Pecking, Plunging and Snatching. Plunging is the only method during which the stilt submerges its head and breast. Cullen (1994) notes that little is known about the foraging ecology of stilts. His study "explores the relationship between macroinvertebrates and water level to the foraging distribution of the Black-necked Stilt and how wind speed affects stilt foraging behavior in relation to prey availability." Cullen (1994) found that 99% of the time black-necked stilts foraged in water > 10cm deep. This is consistent with Isola et al.'s (2000) observations on the niche separation of large and small shorebirds and large and small waterfowl based on water depth. Cullen (1994) observed only two foraging methods among the stilts in his study: Pecking and Single-Scything. To determine the depth of the water being used by a given individual, the water level in relation to leg length was noted and depths assigned based on Helmers (1991). As of 1999, only on wintering grounds have tactile foraging methods been noted. Cullen (1994) and Robert and McNeil (1989) which is cited by Robinson et al. (1999) both observed Scything, but Robert and McNeil found black-necked stilts switched to tactile Plunging when winds were > 30km/hr.

Robinson et al. (1999) speculate that Hamilton's (1975) Plunging and Robert and McNeil's (1989) head immersion may be the same thing. It is used to visually locate brine shrimp (*Artemia salina*) on the water surface and brine flies (*Ephydra* spp.) along the shoreline. Other species found in the diet are cited by Robinson et al. (1999) from Wetmore (1925). Wetmore found 35% true bugs (*Hemiptera*), 32.4% beetles, 9.7% flies, 7.9% snails, 3.3% caddisflies (*Trichoptera*), 3.2% fish, 2.7% miscellaneous animals (grasshoppers and crickets (*Orthoptera*) and a frog (*Anura*), 2.9% dragon flies nymphs (*Odonata*), 1.3% mayflies (*Ephemeroptera*), 1.1% seeds and vegetative matter, 0.5% crawfish by weight. Interestingly, Bolduc and Afton (2003) state that, "Shapes and sizes of invertebrates are probably more important to waterbirds than are taxonomic classifications of food items."

Use of Evolutionary Trajectory Stages

Subtidal. As with the other two shorebird guilds, the expected use by shallow feeders of the earliest evolutionary stages of tidal marsh development in Suisun will largely depend upon the physical layout of the site and the presence of at least one broad sloping levee with surfaces that provide adequate area and exposure duration for foraging shallow feeders to take advantage of the site. The avian community and the invertebrate species they depend upon during the winter will be directly affected by the soil characteristics of the levee. Mud is clearly the preferred substrate for this guild. In addition, the soil type will determine not only the invertebrate community that develops, but also the availability of that community to foraging shallow feeders. As pointed out above, the ability of shorebirds to easily penetrate the soil to access prey is important albeit less important for the surface feeders than the shallow and deep probers. Shallow feeders can rely upon invertebrates on the surface of the exposed flat, those in the water column and existing along

the edge of the site, e.g., flying insects. Bolduc and Afton (2003) point out that the composition of the invertebrate community is related to the type of sediment, hydrologic characteristics of the site and salinity.

Low intertidal. This stage of development with shallow open water and intertidal mudflats should be readily used by surface feeding shorebirds provided the mud is of the appropriate consistency and composition to allow penetration of the substrate and to support the preferred invertebrates of these species. At this stage, the question of adequate area being available to meet the needs of the birds is probably not a concern given that acres of habitat are being acquired and converted to tidal marsh.

Low marsh. When the site reaches this stage, surface foraging shorebirds will probably cease using the site except for occasional use of the developing tidal channels. These species show a definite preference for mudflats or shallow water ponds in which to forage. Although they are known to use tidal channels, there is a definite selection for large blocks of shallow water covered mudflats. At this evolutionary stage, these features will be gone

Mid marsh. The site at this stage will remain inconsistent with the needs of shallow feeding shorebirds, except as noted earlier with some use of exposed tidal channels.

High marsh. If high marsh develops with pannes that are flooded during extreme high tide events, the return of shallow feeding shorebirds may occur. It would require the depth of the pannes to be appropriate to their needs, basically up to 25cm deep or deeper with shallower areas adjacent to the shoreline. Again, the consistency of the substrate and the composition of the invertebrate community will be important.

Upland transition. Upland areas may be useful as refugia for these shorebirds, but generally they only use upland areas around ponds for nesting. Nest site selection for at least avocets requires nearly 360° of visibility and access to water for chicks close at hand. Because avocet are semi-colonial, the area would have to be such as to accommodate some number of nests.

4.3.3 Sportfish and Native Fish

Suisun Marsh's subtidal habitats support a diverse assemblage of fish species. At one or more points in their life cycles, these species use bays and sloughs for functions such as breeding, refuge, foraging, and/or migration. Sportfish in Suisun Marsh include the non-native striped bass (*Morone saxatilis*) and white sturgeon (*Acipenser medirostris*). Resident native fishes in Suisun Marsh include prickly sculpin (*Cottus asper*), tule perch (*Hysterocarpus traski*), and threespine stickleback (*Gasterosteus aculeatus*).

Compared to non-native species, natives are more abundant earlier in the year and show less variability in abundance throughout the year (Matern et al. 2002). It appears that native fishes of Suisun Marsh respond to their highly variable but predictable environment by exploiting seasonally abundant prey, and then changing their diets to maintain stomach fullness and to minimize dietary overlap during seasons when food is less abundant (Feyrer et al. 2003). Fish diversity and distribution in Marsh slough habitat has been

linked to slough size and environmental variability. Habitat study results presented in the Suisun Ecological Workgroup Final Report (2001) showed that species diversity and native fish abundance in the Marsh tends to be higher in smaller sloughs than in medium and large sloughs (SEW 2001). The Conceptual Model for Suisun Marsh Tidal Wetlands by Brown (2003) demonstrates that environmental variability such as water year type (i.e. wet or dry) is important in determining reproductive success of native freshwater spawners. The model also shows that seasonal changes in Marsh conditions determine spawning success of resident species and distribution and survival of all species in large and small sloughs throughout the year (Brown 2003).

Although there have been general declines in fish abundance over the last 20 years throughout the San Francisco Estuary, the greatest declines have been in the Suisun Bay region. Since the early 1980s, populations of open-water fish species have declined by 85% in Suisun Bay (Bay Institute 2005). The percentage of non-native fish species has increased and now represents almost 30% of the total fish abundance (Bay Institute 2003). Native species have been declining in numbers in Suisun Marsh for several years, but appear to have stabilized in the most recent wet years.

4.3.3.1 Striped Bass (*Morone saxatilis*) (DFG)

Species Description

Striped bass (*Morone saxatilis*) are native to the Atlantic Coast and were first introduced to the Pacific Coast in 1879 when they were planted in the San Francisco Estuary. Within 10 years, they provided a successful commercial fishery (Goals Project 2000). They are presently the principal sport fish caught in the San Francisco Bay. Striped bass move regularly between salt and freshwater, and they usually spend much of their life cycle in estuaries (Moyle 2002). Adults and juveniles can survive temperatures up to 34°C for short periods of time, although once temperatures exceed 25°C they are under stress. They can also withstand oxygen levels as low as 4 ppm, as well as high turbidity, although extreme conditions can inhibit reproduction. Spawning begins in the spring during April and May and optimal temperatures for spawning range from 15.6° to 20.0°C (Goals Project 2000). About one-half to two-thirds of the striped bass move into the Sacramento River to spawn, while the remaining spawn in the lower San Joaquin River (SEW 2001). Spawning occurs where there are moderate to swift currents that carry the striped bass eggs downstream to their rearing habitat. If the current is too slow, the eggs will sink and die.

The abundance of striped bass in the estuary has been on the decline. A number of factors are believed to be playing a part in the decline, including climate factors, South Delta pumps and other diversions, pollutants, reduction of estuarine productivity, invasions by alien species, and exploitation (Moyle 2002).

Conceptual Model for Striped Bass Use of Tidal Marshes in Suisun Marsh

The conceptual model for striped bass is displayed in Figure 4-24. Striped bass occur in Suisun Marsh throughout the year, and utilize the fresher parts of the Marsh and Bay from April through July for spawning

(SEW 2001). Temperature is a major driving factor for striped bass spawning, with preferred spawning temperatures ranging from 15.6°-20.0°C.

According to the UC Davis studies (Moyle et al. 2006), it appears that lower Suisun, Spring Branch, and Goodyear sloughs are the three areas that are heavily used by striped bass. In 2004, it was observed that fewer striped bass were caught in Goodyear Slough, which may suggest that the low levels of dissolved oxygen in Goodyear Slough during 2004 may have affected their use of that slough. It is also likely that high availability of prey, shallow depth, and proximity to larger bays are determining factors for use of the marsh as important rearing areas. Larval growth and survival rates are highest in areas of brackish water, which is thought to be due to a reduction in energy costs for osmoregulation.

Large striped bass frequently feed heavily on threespine sticklebacks that are coming out of marsh drains from managed wetlands in Suisun Marsh (Moyle 2002). Striped bass are also often found hanging out near screened diversions feeding on small fish. Kimmerer et al. (2000) found a significant positive relationship between the abundance of mysids and the abundance of juvenile striped bass, which suggest that the extended period of low mysid populations may have contributed to poor survival of juvenile striped bass (Feyrer et al. 2003). The low mysid population has been linked to the invasion of the overbite clam and striped bass have been observed to have significantly less stomach fullness during the spring after the invasion of the overbite clam (*Potamocorbula amurensis*) when compared to the pre-clam period.

Expected Restoration Effects at Each Trajectory Stage

Striped bass are known to occur in areas throughout the Marsh, but are found most commonly in shallow areas with proximity to larger bays. They are relatively tolerant of a wide range of water quality conditions. Therefore, it is reasonable to conclude that striped bass will directly utilize restoration stages from subtidal through mid-marsh, particularly those sites that are shallow and have good connectivity with larger open water areas. They are also likely to derive indirect benefits through increased export of primary and secondary pelagic production. Striped bass are not expected to gain any direct benefit from high-marsh sites, but may benefit indirectly through increased production. The upland transition stage is unlikely to provide any direct or indirect benefits to striped bass.

4.3.3.2 White Sturgeon (*Acipenser medirostris*) (NMFS)

Species Description

White sturgeon are an anadromous, iteroparous and long-lived fish species. White sturgeon in the Central Valley spend most of their lives in estuaries of large rivers, moving into the freshwater of large rivers from the Sacramento-San Joaquin system northward to spawn (Moyle 2002). White sturgeon males reach sexual maturity between 10-12 years and between 12-16 years for females (Moyle 2002). Females are capable of spawning every 2-4 years, depending on water quality conditions (Moyle 2002).

Migration of white sturgeon to freshwater may occur in winter months or may occur closer to spawning times between late February and early June (Moyle 2002). Spawning for this population primarily takes

place in the Sacramento and Feather rivers. It has been speculated that when flows and water quality are adequate, spawning may also occur in the San Joaquin River (Moyle 2002). Adult white sturgeon spawn in deep pools in large, turbulent, freshwater rivers.

Juveniles reside in fresh and estuarine waters before migration to the ocean. Adults reside in nearshore oceanic waters, bays and estuaries when not spawning. In California, white sturgeon are most abundant in brackish portions of estuaries, such as the San Francisco Estuary (Moyle 2002). They often enter estuaries in summer and fall, with movements often not linked to spawning.

Conceptual Model of Sturgeon Use of Tidal Marshes in Suisun Marsh

The conceptual models for white sturgeon rearing and migration are displayed in Figure 4-25 and Figure 4-26, respectively. The Suisun Marsh Fish Monitoring (SMFM) program has documented the presence of juvenile white sturgeon in the Marsh (BDAT 2007). However, the methods used for sampling are not effective at capturing fish with strong swimming abilities. Therefore, the number of white sturgeon sampled should not be considered an accurate population estimate for individuals that utilize the Marsh.

Not much information exists regarding white sturgeon use of the Marsh. Montezuma Slough, as well as Suisun and Grizzly Bay, are located between Central Valley freshwater spawning habitat and the Pacific Ocean. Adult and juvenile white sturgeon likely utilize these areas as a migratory corridor, although it is unclear what portion of the population utilize these routes. Juvenile white sturgeon could be present in all regions of the Marsh throughout the year. The primary drivers that likely influence sturgeon connectivity throughout the Marsh are physical barriers and adverse water quality conditions, rendering the water column unsuitable for occupancy by this species.

The ability of white sturgeon to access the majority of tidal marsh habitat in Suisun is excluded by levees and gates. Levees prevent the development of edge habitat and can obstruct hydraulic connectivity between tidal marshes and adjacent aquatic habitat. Since no scientific data currently exists relating to white sturgeon use of the tidal marsh habitat, it is unknown what features of marsh geomorphology would provide the most valuable habitat.

Suitable water quality for white sturgeon may include appropriate levels for water temperature, salinity, turbidity, and dissolved oxygen (DO). When temperatures reach 15, 20, and 25 °C and dissolved oxygen concentrations drop to 58 percent of air saturation, juveniles show a significant decrease in growth rate, presumably due to reduced food consumption (Cech and Crocker 2002). White sturgeon are thought to move in response to salinity changes (Moyle 2002). Salinity tolerances for white sturgeon may increase with size, this could explain the tendency of juveniles to concentrate in the upper reaches of the estuary (Moyle 2002). Sturgeon can tolerate elevated levels of turbidity, although thresholds have not been well studied, especially for juveniles. In the Marsh, significant depressions in DO concentrations (DO sags) that are associated with managed marsh pond discharge and flood up activities, have been reported since fall of 1999 (Schroeter 2004). DO levels below 5 mg/l are known to be deleterious to fish and likely block

migration corridors for anadromous fish such as sturgeon (Schroeter 2004). Thus, areas of the Marsh with low dissolved oxygen levels are unlikely to be used by white sturgeon.

Although it is uncertain if and for what functions white sturgeon would utilize tidal marsh habitat in Suisun, the availability of prey items could influence potential site use for foraging. In estuaries, white sturgeon adults are known to concentrate in deep areas with soft bottoms and may also move to intertidal areas to feed at high tides (Moyle 2002). White sturgeon are highly adapted to prey upon benthic species, with primary diet items made up of bottom dwelling estuarine invertebrates and, as sturgeon grow and age, fish also become important in their diet. White sturgeon are known to be feeding on the invasive overbite clam. Invasive overbite clams are known to effectively bioaccumulate toxic levels of the trace element selenium, which is known to have deleterious health effects to fish (Deng et al. 2007, Higashi et al. 2005).

Expected Restoration Effects at Each Trajectory Stage

White sturgeon are likely utilizing the Marsh for migration, foraging and rearing. Although it is unknown if juvenile white sturgeon would utilize any restoration stages of tidal marsh habitat, appropriate accessibility, water quality conditions and prey items could increase the likelihood of providing suitable habitat for direct use. Restoration stages such as subtidal, low intertidal, low marsh, mid marsh and high marsh could provide indirect benefits to white sturgeon in adjacent aquatic habitats through an increased export in productivity.

4.3.3.3 Prickly Sculpin (*Cottus asper*) (DFG)

Sculpins are small bottom-dwelling fishes with large flattened heads, fanlike pectoral fins, and smooth, scaleless bodies (Moyle 2002). Prickly sculpin (*Cottus asper*) are distinguished by their long anal fin (16-19 rays), which is about three times longer than the caudal peduncle. Prickly sculpin can occupy a very large range of habitats; they live in waters ranging from fresh to salt, in streams ranging from small, cold, and clear to large, warm, and turbid, and in lakes and reservoirs ranging from small to large, eutrophic to oligotrophic (SEW 2001). They can tolerate temperatures up to 28°C but spawn in temperatures ranging from 8-13°C (Moyle 2002). Many populations have been eliminated or reduced by the construction of flow barriers that block upstream movement, which can prevent sculpin from completing their life cycle (Moyle 2002).

Prickly sculpin are benthic and are primarily associated with submerged objects such as rocks, logs, and trash. Prickly sculpin have also been found in association with vegetated areas (Brown 2003). Prickly sculpin in Suisun Marsh tend to be found with other native fishes and in less disturbed habitats. Matern et al. (1996) observed that prickly sculpin populations respond strongly to changes in outflow, with high outflow years producing peaks in annual mean catches. Larvae can be found in Suisun Marsh from February through May, peaking in March in response to increased outflow and cool (<15°C) temperatures (Moyle 2002).

In the estuary, prickly sculpin feed predominately on benthic amphipods (*Gammurus*), mysid shrimp, and postlarval fish. However, when mysid shrimp populations collapsed, sculpins switched to feeding more heavily on amphipods (Moyle 2002).

Conceptual Model of Prickly Sculpin Use of Tidal Marshes in Suisun

Figure 4-27 presents the conceptual model for Prickly sculpin. Prickly sculpin are fairly well distributed throughout the sloughs in Suisun Marsh (Meng and Matern 2001) and derive direct benefit from the marsh in the form of food, shelter, and spawning habitat. They are more abundant in small, dead-end sloughs; therefore, marsh geomorphology is an important driver of abundance. Prickly sculpin feed primarily on benthic amphipods; therefore, this food source may be an important driver of prickly sculpin abundance in the marsh. Prickly sculpin are bottom-dwelling fish that are associated with vegetated habitat and require structural complexity for spawning; therefore, access to the marsh floodplain may help to increase their distribution (find reference for this statement). Most water quality parameters are unlikely to be significant factors affecting marsh use, as prickly sculpin are tolerant of a wide range of water quality conditions. However, spawning is generally tied to cooler water conditions; therefore, water temperature is considered to be a moderately important driver of prickly sculpin abundance. Individual club water control structures, including levees, are physical barriers between preferred habitat and food sources and may function to reduce local population sizes.

Expected Restoration Effects at Each Trajectory Stage

Prickly sculpin are likely to directly benefit from restoration of subtidal through mid-marsh areas. Site revegetation is likely to benefit prickly sculpin once individual plants grow to a size that provides suitable hiding and foraging opportunities. Placement of hard structures such as boulders or riprap may benefit prickly sculpin by providing structural complexity which they can use as spawning substrate. Prickly sculpin are also expected to derive indirect benefits through increased export of primary and secondary production that results from marsh restoration.

Prickly sculpin are not expected to gain any direct benefit from restoration actions in high-marsh sites, but may benefit indirectly through increased production. The upland transition stage is unlikely to provide any direct or indirect benefits to prickly sculpin.

4.3.3.4 Tule Perch (*Hysterocarpus traski*) (DFG)

Tule perch (*Hysterocarpus traski*) occupy a wide range of habitats from sluggish, turbid channels in the Delta to clear, swift flowing sections of river (Moyle 2002). In tidal marshes, tule perch prefer slow-moving backwater and slough habitats with structurally-complex beds of floating or emergent aquatic vegetation, overhanging bank, and/or submerged woody debris (Goals Project 2000). These areas serve as important feeding and breeding habitats, as well as protective rearing areas. However, tule perch can also be common in riprap (Moyle 2002). Tule perch prefer cool, well oxygenated water with temperatures below 22°C but can tolerate temperatures up to 25°C (Moyle 2002). Tule perch have high salinity tolerance. In

Suisun Marsh they are found in areas that have annual salinity ranges of 0 to 19 ppt (SEW 2001). They have been found to be particularly sensitive to low dissolved oxygen concentrations and may be limited by the seasonal dissolved oxygen sags observed in several areas of the marsh.

In Suisun Marsh, tule perch are year round residents and are most frequently collected in small, heavily vegetated, dead-end sloughs where introduced centrarchids are uncommon. They have historically been one of the most abundant fishes in the Suisun Marsh and, despite declines in 2004 and 2005, abundance remains high and multiple age classes present in the population suggest that a continued increase in abundance is possible if conditions remain favorable for growth (Schroeter et al. 2006). Their absence from areas dominated by nonnative species is likely to be a function of poor water quality rather than competition (Moyle 2002).

Tule perch in the San Francisco Estuary mostly feed on small amphipods (especially *Corophium*), and secondarily on other benthic prey, such as midge larvae (Chironomidae), small clams, brachyuran crabs, and mysid shrimp (Moyle 2002).

Conceptual Model of Tule Perch use of Tidal Marshes in Suisun Marsh

The conceptual model for tule perch is presented in Figure 4-28. Tule perch are relatively sensitive to water quality conditions, which are likely a major driver of marsh use. Tule perch have been found to be particularly sensitive to low dissolved oxygen concentrations and may be limited by the seasonal dissolved oxygen sags observed in several areas of the Marsh (Schroeter *et al.* 2006). Areas with continued low dissolved oxygen conditions (Peytonia, Boynton, and Goodyear Sloughs) remain largely devoid of tule perch, but areas such as Spring Branch and Cutoff Slough, which are generally high in DO, maintain the largest numbers of tule perch. Slough geomorphology is likely also a major driver of marsh use, as tule perch are found more often in small, dead-end sloughs. Tule perch prefer habitats with structurally-complex vegetation therefore access to shallow-water floodplain habitat is considered to increase tule perch distribution.

Expected Restoration Effects at Each Trajectory Stage

It is anticipated that tule perch will directly utilize restored subtidal through mid-marsh areas. Restoration of sites that are in the eastern marsh and have good connectivity with adjacent sloughs may be particularly beneficial for tule perch. Tule perch are also likely to derive indirect benefits through increased export of primary and secondary pelagic production. Tule perch are not expected to gain any direct benefit from restored high-marsh sites, but may benefit indirectly through increased production. The upland transition stage is unlikely to provide any direct or indirect benefits to tule perch.

4.3.3.5 Threespine Stickleback (*Gasterosteus aculeatus*) (DFG)

Threespine stickleback (*Gasterosteus aculeatus*) is a small (3-5 cm total length) fish with 3 sharp spines in front of a soft dorsal fin (Moyle 2002). Threespine sticklebacks have a broad salinity tolerance and are capable of completing their entire life cycle in either fresh or salt water, or migrating between the two

(Moyle 2002). They generally require cool water (<23-24°C) for long-term survival, and water that is low in turbidity since they are visual feeders (Moyle 2002). Spawning typically occurs where temperatures are between 15° and 18°C. Threespine stickleback are often found in quiet, shallow, weedy pools and backwater or among emergent plants at stream edges over bottoms of gravel, sand, and mud (Moyle 2002). In waters with piscivorous fish they are typically found in beds of aquatic plants or in other dense cover which helps them avoid predation (Moyle 2002).

Threespine stickleback are sporadically very abundant in Suisun Marsh, with numbers peaking January–April (Matern et al. 2002). They have been found to be especially abundant in Goodyear Slough near managed wetland pond drains (Matern et al. 2002). The habitat within managed wetland ponds is likely conducive to threespine stickleback spawning (Brown 2003), and high catches found during fish monitoring in Suisun Marsh corresponded closely with the seasonal patterns of pond draining (Matern et al. 2002)

Threespine sticklebacks are primarily visual feeders with diets consisting of small benthic organisms living on submerged, rooted, or floating macrophytes such as insect larvae, chironomid midge larva, and ostracods (Goals Project 2002).

Conceptual Model of Threespine Stickleback Use of Tidal Marshes in Suisun Marsh:

The conceptual model for threespine stickleback is presented in Figure 4-29. Evidence suggests that threespine stickleback may reproduce in managed wetland ponds and enter sloughs through drainage water. Thus, connectivity between the sloughs and managed wetland ponds is likely an important driver of Marsh use. Salinity is unlikely to have a significant effect on marsh use, as threespine stickleback have been found in to move between fresh water and salt water habitats. There is indication that low turbidity and cool water conditions increase long-term survival; therefore these parameters are considered to be moderately important drivers of marsh use. Threespine stickleback prefer vegetated habitats with structural complexity and are found to be most abundant in small dead-end slough; therefore, floodplain access and marsh geomorphology are also likely moderately important driver of distribution within the marsh.

Expected Restoration Effects at Each Trajectory Stage

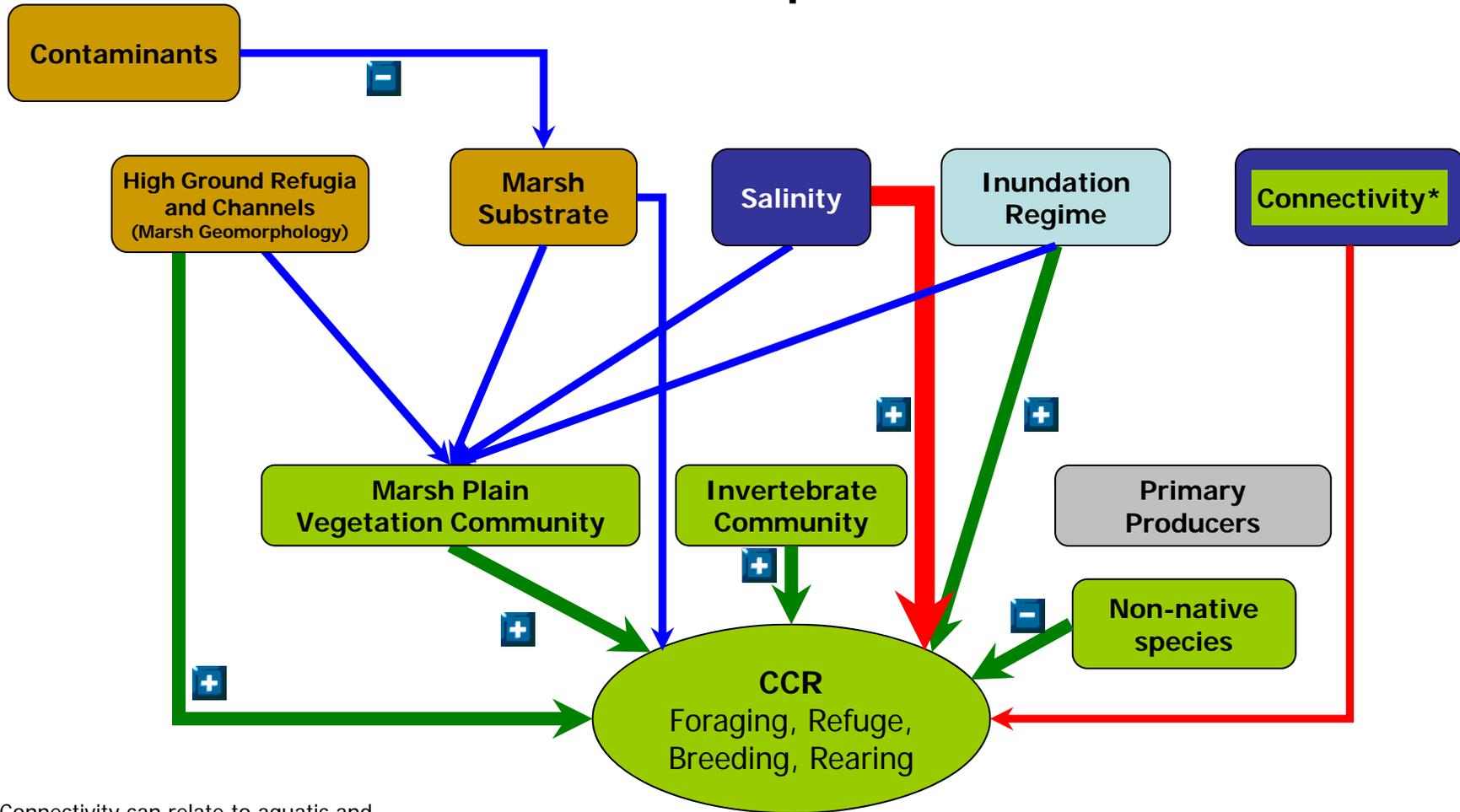
It is anticipated that threespine will directly utilize restored subtidal through mid-marsh areas. Site revegetation is likely to benefit threespine stickleback once individual plants grow to a size that provides suitable hiding habitat. They are also likely to derive indirect benefits through increased export of primary and secondary pelagic production. Threespine stickleback are not expected to gain any direct benefit from high-marsh sites, but may benefit indirectly through increased pelagic production. The upland transition stage is unlikely to provide any direct or indirect benefits to threespine stickleback.

4.3.4 Mammals (DFG)

Mammals such as the harbor seal (*Phoca vitulina*), California sea lion (*Zalophus californianus*), North American river otter (*Lutra canadensis*), and American beaver (*Castor canadensis*) utilize subtidal habitat (Table 2) (DFG 2005 and Goals Project 1999). Harbor seals typically forage in subtidal habitat 20 meters or

less in depth (subtidal depths are described in more detail in the Physical Resources description). Prey items include fish, crustaceans, cephalopods, and benthic and schooling fishes (DFG 2005). California sea lions utilize deep subtidal habitat and feed on fish and cephalopods (DFG 2005). River otters occur throughout the Marsh in subtidal habitats primarily associated with good river bank cover (Goals Project 2000). Scat analysis of river otters in the Marsh showed that crayfish were the most frequent prey item, followed by birds and fish which were the second most frequent prey items depending on season (Goals Project 2000). American beavers can be found in slough habitats and utilize aquatic vegetation, such as tules and cattails, as a portion of their diet. Beavers also use sloughs for reproduction and cover (Zeiner et al. 1990).

Figure 4-1 California Clapper Rail Suisun Conceptual Model



* Connectivity can relate to aquatic and aerial (e.g., bird flight) pathways

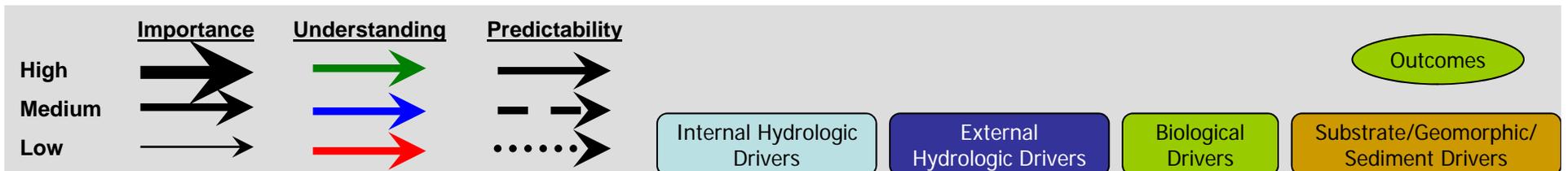


Figure 4-2 California Black Rail Suisun Conceptual Model

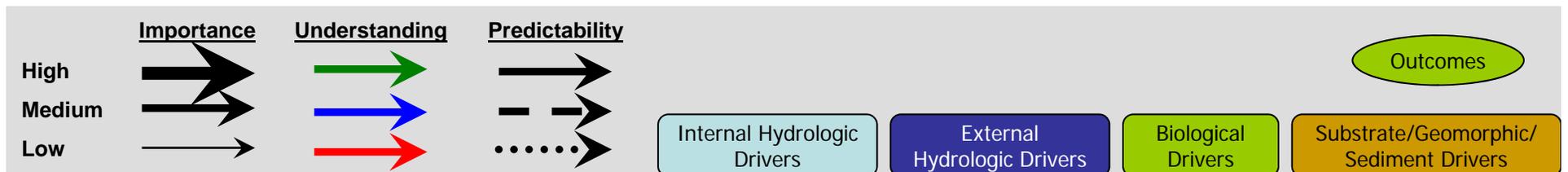
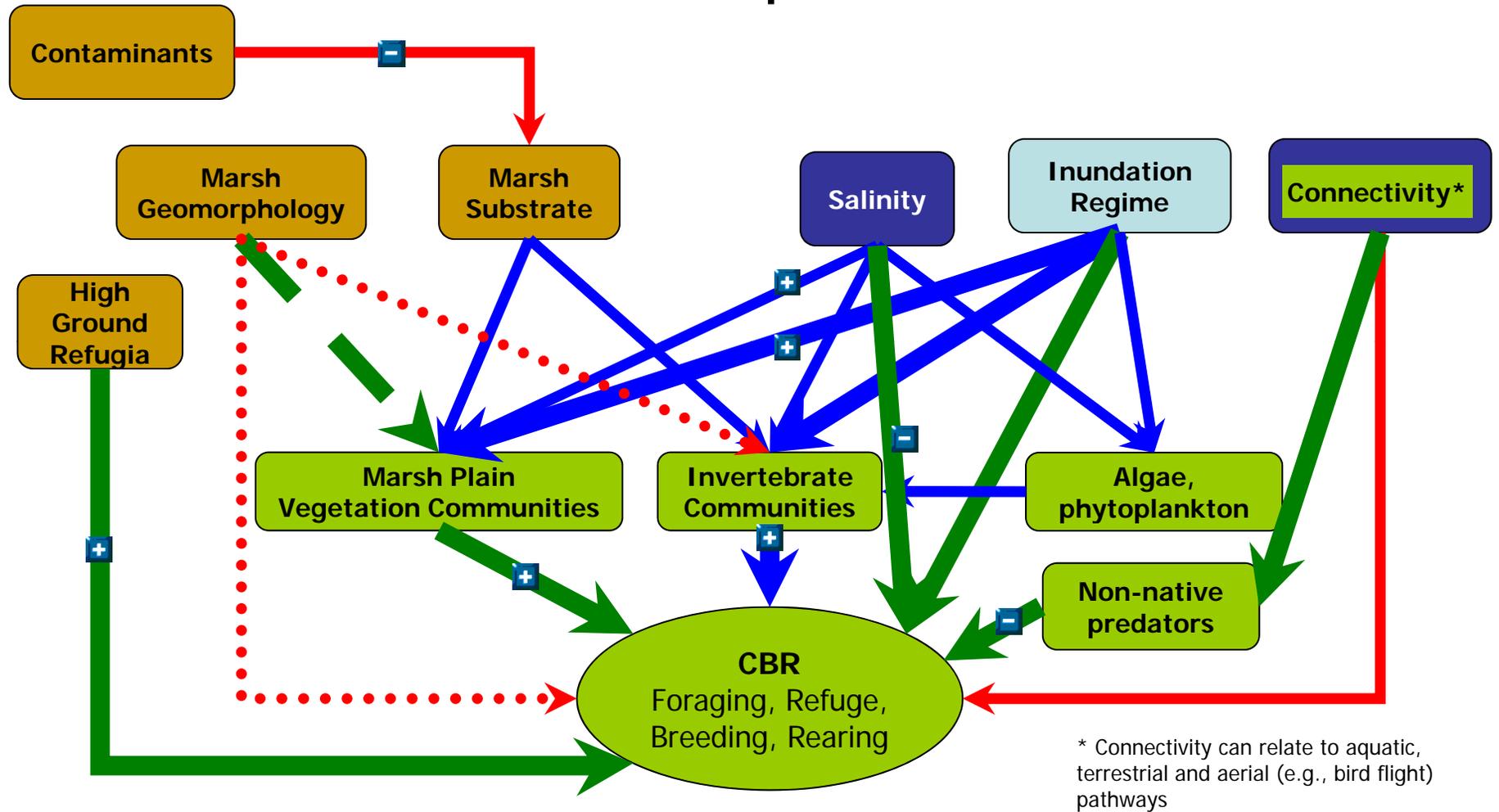
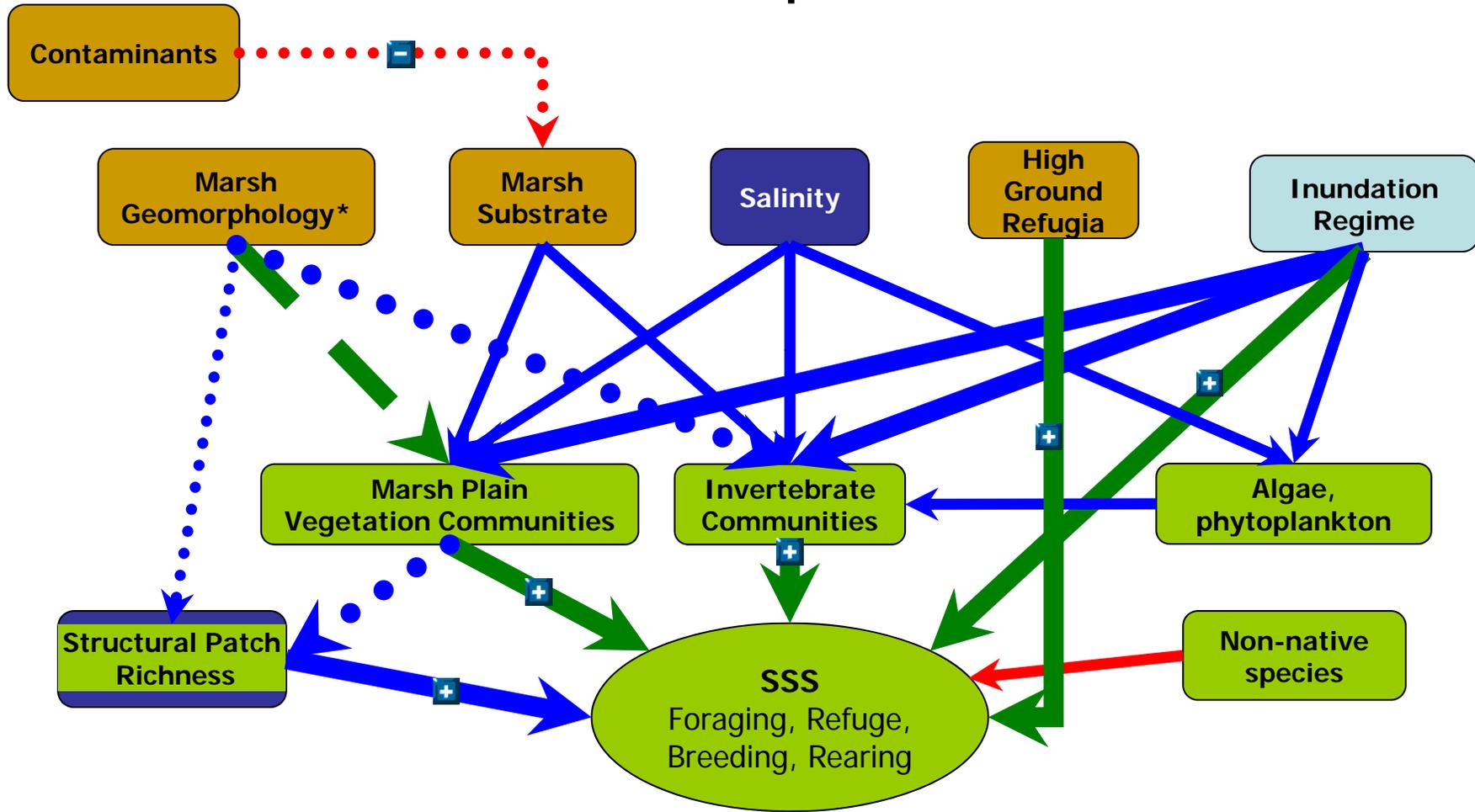


Figure 4-3 Suisun Song Sparrow Suisun Conceptual Model



*Can relate to topographic complexity, slope and transitional elevations

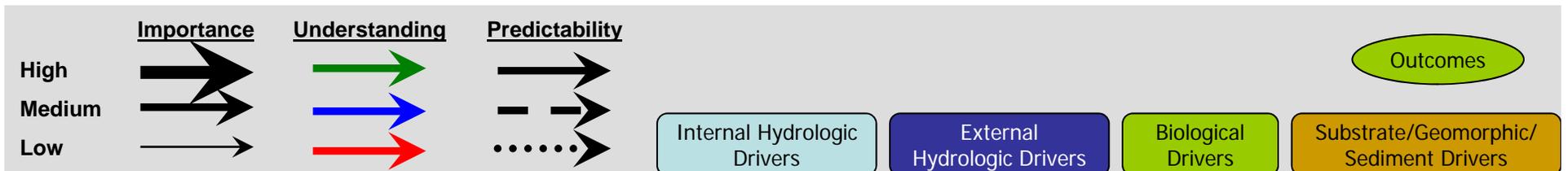
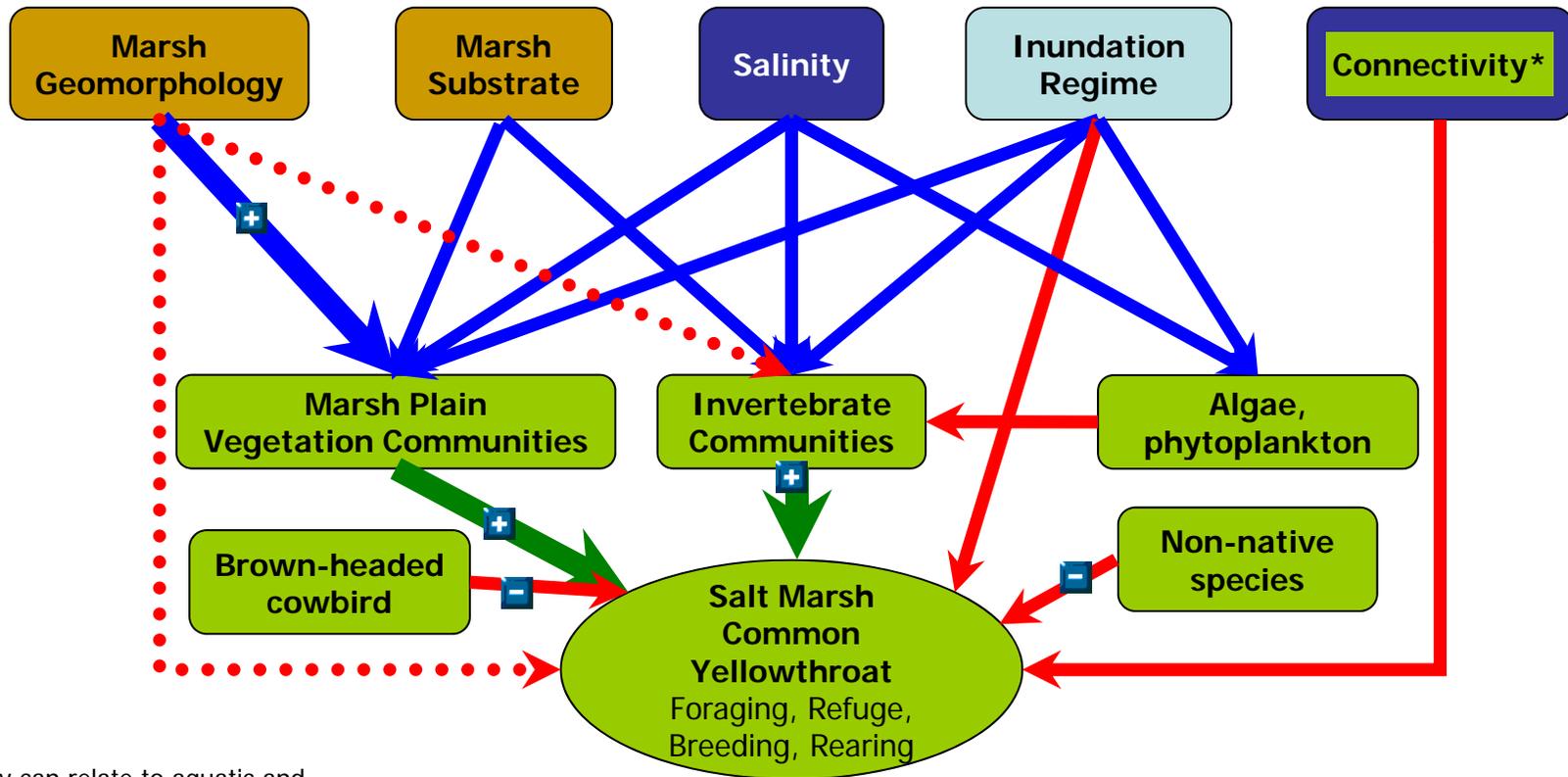


Figure 4-4 Salt Marsh Common Yellowthroat Suisun Conceptual Model



* Connectivity can relate to aquatic and aerial (e.g., bird flight) pathways

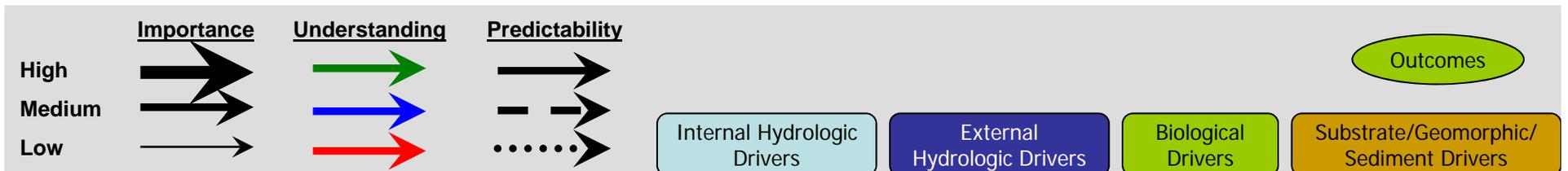
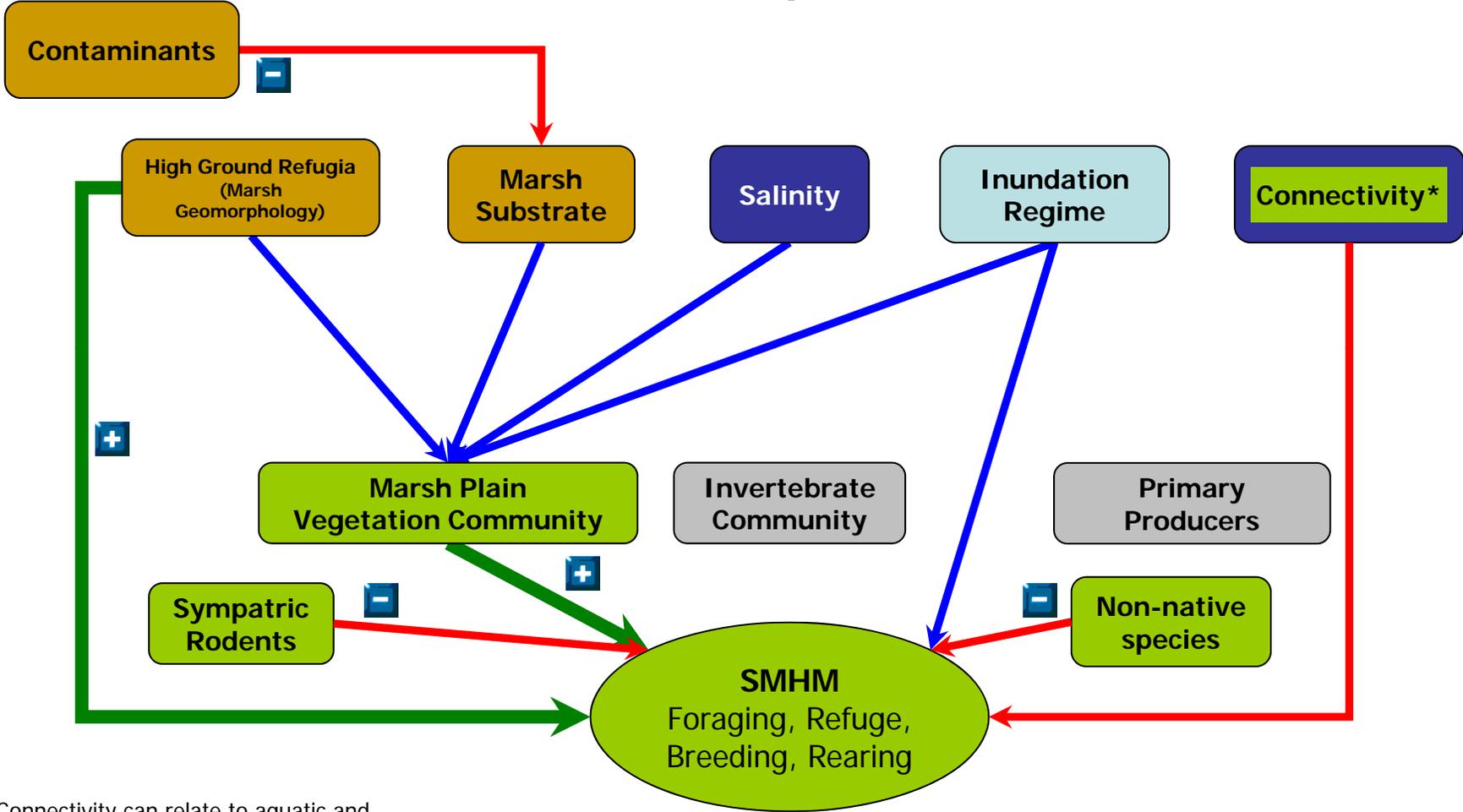


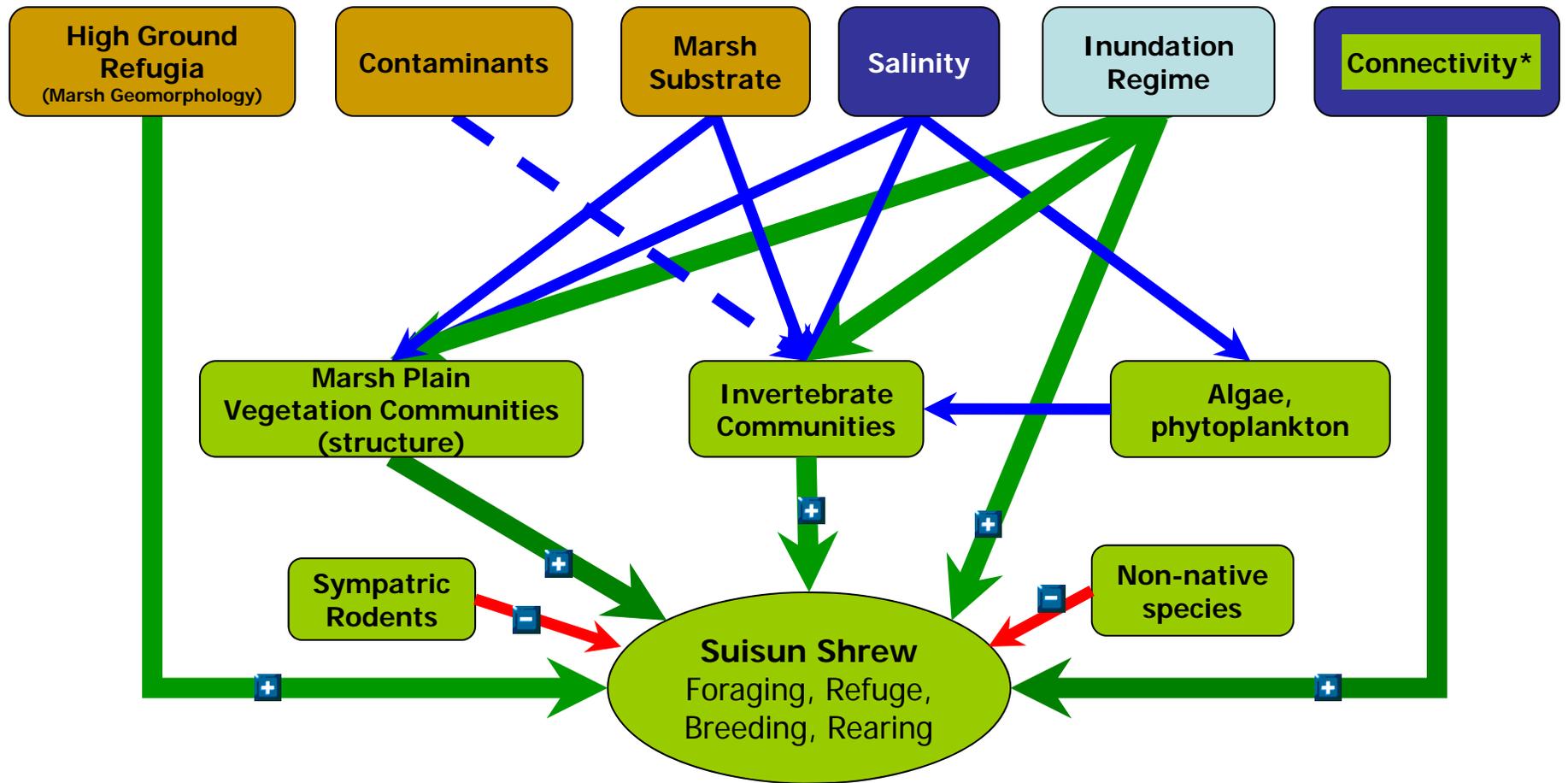
Figure 4-5 Salt Marsh Harvest Mouse Suisun Conceptual Model



* Connectivity can relate to aquatic and aerial (e.g., bird flight) pathways

| | <u>Importance</u> | <u>Understanding</u> | <u>Predictability</u> | | | | |
|--------|-------------------|----------------------|-----------------------|-----------------------------|-----------------------------|--------------------|---------------------------------------|
| High | → | → | → | | | | Outcomes |
| Medium | → | → | → | | | | |
| Low | → | → | → | | | | |
| | | | | Internal Hydrologic Drivers | External Hydrologic Drivers | Biological Drivers | Substrate/Geomorphic/Sediment Drivers |

Figure 4-6 Suisun Shrew Suisun Conceptual Model



* Connectivity can relate to edge habitat, upland transitions and shallow sloped banks

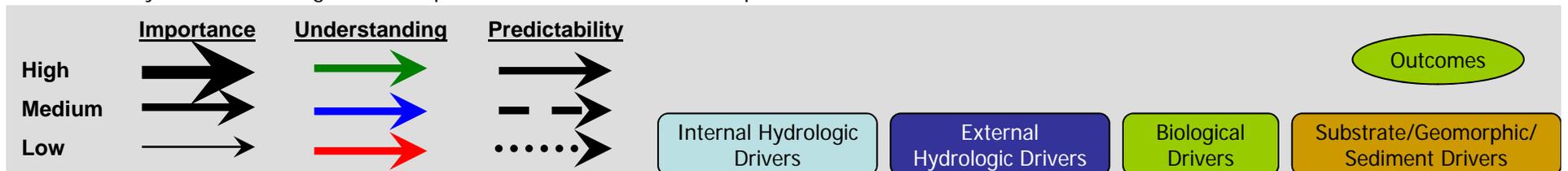
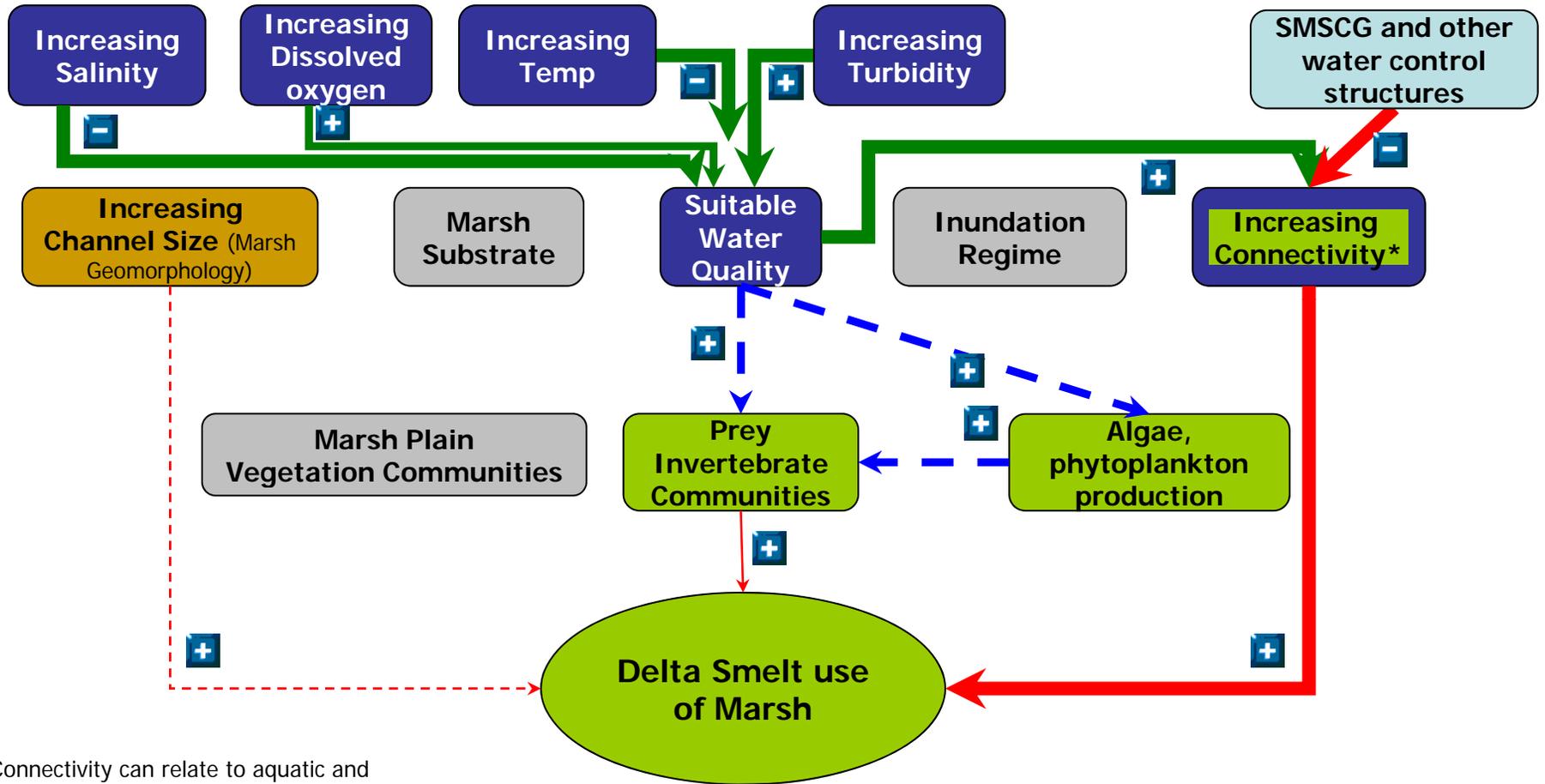


Figure 4-7 Delta Smelt Suisun Conceptual Model



* Connectivity can relate to aquatic and aerial (e.g., bird flight) pathways

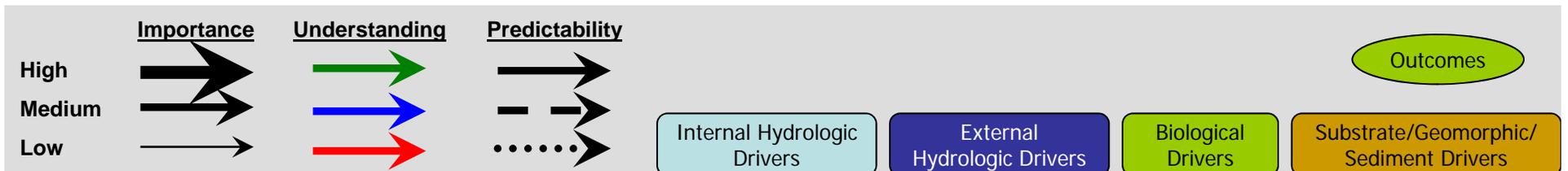
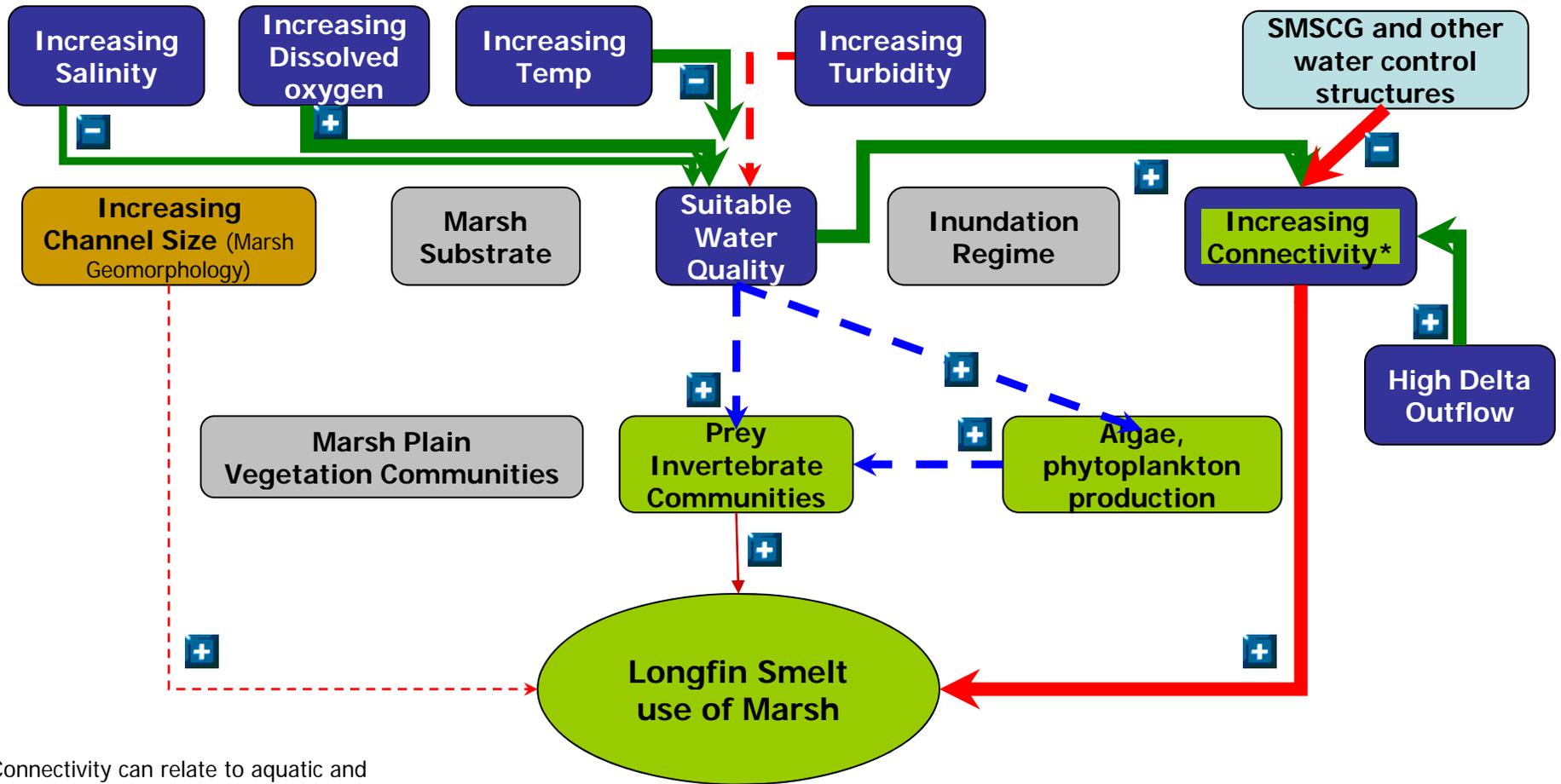


Figure 4-8 Longfin Smelt Suisun Conceptual Model



* Connectivity can relate to aquatic and aerial (e.g., bird flight) pathways

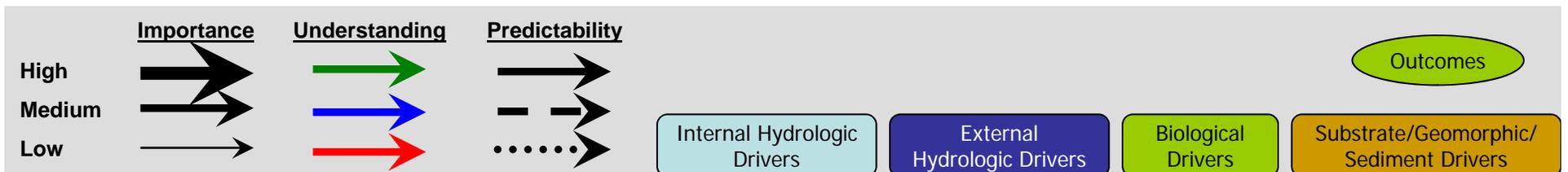
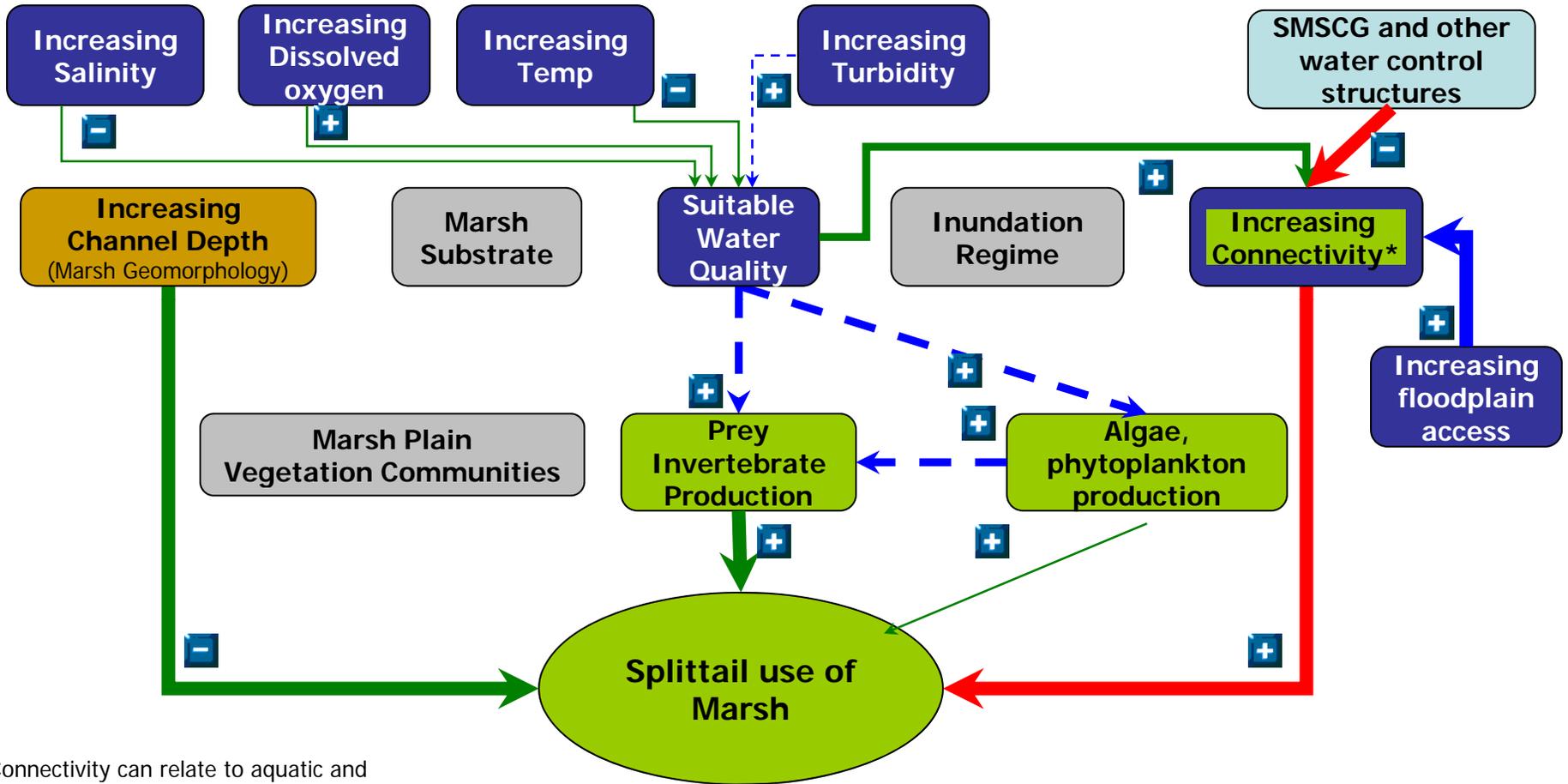


Figure 4-9 Splittail Suisun Conceptual Model



* Connectivity can relate to aquatic and aerial (e.g., bird flight) pathways

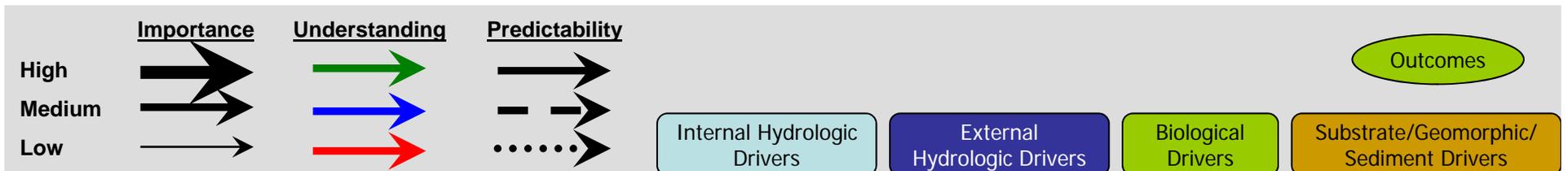
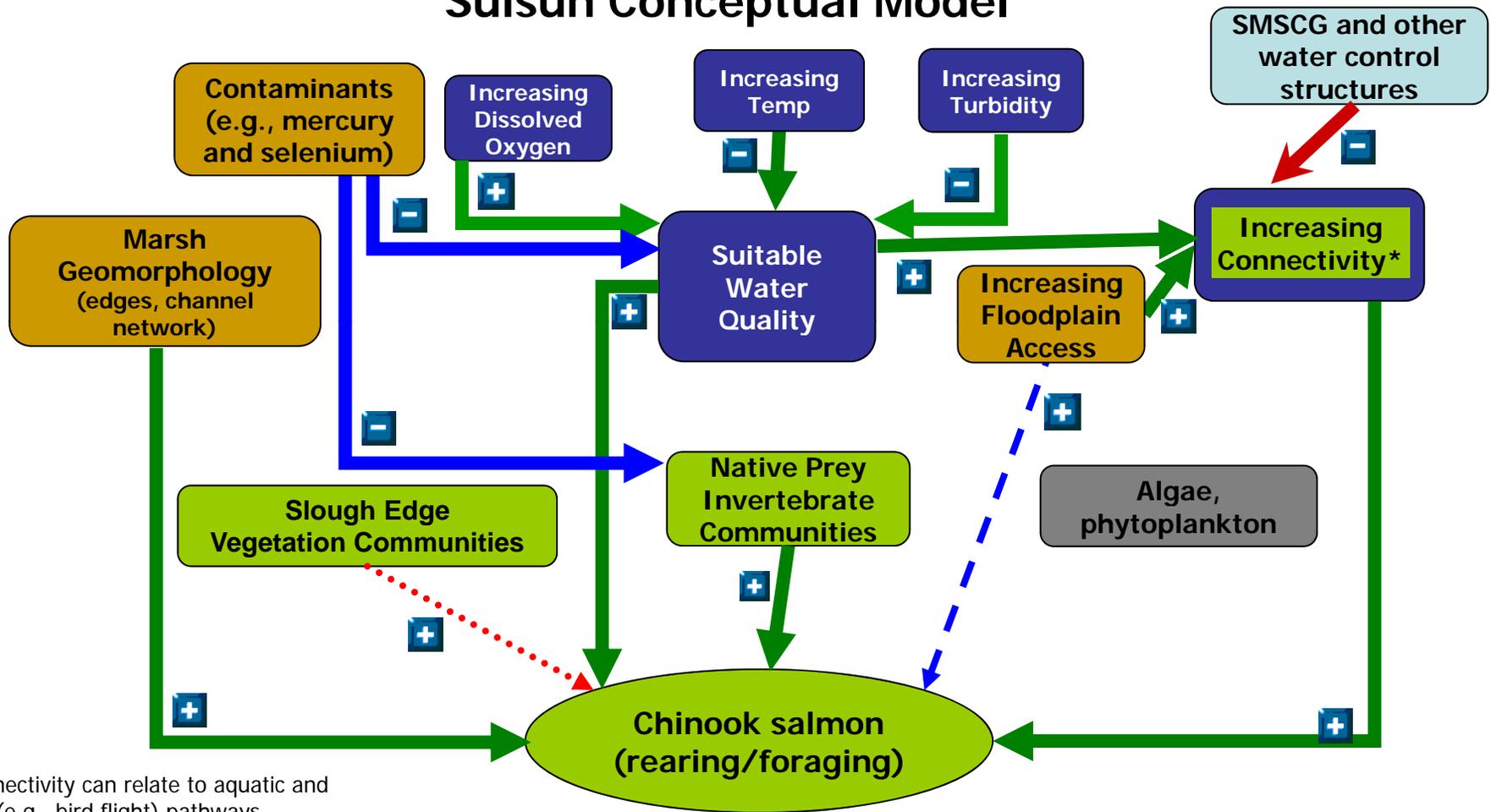


Figure 4-10
Central Valley Fall/Late-Fall, Sacramento River Winter-Run and
Central Valley Spring-Run Chinook Salmon (rearing/foraging)
Suisun Conceptual Model



* Connectivity can relate to aquatic and aerial (e.g., bird flight) pathways

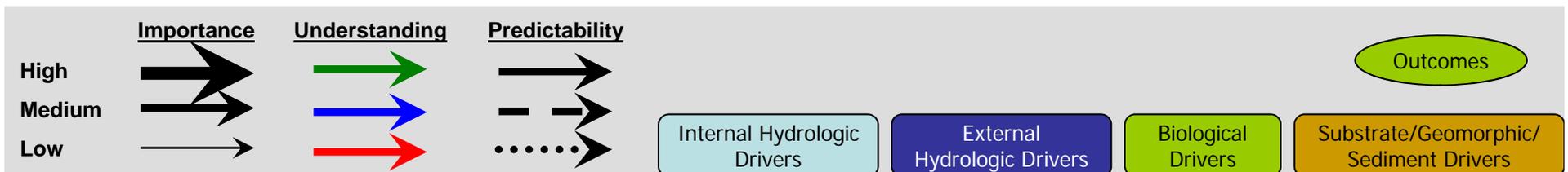
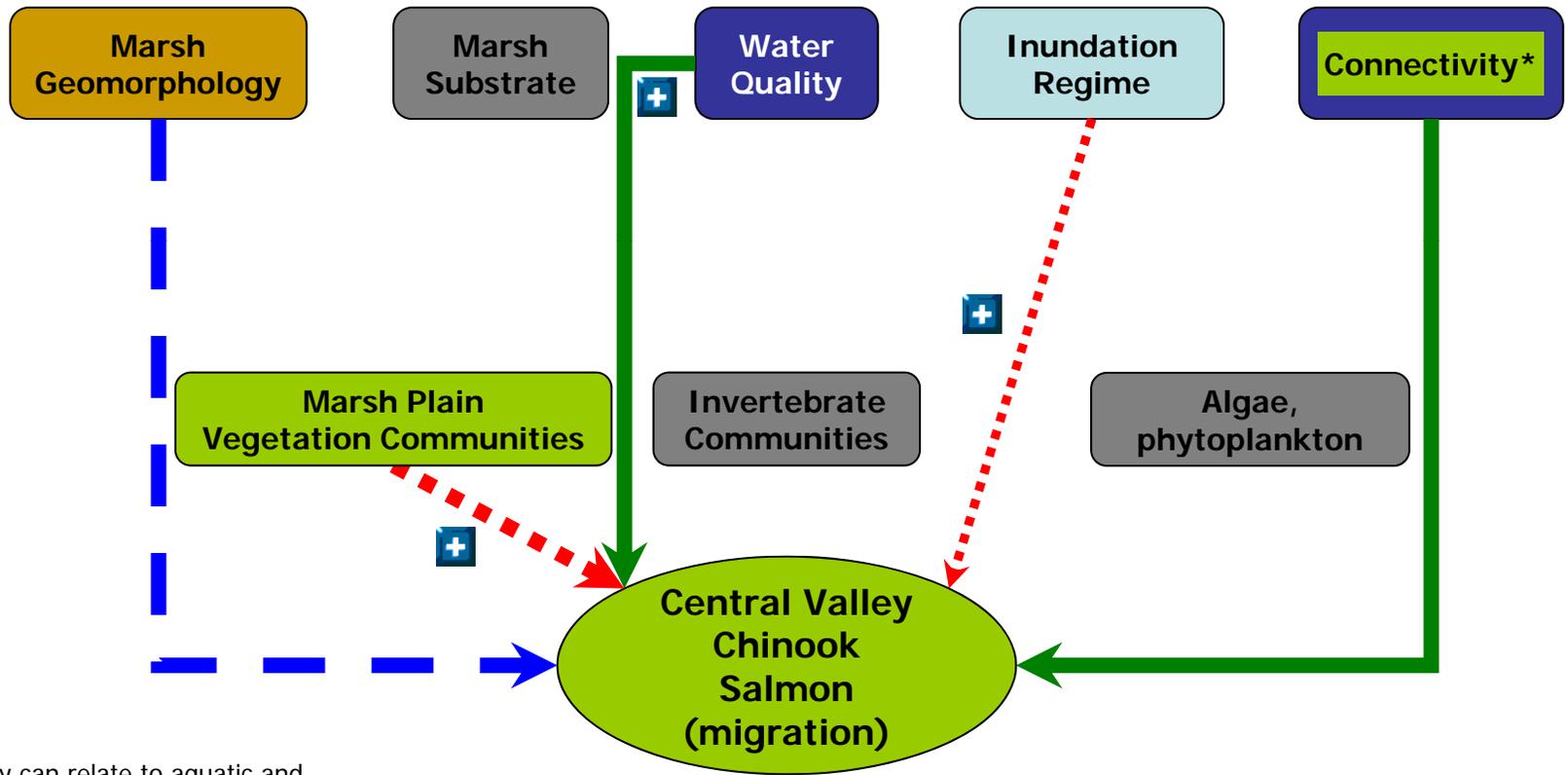


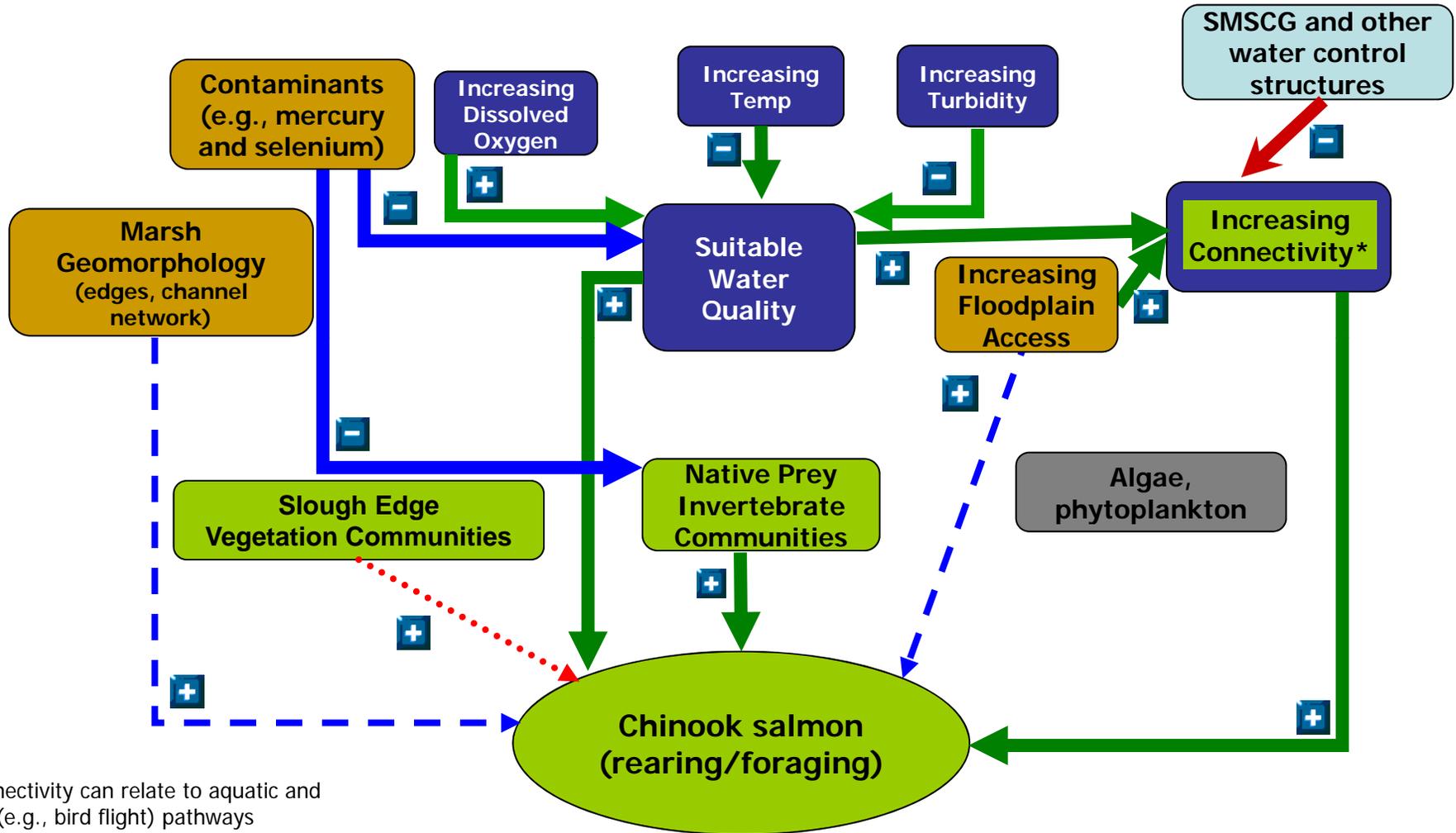
Figure 4-11 Chinook Salmon (migration) Suisun Conceptual Model



* Connectivity can relate to aquatic and aerial (e.g., bird flight) pathways

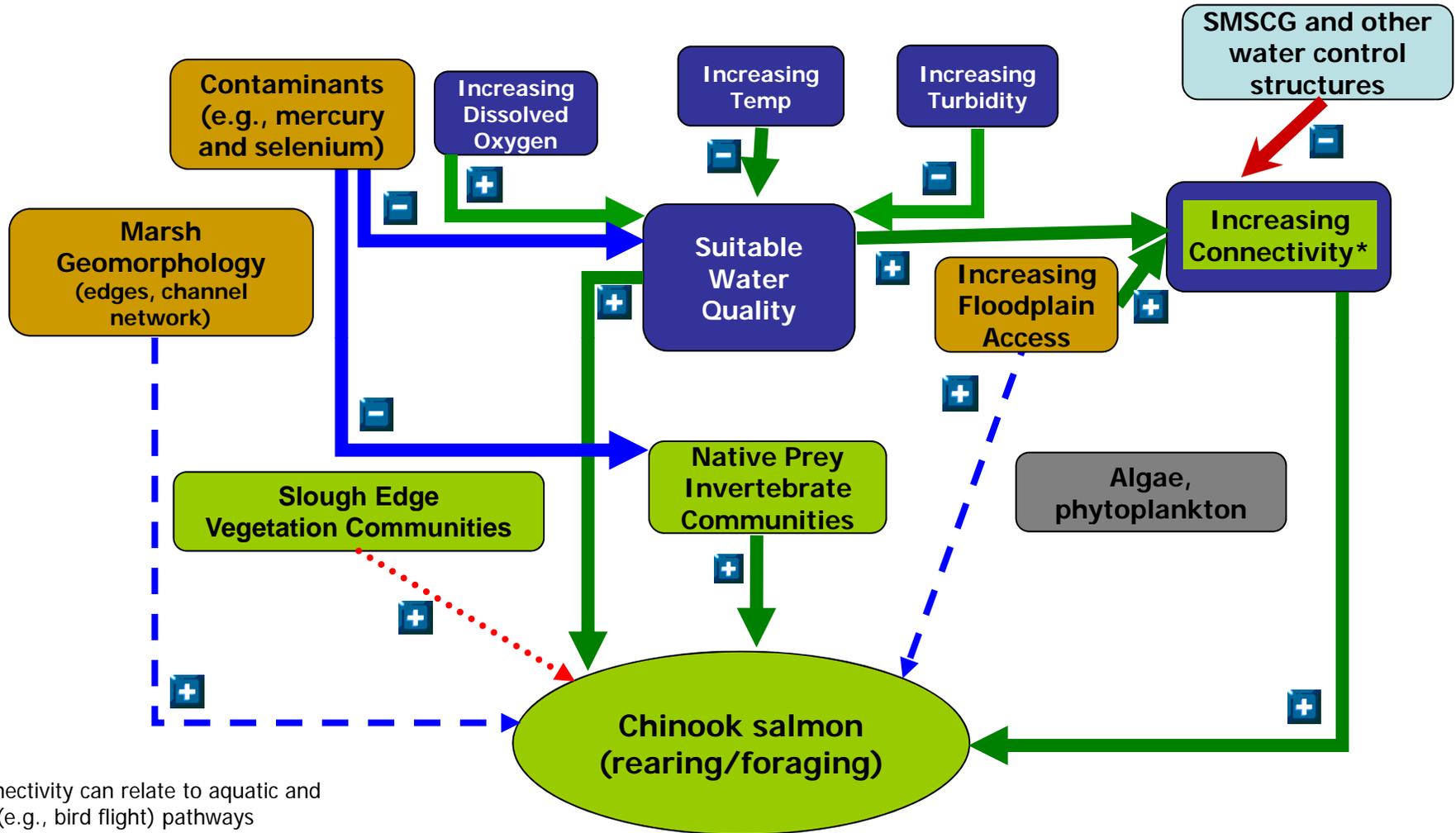
| | <u>Importance</u> | <u>Understanding</u> | <u>Predictability</u> | | | | |
|--------|-------------------|----------------------|-----------------------|--|--|--|--|
| High | | | | | | | |
| Medium | | | | | | | |
| Low | | | | | | | |

Figure 4-12 Central Valley Steelhead (rearing/foraging) Suisun Conceptual Model



| | <u>Importance</u> | <u>Understanding</u> | <u>Predictability</u> | |
|--------|-------------------|----------------------|-----------------------|--|
| High | | | | <div style="border: 1px solid black; border-radius: 10px; padding: 5px; display: inline-block;">Outcomes</div> |
| Medium | | | | |
| Low | | | | |
| | | | | <div style="border: 1px solid black; border-radius: 10px; padding: 5px; display: inline-block; margin-right: 10px;">Internal Hydrologic Drivers</div> <div style="border: 1px solid black; border-radius: 10px; padding: 5px; display: inline-block; margin-right: 10px;">External Hydrologic Drivers</div> <div style="border: 1px solid black; border-radius: 10px; padding: 5px; display: inline-block; margin-right: 10px;">Biological Drivers</div> <div style="border: 1px solid black; border-radius: 10px; padding: 5px; display: inline-block;">Substrate/Geomorphic/Sediment Drivers</div> |

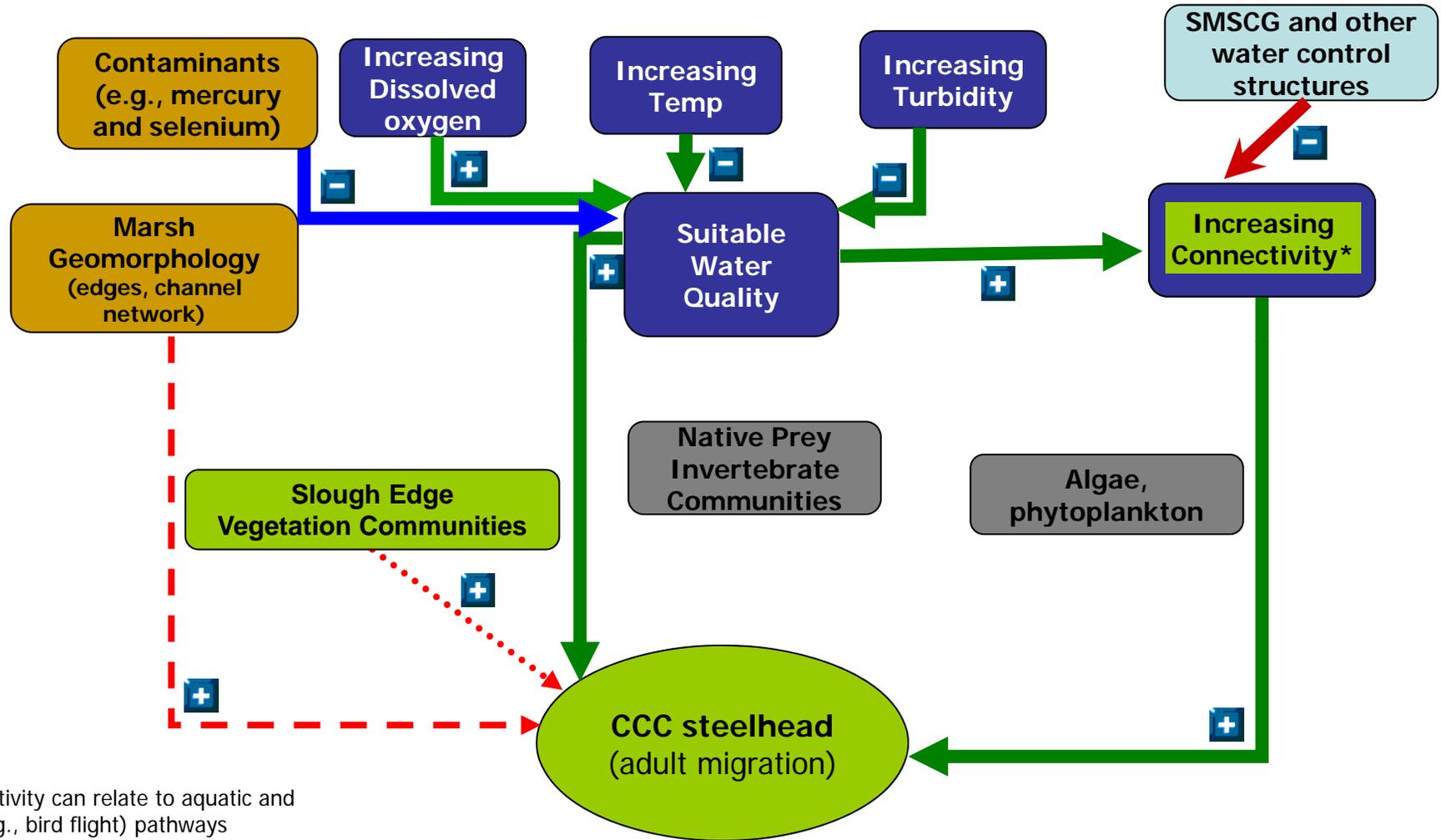
Figure 4-13 Central California Coast Steelhead (rearing/foraging) Suisun Conceptual Model



* Connectivity can relate to aquatic and aerial (e.g., bird flight) pathways

| | <u>Importance</u> | <u>Understanding</u> | <u>Predictability</u> | | | | |
|--------|-------------------|----------------------|-----------------------|-----------------------------|-----------------------------|--------------------|---------------------------------------|
| High | | | | | | | |
| Medium | | | | | | | |
| Low | | | | Internal Hydrologic Drivers | External Hydrologic Drivers | Biological Drivers | Substrate/Geomorphic/Sediment Drivers |

Figure 4-14 Central Valley Steelhead (adult migration) Suisun Conceptual Model



* Connectivity can relate to aquatic and aerial (e.g., bird flight) pathways

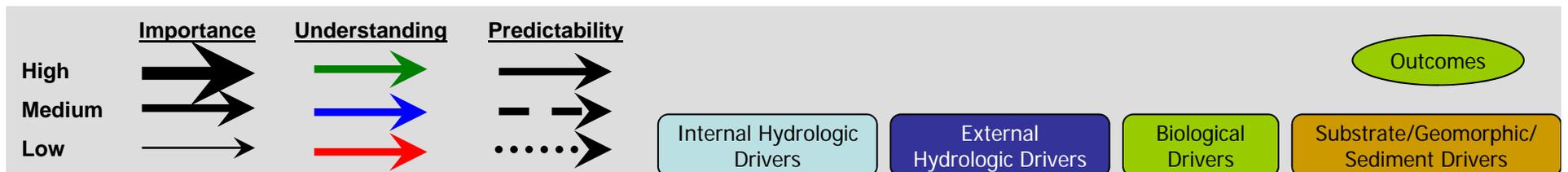
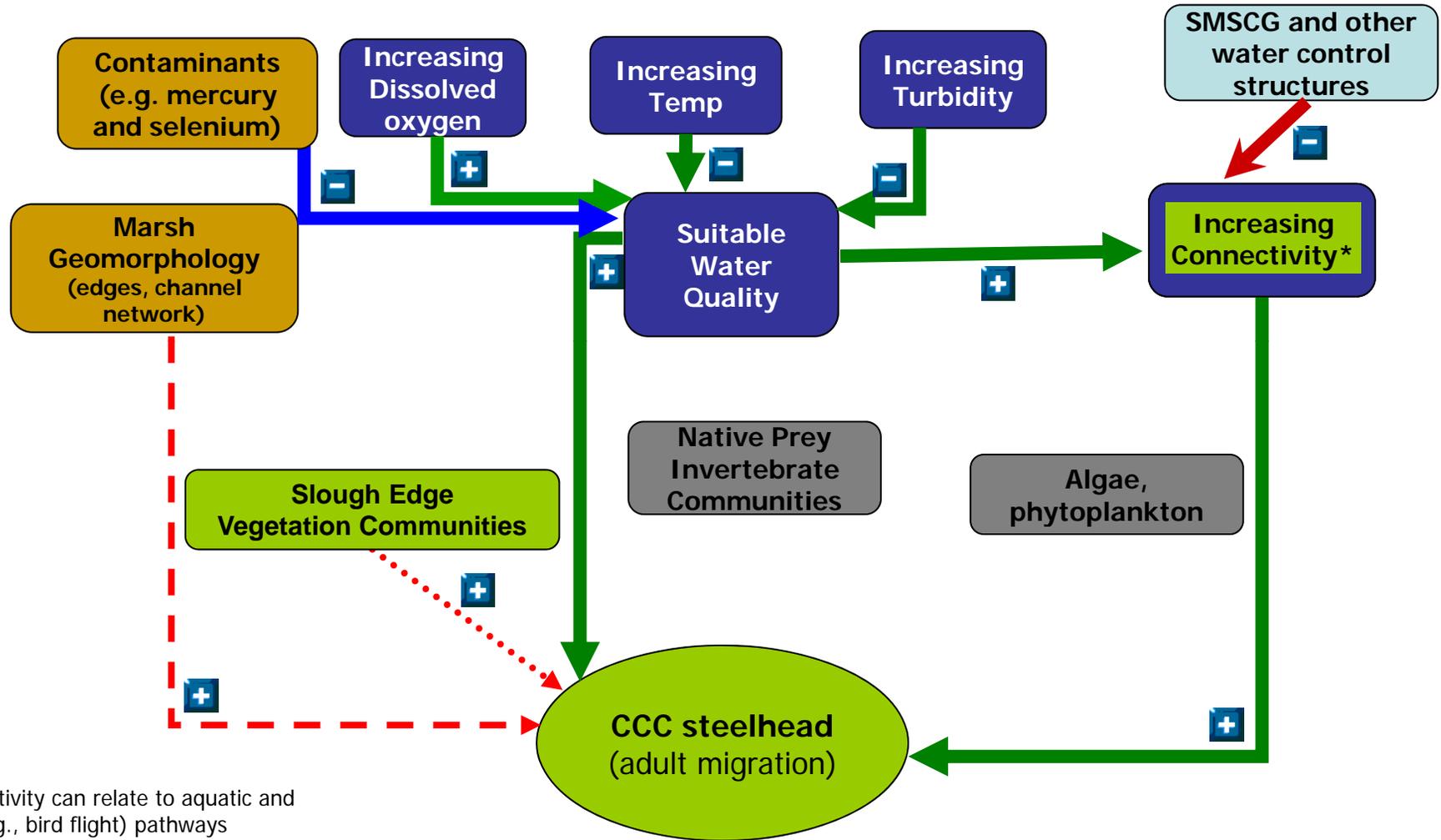


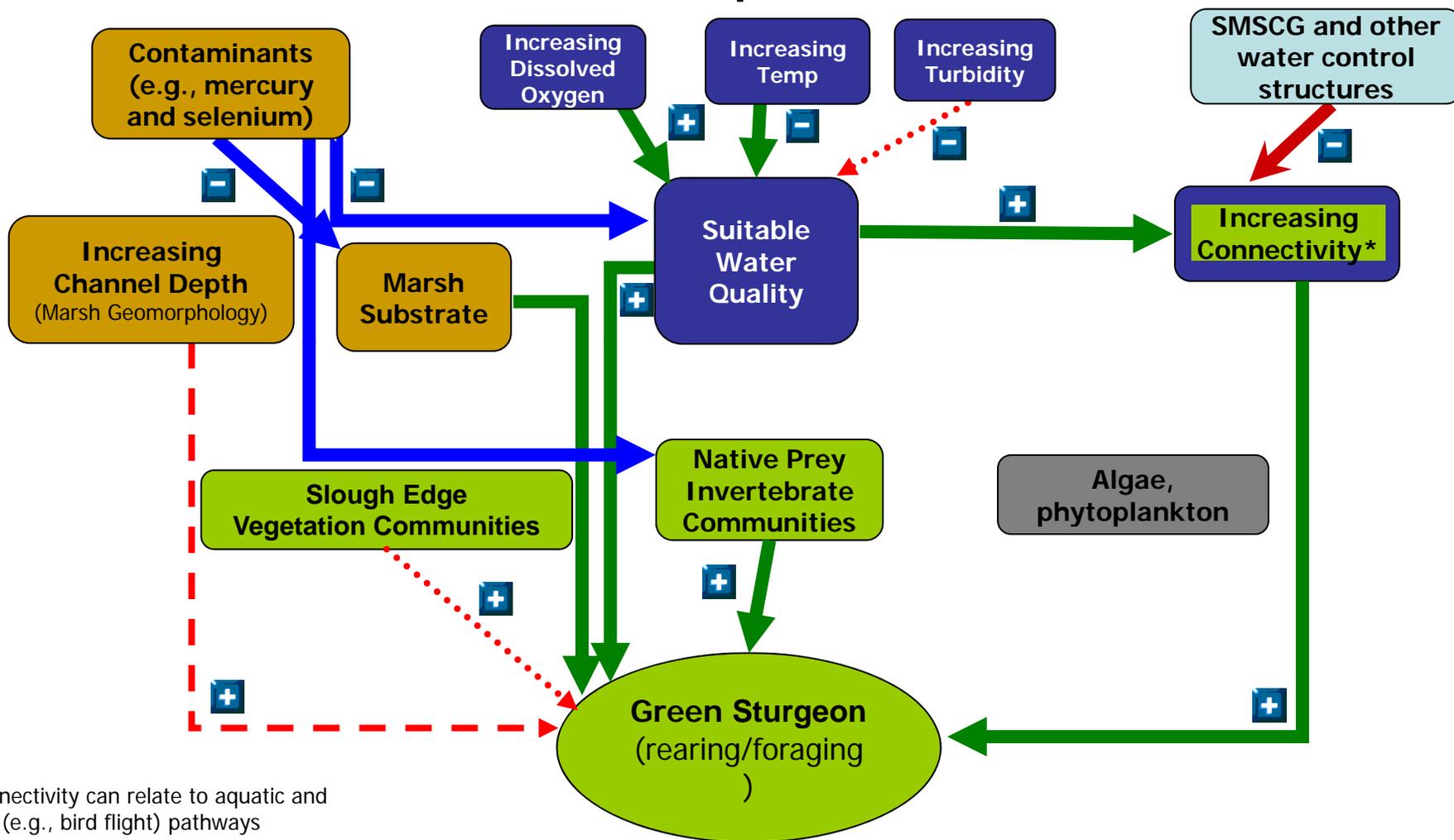
Figure 4-15
Central California Coast (CCC) steelhead (adult migration)
Suisun Conceptual Model



* Connectivity can relate to aquatic and aerial (e.g., bird flight) pathways

| | <u>Importance</u> | <u>Understanding</u> | <u>Predictability</u> | | | | |
|--------|-------------------|----------------------|-----------------------|-----------------------------|-----------------------------|--------------------|---------------------------------------|
| High | | | | | | | |
| Medium | | | | | | | |
| Low | | | | Internal Hydrologic Drivers | External Hydrologic Drivers | Biological Drivers | Substrate/Geomorphic/Sediment Drivers |

Figure 4-16 Green Sturgeon (rearing/foraging) Suisun Conceptual Model



* Connectivity can relate to aquatic and aerial (e.g., bird flight) pathways

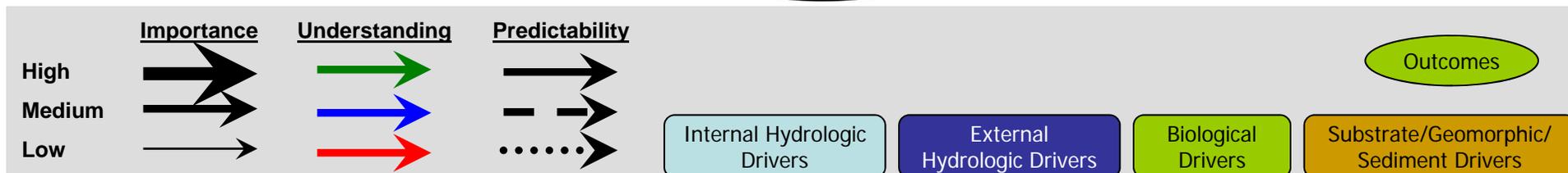
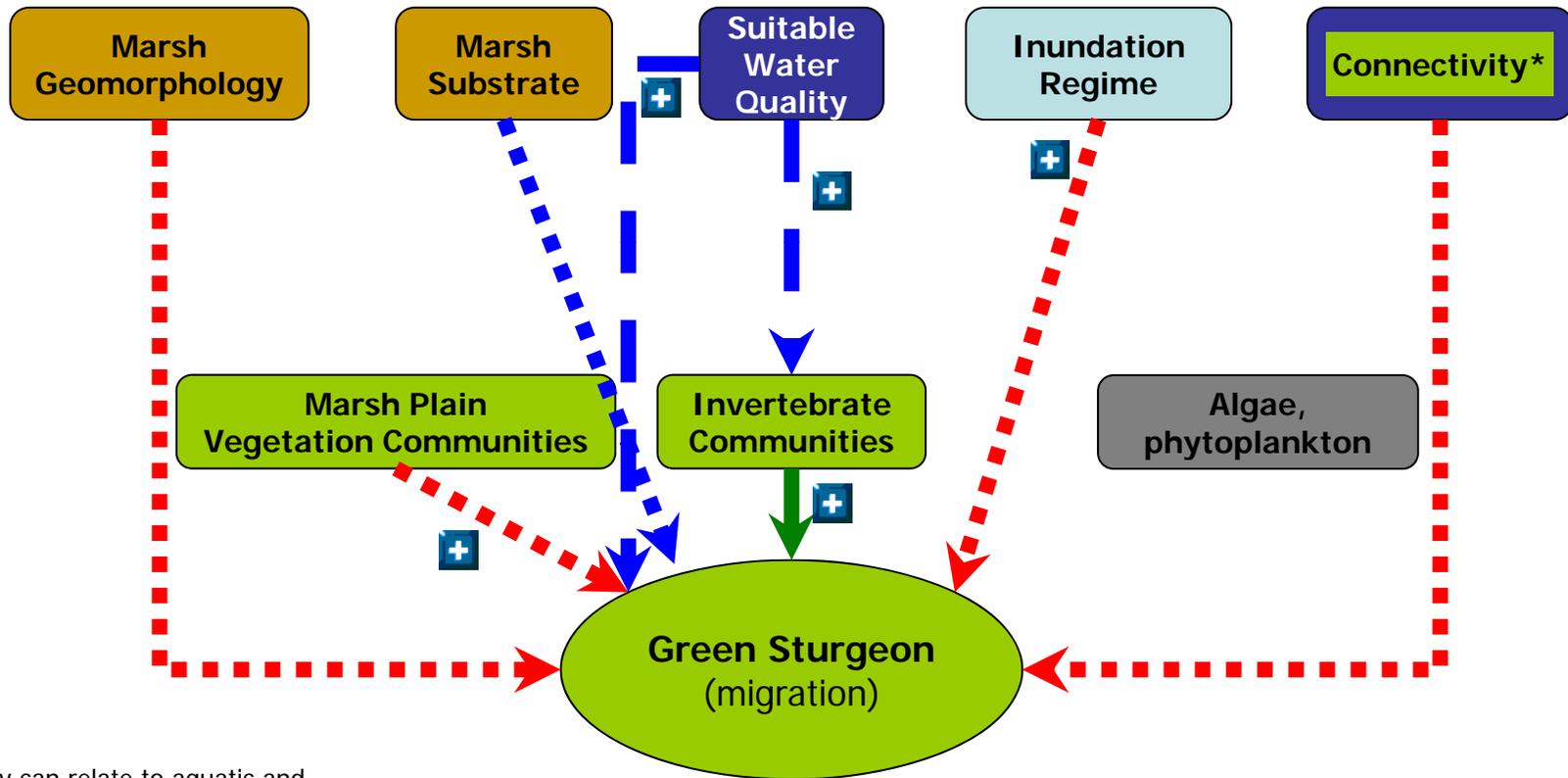


Figure 4-17 Green Sturgeon (migration) Suisun Conceptual Model



* Connectivity can relate to aquatic and aerial (e.g., bird flight) pathways

| | <u>Importance</u> | <u>Understanding</u> | <u>Predictability</u> | | | | |
|--------|-------------------|----------------------|-----------------------|-----------------------------|-----------------------------|--------------------|---------------------------------------|
| High | | | | | | | |
| Medium | | | | | | | |
| Low | | | | | | | |
| | | | | Internal Hydrologic Drivers | External Hydrologic Drivers | Biological Drivers | Substrate/Geomorphic/Sediment Drivers |

Figure 4-19 Waterfowl Diving Benthivores Suisun Conceptual Model

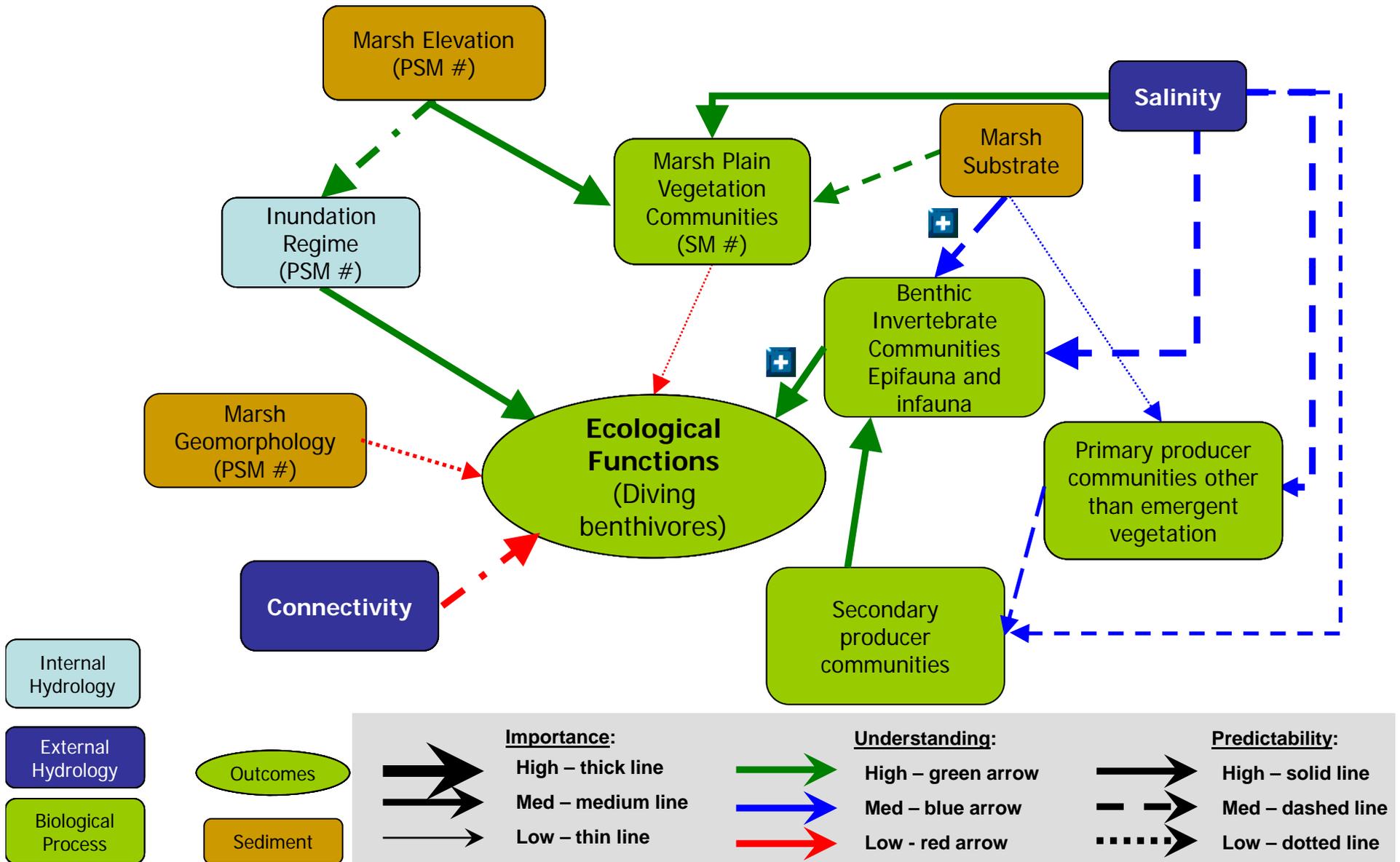


Figure 4-20 Waterfowl Diving Piscivores Suisun Conceptual Model

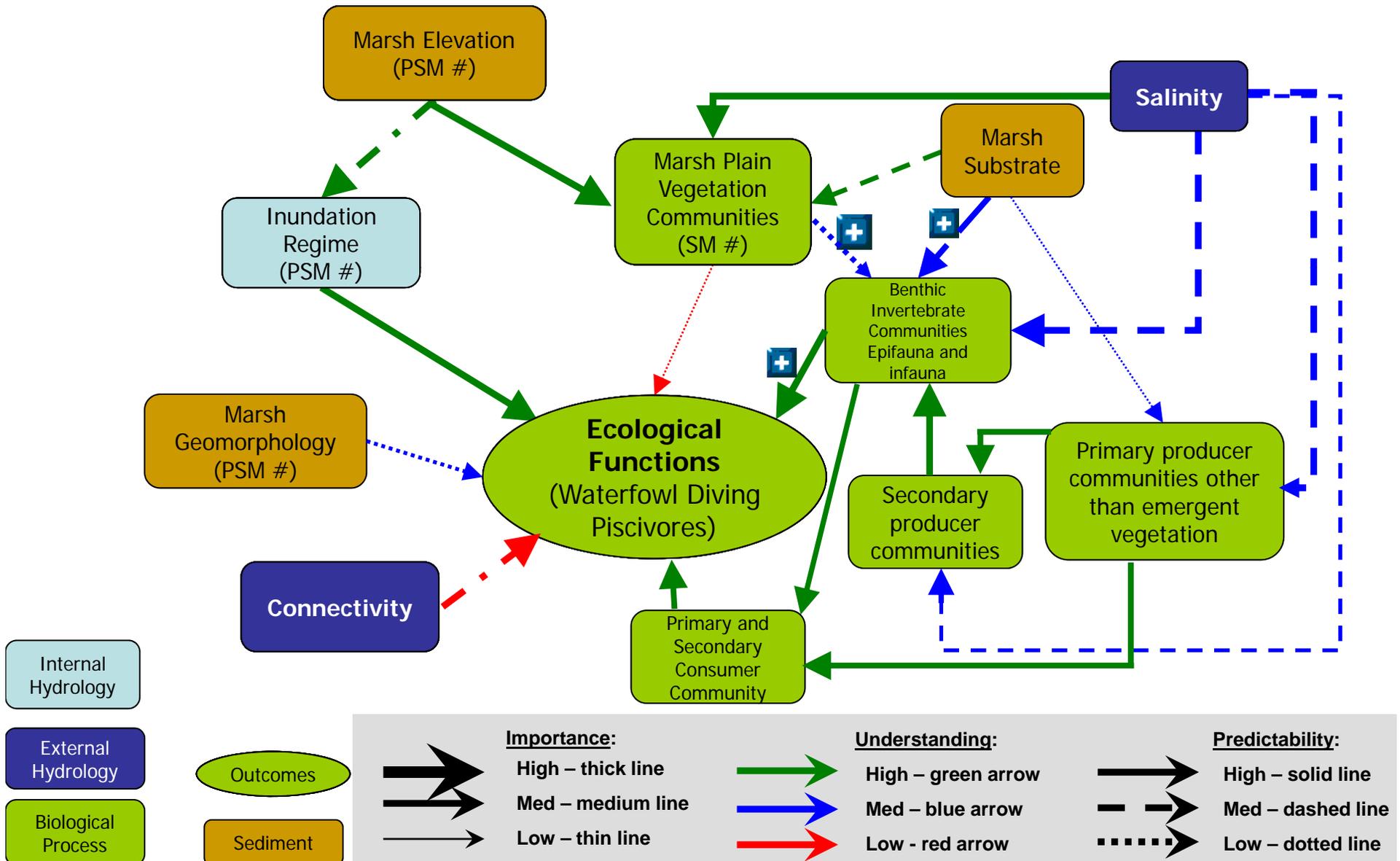


Figure 4-21 Waterfowl Dabbling Omnivores Suisun Conceptual Model

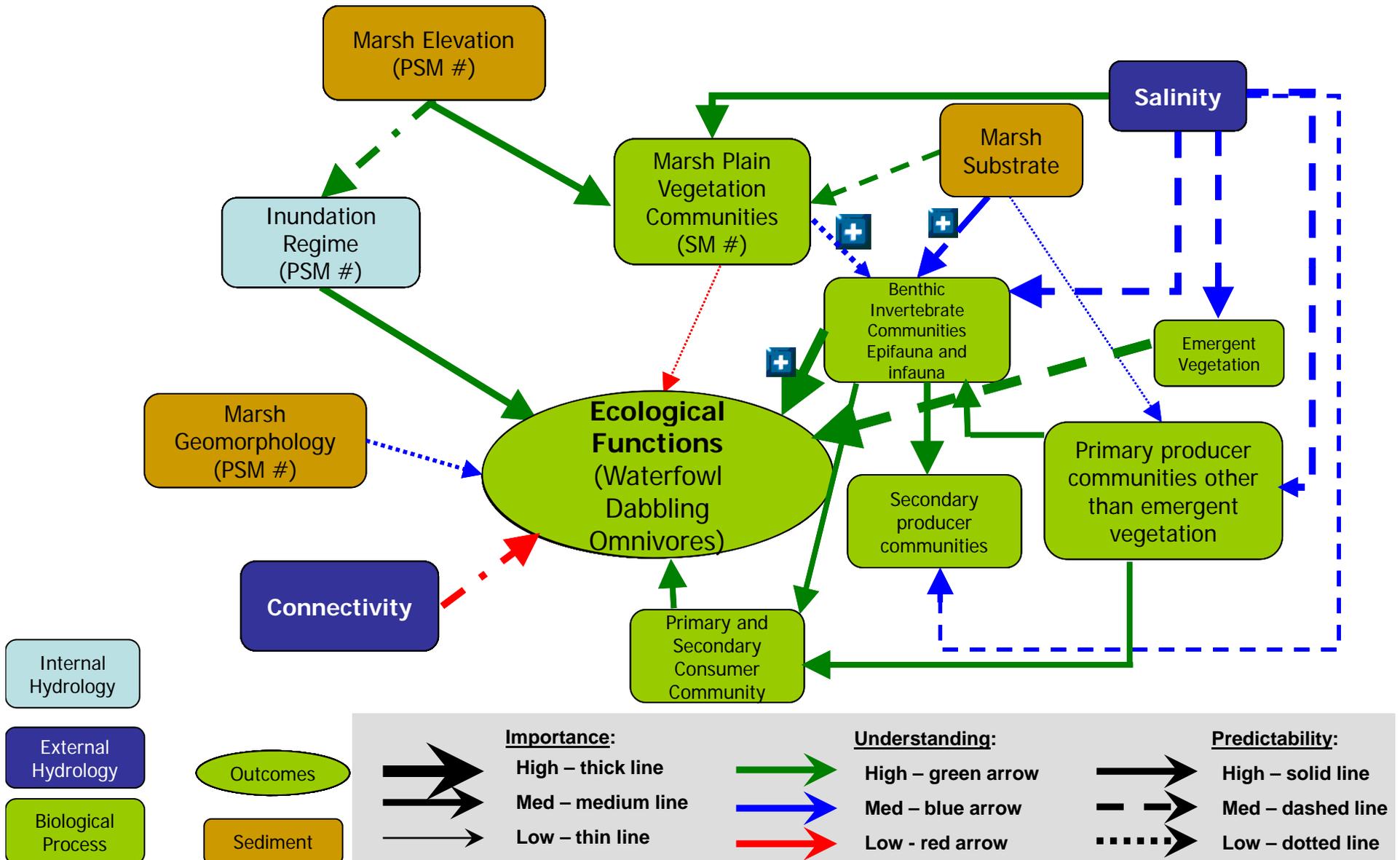


Figure 4-22 Waterfowl Dabbling Herbivores Suisun Conceptual Model

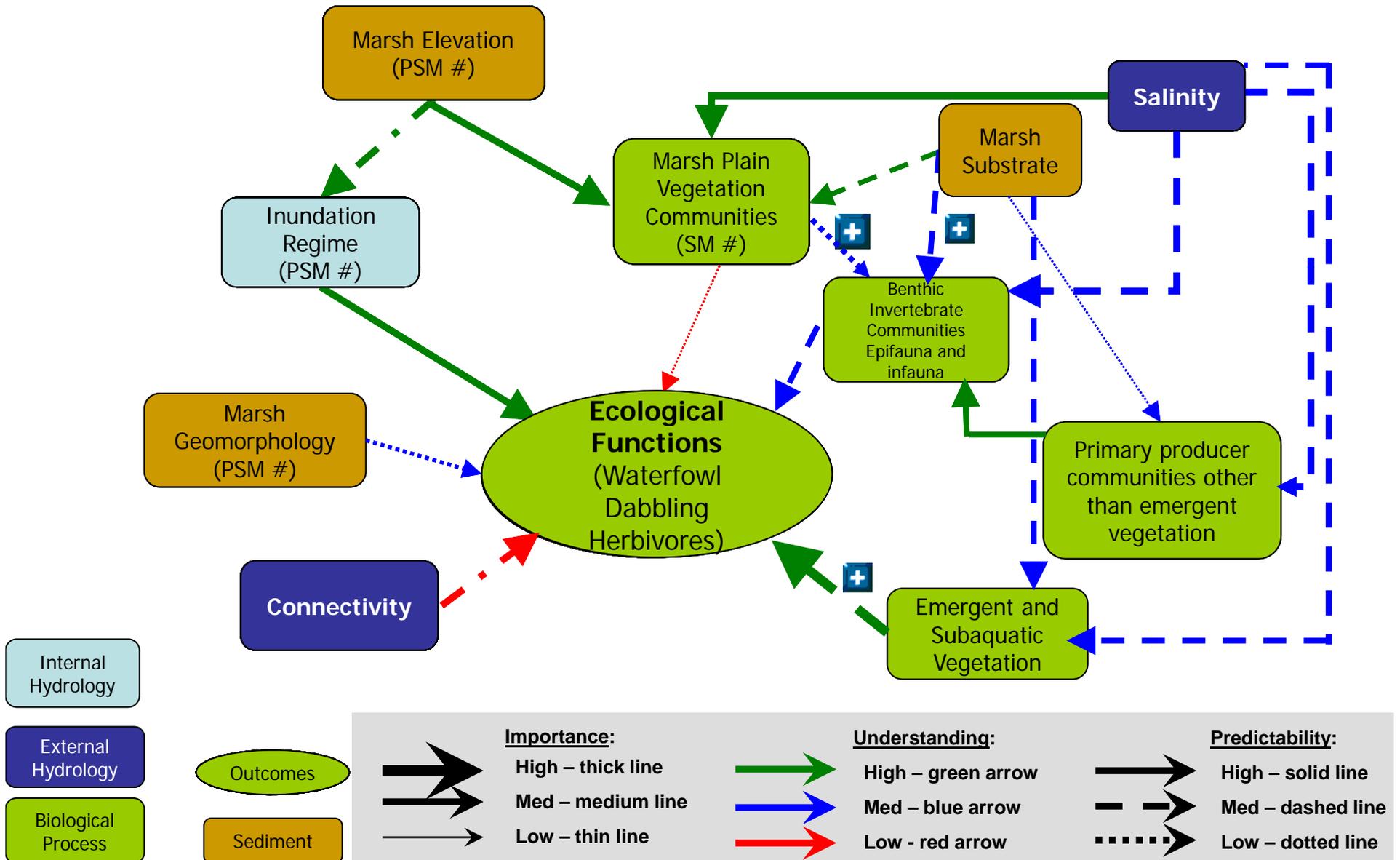


Figure 4-23 Shorebird Suisun Conceptual Model

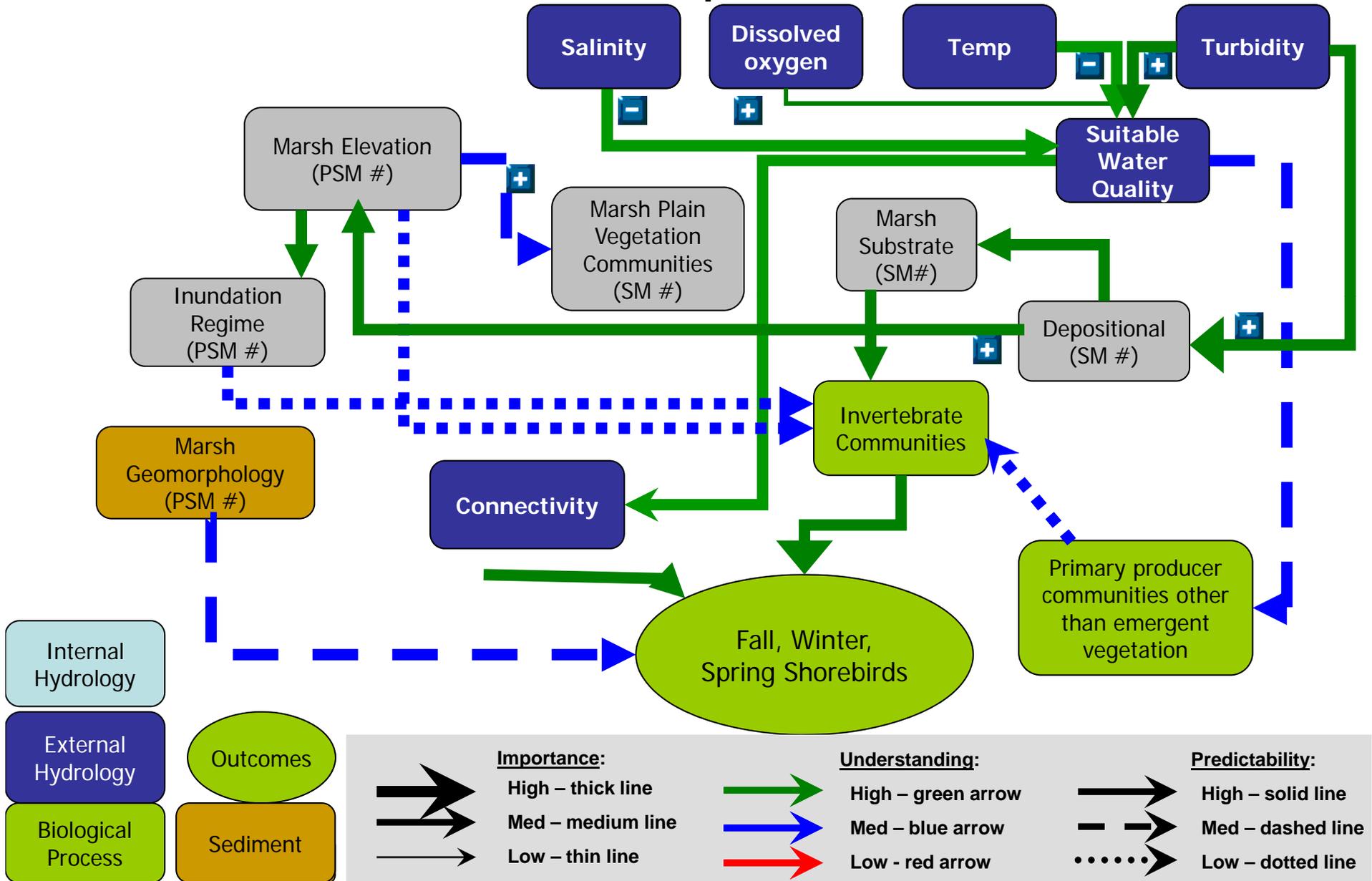
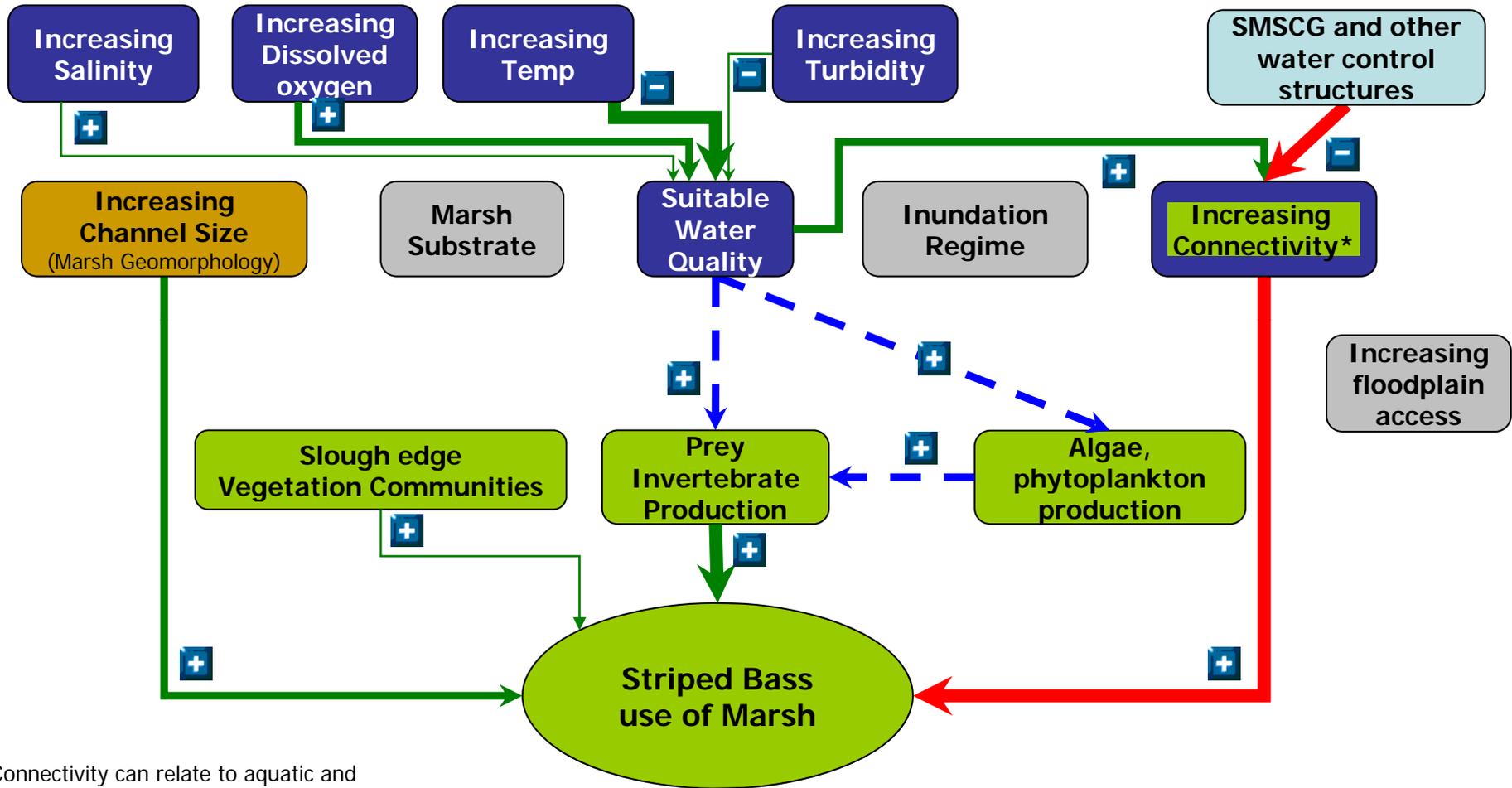


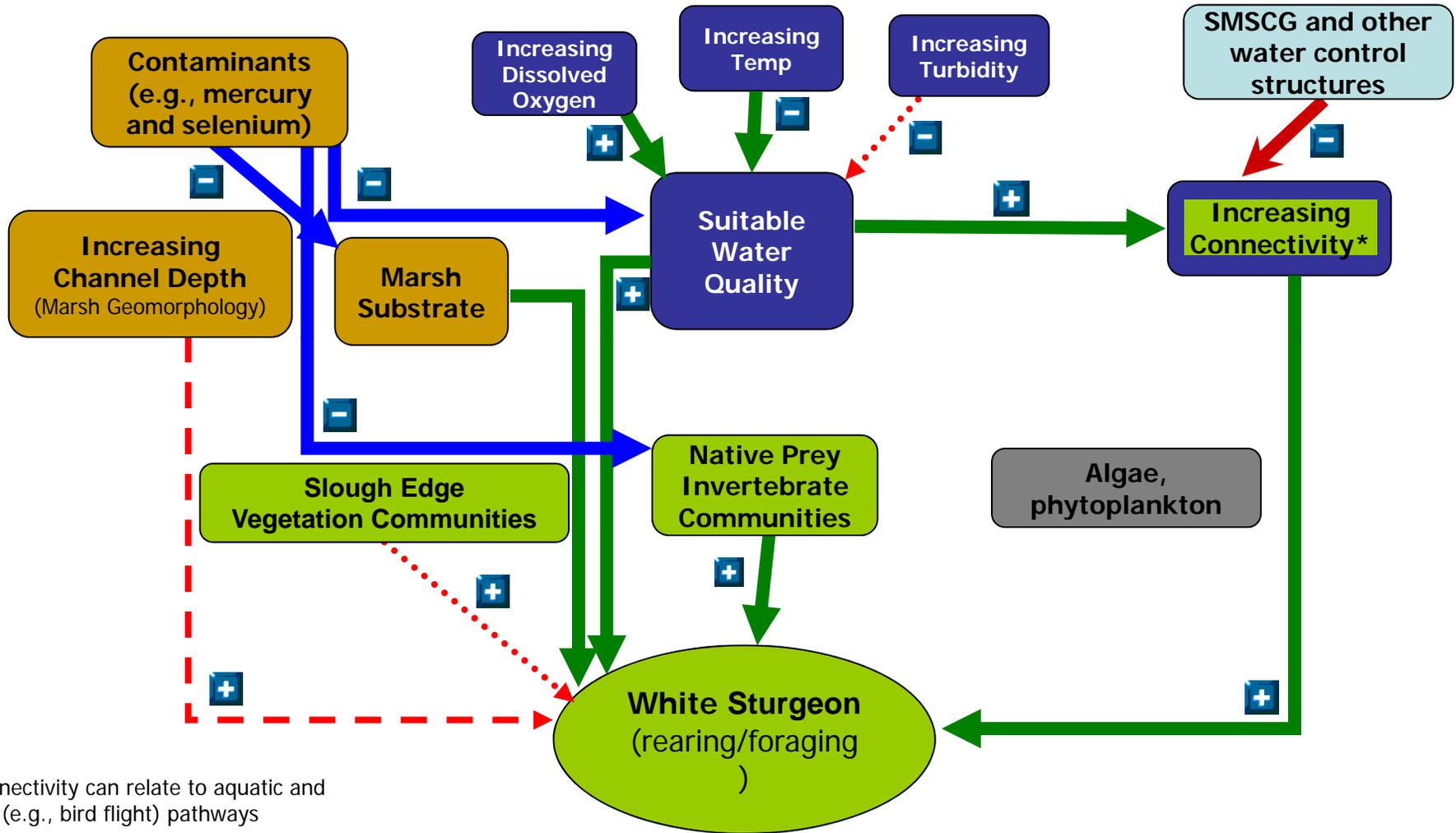
Figure 4-24 Striped Bass Suisun Conceptual Model



* Connectivity can relate to aquatic and aerial (e.g., bird flight) pathways

| | <u>Importance</u> | <u>Understanding</u> | <u>Predictability</u> | | | | |
|--------|-------------------|----------------------|-----------------------|-----------------------------|-----------------------------|--------------------|---------------------------------------|
| High | | | | | | | |
| Medium | | | | | | | |
| Low | | | | Internal Hydrologic Drivers | External Hydrologic Drivers | Biological Drivers | Substrate/Geomorphic/Sediment Drivers |

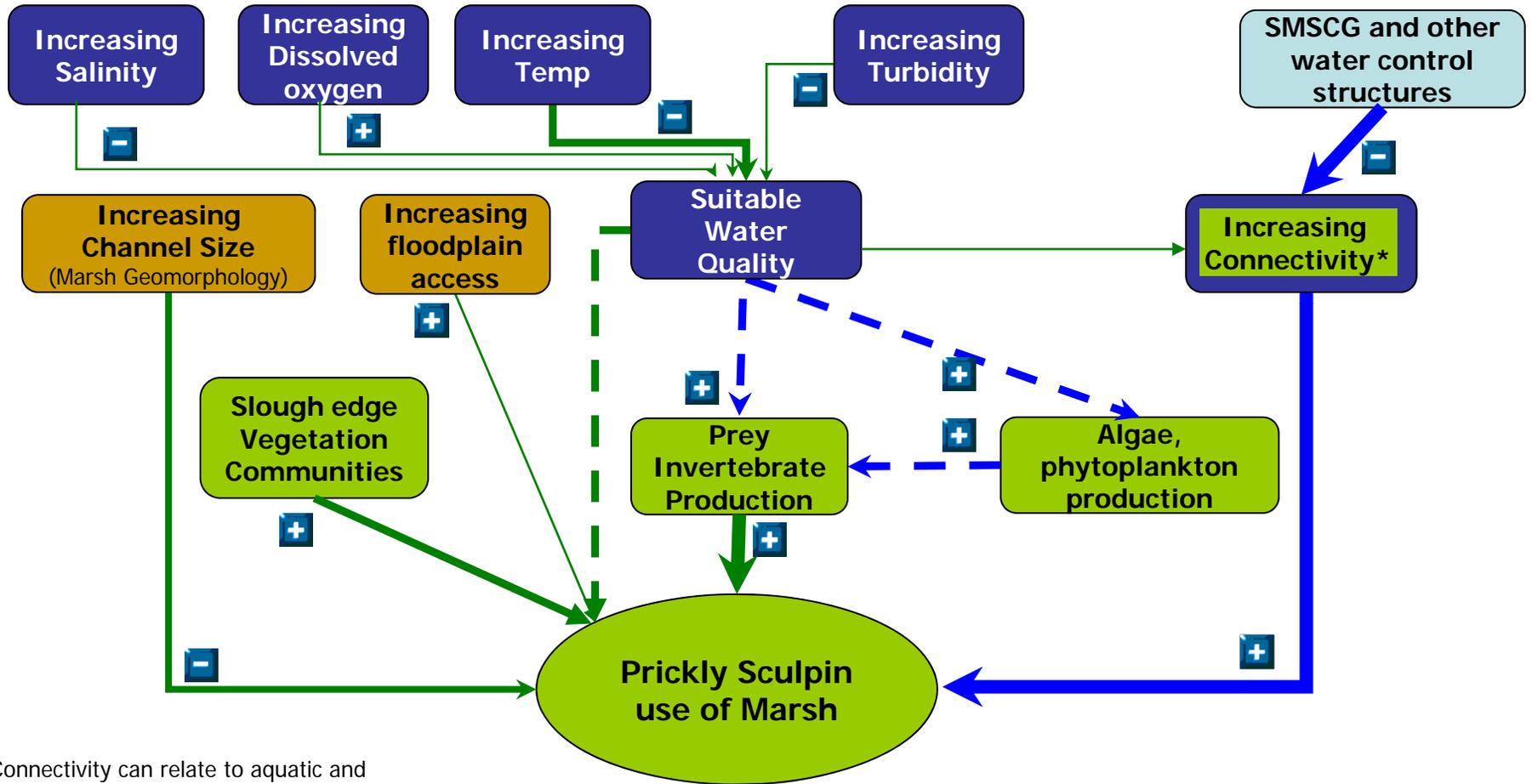
Figure 4-25 White Sturgeon (rearing) Suisun Conceptual Model



* Connectivity can relate to aquatic and aerial (e.g., bird flight) pathways

| | <u>Importance</u> | <u>Understanding</u> | <u>Predictability</u> | | | | |
|--------|-------------------|----------------------|-----------------------|-----------------------------|-----------------------------|--------------------|---------------------------------------|
| High | | | | | | | |
| Medium | | | | | | | |
| Low | | | | Internal Hydrologic Drivers | External Hydrologic Drivers | Biological Drivers | Substrate/Geomorphic/Sediment Drivers |

Figure 4-27 Prickly Sculpin Suisun Conceptual Model



* Connectivity can relate to aquatic and aerial (e.g., bird flight) pathways

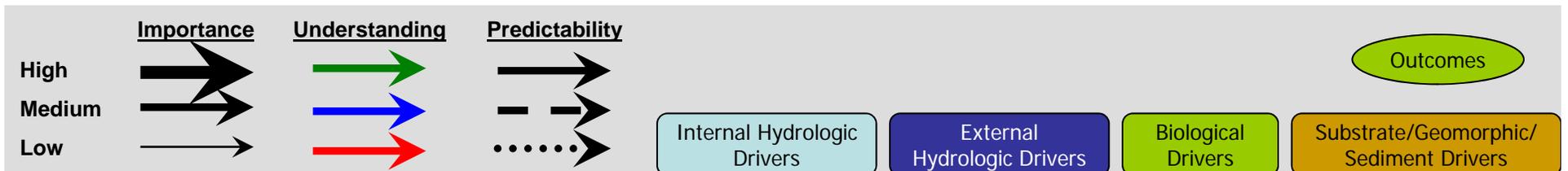
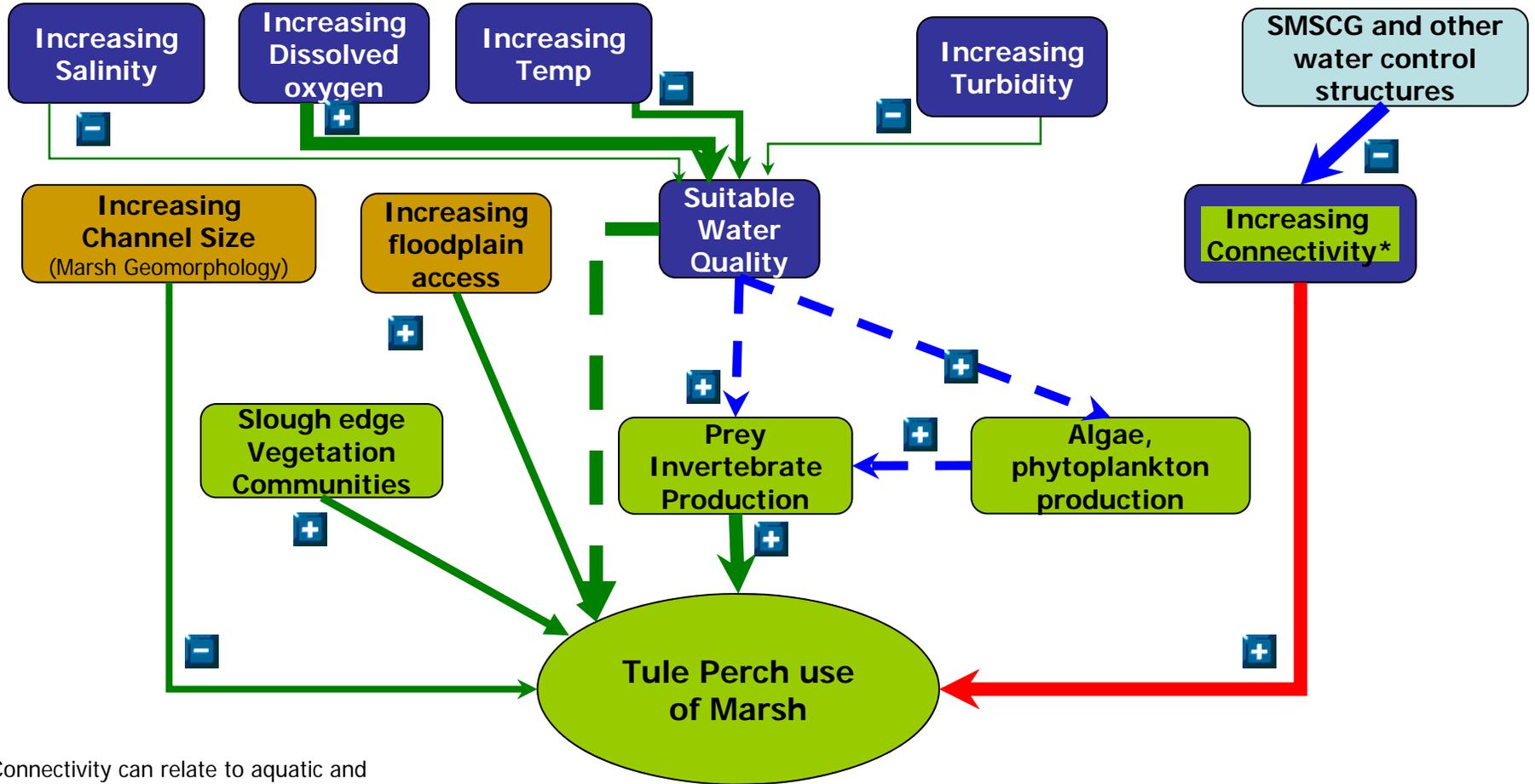


Figure 4-28 Tule Perch Suisun Conceptual Model



* Connectivity can relate to aquatic and aerial (e.g., bird flight) pathways

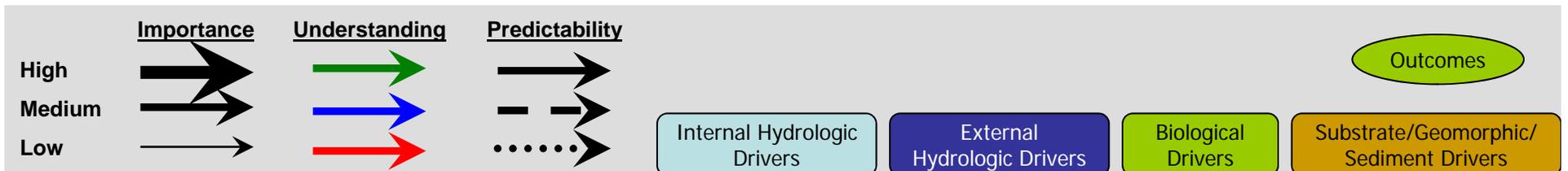
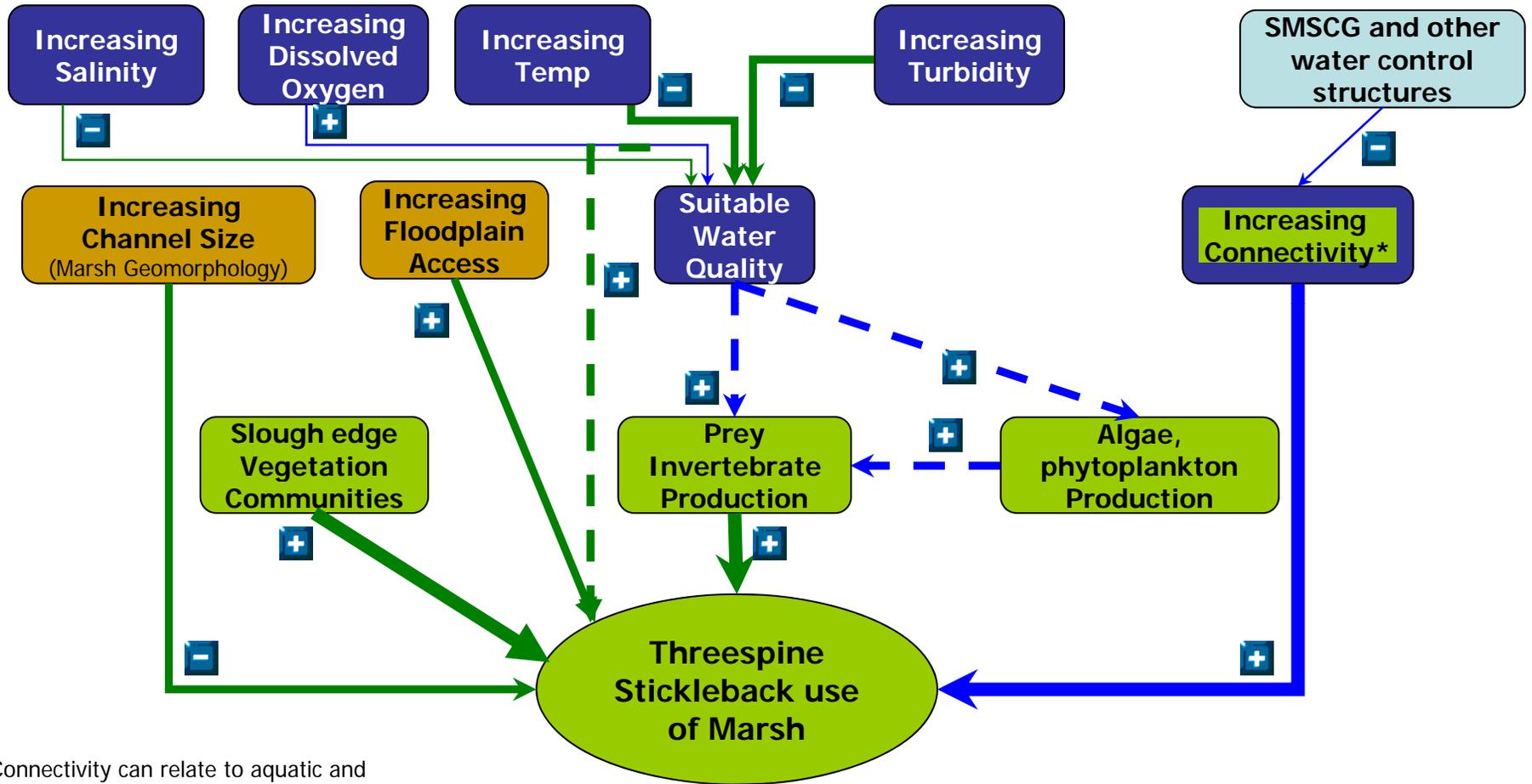
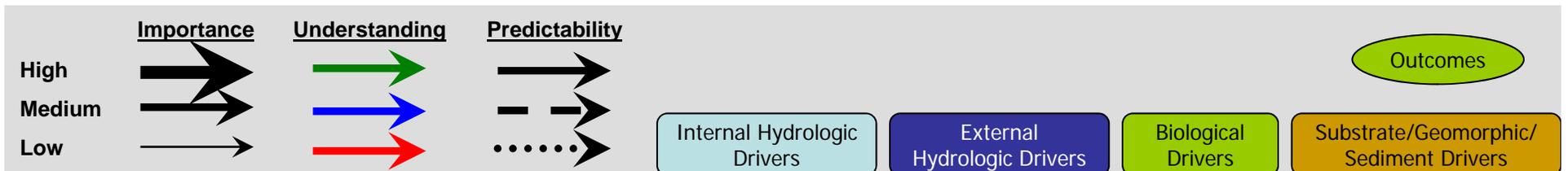


Figure 4-29 Threespine Stickleback Suisun Conceptual Model



* Connectivity can relate to aquatic and aerial (e.g., bird flight) pathways



Appendix 4-A: Wildlife of the Suisun Marsh

compiled by DFG-CVBDB 5/19/2006; updated Laureen Thompson March 2009

| | Bays & Large Sloughs | Tidal Wetlands | Diked Wetlands | Vernal Pools | Riparian | Upland | Status | Comments |
|---|----------------------|----------------|----------------|--------------|----------|--------|------------|----------|
| Fish | | | | | | | | |
| Chinook Salmon -Sacramento river winter run | X | | | | | | FE | |
| Chinook Salmon -Central Valley spring run | X | | | | | | FT | |
| Delta smelt | X | X | X | | | | FT/ST | |
| Steelhead -Central Calif. Coast | X | | | | | | MSCS:m | |
| Speckled sanddab | X | | | | | | MSCS:R | |
| Splittail (adult) | X | | | | | | MSCS:R | |
| Chinook Salmon -Central Calif. Fall/late fall run | X | X | X | | | | FCS/SC/MSC | |
| Green sturgeon | X | X | X | | | | FCS/SC/MSC | |
| Pacific lamprey | X | X | X | | | | S:R | |
| River lamprey | | | | | | | SC | |
| Sacramento splittail | X | X | X | | | | SC | |
| Longfin smelt | X | X | X | | | | SC/MSCS:R | |
| American shad | X | X | X | | | | | |
| Bay pipefish | X | | | | | | | |
| Bigscale logperch | X | | | | | | | |
| Black bullhead | X | X | X | | | | | |
| Black crappie | X | X | X | | | | | |
| Bluegill | X | X | X | | | | | |
| Brown bullhead | X | X | X | | | | | |
| California halibut | X | | | | | | | |
| Channel catfish | X | X | X | | | | | |
| Common carp | X | X | X | | | | | |
| Fathead minnow | X | | | | | | | |
| Golden shiner | X | X | X | | | | | |
| Goldfish | X | X | X | | | | | |
| Green sunfish | X | X | X | | | | | |
| Hitch | X | | | | | | | |
| Inland silverside | X | X | X | | | | | |
| Largemouth bass | X | | | | | | | |
| Longjaw mudsucker | X | | | | | | | |
| Northern anchovy | X | | | | | | | |
| Pacific herring | X | X | X | | | | | |
| Pacific sanddab | X | | | | | | | |
| Pacific staghorn sculpin | X | X | X | | | | | |
| Plainfin midshipman | X | | | | | | | |
| Prickly sculpin | X | X | X | | | | | |
| Rainbow trout | X | | | | | | | |
| Rainwater killifish | X | X | X | | | | | |
| Sacramento blackfish | X | X | X | | | | | |
| Sacramento pikeminnow | X | X | X | | | | | |
| Sacramento sucker | X | X | X | | | | | |
| Shimofuri goby | X | X | X | | | | | |
| Shokihaze goby | X | X | X | | | | | |
| Shiner perch | X | | | | | | | |
| Starry flounder | X | X | X | | | | | |
| Striped bass | X | X | X | | | | | |
| Surf smelt | X | | | | | | | |
| Threadfin shad | X | X | X | | | | | |
| Threespine stickleback | X | X | X | | | | | |
| Topsmelt | X | | | | | | | |
| Tule perch | X | X | X | | | | | |
| Warmouth | X | X | X | | | | | |
| Western mosquitofish | X | X | X | | | | | |
| Western roach | X | | | | | | | |
| White catfish | X | X | X | | | | | |
| White crappie | X | | | | | | | |
| White croaker | X | | | | | | | |
| White sturgeon | X | | | | | | | |
| Yellowfin goby | X | X | X | | | | | |
| Reptiles and Amphibians | | | | | | | | |
| Western skink | | | | X | X | X | FT | |
| California red-legged frog | | | | X | X | X | MSCS:m/SPA | |

Appendix 4-A: Wildlife of the Suisun Marsh

compiled by DFG-CVBDB 5/19/2006; updated Laureen Thompson March 2009

| | Bays & Large Sloughs | Tidal Wetlands | Diked Wetlands | Vernal Pools | Riparian | Upland | Status | Comments |
|--|----------------------|----------------|----------------|--------------|----------|--------|--------------------|----------|
| Western spadefoot | | | | X | X | X | SC/MSCS:m | |
| Aquatic garter snake | X | X | X | | X | | SC/m | |
| Northwestern pond turtle | X | X | X | | X | | | |
| Western aquatic garter snake | X | X | X | X | X | | | |
| Common garter snake | X | X | X | X | X | | | |
| Bullfrog | | X | X | X | X | | | |
| Pacific treefrog | | X | X | X | X | X | | |
| Racer | | X | X | X | X | X | | |
| California king snake | | X | X | X | X | X | | |
| Gopher snake | | X | X | X | X | X | | |
| Western terrestrial coast garter snake | | X | X | X | X | X | | |
| Northwestern fence lizard | | | X | X | X | X | | |
| Ring-neck snake | | | X | X | X | X | | |
| Western rattlesnake | | | X | X | X | X | | |
| Southern alligator lizard | | | | X | X | X | | |
| Western whiptail | | | | X | X | X | | |
| Western toad | | | | X | X | X | | |
| California newt | | | | X | | X | | |
| Coachwhip | | | | X | | X | | |
| Pacific rubber boa | | | | X | X | | | |
| California alligator lizard | | | | | X | X | | |
| Pacific ring-neck snake | | | | | X | X | | |
| Western yellow-bellied racer | | | | | X | X | | |
| California whipsnake | | | | | X | | | |
| California slender salamander | | | | | X | | | |
| Alligator lizard | | | | | | X | | |
| California tiger salamander | | | | | | X | | |
| Night snake | | | | | | X | | |
| Birds, Non-Waterfowl | | | | | | | | |
| California clapper rail | | X | | | | | FE/SE/SFP FT | |
| Bald eagle | | | | | | | MSCS:m | |
| Black tern | | | | | | | MSCS:m | 1 |
| Black-crowned night heron | | X | X | X | | | MSCS:m | 1 |
| Cooper's hawk | | | | | X | | MSCS:m | 1 |
| Double-crested cormorant | X | X | X | | | | MSCS:m | 1 |
| Golden eagle | | X | X | X | | X | SFP/MSCS:m | |
| Great blue heron | | X | X | X | X | X | MSCS:m | 1 |
| Great egret | | X | X | X | X | X | MSCS:m | |
| Long eared owl | | | X | | | X | MSCS:m | |
| Northern harrier | | X | X | X | | X | SC/MSCS:m | |
| Osprey | X | X | X | | | | MSCS:m | |
| Peregrine falcon | | X | X | X | | X | SFP:MSCS:m | |
| Short-eared owl | | | X | | | X | MSCS:m | |
| Snowy egret | | X | X | | | X | MSCS:m | |
| White-faced ibis | | | | | | | MSCS:m | |
| Yellow-breasted chat | | | | | | | MSCS:m | |
| Allen's Hummingbird | | | X | | X | X | SC | |
| Ferruginous hawk | | | X | X | | X | SC | |
| Loggerhead shrike | | X | X | X | | X | SC | |
| Marbled godwit | | X | X | | | X | SC | |
| Prairie falcon | | X | X | | X | X | SC | 1 |
| Burrowing owl | | | X | | | X | SC/MSCS:m | |
| Long-billed curlew | | | | | | X | SC/MSCS:m | |
| Tricolored blackbird | | | X | | | | SC/MSCS:m | |
| Suisun song sparrow | | X | X | | | | SC/MSCS:r | |
| White-tailed kite | | X | X | X | | X | SFP/SC/MSC S:m | |
| California black rail | | X | X | | | | ST/ SFP/ MSCS:r | |
| Swainson's hawk | | | | | | X | ST/MSCS:r | |
| Greater sandhill crane | | | ? | | | ? | ST/SFP/ MSCS:r | |
| American avocet | | X | X | | | | | |
| American bittern | | X | X | | | | | |
| American crow | | | X | X | X | X | | |

Appendix 4-A: Wildlife of the Suisun Marsh

compiled by DFG-CVBDDB 5/19/2006; updated Laureen Thompson March 2009

| | Bays & Large Sloughs | Tidal Wetlands | Diked Wetlands | Vernal Pools | Riparian | Upland | Status | Comments |
|---------------------------------|----------------------|----------------|----------------|--------------|----------|--------|-----------|----------|
| American goldfinch | | | | | X | X | | |
| American kestrel | | X | X | X | X | | | 1 |
| American robin | | X | X | X | X | X | | |
| American white Pelican | X | X | X | | | | | |
| Anna's Hummingbird | | | X | | X | | | |
| Arctic loon | X | | | | | | | |
| Barn owl | | X | X | X | X | X | | 1 |
| Barn swallow | X | X | X | | X | X | | |
| Belted kingfisher | X | X | X | X | X | | | |
| Black phoebe | | | X | X | X | X | | |
| Black-bellied plover | | | | | | | | |
| Black-headed grosbeak | | | | | X | X | | |
| Black-necked stilt | | | X | X | | | | |
| Bonaparte's gull | X | | | | | | | |
| Brandt's cormorant | X | X | X | | | | | |
| Brewer's blackbird | | | X | X | X | X | | |
| Brown towhee | | | | | X | | | |
| Brown-headed cowbird | | | | | X | | | |
| California gull | X | X | X | | | | | |
| California quail | | | | | X | X | | |
| Caspian tern | X | X | | | | | | |
| Cattle egret | | X | X | X | | X | | 1 |
| Cedar waxwing | | | | | | | | |
| Chipping sparrow | | | X | | | X | | |
| Clark's grebe | X | X | X | | | | | |
| Cliff swallow | X | X | X | | | | | |
| Common bush tit | | | | | | X | | |
| Common loon | X | | | | | | | |
| Common moorhen | | X | X | | | | | |
| Common poorwill | | | | | | X | | |
| Common raven | | | X | X | X | X | | |
| Common snipe | | | X | | | X | | |
| Common yellow-throat | | X | X | | | | | |
| Salt marsh common yellow-throat | | X | X | | | | SC/MSCS:r | |
| Dark-eyed junco | | | | | | | | |
| Dunlin | | | X | | | | | |
| Eared grebe | | | | | | | | |
| European starling | | X | X | X | X | X | | |
| Forster's tern | X | | X | | | | | |
| Fox sparrow | | | | | | X | | |
| Glaucous-winged gull | X | | X | | | | | |
| Golden-crowned sparrow | | | | | | | | |
| Great horned owl | | X | X | X | X | X | | 1 |
| Greater yellowlegs | | | X | X | | | | |
| Green heron | | X | X | | X | | | 1 |
| Heerman's gull | X | | X | | | | | |
| Hermit thrush | | | | | X | | | |
| Herring gull | X | | X | | | | | |
| Horned grebe | X | X | X | | | | | |
| Horned lark | | | | | | X | | |
| House finch | | | X | | | X | | |
| House sparrow | | | X | | | | | |
| House wren | | | | | | | | |
| Killdeer | | X | X | X | | X | | |
| Least sandpiper | | | X | X | | | | |
| Least tern | X | | | | | | | |
| Lesser goldfinch | | | | | X | X | | |
| Lesser yellowlegs | | | X | X | | | | |
| Lincoln's sparrow | | | | | X | | | |
| Long-billed dowitcher | | | X | X | | | | |
| Marsh wren | | X | X | | | | | |
| Merlin | | | | | | | | |
| Mew gull | X | X | X | | | | | |
| Mourning dove | | | X | X | X | X | | |
| Northern flicker | | | | | X | X | | 1 |

Appendix 4-A: Wildlife of the Suisun Marsh

compiled by DFG-CVBDB 5/19/2006; updated Laureen Thompson March 2009

| | Bays & Large Sloughs | Tidal Wetlands | Diked Wetlands | Vernal Pools | Riparian | Upland | Status | Comments |
|-----------------------------------|----------------------|----------------|----------------|--------------|----------|--------|-----------|----------|
| Northern mockingbird | | | | | | | | |
| Northern oriole | | | | | X | | | |
| Northern phalarope | | X | X | | | | | |
| Northern rough-winged swallow | X | X | X | | | X | | |
| Northern screech owl | | | X | | X | | | 1 |
| Northern shrike | | | X | | | X | | |
| Orange-crowned warbler | | | X | | X | X | | 1 |
| Pectoral sandpiper | | X | X | | | | | |
| Pied-billed grebe | X | X | X | | | | | |
| Purple finch | | | | | X | X | | |
| Purple gallinule | | X | X | | | | | |
| Red-breasted nuthatch | | | | | X | | | 1 |
| Red phalarope | | | X | | | | | |
| Red-shouldered hawk | | | | | X | | | 1 |
| Red-tailed hawk | | X | X | X | X | X | | |
| Red-winged blackbird | | X | X | X | | X | | |
| Ring-billed gull | X | X | X | | | | | |
| Ring-necked pheasant | | X | X | X | | X | | |
| Rock dove | | | | | | X | | |
| Rough-legged hawk | | X | X | | | X | | |
| Sanderling | | X | X | | | | | |
| Sandhill crane | | | | | | X | | |
| Savannah sparrow | | | X | | | X | | |
| Say's phoebe | | X | X | | | X | | |
| Scrub jay | | | | | X | X | | |
| Semipalmated plover | | X | X | | | | | |
| Sharp-shinned hawk | | | X | | X | | | 1 |
| Short-billed dowitcher | | X | X | | | | | |
| Song sparrow | | X | X | | | | | |
| Sora | | X | X | | | | | |
| Spotted sandpiper | | | | | | | | |
| Spotted towhee | | | X | | X | X | | 1 |
| Tree swallow | X | X | X | | X | | | 1 |
| Turkey vulture | | X | X | X | X | X | | |
| Violet-green swallow | X | X | X | | X | | | 1 |
| Virginia rail | | X | X | | | | | |
| Western grebe | X | X | | | | | | |
| Western gull | X | X | X | | | | | |
| Western kingbird | | X | X | | X | X | | |
| Western meadowlark | | | X | X | | X | | |
| Western sandpiper | | | X | | | | | |
| Whimbrel | | | | | | | | |
| White-breasted nuthatch | | | | | X | | | 1 |
| White-crowned sparrow | | X | X | | | X | | |
| White-throated swift | | | | | | | | |
| Willet | | | | | | | | |
| Wilson's warbler | | | | | X | | | |
| Yellow warbler | | | | | X | | | |
| Yellow-headed blackbird | | | | | | | | |
| Yellow-rumped warbler (Audubon's) | | | | | | | | |
| Yellow-rumped warbler (Myrtle) | | | | | | | | |
| Birds, Waterfowl | | | | | | | | |
| Geese/swans | | | | | | | | |
| Western Canada Goose | | X | X | X | | X | SC/MSCS:m | |
| Aleutian Canada Goose | | | | | | | | |
| Cackling Canada Goose | | | | | | | | |
| Greater White-fronted Goose | | X | X | | | X | | |
| Tule White-fronted Goose | | X | X | | | | | |
| Ross Goose | | | | | | X | | |
| Snow Goose | X | X | X | | | X | | |
| Tundra swan | | | | | | | | |
| Whistling ducks | | | | | | | | |
| Wood Duck | | | X | | X | | | |

Appendix 4-A: Wildlife of the Suisun Marsh

compiled by DFG-CVBDB 5/19/2006; updated Laureen Thompson March 2009

| | Bays & Large Sloughs | Tidal Wetlands | Diked Wetlands | Vernal Pools | Riparian | Upland | Status | Comments |
|---------------------------|----------------------|----------------|----------------|--------------|----------|--------|-----------|-----------|
| Dabbling ducks | | | | | | | | |
| Mallard | | X | X | | X | | | |
| Gadwall | | X | X | | | | | |
| Northern Pintail | | X | X | | | | | |
| Northern Shoveler | | X | X | | | | | |
| American Wigeon | | X | X | | | | | |
| Eurasian Wigeon | | X | X | | | | | |
| Cinnamon Teal | | X | X | | | | | |
| Green-winged Teal | | X | X | | | | | |
| Blue-winged Teal | | X | X | | | | | |
| American coot | | X | X | | | X | | |
| Diving ducks | | | | | | | | |
| Canvasback | X | X | X | | | | | |
| Redhead | X | X | X | | | | | |
| Ring-necked duck | | X | X | | | | | |
| Greater Scaup | X | X | | | | | | |
| Lesser Scaup | X | X | X | | | | | |
| Sea ducks | | | | | | | | |
| Common Goldeneye | X | X | X | | | | | |
| Barrow Goldeneye | X | X | X | | | | | |
| Black Scoter | X | | | | | | | |
| White-winged Scoter | X | | | | | | | |
| Surf Scoter | X | | | | | | | |
| Common Merganser | X | X | X | | | | | |
| Hooded Merganser | X | | | | | | | |
| Red-breasted Merganser | X | | | | | | | |
| Bufflehead | X | X | X | | | | | |
| Stiff-tailed Ducks | | | | | | | | |
| Ruddy Duck | X | X | X | | | | | |
| Mammals | | | | | | | | |
| Audubon cottontail | | | X | | | X | | |
| Hairy-winged myotis | | | | | | | | |
| River otter | X | X | X | | | | | |
| Muskrat | X | X | X | | | | | |
| Long-legged myotis | ? | ? | ? | | | | SC | MIGRATORY |
| Little brown myotis | ? | ? | ? | | | | | MIGRATORY |
| Long-eared myotis | ? | ? | ? | | | | SC | MIGRATORY |
| Fringed myotis | ? | ? | ? | | | | | MIGRATORY |
| Silvery-haired bat | ? | ? | ? | | | | | MIGRATORY |
| Small-footed myotis | ? | ? | ? | | | | SC | MIGRATORY |
| Feral pig | X | X | X | | X | | | |
| California myotis | ? | ? | ? | ? | ? | | | |
| Yuma myotis | ? | ? | ? | ? | ? | | SC | |
| Big brown bat | ? | ? | ? | ? | ? | ? | | |
| Salt-marsh harvest mouse | | X | X | | | X | FE/SE/SFP | |
| Western mastiff bat | ? | ? | ? | ? | ? | ? | SC/MSCS:m | |
| Townsend's big-eared bat | ? | ? | ? | ? | ? | ? | SC | |
| Suisun ornate shrew | | X | X | X | | | SC/MSCS:R | |
| Hoary bat | ? | ? | ? | ? | ? | ? | | MIGRATORY |
| Red bat | ? | ? | ? | ? | ? | ? | | MIGRATORY |
| Pallid bat | ? | ? | ? | ? | ? | ? | | |
| Mexican freetail bat | ? | ? | ? | ? | ? | ? | | |
| Western pipistrelle | ? | ? | ? | ? | ? | ? | | |
| Virginia opossum | | X | X | X | X | | | |
| Mink | | X | X | ? | X | | | |
| Badger | | ? | ? | ? | | X | | |
| Black-tailed hare | | X | X | X | | X | | |
| Audubon cottontail | | | | | | | | |
| Porcupine | | ? | ? | | ? | | | |
| Beaver | | X | X | | X | | | |
| Western spotted skunk | | ? | ? | | X | | | |
| Muskrat | | | | | | | | |

Appendix 4-A: Wildlife of the Suisun Marsh

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| | Bays & Large Sloughs | Tidal Wetlands | Diked Wetlands | Vernal Pools | Riparian | Upland | Status | Comments |
|----------------------------|----------------------|----------------|----------------|--------------|----------|--------|--------|----------|
| California ground squirrel | | X | X | X | X | X | | |
| Gray fox | | ? | ? | X | X | X | | |
| Long-tailed weasel | | X | X | ? | ? | ? | | |
| House mouse | | X | X | X | X | X | | |
| Ornate shrew | | X | X | X | X | X | | |
| Coyote | | X | X | X | X | X | | |
| Feral house cat | | X | X | X | X | X | | |
| California vole | | X | X | X | X | X | | |
| Botta pocket gopher | | X | X | X | X | X | | |
| Black rat | | X | X | X | X | X | | |
| Striped skunk | | X | X | X | X | X | | |
| River otter | | | | | | | | |
| Norway rat | | X | X | X | X | X | | |
| Raccoon | | X | X | X | X | X | | |
| Western harvest mouse | | X | X | X | X | X | | |
| Valley pocket gopher | | | | | | | | |
| Deer mouse | | | X | X | X | X | | |
| Bobcat | | | | ? | X | ? | | |
| Tule Elk | | | X | | | X | | |
| Broad-handed mole | | | | | X | X | | |

1 - Eucalyptus tree groves on/near diked wetlands.

SPA- State protected amphibian

ST - State Threatened

SE - State Endangered

SFP - State Fully Protected

FE - Federal Endangered

FT - Federal Threatened

FCS - Federal concern species

SC - State species of concern

MSCS - multispecies conservation strategy

:R -recover

:m -maintain

:r -contribute to recovery