

Chapter B2:

Evaluation of Impingement and Entrainment in California

BACKGROUND: CALIFORNIA MARINE FISHERIES

The oceanic transition zone off Point Conception creates a natural ecological separation between northern and southern California (Leet et al., 2001). North of Point Conception, coastal waters are cold and oceanic conditions are harsh, whereas to the south waters are warmer and conditions are moderate. As a result, the fish species composition differs between the two regions. Surface and bottom temperatures along the continental shelf off northern California support polar and cold-temperate species such as chinook salmon, coho salmon, striped bass, rock gunnels, and lanternfish (Leet et al., 2001). In

Southern California, warm waters from the south join with the cold California current to provide habitat for a wide variety of seasonal subtropical visitors like yellowtail, white seabass, Pacific bonito, and California barracuda, all found in close association with the abundant strands of giant kelp (Pacific Fishery Management Council, 2003b). Major resident species such as kelp bass, sheephead, halfmoon and olive rockfish sustain year-round nearshore fisheries (Leet et al., 2001).

California fisheries are managed by the Pacific Fishery Management Council (PFMC), which governs commercial and recreational fisheries in Federal waters from 3 to 200 nautical miles off the coasts of Washington, Oregon, and California (Pacific Fishery Management Council, 2003a). The National Marine Fisheries Service (NMFS) Northwest Fisheries Science Center provides scientific and technical support for management, conservation, and fisheries development for Northern California. The NMFS Southwest Fisheries Science Center provides support for Southern California.

There are 83 species of groundfish included under PFMC's Groundfish Fishery Management Plan, including nearly 50 species of rockfish (*Sebastes* spp.) (Table 3 in NMFS, 2002a). The midwater trawl fishery for Pacific whiting (*Merluccius productus*) dominates the commercial fishery, accounting for 78 percent of Pacific Coast landings (NMFS, 1999b). Important deepwater trawl fisheries also exist for sablefish, Dover sole, and thornyheads. During the 1990s a major fishery developed for nearshore species, including rockfishes, cabezon, and sheephead (Leet et al., 2001). Rockfishes are important for both commercial and recreational fisheries (NMFS, 1999b). In 1994, a limited entry program was implemented for the groundfish fishery because of concerns about overfishing (NMFS, 1999b). Most major West Coast groundfishes are now fully harvested, and catches have recently been controlled by quotas and trip limits (Pacific Fishery Management Council, 2003c).

Pacific Coast pelagic species managed by the PFMC include Pacific mackerel (*Scomber japonicus*), jack mackerel (*Trachurus symmetricus*), Pacific sardine (*Sardinops sagax*), northern anchovy (*Engraulis mordax*), and California market squid (*Loligo opalescens*) (NMFS, 2002a). These species typically fluctuate widely in abundance, and currently most stocks are low relative to historical levels (NMFS, 1999b). Pacific mackerel and Pacific sardine are not overfished, but the stock size of the other species governed by the Coastal Pelagic FMP is unknown (Table 3 in NMFS, 2002a). Because of increases in abundance in recent years, Pacific mackerel now accounts for over half of recent landings of Pacific Coast pelagic species (NMFS, 1999b). At times, Pacific sardine has been the most abundant fish species in the California current. When the population is large, it is abundant from the tip of Baja California to southeastern Alaska (Pacific Fishery Management Council, 2003b).

CHAPTER CONTENTS

B2-1	Fishery Species Impinged and Entrained	B2-2
B2-2	I&E Species and Species Groups Evaluated	B2-3
B2-3	Life Histories of Primary Species Impinged and Entrained in California	B2-11
B2-4	I&E Data Evaluated	B2-20
B2-5	EPA's Estimate of Current I&E in California Expressed as Age 1 Equivalents, Foregone Yield, and Production Foregone	B2-20
B2-6	Assumptions Used in Calculating Recreational and Commercial Losses	B2-22

Five species of anadromous Pacific salmon support coastal and freshwater commercial and recreational fisheries along the Pacific Coast, including chinook (*Oncorhynchus tshawytscha*), coho (*O. kisutch*), sockeye (*O. nerka*), pink (*O. gorbuscha*), and chum (*O. keta*) salmon (NMFS, 1999b). The Sacramento River is a major producer of chinook salmon in California. Since 1991, NMFS has listed 20 Evolutionary Significant Units (ESUs)¹ of Pacific Coast salmon and steelhead trout (*O. mykiss*) under the Federal Endangered Species Act (ESA) (NMFS, 1999c). In NMFS's Northern California region, listed species include steelhead, coho salmon, and chinook salmon of the central California Coast and steelhead and chinook salmon of California's Central Valley.

Ocean fisheries for chinook and coho salmon are managed by the PFMC under the Pacific Coast Salmon FMP. In Puget Sound and the Columbia River, chinook and coho fisheries are managed by the States and Tribal fishery agencies. Declines in chinook and coho salmon along the coast have led to reductions and closures of ocean fisheries in recent years (NMFS, 1999b).

The Pacific Salmon FMP contains no fishery management objectives for sockeye, chum, even-year pink, and steelhead stocks because fishery impacts are considered inconsequential (Table 3 in NMFS, 2002a). Pink, chum, and sockeye salmon are managed jointly by the Pacific Salmon Commission, Washington State, and Tribal agencies (NMFS, 1999b).

Pacific Coast shellfish resources are important both commercially and recreationally (NMFS, 1999b). Shrimps, crabs, abalones, and clams command high prices and contribute substantially to the value of Pacific Coast fisheries, even though landings are small.

B2-1 FISHERY SPECIES IMPINGED AND ENTRAINED

Available impingement and entrainment (I&E) data indicate that 20 of the 248 distinct species that are impinged and entrained by California facilities are harvested species subject to FMPs developed by the PFMC. Table B2-1 summarizes information on the stock status of these species. Note that stock status is known for only 4 of these species. Most of the species listed are rockfish species. Northern anchovy falls under the Coastal Pelagic FMP, and the other species in the table are included in the Groundfish FMP. Although under the jurisdiction of the PFMC, there are no fishery management objectives for Central Valley chinook salmon and Central California Coast coho salmon because of their ESA listing (NMFS, 2002a). There are also no fishery management goals for steelhead because fishery impacts are considered inconsequential (NMFS, 2002a).

Table B2-1: Summary of Stock Status of Harvested Species in California that are Impinged and Entrained and are Included in Federal FMPs

Stock (Species in bold are major stocks, with annual landings over 200,000 pounds)	Overfishing? (Is fishing mortality above threshold?)	Overfished? (Is stock size below threshold?)	Approaching Overfished Condition?
Aurora rockfish	Unknown	Unknown	Unknown
Black rockfish	No	No	No
Black-and-yellow rockfish	Unknown	Unknown	Unknown
Blue rockfish	Unknown	Unknown	Unknown
Bocaccio	No	Yes	N/A
Cabazon	Unknown	Unknown	Unknown
California scorpionfish	Unknown	Unknown	Unknown
Central California Coast coho salmon ^a	N/A	N/A	N/A

¹ An Evolutionarily Significant Unit (ESU) is a term introduced by NMFS in 1991 to refer to the Endangered Species Act (ESA) interpretation of "distinct population segment." A stock must satisfy two criteria to be considered an ESU: (1) "it must be substantially reproductively isolated from other conspecific population units," and (2) "it must represent an important component in the evolutionary legacy of the species."

Stock (Species in bold are major stocks, with annual landings over 200,000 pounds)	Overfishing? (Is fishing mortality above threshold?)	Overfished? (Is stock size below threshold?)	Approaching Overfished Condition?
Central Valley chinook salmon ^a	N/A	N/A	N/A
Chilipepper rockfish	No	No	No
Copper rockfish	Unknown	Unknown	Unknown
Gopher rockfish	Unknown	Unknown	Unknown
Grass rockfish	Unknown	Unknown	Unknown
Kelp rockfish	Unknown	Unknown	Unknown
Northern anchovy-central subpopulation		Undefined	Unknown
Olive rockfish	Unknown	Unknown	Unknown
Shortbelly rockfish	No	No	No
Starry flounder	Unknown	Unknown	Unknown
Steelhead ^b	N/A	N/A	N/A
Yellowtail rockfish	No	No	No

^a There are no fishery management goals for Central Valley chinook salmon and Central California Coast coho salmon because of their ESA listing (NMFS, 2002a).

^b There are no fishery management goals for steelhead because fishery impacts are considered inconsequential (NMFS, 2002a).

Source: Table 4 in NMFS (2002a).

B2-2 I&E SPECIES AND SPECIES GROUPS EVALUATED

Table B2-2 provides a list of species in the California region that are impinged and entrained at cooling water intake structures in scope of the section 316(b) Phase II rule that were evaluated in EPA's analysis of regional I&E. Life histories of the species with the highest losses are summarized in the following section. The life history data used in EPA's analysis and associated data sources are provided in Appendix B1 of this report.

Species Group	Species	Recreational	Commercial	Forage	Special Status^a
Anchovies	Deepbody anchovy		X		
	Northern anchovy		X		
	Slough anchovy		X		
Blennies	Bay blenny			X	
	Combtooth blennies			X	
	Mussel blenny			X	
	Orangethroat pikeblenny			X	
	Rockpool blenny			X	
	Tube blenny			X	
Cabezon	Cabezon	X	X		
California halibut	California halibut	X	X		
California scorpionfish	California scorpionfish	X	X		

Table B2-2: Species Evaluated by EPA that are Subject to I&E in California

Species Group	Species	Recreational	Commercial	Forage	Special Status ^a
	Spotted scorpionfish	X	X		
Chinook salmon	Chinook salmon				X (FT, ST, FE, SE, FCT)
Commercial sea basses	Giant sea bass		X		
Commercial shrimp	Alaskan bay shrimp		X		
	Franciscan bay shrimp		X		
	Ghost shrimp		X		
	Smooth bay shrimp		X		
	Black-tailed shrimp		X		
Delta smelt	Delta smelt				X (FT, ST)
Drums croakers	Black croaker	X	X		
	California corbina	X	X		
	Queenfish	X	X		
	Spotfin croaker	X	X		
	White croaker	X	X		
	White sea bass	X	X		
	Yellowfin croaker	X	X		
Dungeness crab	Dungeness crab		X		
Flounders	Bigmouth sole	X	X		
	CO sole	X	X		
	Curlfin sole	X	X		
	Diamond turbot	X	X		
	Dover sole	X	X		
	English sole	X	X		
	Fantail sole	X	X		
	Hornyhead turbot	X	X		
	Longfin sanddab	X	X		
	Pacific sand sole	X	X		
	Pacific sanddab	X	X		
	Petrals sole	X	X		
	Rock sole	X	X		
	Slender sole	X	X		
	Speckled sanddab	X	X		
	Spotted turbot	X	X		
	Starry flounder	X	X		
Forage shrimp	Anemone shrimp			X	
	Blue mud shrimp			X	
	Broken back shrimp			X	
	California green shrimp			X	
	Dock shrimp			X	

Species Group	Species	Recreational	Commercial	Forage	Special Status^a
	Mysids			X	
	Opossum shrimp			X	
	Oriental shrimp			X	
	Pistol shrimp			X	
	Sidestriped shrimp			X	
	Skeleton shrimp			X	
	Stout bodied shrimp			X	
	Striped shrimp			X	
	Tidepool shrimp			X	
	Twistclaw pistol shrimp			X	
Gobies	Arrow goby			X	
	Bay goby			X	
	Blackeyed goby			X	
	Blind goby			X	
	Chameleon goby			X	
	Cheekspot goby			X	
	Long jaw mudsucker			X	
	Shadow goby			X	
	Yellowfin goby			X	
Herrings	Middling thread herring			X	
	Pacific herring			X	
	Pacific sardine			X	
	Round herring			X	
	Threadfin shad			X	
Longfin smelt	Longfin smelt				X (SOC)
Other commercial species	Basketweave cusk-eel		X		
	California moray		X		
	Catalina conger		X		
	Leopard shark		X		
	Monkeyface prickleback		X		
	Moray eel		X		
	Pacific hagfish		X		
	Pacific hake		X		
	Pricklebreast poacher		X		
	Rock prickleback		X		
	Spotted cusk-eel		X		
	Yellow snake-eel		X		
Other forage species	Barcheek pipefish			X	
	Bay pipefish			X	
	Bigscale goatfish			X	

Table B2-2: Species Evaluated by EPA that are Subject to I&E in California

Species Group	Species	Recreational	Commercial	Forage	Special Status ^a
	Black bullhead			X	
	Blacksmith			X	
	Blue lanternfish			X	
	Broadfin lampfish			X	
	Bullseye puffer			X	
	California clingfish			X	
	California flyingfish			X	
	California killifish			X	
	California lizardfish			X	
	California needlefish			X	
	California tonguefish			X	
	Combfish			X	
	Cortez angelfish			X	
	Crevice kelpfish			X	
	Finescale triggerfish			X	
	Flathead mullet			X	
	Fringehead			X	
	Garibaldi			X	
	Giant kelpfish			X	
	Hatchet fish			X	
	High cockscomb			X	
	Island kelpfish			X	
	Kelp gunnel			X	
	Kelp pipefish			X	
	Kelpfish			X	
	Lampfish			X	
	Lanternfish			X	
	Longfin lanternfish			X	
	Longspine combfish			X	
	Medusafish			X	
	Mexican lampfish			X	
	Northern clingfish			X	
	Northern lampfish			X	
	Northern spearnose poacher			X	
	Ocean sunfish			X	
	Ocean whitefish			X	
	Onespot fringehead			X	
	Pacific butterfish			X	
	Pacific cornetfish			X	
	Pacific cutlassfish			X	

Species Group	Species	Recreational	Commercial	Forage	Special Status^a
	Pacific lampray			X	
	Pacific sand lance			X	
	Penpoint gunnel			X	
	Pipefish species			X	
	Plainfin midshipman			X	
	Popeye smelt			X	
	Pygmy poacher			X	
	Ratfish			X	
	Red brotula			X	
	Reef finspot			X	
	Ribbonfish			X	
	Rockweed gunnel			X	
	Ronquil			X	
	Saddleback gunnel			X	
	Salema			X	
	Sarcastic fringehead			X	
	Sargo			X	
	Scarlet kelpfish			X	
	Sea porcupine			X	
	Sharksucker			X	
	Shovelnose guitarfish			X	
	Slimy snailfish			X	
	Smalleye squaretail			X	
	Snubnose pipefish			X	
	Southern poacher			X	
	Southern spearnose poacher			X	
	Specklefin midshipman			X	
	Spotted kelpfish			X	
	Spotted ratfish			X	
	Squid			X	
	Striped kelpfish			X	
	Thornback			X	
	Threespine stickleback			X	
	Tubesnout			X	
	Zebra perch			X	
Other recreational species	Angel shark	X			
	Bat ray	X			
	Big skate	X			
	Black skate	X			
	Broadnose sevengill shark	X			

Table B2-2: Species Evaluated by EPA that are Subject to I&E in California

Species Group	Species	Recreational	Commercial	Forage	Special Status ^a
	Brown smoothhound	X			
	California butterfly ray	X			
	Chub mackerel	X			
	Diamond stingray	X			
	Gray smoothhound	X			
	Halfmoon	X			
	Horn shark	X			
	Kelp greenling	X			
	Mexican scad	X			
	Monterey spanish mackerel	X			
	Opaleye	X			
	Pacific angel shark	X			
	Pacific bonito	X			
	Pacific bumper	X			
	Pacific electric ray	X			
	Pacific mackerel	X			
	Pacific moonfish	X			
	Pacific pompano	X			
	Painted greenling	X			
	Rock wrasse	X			
	Round stingray	X			
	Senorita	X			
	Sevengill shark	X			
	Soupfin shark	X			
	Striped mullet	X			
	Swellshark	X			
	Thornback ray	X			
	California sheephead	X			
	Jack mackerel	X			
	Lingcod	X			
	Pacific barracuda	X			
	Piked dogfish	X			
	Spiny dogfish	X			
Other commercial crabs	Anthony's rock crab		X		
	Black clawed crab		X		
	Brown rock crab		X		
	Common rock crab		X		
	Cryptic kelp crab		X		
	Dwarf crab		X		
	Elbow crab		X		

Species Group	Species	Recreational	Commercial	Forage	Special Status^a
	European green crab		X		
	Graceful kelp crab		X		
	Hairy rock crab		X		
	Kelp crab		X		
	Lined shore crab		X		
	Lumpy crab		X		
	Majid crab		X		
	Masking crab		X		
	Mole crab		X		
	Moss crab		X		
	Mud/Stone crab		X		
	Northern kelp crab		X		
	Pacific sand crab		X		
	Pea crab		X		
	Pebble crab		X		
	Porcelain crab		X		
	Porcelain crabs		X		
	Purple shore crab		X		
	Red crab		X		
	Red rock crab		X		
	Sharp nosed crab		X		
	Shore crab		X		
	Slender crab		X		
	Slender rock crab		X		
	Southern kelp crab		X		
	Spider crab		X		
	Striped shore crab		X		
	Thickclaw porcelain crab		X		
	Xantus swimming crab		X		
	Yellow crab		X		
	Yellow shore crab		X		
Rec sea basses	Barred sand bass	X			
	Broomtail grouper	X			
	Kelp bass	X			
	Spotted sand bass	X			
Rockfishes	Aurora rockfish	X	X		
	Black and yellow rockfish	X	X		
	Black rockfish	X	X		
	Blue rockfish	X	X		
	Bocaccio	X	X		

Table B2-2: Species Evaluated by EPA that are Subject to I&E in California

Species Group	Species	Recreational	Commercial	Forage	Special Status ^a
	Brown rockfish	X	X		
	Calico rockfish	X	X		
	Chilipepper	X	X		
	Copper rockfish	X	X		
	Flag rockfish	X	X		
	Grass rockfish	X	X		
	Kelp rockfish	X	X		
	Olive rockfish	X	X		
	Shortbelly rockfish	X	X		
	Treefish	X	X		
	Vermilion rockfish	X	X		
	Yellowtail rockfish	X	X		
Sacramento splittail	Sacramento splittail				X (FT)
Salmon	Coho salmon	X			
Sculpins	Bonehead sculpin	X	X		
	Brown Irish lord	X	X		
	Buffalo sculpin	X	X		
	Coralline sculpin	X	X		
	Fluffy sculpin	X	X		
	Manacled sculpin	X	X		
	Pacific staghorn sculpin	X	X		
	Prickly sculpin	X	X		
	Rosy sculpin	X	X		
	Roughcheek sculpin	X	X		
	Roughneck sculpin	X	X		
	Smoothhead sculpin	X	X		
	Snubnose sculpin	X	X		
	Staghorn sculpin	X	X		
	Tidepool sculpin	X	X		
	Woolly sculpin	X	X		
Silversides	California grunion			X	
	Jacksmelt			X	
	Topsmelt			X	
Smelts	Night smelt	X	X		
	Surf smelt	X	X		
Steelhead	Steelhead				X (FT)
Striped bass	Striped bass	X			
Surfperches	Barred surfperch	X	X		
	Black surfperch	X	X		
	Calico surfperch	X	X		

Species Group	Species	Recreational	Commercial	Forage	Special Status ^a
	Dwarf surfperch	X	X		
	Island surfperch	X	X		
	Kelp surfperch	X	X		
	Pile surfperch	X	X		
	Pink seaperch	X	X		
	Rainbow surfperch	X	X		
	Rubberlip surfperch	X	X		
	Shiner surfperch	X	X		
	Silver surfperch	X	X		
	Spotfin surfperch	X	X		
	Striped seaperch	X	X		
	Walleye surfperch	X	X		
	White surfperch	X	X		

^a FT = Federally listed as threatened.
 ST = State listed as threatened.
 FE = Federally listed as endangered.
 SE = State listed as endangered.
 FCT = Federal candidate for listing as threatened.
 SOC = Species of concern.

B2-3 LIFE HISTORIES OF PRIMARY SPECIES IMPINGED AND ENTRAINED IN CALIFORNIA

Chinook salmon (*Oncorhynchus tshawytscha*)

Chinook salmon are anadromous members of the salmon and trout family (Salmonidae) (Moyle, 1976; Emmett et al., 1991; Boydston et al., 1992). The San Francisco Bay-Delta is an important nursery area and migration route for chinook salmon (Kennish, 2000). Eggs, alevins (larvae), and young juveniles (fry and parr) use freshwater streams and rivers upstream of the delta, and juveniles migrate through the delta and use it as a nursery area (Emmett et al., 1991). Juveniles eventually migrate downstream to the Pacific Ocean as they transform into smolts, the ocean-dwelling stage. Chinook salmon spend from 1-8 years in the ocean before returning to their natal stream to spawn.

Four races of chinook salmon use the Sacramento-San Joaquin River system (Moyle, 1976; Yoshiyama et al., 2000). These include the fall run, late fall run, winter run, and spring run chinook salmon. In the Sacramento River, the winter run spawns from April to July, and the other runs spawn from July to December (Moyle, 1976). Spawning once occurred into the upper reaches of both the Sacramento and San Joaquin rivers, but dams have limited spawning to the lower reaches of these rivers and their tributaries (Moyle, 1976; Yoshiyama et al., 2000). The Central Valley late fall run was recently evaluated as a part of a proposed listing of the fall run under the Federal Endangered Species Act (ESA). Although it was decided that the combined Central Valley fall/late-fall run currently does not qualify for formal protection, both runs remain under consideration as candidate species (Yoshiyama et al., 2000). The Sacramento River winter run is listed as endangered under both the State and Federal ESA. The Central Valley spring run is listed as threatened under both statutes.

The four Central Valley runs of chinook salmon are vulnerable to I&E at the Pittsburg and Contra Costa power plants. Adults have been observed near the plants in October, and larvae (alevins) have been collected from inshore, shallow areas of Suisun Bay in January and February (Wang, 1986). Parr have been observed throughout the estuary in spring, with peak migration occurring in May and June (Wang, 1986).



CHINOOK SALMON
(*Oncorhynchus tshawytscha*)

Family: Salmonidae (salmon and trout).

Common names: Blackmouth, king salmon, quinnat salmon, spring, tyee.^a

Similar species: Steelhead.

Geographic range: Arctic and Pacific from Point Hope, Alaska to Ventura River, California.^a

Habitat: Oceans, streams and lakes.^a Prefers gravel substrates for spawning.^b

Lifespan: Can live up to 9 years.^a

Fecundity: 2,000 to 14,000 eggs.^b

Food sources:

- ▶ In streams, food is mainly terrestrial insects and small crustaceans.^a
- ▶ In oceans, chinook salmon consume fish, crustaceans, and other invertebrates.^a

Prey for:

- ▶ Striped bass, American shad, sculpins, Sacramento squawfish, sea gulls, mergansers, kingfishers.^{a,b}

Life stage information:

Eggs: demersal

- ▶ Eggs range from 6.0 to 8.5 mm (0.24 to 0.33 in).^b
- ▶ Deposited and buried in gravel, and are bright orange-red in color.^b

Larvae: demersal for 2-3 weeks, then free-swimming.^b

- ▶ Approximately 20 mm (0.79 in) at hatching.

Juveniles:

- ▶ Found in shallow and open waters of the Sacramento - San Joaquin Estuary.^b
- ▶ Remain in freshwater for 1-2 years.^b
- ▶ Drift feeders.^b

Adults:

- ▶ Return to natal streams from the sea for spawning.^a
- ▶ Reach up to 147 cm (58 in).^a

^a Froese and Pauly, 2001.

^b Wang, 1986.

Fish graphic from NEFSC, 2001.

Delta smelt (*Hypomesus transpacificus*)

The delta smelt is a pelagic member of the smelt family (Osmeridae). It is a small, short-lived species that is found only in the bay-delta estuary, in areas with low salinities (Moyle, 1976; Moyle et al., 1992; U.S. Fish and Wildlife Service, 1996b). It is the only smelt species endemic to California and the only true native estuarine species found in the delta (Moyle et al., 1992).

The spawning period of delta smelt is relatively long, and adults may spawn from December to May, although most spawning occurs in February and March (Moyle, 1976). Before spawning in the fall, delta smelt congregate in upper Suisun Bay and the lower reaches of the delta (Moyle, 1976). Spawning takes place in freshwater along river margins and adjoining dead-end sloughs of the western delta. Fecundity is low, ranging from only 1,247 to 2,590 eggs per female (Moyle, 1976). Adults apparently die shortly after spawning, at the end of their 1-year life span (Moyle et al., 1992).

Eggs are demersal and adhesive, sticking to aquatic plants and gravel, and are therefore unlikely to be drawn into cooling water intakes, although the larvae are vulnerable (Bruce Herbold, EPA Region 9, personal communication, September 1, 2000). After hatching, the buoyant larvae are carried downstream to the entrapment zone, the highly productive areas where freshwater and salt water mix. This zone is located in Suisun Bay in years of high freshwater inflow. Juveniles move downstream to San Pablo Bay and Carquinez Strait before turning back to Suisun Bay for spawning.

The delta smelt was once one of the most common fish species in the bay-delta estuary, but the species has declined nearly 90 percent over the last 20 years. A number of physical and biological factors have contributed to declines in recent years, including increased water exports, competition and predation from the accidentally introduced inland silverside (*Menidia beryllina*), drought conditions in the late 1980s and early 1990s, and changes in food availability (CDWR, 1994; U.S. Fish and Wildlife Service, 1996b). Another major factor is the seasonal location of the entrapment zone. The location of the entrapment zone is a function of the timing and magnitude of delta outflow. There is a significant positive relationship between delta smelt abundance and the number of days that the entrapment zone is located within Suisun Bay from February through June (Moyle et al., 1992). Habitat and prey availability for delta smelt are greater when the entrapment zone is in this area because Suisun Bay is broad and shallow, and therefore light penetrates most of its waters, promoting algal growth (U.S.

Fish and Wildlife Service, 1996b). Algal growth under these conditions provides an abundant food supply for zooplankton, which in turn provide food for plankton-eating fish like delta smelt.

Altered flow patterns caused primarily by agricultural water diversions during spawning also appear to contribute to delta smelt population losses by increasing the likelihood of entrainment of spawning adults and newly hatched larvae in diversion pumps (Moyle et al., 1992). In dry years, delta smelt are concentrated in upstream areas, whereas in wet years overall habitat conditions are more favorable and delta smelt are more widely distributed. When favorable conditions result in wider distribution, more delta smelt are affected by water diversion pumps (CDWR, 1994). The California Department of Water Resources (CDWR) estimated that entrainment losses of delta smelt at delta diversions reached 1.2 million in 1992 (CDWR, 1994).

Losses of delta smelt related to other water uses equal or exceed those at government water project pumps (CDWR, 1994). For example, because of their schooling behavior and preference for the region around Suisun Bay, delta smelt are highly vulnerable to the intakes of the Pittsburg and Contra Costa power plants. Monitoring of this species has not been required of the power plants, and the only estimates of I&E are based on incidental collection in striped bass monitoring samples in the late 1970's (Ecological Analysts, 1981b, 1981e). Nonetheless, the data indicate that in the late 1970's delta smelt were one of the most common fish species in the vicinity of the plants and experienced I&E in the millions each year.

Delta smelt is currently listed as a threatened species by both the USFWS and California. Historically, the delta smelt occurred from Suisun Bay upstream to the city of Sacramento on the Sacramento River and upstream to Mossdale on the San Joaquin River (Moyle et al., 1992). The size of the current population is uncertain, but in the early 1990's the population was estimated to be about 280,000 (Southern Energy Delta, LLC, 2000). Even at this population size, the delta smelt is considered highly vulnerable to environmental stressors because of its 1-year life cycle and low fecundity. Low fecundity and a short life span mean that even as few as 2 successive years of low reproductive success could decimate the population (Moyle, 1976).



DELTA SMELT
(*Hypomesus transpacificus*)

Family: Osmeridae (smelt).

Common names: none.

Similar species: Longfin smelt.

Geographic range: Sacramento - San Joaquin Delta.^a

Habitat: Deadend sloughs, inshore areas of the delta and lower reaches of the Sacramento and San Joaquin rivers.^b

Lifespan: Only live for one year.^c

Fecundity: Fecundity is low, ranging from only 1,247 to 2,590 eggs per female.^d Delta smelt die shortly after spawning.^c

Food sources:

- ▶ Juveniles eat planktonic crustaceans, small insect larvae, and mysid shrimp.^b

Prey for:

Life stage information:

Eggs: demersal

- ▶ Eggs are adhesive and stick to aquatic plants and gravel.^c
- ▶ Approximately 1mm (0.04 in) in diameter.^b

Larvae: pelagic

- ▶ Larvae are approximately 5.5 to 6.0 mm (0.22 to 0.24 in) at hatching.^b
- ▶ Found near surface of water column.^b

Juveniles: pelagic

- ▶ Juveniles are concentrated in the Suisun Bay and the delta and in the lower reaches of the Sacramento and San Joaquin rivers.^b

Adults:

- ▶ Reach 12 cm (4.7 in).^a

^a Froese and Pauly, 2001.

^b Wang, 1986.

^c Moyle et al., 1992.

^d Moyle, 1976.

^e Bruce Herbold, EPA Region 9, personal communication, September 1, 2000.

Fish graphic from California Department of Fish and Game, 2002b.

Green sturgeon (*Acipenser medirostris*)

The green sturgeon is a member of the sturgeon family Acipenseridae (Emmett et al., 1991; Southern Energy Delta, LLC, 2000). It is an anadromous species that is closely related to the white sturgeon (*A. transmontanus*), though it shows a greater preference for marine waters, spending little time in freshwater. It is not abundant in any Pacific Coast estuary, and therefore life history characteristics are poorly known (Emmett et al., 1991). Along the North America coast it is found from Mexico north to the Bering Sea (Southern Energy Delta, LLC, 2000).

Although not abundant in the bay-delta, in the Columbia River green sturgeon is caught commercially with the white sturgeon, but it is considered inferior eating and therefore less valuable (Emmett et al., 1991). Green sturgeon is also incidentally captured in the white sturgeon recreational fishery.

Females mature at 15 to 20 years of age (Southern Energy Delta, LLC, 2000). Spawning occurs in California in spring and early summer in deep, fast water in the lower reaches of the Sacramento and Klamath Rivers (Emmett et al., 1991; Southern Energy Delta, LLC, 2000). The green sturgeon is a broadcast spawner, with fecundity ranging from 60,000 to 140,000 eggs per female (Emmett et al., 1991). Juveniles are found in freshwater areas of the San Joaquin Delta in summer (Emmett et al., 1991). By age 2, juveniles move to the ocean. Adults move back into estuaries in spring and early summer to feed and spawn. Adults can reach up to 2.1 m (6.9 ft) in length and live up to 60 years (Emmett et al., 1991).

Green sturgeon are found near the Pittsburg and Contra Costa power plants as adults migrating to freshwater rivers to spawn in spring and as juveniles moving to the ocean (Southern Energy Delta, LLC, 2000). Green sturgeon has been identified as a species of concern in this area (Southern Energy Delta, LLC, 2000).

 <p style="text-align: center;">GREEN STURGEON (<i>Acipenser medirostris</i>)</p>	<p>Food sources:</p> <ul style="list-style-type: none"> ▶ Juveniles consume amphopods and mysid shrimp.^d <p>Prey for:</p> <p>Life stage information:</p> <p>Eggs:</p> <ul style="list-style-type: none"> ▶ Little known, difficult to differentiate from white sturgeon.^d <p>Larvae:</p> <ul style="list-style-type: none"> ▶ Little known, difficult to differentiate from white sturgeon.^d <p>Juveniles:</p> <ul style="list-style-type: none"> ▶ Found in freshwater areas of the San Joaquin Delta in summer.^c <p>Adults: anadromous</p> <ul style="list-style-type: none"> ▶ Prefer marine environments.^c
<p>Family: Acipenseridae (sturgeon).</p> <p>Common names: none.</p> <p>Similar species: White sturgeon.</p> <p>Geographic range: North America from the Aleutian Islands and the Gulf of Alaska to Ensenada, Mexico.^a</p> <p>Habitat: Spawn in freshwater rivers, found in estuaries in spring, and in oceans.^{b,c}</p> <p>Lifespan: Live up to 60 years.^c</p> <p>Fecundity: Females mature at 15 to 20 years.^b Females produce 60,000 to 140,000 eggs.^c</p>	
<p>^a Froese and Pauly, 2001.</p> <p>^b Southern Energy Delta, LLC, 2000.</p> <p>^c Emmett et al., 1991.</p> <p>^d Wang, 1986.</p> <p>Fish graphic from California Department of Fish and Game, 2002a.</p>	

Longfin smelt (*Spirinchus thaleichthys*)

Longfin smelt is a member of the smelt family (Osmeridae) (Moyle, 1976). Longfin smelt is a native planktivore with a reproductive biology that is similar to delta smelt (Moyle, 1976; Wang, 1986; Herbold and Moyle, 1989; Emmett et al., 1991). It is an anadromous species that is abundant in many Pacific Coast estuaries from Monterey Bay, California, as far north as Prince William Sound, Alaska (Emmett et al., 1991). Longfin smelt have been sold seasonally in bay-delta fish markets (Wang, 1986). They also provide food for numerous predatory fishes, birds, and marine mammals (Emmett et al., 1991).

Adult longfin smelt are found in conditions ranging from seawater to freshwater during their upstream spawning migrations (Moyle, 1976; Wang, 1986; Herbold and Moyle, 1989; Emmett et al., 1991). Adults also show vertical migrations within the water column, concentrating in bottom waters during the day and surface waters at night. Spawning occurs in winter and spring in rivers (Kennish, 2000).

In California, longfin smelt are concentrated around San Pablo Bay, but the population also shows distinct seasonal movements (Moyle, 1976). Early summer is spent in San Francisco and San Pablo bays. In August, longfin smelt move into Suisun Bay, and in winter they congregate for spawning in upper Suisun Bay and the lower delta. In April and May, large schools of juveniles move back downstream, and concentrate in the Carquinez Strait, San Pablo Bay, and San Francisco Bay throughout spring and summer.

Most longfin smelt reach maturity at age 2 (Moyle, 1976; Wang, 1986; Herbold and Moyle, 1989; Emmett et al., 1991). Spawning takes place in freshwater at night from December to June, and is known to occur near both the Pittsburg and Contra Costa plants (Wang, 1986). The majority of adults die after spawning, but some females apparently live to spawn a second time (Moyle, 1976). The average female produces 18,000 to 24,000 eggs (Emmett et al., 1991). Eggs are demersal and adhesive and are deposited singly over rocks and submerged vegetation. Larvae are pelagic, and are found in surface waters from the Carquinez Strait to the lower reaches of the Sacramento and San Joaquin rivers. Schools of larvae often also include delta smelt (Wang, 1986), and it can be difficult to distinguish the two species in I&E samples. Juveniles range from 22 to 88 mm (0.9 to 3.5 in) in length, while adults average 100 mm (3.9 in) (Emmett et al., 1991). In the bay-delta estuary, abundance is positively correlated with the amount of freshwater inflow from February to September (Herbold and Moyle, 1989). Longfin smelt has been identified as a species of concern (Southern Energy Delta, LLC, 2000).



LONGFIN SMELT
(*Spirinchus thaleichthys*)

Family: Osmeridae (smelt).

Common names: Pacific smelt, Sacramento smelt.^a

Similar species: Delta smelt.

Geographic range: Northern Pacific from Prince William Sound, Alaska to Monterey Bay, California.^a

Habitat: Close to shore, in bays and estuaries.^a Prefers rocky, hard or sandy substrates and aquatic vegetation for cover.^b

Lifespan: Live up to 3 years.^a

Fecundity: Females mature at 2 years and usually spawn only once, producing 18,000 to 24,000 eggs.^c

^a Froese and Pauly, 2001.

^b Wang, 1986.

^c Emmett et al., 1991.

Fish graphic from California Department of Fish and Game, 2002b.

Food sources:

- ▶ Diaphanosoma, Diaptomus, Epischura, mysid shrimp, and other small crustaceans.^b

Prey for:

- ▶ Predatory fish, birds, and marine mammals.^b

Life stage information:

Eggs: demersal

- ▶ Eggs are approximately 1.2mm (0.04 in).^b
- ▶ Eggs are deposited singly.^b

Larvae: pelagic

- ▶ Larvae are 6.9 to 8 mm (0.27 to 0.31 in) at hatching.^b
- ▶ Larvae are found mostly on the surface of the water.^b

Juveniles:

- ▶ Range from 22 to 28 mm (0.9 to 3.5 in) in length.^c
- ▶ Juveniles are found in the middle to bottom of the water column.^b

Adults:

- ▶ Adults average 100 mm (3.9 in).^c

Sacramento splittail (*Pogonichthys macrolepidotus*)

Sacramento splittail is a member of the minnow family (Cyprinidae) and a freshwater native of California's Central Valley (Moyle, 1976; Daniels and Moyle, 1983; Wang, 1986). Splittail are bottom foragers that can reach up to 40.6 cm (16 in) in length. Juveniles provide forage for squawfish and striped bass.

Historically, splittail were abundant in the lakes and rivers of the Central Valley, including upstream reaches of the Sacramento and San Joaquin rivers and their tributaries. However, dams and diversions have restricted upstream access, and splittail are now limited in their distribution to freshwater and brackish conditions in the lower reaches of the Sacramento River, the delta, Suisun Marsh, San Pablo Bay, and Napa Marsh. Over the past 15 years, the species has declined by over 60 percent, primarily as a result of increasing water exports and the loss of shallow-water habitat (Meng and Moyle, 1995). Sacramento splittail was listed as threatened under the Federal Endangered Species Act by the USFWS effective March 1999.

Splittail spawn in the delta in spring over flooded vegetation in tidal freshwater and oligohaline areas (Wang, 1986; Kennish, 2000). The spawning season can extend from late January to July, but most spawning occurs from March through May as water levels and temperatures increase. Females mature at 1-2 years and produce up to 250,000 eggs (Daniels and Moyle, 1983). Eggs are demersal and adhesive and therefore unlikely to be entrained, but larvae and small juveniles are vulnerable. The delta and Suisun Bay are important nursery areas (Kennish, 2000). Larvae are known to concentrate near the Pittsburg plant at New York Slough (Wang, 1986). Juveniles are particularly abundant in Suisun Marsh and the Montezuma Slough of Suisun Bay (Meng and Moyle, 1995). Most splittail complete their life cycle in 5 years.

	<p>Food sources:</p> <ul style="list-style-type: none"> ▶ Bottom foragers.^d ▶ Juveniles prey on algae, pelecypods, and amphipods.^e <p>Prey for:</p> <ul style="list-style-type: none"> ▶ Juveniles are prey for squawfish and striped bass.^d <p>Life stage information:</p> <p>Eggs: demersal</p> <ul style="list-style-type: none"> ▶ Eggs are adhesive, and unlikely to be entrained.^f ▶ Mature eggs are 1.3 to 1.6 mm (0.05 to 0.06 in).^e <p>Larvae: planktonic</p> <ul style="list-style-type: none"> ▶ Hatch at less than 6.5 mm (0.26 in).^e <p>Juveniles:</p> <ul style="list-style-type: none"> ▶ Found in shallow and open water from the delta to San Pablo Bay.^e <p>Adults:</p> <ul style="list-style-type: none"> ▶ Spawn in the delta in spring over flooded vegetation in tidal freshwater and oligohaline areas.^{e,f} ▶ May reach 40.6 cm (16 in) in length.^d
<p>SACRAMENTO SPLITTAIL (<i>Pogonichthys macrolepidotus</i>)</p> <p>Family: Cyprinidae (minnow).</p> <p>Common names: Splittail.^a</p> <p>Similar species:</p> <p>Geographic range: Formerly throughout the Sacramento-San Joaquin River drainage, now restricted to the San Francisco Bay Delta and lower Sacramento River.^a</p> <p>Habitat: Backwaters and pools of rivers and lakes.^a</p> <p>Lifespan: Live for 5 years.^b</p> <p>Fecundity: Females mature at 1-2 years and produce up to 250,000 eggs.^c</p>	
<p>^a Froese and Pauly, 2001. ^b Meng and Moyle, 1995. ^c Daniels and Moyle, 1983. ^d Moyle, 1976. ^e Wang, 1986. ^f Kennish, 2000.</p> <p>Fish graphic from California Department of Fish and Game, 2002b.</p>	

Steelhead (*Oncorhynchus mykiss*)

Steelhead is an anadromous form of rainbow trout and is part of the salmon and trout family (Salmonidae) (Moyle, 1976; Herbold and Moyle, 1989; Emmett et al., 1991). It is ecologically similar to chinook salmon.

There are at least two subspecies or races of steelhead in California, defined by when adult fish enter freshwater to spawn (Emmett et al., 1991). The winter run of steelhead that uses the Central Valley migrates upstream during fall, winter, and early spring and spawns from December to June, while the summer run migrates during spring, summer, and early fall and spawn the following spring.

Construction of Shasta Dam blocked access to half of the suitable spawning habitat for steelhead in the Sacramento River drainage, contributing to serious population declines (Herbold and Moyle, 1989). Other causes of decline include dewatered streams resulting from excessive water diversions, rapid flow fluctuations from water conveyance, high water temperatures in summer below reservoirs, and entrainment of juveniles into government water project pumps (McEwan, 1992). In March 1998, the winter run was listed as threatened by the NMFS. Much of the production of steelhead now occurs in hatcheries. Hatchery steelhead have lower survival and reproductive rates than wild steelhead and can reduce the genetic diversity of wild stocks by interbreeding (Emmett et al., 1991).

Steelhead eggs, larvae (alevins), and young juveniles (fry and parr) are riverine life stages that normally remain in freshwater for 1-4 years (Emmett et al., 1991). Alevins range from 14 mm (0.55 in.) at hatching to about 28 mm (1.1 in.). Eggs and alevins are benthic and infaunal. Fry and parr are found in areas with cover and move to deeper water as they grow. Parr transform into smolts as they move through rivers and estuaries on their migration to the ocean, where they remain for 1-5 years before returning to their natal river as adults to spawn. The average female produces 1,500 to 5,000 eggs (Emmett et al., 1991).

Juveniles are found in all habitats of the delta, but it is unknown how long the delta is used as a nursery area (Herbold and Moyle, 1989). Food sources in freshwater and estuarine areas include gammarid amphipods, crustaceans, and small fish (Moyle, 1976). Juveniles range from 28 mm (1.1 in.) to 400 mm (15.7 in.) (Emmett et al., 1991).



STEELHEAD
(*Oncorhynchus mykiss*)

Family: Salmonidae (salmon and trout).

Common names: Coast range trout, hardhead, rainbow trout, salmon trout.^a

Similar species: Chinook salmon.

Geographic range: Eastern Pacific from Alaska to Baja California, Mexico.^a

Habitat:

Lifespan: Adults may reach 11 years.^a

Fecundity: Females produce from 1,500 to 5,000 eggs.^b

Food sources:

- ▶ Gammarid amphipods, crustaceans, small fish.^c

Prey for:

Life stage information:

Eggs: benthic

- ▶ Spawning in riverine fresh water.

Larvae: benthic

- ▶ Larvae range from 14 to 28 mm (0.55 to 1.1 in).^b

Juveniles:

- ▶ Juveniles range from 28 to 400 mm (1.1 to 15.7 in).^b
- ▶ Found in all habitats of the delta.^d

Adults: Anadromous

- ▶ Two subspecies or races of steelhead are defined by the timing of spawning (winter run & summer run).^b
- ▶ May grow as large as 120 cm (47 in).^a

^a Froese and Pauly, 2001.

^b Emmett et al., 1991.

^c Moyle, 1976.

^d Herbold and Moyle, 1989.

Fish graphic from Mason, 2002.

Striped bass (*Morone saxatilis*)

Striped bass was intentionally introduced to the Sacramento-San Joaquin River system during the 1870's (Moyle, 1976; Emmett et al., 1991; Stevens, 1992). Unlike some East Coast populations that make extensive coastal migrations, Sacramento-San Joaquin River populations appear to spend most of their lives in bays and estuaries. Adults move into bays (some into the delta) in the fall, overwinter in the bay and delta, and then after spawning in spring, move back to the ocean (Moyle, 1976).

Commercial fishing for striped bass in the San Francisco Bay system has been prohibited since 1935 because of demands by sport anglers (Stevens, 1992). The San Francisco striped bass recreational fishery is one of the most important recreational fisheries on the Pacific Coast. In 1985, it was valued at over \$45 million annually (Stevens, 1992). However, the Sacramento-San Joaquin population has declined since the early 1960's. Poor recruitment of young striped bass is thought to be the primary reason for the decline in the adult stock (Stevens, 1992).

Striped bass spawn in schools at night (Stevens, 1992). Spawning occurs in freshwater, beginning in April in California and peaking in May and early June. Females mature at age 5, producing an average of 250,000 eggs per year. Striped bass can live up to 20 years, and exceed 22.7 kg (50 lb) in weight, thus showing high reproductive potential.

Larval striped bass feed on opossum shrimp in the delta and Suisun Bay, reaching about 3.8 cm (1.5 in) in length by late summer (Stevens, 1992). Large numbers of eggs and larvae are killed by the intakes of the Pittsburg and Contra Costa plants and government water projects, contributing to poor recruitment (Stevens, 1992; Southern Energy Delta, LLC, 2000). A number of restoration and management actions are in place to improve recruitment. However, striped bass are voracious predators on small fish, including several delta T&E species or species of concern such as delta smelt, longfin smelt, and Sacramento splittail, complicating management efforts.



STRIPED BASS
(*Morone saxatilis*)

Family: Moronidae (temperate basses).

Common names: Striper, rockfish, linesider, and sea bass.^a

Similar species: White perch.

Geographic range: St. Lawrence River in Canada to the St. Johns River in Florida, and from the Suwannee River in western Florida to Lake Pontchartrain, Louisiana.^b

Intentionally introduced to Sacramento-San Joaquin River system.^c

Habitat: Sacramento-San Joaquin River populations spend most of their lives in bays and estuaries.^c Juveniles prefer shallow rocky to sandy areas. Adults in inshore areas use a variety of substrates, including rock, boulder, gravel, sand, detritus, grass, moss, and mussel beds.^b

Lifespan: Adults may reach 30 years.^d

Fecundity: Females mature at age 5 and produce an average of 250,000 eggs per year.^e

^a Froese and Pauly, 2001.

^b Hill et al., 1989.

^c Moyle, 1976.

^d Atlantic States Marine Fisheries Commission, 2000d.

^e Stevens, 1992.

^f Bigelow and Schroeder, 1953.

Fish graphic from California Department of Fish and Game, 2002a.

Food sources:

- ▶ Larvae feed primarily on mobile planktonic invertebrates (beetle larvae, copepodids *Daphnia* spp.).^b
- ▶ Juveniles eat larger aquatic invertebrates and small fishes.^b
- ▶ Adults are piscivorous. Clupeid fish are the dominant prey and adults prefer soft-rayed fishes.^b

Prey for: Any sympatric piscivorous fish.^b

Life stage information:

Eggs: pelagic

- ▶ Eggs and newly hatched larvae require sufficient turbulence to remain suspended in the water column; otherwise, they can settle to the bottom and be smothered.^f

Larvae: pelagic

- ▶ Larvae range from 5 to 30 mm (0.2 to 1.2 in).^b

Juveniles:

- ▶ Most striped bass enter the juvenile stage at 30 mm (1.2 in) total length.^f
- ▶ Juveniles school in larger groups after 2 years of age.^f

Adults: Anadromous

- ▶ Adults move into bays in the fall, overwinter in the bay and delta, and after spawning in the spring, return to the ocean.^c
- ▶ May grow as large as 200 cm (79 in).^a

B2-4 I&E DATA EVALUATED

Table B2-3 lists California facilities in scope of the Phase II rule and the facility I&E data evaluated by EPA. See Chapter A5 of Part A for a discussion of extrapolation methods.

In Scope Facilities	I&E Data?	Years of Data
Contra Costa	Yes	1978, 1986-1992
Diablo Canyon Nuclear	Yes	1985, 1987-1988
El Segundo	Yes	1990-2001
Encina	Yes	1979
Harbor	Yes	1979
Haynes	Yes	1979, 2001
Humboldt Bay	Yes	1980
Hunter's Point	Yes	1978
Huntington Beach	Yes	1979-2001
Long Beach	No - extrapolated	
Mandalay	Yes	2001
Morro Bay	Yes	2000
Moss Landing	Yes	1979, 1999
Ormond Beach	Yes	1979, 1990-2001
Pittsburg	Yes	1978, 1986-1992
Potrero	Yes	1978, 2001
AES Redondo Beach	Yes	1979, 1991-2001
San Onofre Nuclear	Yes	1979, 1990-2001
Scattergood	Yes	1990-2002
South Bay	No - extrapolated	

B2-5 EPA'S ESTIMATE OF CURRENT I&E IN CALIFORNIA EXPRESSED AS AGE 1 EQUIVALENTS, FOREGONE YIELD, AND PRODUCTION FOREGONE

Table B2-4 provides EPA's estimate of the annual age 1 equivalents, foregone fishery yield, and production foregone resulting from the impingement of aquatic species at facilities located in California. Table B2-5 displays this information for entrainment.

Table B2-4: Current Annual Impingement in California Expressed as Age 1 Equivalents, Foregone Fishery Yield, and Production Foregone			
Species Group	Age 1 Equivalents (#s)	Yield (lbs)	Production Foregone
American shad	14	3	8
Anchovies	2,397,761	3,756	10,009
Blennies	3,370	0	2
Cabezon	672	1,131	372
California halibut	4,633	17,439	2,173
California scorpionfish	1,964	1,334	264
Chinook salmon	63	0	198
Commercial crabs	102,662	20	1,058
Commercial sea basses	7	2	0
Commercial shrimp	49,058	1	3
Delta smelt	638	0	1
Drums and croakers	366,466	21,226	6,936
Dungeness crab	6,084	2,807	763
Flounders	69,439	5,690	5,188
Forage shrimp	1,747	0	0
Gobies	19,141	0	8
Herrings	371,810	0	15,335
Longfin smelt	6,774	0	28
Other (commercial)	922	179	118
Other (forage)	325,787	0	35
Other (commercial & recreational)	23,877	4,642	3,063
Other (recreational)	16,989	3,303	2,179
Recreational sea basses	8,351	2,058	194
Rockfishes	102,570	24,711	7,693
Sacramento splittail	911	0	93
Salmon	2	7	5
Sculpins	88,869	2,711	2,121
Silversides	635,963	0	27,502
Smelts	36,502	830	991
Steelhead	1	0	3
Striped bass	44,501	37,516	10,613
Surfperches	782,637	48,722	41,470

Species Group	Age 1 Equivalents (#s)	Total Yield (lbs)	Production Foregone (lbs)
American shad	1	0	630
Anchovies	282,880	443	185,331
Blennies	80,359,464	0	395,364
Cabezon	500,110	842,357	743,502
California halibut	583,490	2,196,315	1,506
Chinook salmon	3	0	27
Commercial crabs	66,096,905	12,990	28,217,407
Commercial shrimp	5,305,810	138	13,165
Delta smelt	115	0	0
Drums and croakers	3,195,329	185,072	1,904,184
Dungeness crab	71,633	33,051	152,571
Flounders	147,615	12,096	170,697
Forage shrimp	16,808,030	0	25,841
Gobies	16,240,573	0	156,209
Herrings	2,728,452	0	350,759
Longfin smelt	51	0	1
Other (commercial)	44,341	8,621	101,838
Other (forage)	53,084,096	0	303,543
Other (recreational)	5,994	1,165	13,765
Recreational sea basses	4,548,657	1,121,173	129,024
Rockfishes	53,654,899	12,926,604	8,380,148
Sacramento splittail	1	0	1
Sculpins	3,684,908	112,404	424,884
Silversides	17,569	0	2,724
Smelts	1,695	39	2,198
Striped bass	102,238	86,189	1,810,779

B2-6 ASSUMPTIONS USED IN CALCULATING RECREATIONAL AND COMMERCIAL LOSSES

The lost yield estimates presented in Tables B2-4 and B2-5 are expressed as total pounds and include losses to both commercial and recreational catch. To estimate the economic value of these losses, total yield was partitioned between commercial and recreational fisheries based on the landings in each fishery. Table B2-6 presents the percentage impacts assumed for each species, as well as the value per pound for commercially harvested species.

Age-1 equivalent fish that are spared from I&E are not necessarily old enough or large enough to be attractive to anglers. It may take one more year for these fish to reach a harvestable age. For this reason, EPA discounts commercial and recreational benefits so that the cost and benefits estimates will be comparable. Tables B2-7 and B2-8 present the multiplicative discounting factors used in discounting benefits assuming a 3 percent real discount rate and a 7 percent real discount rate. For details on how these factors are developed, see Chapter A14.

Table B2-6: Percentage of Total Impacts Occurring to the Commercial and Recreational Fisheries and Commercial Value per Pound for Species Impinged and Entrained at California Facilities			
Species Group	Percent Impact to Recreational Fishery^{a,b}	Percent Impact to Commercial Fishery^{a,b}	Commercial Value per Pound (2002\$)^c
American shad	0.0%	100.0%	\$1.36
Anchovies	0.0%	100.0%	\$0.06
Cabezon	45.9%	54.1%	\$3.70
California halibut	85.6%	14.4%	\$2.66
California scorpionfish	83.7%	16.3%	\$1.83
Commercial sea basses	0.0%	100.0%	\$1.63
Commercial shrimp	0.0%	100.0%	\$0.99
Drums and croakers	69.1%	30.9%	\$1.01
Dungeness crab	0.0%	100.0%	\$1.68
Flounders	1.0%	99.0%	\$0.39
Other (commercial)	0.0%	100.0%	\$0.05
Other (recreational)	100.0%	0.0%	na
Other (commercial & recreational)	54.0%	46.0%	\$0.25
Northern anchovy	0.0%	100.0%	\$0.06
Other commercial crabs	0.0%	100.0%	\$1.16
Recreational sea basses	100.0%	0.0%	na
Rockfishes	23.6%	76.4%	\$0.52
Salmon	100.0%	0.0%	na
Sculpins	85.0%	15.0%	\$2.55
Smelts	6.2%	93.8%	\$0.27
Striped bass	100.0%	0.0%	na
Surfperches	93.0%	7.0%	\$1.60
Other (forage) ^d	50.0%	50.0%	\$0.27

^a Based on landings from 1993 to 2001.

^b Calculated using recreational landings data from NMFS (2003c, <http://www.st.nmfs.gov/recreational/queries/catch/snapshot.html>) and commercial landings data from NMFS (2003a, http://www.st.nmfs.gov/commercial/landings/annual_landings.html).

^c Calculated using commercial landings data from NMFS (2003a).

^d Assumed equally likely to be caught by recreational or commercial fishermen. Commercial value calculated as overall average for region based on data from NMFS (2003a).

Species Group	Discount Factors for Entrainment		Discount Factors for Impingement	
	3% Discount Rate	7% Discount Rate	3% Discount Rate	7% Discount Rate
Cabezon	0.865	0.723	0.891	0.774
California halibut	0.781	0.573	0.805	0.613
California scorpionfish	na	na	0.877	0.749
Drums and croakers	0.860	0.711	0.886	0.761
Flounders	0.945	0.878	0.973	0.940
Other recreational species	0.922	0.831	0.950	0.889
Other rec. and com. species	na	na	0.950	0.889
Recreational sea basses	0.817	0.632	0.842	0.677
Rockfishes	0.787	0.585	0.811	0.626
Sculpins	0.953	0.896	0.982	0.959
Smelts	0.954	0.899	0.983	0.962
Striped bass	0.864	0.717	0.879	0.749
Surfperches	na	na	0.935	0.859
Other unidentified fish (from forage losses)	0.919	0.829	0.919	0.829

Species Group	Discount Factors for Entrainment		Discount Factors for Impingement	
	3% Discount Rate	7% Discount Rate	3% Discount Rate	7% Discount Rate
American shad	na	na	0.893	0.773
Anchovies	0.933	0.856	0.961	0.916
Cabezon	0.832	0.663	0.857	0.710
California halibut	0.755	0.532	0.778	0.569
California scorpionfish	na	na	0.818	0.643
Commercial sea basses	na	na	0.819	0.637
Commercial shrimp	0.969	0.932	0.999	0.997
Drums and croakers	0.842	0.680	0.868	0.727
Dungeness crab	0.916	0.819	0.944	0.877
Flounders	0.930	0.847	0.958	0.907
Other commercial species	0.913	0.813	0.940	0.870
Other rec. and com. species	na	na	0.940	0.870
Northern anchovy	0.938	0.865	na	na
Other commercial crabs	0.882	0.750	0.908	0.803
Rockfishes	0.764	0.547	0.787	0.586
Sculpins	0.943	0.875	0.971	0.936
Smelts	0.922	0.832	0.950	0.890
Surfperches	na	na	0.926	0.840
Other unidentified fish (from forage losses)	0.900	0.792	0.900	0.792