Cumulative Effects

Cumulative effects include the effects of future State, tribal, local, or private actions that are reasonably certain to occur in the Action Area considered in this BiOp. Future Federal actions that are unrelated to the proposed project are not considered in this section; they require separate consultation pursuant to Section 7 of the Act.

Major human interactions and uses of the landscape within the Action Area include: agricultural practices; recreational uses; urbanization and industrialism - commercial and private; and greenhouse gas emissions.

Agriculture

Farming occurs throughout the Delta adjacent to many waterways used by delta smelt. Levees are reinforced with continual vegetation removal and riprapping to stabilize the levees and protect the land behind the levees for agricultural purposes. Agricultural practices introduce nitrogen, ammonium, and other nutrients into the watershed, which then flow into receiving waters, adding to other inputs such as wastewater treatment (Lehman *et al.* 2014); however, wastewater treatment provides the bulk of ammonium loading, for example (Jassby 2008). Stormwater and irrigation discharges related to both agricultural and urban activities contain numerous pesticides and herbicides that may negatively affect delta smelt reproductive success and survival rates (Dubrovsky *et al.*1998; Kuivila *et al.* 2004; Scholz *et al.* 2012). Discharges occurring outside the Action Area that flow into the Action Area also contribute to cumulative effects of contaminant exposure.

Water diversions for irrigated agriculture, municipal and industrial use, and managed wetlands are found throughout the Action Area, and many of them remain unscreened. Most diversions of any substantial size and cost have been screened, such as new municipal water diversions, and are routinely screened per existing BiOps. Private irrigation diversions in the Delta are mostly unscreened, but the total amount of water diverted onto Delta farms has remained stable for decades (Culberson *et al.* 2008) so the cumulative impact should remain similar to baseline. Irrigated agriculture is anticipated to continue into the future, especially for permanent crops that rely on Delta water as a controlled water source for growth. Depending on the size, location, and season of operation, these unscreened diversions have the potential to entrain many life stages of aquatic species, including delta smelt. However, the vast majority of private unscreened diversions in the Action Area are small pipes in large channels that operate intermittently, and mainly during the spring and summer. As a result, even where they do regularly co-occur with these diversions, delta smelt appear to have low vulnerability to entrainment (Nobriga *et al.* 2004). Nobriga *et al.* (2004) reasoned that the littoral location and small size of these diversions reduced their risk of entraining delta smelt.

Urbanization and Industrialism

The Delta Protection Commission's Economic Sustainability Plan for the Delta reported an urban growth rate of about 54% within the statutory Delta between 1990 and 2010, as compared with a 25% growth rate statewide during the same period (Delta Protection Commission 2012). The report also indicated that population growth had occurred in the Secondary Zone of the

Delta but not in the Primary Zone and that population in the central and south Delta areas had decreased since 2000. Growth projections through 2050 indicate that all counties overlapping the Delta are projected to grow at a faster rate than the State as a whole. Total population in the Delta counties is projected to grow at an average annual rate of 1.2% through 2030 (California Department of Finance 2012). Table 1 illustrates past, current, and projected population trends for the five counties in the Delta. As of 2010, the combined population of the Delta counties was approximately 3.8 million. Sacramento County contributed 37.7% of the population of the Delta counties, and Contra Costa County contributed 27.8%. Yolo County had the smallest population (200,849 or 5.3%) of all the Delta counties.

Table 1. Delta counties and California population, 2000–2050.

Area	2000 Population (millions)	2010 Population (millions)	2020 Projected Population (millions)	2025 Projected Population (millions)	2050 Projected Population (millions)
Contra Costa County	0.95	1.05	1.16	1.21	1.50
Sacramento County	1.23	1.42	1.56	1.64	2.09
San Joaquin County	0.57	0.69	0.80	0.86	1.29
Solano County	0.40	0.41	0.45	0.47	0.57
Yolo County	0.17	0.20	0.22	0.24	0.30
Delta Counties	3.32	3.77	4.18	4.42	5.75
California	34.00	37.31	40.82	42.72	51.01
Sources: California Department of Finance 2012.					

Table 2 presents more detailed information on populations of individual communities in the Delta. Growth rates from 2000 to 2010 were generally higher in the smaller communities than in larger cities such as Antioch and Sacramento. This is likely a result of these communities having lower property and housing prices, and their growth being less constrained by geography and adjacent communities.

Table 2. Delta communities population, 2000 and 2010.

Community	2000	2010	Average Annual Growth Rate 2000–2010
Contra Costa County			
Incorporated Cities and Towns			
Antioch	90,532	102,372	1.3%
Brentwood	23,302	51,481	12.1%
Oakley	25,619	35,432	3.8%
Pittsburg	56,769	63,264	1.1%
Small or Unincorporated Communities			
Bay Point	21,415	21,349	-0.0%
Bethel Island	2,252	2,137	-0.5%
Byron	884	1,277	4.5%
Discovery Bay	8,847	13,352	5.1%
Knightsen	861	1,568	8.2%
Sacramento County			
Incorporated Cities and Towns			
Isleton	828	804	-0.3%
Sacramento	407,018	466,488	1.5%
Small or Unincorporated Communities			
Courtland	632	355	-4.4%
Freeport and Hood	467	309[a]	-3.4%
Locke	1,003	Not available	—
Walnut Grove	646	1,542	13.9%
San Joaquin County			
Incorporated Cities and Towns			
Lathrop	10,445	18,023	7.3%
Stockton	243,771	291,707	2.0%
Tracy	56,929	82,922	4.6%
Small or Unincorporated Communities			
Terminous	1,576	381	-7.6%

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Solano County			
Incorporated Cities and Towns			
Rio Vista	4,571	7,360	6.1%
Yolo County			
Incorporated Cities and Towns			
West Sacramento	31,615	48,744	5.4%
Small or Unincorporated Communities			
Clarksburg	681	418	-3.9%
Sources: U.S. Census Bureau 2000; U.S. Census Bureau 2011. [a] Freeport had a population of 38; Hood had a population of 271.			

Increases in urbanization and housing development can impact habitat by altering watershed characteristics, and changing both water use and stormwater runoff patterns. Increased growth will place additional burdens on resource allocations, including natural gas, electricity, and water, as well as on infrastructure such as wastewater sanitation plants, roads and highways, and public utilities. Some of these actions will not require consultation with the Service. State or local levee maintenance may also destroy or adversely affect delta smelt spawning or rearing habitat and interfere with natural, long-term spawning habitat-maintaining processes. Adverse effects on delta smelt and its critical habitat may result from urbanization-induced point and non-point source chemical contaminant discharges within the Action Area. These contaminants include, but are not limited to, ammonia and free ammonium ion, numerous pesticides and herbicides, pharmaceuticals, and oil and gasoline product discharges. Oil and gasoline product discharges may be introduced into Delta waterways from shipping and boating activities and from urban activities and runoff. Implicated as potential stressors to delta smelt, these contaminants may adversely affect delta smelt reproductive success, survival rates, and food supply.

Contaminants are suspected to be a stressor on delta smelt (Kuivila and Moon 2004; Brooks *et al.* 2012). A study of juvenile delta smelt in five regions encompassing their range examined delta smelt for signs of contaminants and food limitation. The histopathological analysis of the 244 fish sampled in 2012 and 2013 found an 11-fold increase in gill and liver lesion scores in Cache Slough as compared to Suisun Marsh. Higher lesion scores indicate less healthy tissues and are indicative of contaminant-related stress (Hammock *et al.* 2015).

The largest urban discharger to the Delta is the Sacramento Regional Wastewater Treatment Plant (SRWTP). In order to comply with Central Valley Regional Water Quality Control Board Order no. R5-2013-0124, SRWTP has begun implementing compliance measures to reduce its discharge of ammonia and ammonium. Construction of treatment facilities for three of the major projects required for ammonia and nitrate reduction was initiated in March 2015 (Sacramento Regional County Sanitation District 2015). Order No. R5-2013-0124, which was modified on October 4, 2013, by the Central Valley Regional Water Quality Control Board, imposed new interim and final effluent limitations, which must be met by May 11, 2021 (Central Valley

Regional Water Quality Control Board 2013). By May 11, 2021, the SRWTP must reach a final effluent limit of 2.0 milligrams per liter (mg/L total ammonia nitrogen) per day from April to October, and 3.3 mg/L per day from November to March (Central Valley Regional Water Quality Control Board 2013). However, the treatment plant is currently releasing several tons of ammonia in the Sacramento River each day. A study by Werner *et al.* (2008) concluded that ammonia concentrations present in the Sacramento River below the SRWTP are not acutely toxic to 55-day-old delta smelt. However, based on information provided by EPA (1999) and other related studies, it is possible that concentrations below the SRWTP may be chronically toxic to delta smelt and other sensitive fish species (Werner *et al.* 2010). In 2010, the same group conducted three exposure experiments to measure the effect concentration of SRWTP effluent. No significant effects of effluent on the survival of larval delta smelt were found. More recent studies (which used concentrations of ammonia higher than typically experienced by delta smelt) have shown that delta smelt that are exposed to ammonia exhibit membrane destabilization. This results in increased membrane permeability and increased susceptibility to synergistic effects of multi-contaminant exposures (Connon *et al.* 2009; Hasenbein *et al.* 2014). Results are unclear at this time as to what the effect of ammonia exposure is on delta smelt, and research is ongoing. EPA published revised national recommended ambient water quality criteria for the protection of aquatic life from the toxic effects of ammonia in 2013. Studies are ongoing to further determine the adverse effects of ammonia on delta smelt.

In addition to concerns about direct toxicity of ammonia to delta smelt, another important concern is that ammonium inputs have suppressed diatom blooms in the Delta and Suisun Bay, thereby reducing the productivity in the delta smelt food web. The IEP (2015) provided the following summary: "Dugdale *et al.* (2007) and Wilkerson *et al.* (2006) found that high ammonium concentrations prevented the formation of diatom blooms but stimulated flagellate blooms in the lower estuary. They propose that this occurs because diatoms preferentially utilize ammonium in their physiological processes even though it is used less efficiently and, at high concentrations, ammonium can prevent uptake of nitrate (Dugdale *et al.* 2007). Thus, diatom populations must consume available ammonium before nitrate, which supports higher growth rates, can be utilized or concentrations of ammonium need to be diluted. A recent independent review panel (Reed *et al.* 2014) found that there is good evidence for preferential uptake of ammonium and sequential uptake of first ammonium and then nitrate, but that a large amount of uncertainty remains regarding the growth rates on ammonium relative to nitrate and the role of ammonium in suppressing spring blooms." The IEP (2015) further discussed this issue as follows: "Glibert (2011) analyzed long-term data (from 1975 or 1979 to 2006 depending on the variable considered) from the Delta and Suisun Bay and related changing forms and ratios of nutrients, particularly changes in ammonium, to declines in diatoms and increases in flagellates and cyanobacteria. Similar shifts in species composition were noted by Brown (2009), with loss of diatom species, such as *Thalassiosira* sp., an important food for calanoid copepods, including *Eurytemora affinis* and *Sinocalanus doerri* (Orsi 1995). More recently, Parker *et al.* (2012) found that the region where blooms are suppressed extends upstream into the Sacramento River to the SRWTP, the source of the majority of the ammonium in the river (Jassby 2008). Parker *et al.* (2012) found that at high ambient ammonium concentrations, river phytoplankton cannot efficiently take up any form of nitrogen including ammonium, leading to often extremely low biomass in the river. A study using multiple stable isotope tracers (Lehman *et al.* 2014) found that the cyanobacterium *M. aeruginosa* utilized ammonium, not nitrate, as the primary source of nitrogen in the central and western Delta. In 2009, the ammonia concentration in effluent from

SRWTP was reduced by approximately 10%, due to changes in operation (K. Ohlinger, Sacramento Regional County Sanitation District, personal communication). In spring 2010, unusually strong spring diatom blooms were observed in Suisun Bay that co-occurred with low ammonia concentrations (Dugdale *et al.* 2013).

Ammonia discharge concerns have also been expressed with respect to the City of Stockton Regional Water Quality Control Plant, but its remoteness from the parts of the estuary frequented by delta smelt and its recent upgrades suggest it is not a significant concern for delta smelt.

Other future, non-Federal actions within the Action Area that are likely to occur and may adversely affect delta smelt and their critical habitat include: the dumping of domestic and industrial garbage that decreases water quality; oil and gas development and production that may affect aquatic habitat and may introduce pollutants into the water; and State or local levee maintenance that may also destroy or adversely affect habitat and interfere with natural, long-term habitat-maintaining processes.

Recreational Uses

Increased urbanization is also expected to result in increased recreational activities in the Action Area. Recreational activities, such as the construction and maintenance of golf courses reduce habitat and introduce pesticides and herbicides into the aquatic environment. The Delta, Yolo Bypass, and Suisun Marsh contain numerous parks, extensive public lands, and many interconnected rivers, sloughs, and other waterways that offer diverse recreation opportunities. Privately owned commercial marinas and resorts allow for boating access to the waterways and a variety of other recreational opportunities and services. Private lands also provide several recreational opportunities, particularly hunting.

The Delta is a regional destination for water-based recreationists because of its climatic conditions, variety and abundance of fish, large maze of navigable waterways, and favorable water levels during summer when most regional reservoirs experience substantial drawdown. Activities in the Delta include cruising, waterskiing, wakeboarding, using personal watercraft, sailing, windsurfing, and kiteboarding, as well as fishing and hunting (from land and by boat). Non-powered boating activities in the Delta include sailing, windsurfing, kiteboarding, canoeing, and kayaking.

Hunting has long been a recreational activity in the Delta, with waterfowl hunting being the primary type. Hunting by boat (typically used as a floating blind) is popular at the larger flooded islands, such as Franks Tract and Sherman Island, because hunters seek open, shallow waters and marsh areas where waterfowl congregate (California Department of Boating and Waterways 2003). Licenses and duck stamps to hunt waterfowl are required by the CDFW and the Service. CDFW manages hunting in California, including the public hunting programs at Sherman Island and other smaller wildlife areas. The California Department of Parks and Recreation allow hunting at Franks Tract, designated as Franks Tract State Recreation Area. Boat hunting is also allowed at Big Break, which is managed by the East Bay Regional Park District (Delta Protection Commission 1997). Late fall through early winter is the designated waterfowl hunting season; starting and ending dates vary each year by species and by hunting method.

Suisun Marsh has historically been a popular duck hunting location; around 1880, the first private duck clubs were established in the marsh, and by 1930, the primary use of Suisun Marsh was waterfowl hunting (DWR 2000). Duck hunting continues to be a use of Suisun Marsh, with 158 private duck clubs located over 52,000 acres in the marsh. These clubs are managed for waterfowl habitat; the wetlands are flooded to coincide with waterfowl season (DWR 2009a, 2011).

Most of the 370 water diversions operating in Suisun Marsh supply water to waterfowl hunting clubs and are unscreened (Herren and Kawasaki 2001). However, the SWP's Roaring River and MIDS diverts most of the water into the marsh. Water is subsequently redistributed further by the many smaller diversions. Roaring River is screened while Morrow Island is not; however, delta smelt entrainment into the MIDS is low due to high salinity in western Suisun Marsh (Enos *et al.* 2007).

Greenhouse Gas Emissions

There is an international scientific consensus that most of the warming observed has been caused by human activities (IPCC 2001; IPCC 2007a; IPCC. *2*007b), and that it is "very likely" that it is largely due to man-made emissions of carbon dioxide and other greenhouse gases in the atmosphere as a result of human activities, particularly carbon dioxide emissions from use of fossil fuels (IPCC 2007b; Solomon *et al.* 2009). Further confirmation of the role of GHGs comes from analyses by Huber and Knutti (2011), who concluded it is extremely likely that approximately 75 percent of global warming since 1950 has been caused by human activities. Scientific measurements spanning several decades demonstrate that changes in climate are occurring, and that the rate of change has increased since the 1950s. Examples include warming of the global climate system, and substantial increases in precipitation in some regions of the world and decreases in other regions (for these and other examples, see Solomon *et al.* 20092009; IPCC 2014).

Scientists use a variety of climate models, which include consideration of natural processes and variability, as well as various scenarios of potential levels and timing of GHG emissions, to evaluate the causes of changes already observed and to project future changes in temperature and other climate conditions (Meehl *et al.* 2007; Ganguly *et al.* 2009). All combinations of models and emissions scenarios yield very similar projections of increases in the most common measure of climate change, average global surface temperature until about 2030. Although projections of the magnitude and rate of warming differ after about 2030, the overall trajectory of all the projections is one of increasing global warming through the end of this century, even for the projections based on scenarios that assume that GHG emissions will stabilize or decline. Thus, there is strong scientific support for projections that warming will continue through the 21st century, and that the magnitude and rate of change will be influenced substantially by the extent of GHG emissions (Meehl *et al.* 2007; Ganguly *et al.* 2009; IPCC 2014).

Ongoing climate change (lnkley *et al.* 2004; IPCC 2007a, b) will likely adversely affect delta smelt, since climate change will likely result in sea level changes and overall wet and dry cycles, it may result in changes to availability and distribution of habitat and prey, and/or increase numbers of predators, parasites, diseases, and non-native competitors. For the endemic delta smelt, a changing climate may result in range shifts precluded by lack of habitat. For additional information on climate change as it relates to delta smelt, see *Status of the Species Within the Action Area*.

Summary of the Cumulative Effects to Delta Smelt

Cumulative effects to delta smelt within the Action Area include: agricultural practices; recreational uses; urbanization and industrialism - commercial and private; and greenhouse gas emissions. Water diversions for irrigated agriculture, municipal and industrial use, and managed wetlands are found throughout the Action Area, and many of them remain unscreened. Most diversions of any substantial size are routinely screened through consultation with the Service. Private irrigation diversions in the Delta are mostly unscreened; however, the vast majority of private unscreened diversions in the Action Area are small pipes in large channels that operate intermittently, and mainly during the spring and summer. As a result, even where they do regularly co-occur with these diversions, delta smelt appear to have low vulnerability to entrainment (Nobriga *et al.* 2004).

With the projected growth rate of 1.2% annually through 2030, we can expect to observe future increases in urbanization and housing developments that may ultimately lead to the destruction of or adverse effects to delta smelt spawning or rearing habitat and interfere with natural, long-term spawning habitat-maintaining processes (California Department of Finance 2012).

Delta smelt's exposure to contaminants are inherent in the Delta, ranging in degree of effects. Sources of introduction vary from agricultural use pesticide runoff to urban wastewater treatment discharge, and other potential sources. Implicated as potential stressors to delta smelt, these contaminants may adversely affect delta smelt reproductive success, survival rates, and food supply.

Greenhouse gas emissions leading to climate change and sea-level rise are likely already effecting delta smelt and its habitat. Ongoing climate change as a result of human activities likely imperils delta smelt and the resources necessary for its survival, since climate change threatens to disrupt annual weather patterns, affecting availability and distribution of habitats and/or food base, and/or increase numbers of predators, parasites, diseases, and non-native competitors. In an isolated population such as that of the delta smelt, a changing climate may result in local extinction, with range shifts precluded by lack of habitat.

Summary of the Cumulative Effects to Critical Habitat

Agriculture, urbanization and climate change are most likely to affect critical habitat. PCE 2 (Water Quality) impairment is likely to continue or increase due to agriculture irrigation and municipal waste water discharge which introduces nutrients and pesticides into the watershed. Water temperatures, influenced by warming air temperatures from climate change, are expected to rise. Delta smelt is currently at the southern limit of the inland distribution of the family Osmeridae along the Pacific Coast of North America and is living in an environment that is energetically stressful. Thus, increased water temperatures associated with climate change may present a significant conservation challenge. PCE 3 (River flow) reductions and the associated PCE 4 (Salinity) intrusion will increase as human population growth places additional demands on water resources and less freshwater will available to maintain the LSZ at a suitable location particularly for juvenile rearing habitat. Climate change will also alter the timing and form of precipitation (rain or snow) in the watershed depending on latitude. Sea level rise will likely influence saltwater intrusion into the Bay-Delta. Elevated salinity could push X2 farther up the estuary with mean values increasing by about 7 km by 2100 (Brown *et al*. 2013). The status of critical habitat (PCEs 2, 3, and 4) will likely be degraded by each of these cumulative effects in the early long-term.

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