Appendix 3.D

Monitoring and Research Actions

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Acronyms and Abbreviations

BDCP or the Plan	Bay Delta Conservation Plan
BMP	best management practices
CDFW	California Department of Fish and Wildlife
CM	conservation measure
DISDON	dual-frequency identification sonar
DO	dissolved oxygen
DWR	California Department of Water Resources
DWSC	deep water ship channel
GIS	geographic information systems
IAV	invasive aquatic vegetation
NPDES	National Pollutant Discharge Elimination System
TMDL	total maximum daily load

Appendix 3.D
Monitoring and Research Actions

This appendix provides a comprehensive list of compliance and effectiveness monitoring actions and research actions applicable to the 22 conservation measures. In most cases, the actions are in a conceptual state that will require development of detailed monitoring protocols. These protocols will include monitoring techniques, measurement and data collection standards, monitoring frequencies, and data management standards. Details of each monitoring action, including monitoring protocols, will be developed during the permit term by the Adaptive Management Team.

3.D.1 Compliance Monitoring Actions

Table 3.D-1 lists compliance monitoring actions identified for the BDCP by conservation measure. Compliance monitoring is intended to verify that the conservation measures are implemented as required pursuant to BDCP permits and authorizations. Fulfillment of compliance monitoring and reporting requirements is the responsibility of the Implementation Office.

Many of these compliance monitoring actions are associated with construction activities and will be undertaken in concert with compliance monitoring for other environmental permits required by the construction actions. Additional monitoring associated with construction activities (i.e., construction monitoring) is described in Appendix 3.C, *Avoidance and Minimization Measures*.

Table 3.D-1. Compliance Monitoring Actions

Conservation Measure	Compliance Monitoring Action	Existing Program[a]	Timing/Duration
CM1 Water Facilities and Operation	Construction: Document compliance with fish screen design criteria.	N/A	Prior to construction and as-built
CM1 Water Facilities and Operation	Document compliance with the operational criteria with reference to existing environmental monitoring programs including: • Interagency Ecological Program's Environmental Monitoring Program: Continuous Multi-Parameter Monitoring, Discrete Physical/Chemical Water Quality Sampling) • DWR and Bureau of Reclamation: Continuous Recorder Sites • Central Valley Water Board: NPDES Self Monitoring Program • U.S. Geological Survey: Delta Flows Network and National Water Quality Assessment Program	• Continuous Multi-parameter Monitoring, Discrete Physical/ Chemical Water Quality Sampling (Interagency Ecological Program's Environmental Monitoring Program)[b] • Continuous Recorder Sites (DWR, Bureau of Reclamation)[c] • NPDES Self Monitoring Program (Central Valley Water Board)[d] • Delta Flows Network and National Water Quality Assessment Program (U.S. Geological Survey)[b] • Other (e.g., DWR, Sacramento Coordinated Monitoring Program, Surface Water Ambient Monitoring Program [SWAMP], Central Valley Water Board, State Water Board, San Francisco Estuary Institute)[d]	Start prior to construction of water diversion facilities and continue for the duration of the Plan
CM1 Water Facilities and Operation	Document compliance with the operational criteria using flow monitoring and models implemented by the Implementation Office. [*Details of monitoring to be developed; must be consistent with data structures supporting real-time operations.*]	N/A	Start prior to completion of water diversion facilities and continue for the duration of the Plan.

Conservation Measure	Compliance Monitoring Action	Existing Program[a]	Timing/Duration
CM1 Water Facilities and Operation	Hydraulic field evaluations to measure velocities over a designated grid in front of each screen panel. Repeat as necessary to set initial baffle positions and confirm compliance with design criteria. This monitoring will be conducted at diversion rates close to maximum diversion rate. Locations of monitoring points, monitoring technology, and frequency/duration of monitoring are to be determined after baffling design is complete but prior to facility operations (same as postconstruction study 1, *Hydraulic Screen Evaluations to Set Baffles* [Fish Facilities Technical Team 2013]).	N/A	Initial studies require approximately 3 months beginning with initial facility operations
CM1 Water Facilities and Operation	Confirm screen operation produces approach velocities no greater than 0.33 foot per second in daytime and 0.2 foot per second at night when delta smelt are present [*indicator of smelt presence to be determined*]. Confirm screen operation produces sweeping velocities greater than or equal to approach velocities. Measure flow velocities within refugia. Approach and sweeping velocities will be measured within 12 inches outside of the screen face to account for boundary effects. This monitoring should be performed to evaluate the range of river stages accounting for the majority of total flow variability and should evaluate both clean and dirty screens at a representative range of river stages. Once compliance has been demonstrated, monitoring may cease. Monitoring should be repeated following any changes to the screens (other than cleaning) that the Adaptive Management Team determines may alter approach or sweeping velocities (seems to be same as postconstruction study 2, *Long-term Hydraulic Screen Evaluations*, combined with study 4, *Velocity Measurement Evaluations* [Fish Facilities Technical Team 2013]).	N/A	Approximately 6 months beginning with initial facility operations
CM2 Yolo Bypass Fisheries Enhancement	Construction: Document in design and as-built reports compliance with Fremont Weir design criteria.	N/A	Prior to construction and as-built

Conservation Measure	Compliance Monitoring Action	Existing Program[a]	Timing/Duration
CM2 Yolo Bypass Fisheries Enhancement	Construction: Document in design and as-built reports compliance with experimental sturgeon ramps.	N/A	Prior to construction and as-built
CM2 Yolo Bypass Fisheries Enhancement	Construction: Document in design and as-built reports compliance with Tule Canal/Toe Drain improvements plan.	N/A	Prior to construction and as-built
CM2 Yolo Bypass Fisheries Enhancement	Construction: Document in design and as-built reports compliance with Sacramento Weir fish passage modification plan.	N/A	Prior to construction and as-built
CM2 Yolo Bypass Fisheries Enhancement	Construction: Document in design and as-built reports compliance with proposed modifications to berms, levees, and water control structures	N/A	Prior to construction and as-built
CM2 Yolo Bypass Fisheries Enhancement	Construction: Document in design and as-built reports compliance with realignment of Lower Putah Creek plan.	N/A	Prior to construction and as-built
CM2 Yolo Bypass Fisheries Enhancement	Operation: Document that flow over Fremont Weir meets flow requirements (details in Chapter 6, *Plan Implementation*)	• DWR/North Central Region Office river stage monitoring gages[b] • N/A	During overflow at Fremont Weir and periods when Fremont Weir is designed to flood, for the duration of the permit term
CM2 Yolo Bypass Fisheries Enhancement	Operation: Document that flow in Tule Canal/Toe Drain meets operational requirements (details in Chapter 6, *Plan Implementation*)	N/A	Prior to completing modifications to the facilities; continue for duration of the BDCP
CM2 Yolo Bypass Fisheries Enhancement	Site-level assessment—plankton and invertebrate sampling: Assess increases in plankton and invertebrate abundance, and transport of plankton and invertebrates off of Yolo Bypass to areas occupied by delta smelt.	N/A	Every 5 years after modifications to Fremont Weir are completed
CM2 Yolo Bypass Fisheries Enhancement	Site-level assessment: Assess use of Yolo Bypass by covered fish species.	N/A	Monthly seine/net surveys between November 10 and May 15 through year 15

Conservation Measure	Compliance Monitoring Action	Existing Program[a]	Timing/Duration
CM2 Yolo Bypass Fisheries Enhancement	Site-level assessment: Assess upstream and downstream fish passage at Fremont Weir.	N/A	Pit tag and other suitable techniques/studies of covered juvenile fish (primarily salmonids as well as lamprey) downstream migration past Fremont Weir, as well as upstream passage of covered adult fish past Fremont Weir (primarily salmonids, sturgeon and lamprey). Monitoring to occur for a period of 5 years, once Fremont Weir modifications are completed. Monitoring will track adult juvenile migration through Yolo Bypass, between Fremont Weir and Cache Slough.
CM3 Natural Communities Protection and Restoration	Document the acquisition or protection of each natural community in a GIS database and track relative to loss.	N/A	Following first acquisition and updated annually
CM4 Tidal Natural Communities Restoration	Document restoration of tidal habitat suitable for covered fish species using a GIS database to map habitat restored for each covered species life stage, using as-built bathymetry, substrate (assessed before levee breaching), and water quality parameters.	• California Bay Delta Authority Science Program—Integrated Regional Wetlands Monitoring (historical pilot program)[d]	Within one year of completing restoration construction for a given site
CM4 Tidal Natural Communities Restoration	Document acquisition or protection of edge habitat in tidal mudflats suitable for associated species (e.g., Delta tule pea, Suisun marsh aster), using a GIS database to track linear miles of tidal marsh edge habitat in the reserve system.	N/A	Following first acquisition and updated annually

Conservation Measure	Compliance Monitoring Action	Existing Program[a]	Timing/Duration
CM5 Seasonally Inundated Floodplain Restoration	Document in a GIS database the extent of floodplain successfully restored by installing and monitoring automated monitoring devices or other appropriate measures to determine inundation depth, stage, and frequency. Obtain data from Integrated Regional Wetlands Monitoring, as relevant. Based on physical data, estimate amount of floodplain restored for each covered species expected to use area.	N/A	Prior to floodplain restoration and annually for the first 5 years following restoration actions
CM6 Channel Margin Enhancement	Delineate extent of channel margin enhanced to provide habitat for covered species using a GIS database. Quantify habitat restored for each covered species expected to use natural community, based on habitat models.	N/A	Annually for the first 5 years following restoration actions
CM7 Riparian Natural Community Restoration	Document the extent of riparian natural community restored in GIS database. Map habitat restored for each covered species expected to use natural community, based on habitat models.	N/A	Annually first 5 years following the riparian restoration projects and every 5 years thereafter
CM8 Grassland Natural Community Restoration	Document the extent of grassland habitat restored in GIS database. Map habitat restored for each covered species expected to use natural community, based on habitat models.	N/A	Annually for the first 5 years following the implementation of individual grassland restoration projects
CM9 Vernal Pool and Alkali Seasonal Wetland Complex Restoration	Document the extent of vernal pool complex restored in a GIS database. Map habitat restored for each covered species expected to use natural community, based on habitat models.	N/A	Following first restoration project and updated annually
CM10 Nontidal Marsh Restoration	Document the extent of nontidal marsh restored in GIS database. Map habitat restored for each covered species expected to use natural community, based on habitat models.	N/A	Following first restoration project and updated annually
CM11 Natural Communities Enhancement and Management	List management actions that occurred in each unit of the reserve system as part of annual report. Document that required Site-Specific Management Plans were prepared as required.	N/A	Annually

Conservation Measure	Compliance Monitoring Action	Existing Program[a]	Timing/Duration
CM11 Natural Communities Enhancement and Management	Document that required site-specific management plans were developed.		By completion of each restoration project.
CM12 Methylmercury Management	Document completion and implementation of site-specific methylmercury management plans for restoration sites.	• Central Valley Water Board total maximum daily load (TMDL) control studies	Within 1 year of each restoration action in which methylmercury management is applied
CM13 Invasive Aquatic Vegetation Control	Document funding provided for IAV control measures. Document areas, type, and extent of control actions in project GIS system. Maintain permanent collection of plans showing proposed and executed control actions.	N/A	Annually
CM14 Stockton Deep Water Ship Channel Dissolved Oxygen Levels	Document funding and operation of the dissolved oxygen facility in the Stockton Deep Water Ship Channel.	• DWR's Stockton Deep Water Ship Channel Demonstration Dissolved Oxygen Project, Bay-Delta Office[c]	Within one year of receiving program funding and annually thereafter
CM15 Localized Reduction of Predatory Fishes	Document progress of the pilot program and research actions in annual adaptive management and monitoring reports.	• Interagency Ecological Program fish predator control studies[b]	Within 1 year of funding and annually thereafter
CM16 Nonphysical Fish Barriers	Document the installation and operation of nonphysical fish barriers in a database that tracks seasonal operation and cost.	• 2009 pilot study (Bowen et al. 2009)[d] • Georgiana Slough Non-Physical Barrier Performance Evaluation Project (DWR 2012) • Various research data[d]	Ongoing as barriers are installed for the duration of the BDCP
CM17 Illegal Harvest Reduction	Document funding and actual costs to provide for required CDFW staff serving in the Plan Area.	N/A	Annually
CM17 Illegal Harvest Reduction	Determine and report compliance ratios in routine enforcement activities including the number of contacts with the public and number of warnings and citations issued per year.	N/A	Annually
CM18 Conservation Hatcheries	Document construction and operation of facilities to expand the refugial population of delta smelt and to establish a refugial population of longfin smelt at the University of California, Davis Fish Conservation and Culture Laboratory.	N/A	Annually

Conservation Measure	Compliance Monitoring Action	Existing Program[a]	Timing/Duration
CM19 Urban Stormwater Treatment	Document funding made available and provided to the Sacramento Stormwater Quality Partnership and/or jurisdictions in the Delta watershed, and how funding was used to support goals of conservation measure.	N/A	Upon request and then annually until funds are exhausted
CM20 Recreational Users Invasive Species Program	Document funding provided to the CDFW Watercraft Inspection Program in the Delta and how funding was spent to support goals of conservation measure.	N/A	Annually
CM21 Nonproject Diversions	Document funding made available, notification and selection process for grants to landowners and water agencies, participation in program, and projects built to reduce covered fish species entrainment.	N/A	Annually
CM22 Avoidance and Minimization Measures	Preconstruction Surveys: Conduct surveys for covered species and prepare reports to document methods and results.	N/A	Preconstruction
CM22 Avoidance and Minimization Measures	Construction: Document compliance with best management practices (BMPs) associated with construction activities by deploying a biological monitor to determine that construction BMPs are implemented following CM22 requirements, and prepare monitoring reports.	N/A	During construction
CM22 Avoidance and Minimization Measures	In the annual progress report, summarize the prior year's compliance monitoring results in support of implementing avoidance and minimization measures required under CM22.	N/A	Annually

[a] These existing programs will supplement programs proposed under the BDCP.

[b] Important and directly related to the BDCP goals and objectives and included in the cost assumptions.

[c] Important and directly related to the BDCP goals and objectives.

[d] Will provide beneficial information, but not directly related to the BDCP goals and objectives.

N/A = Not applicable; all compliance monitoring will be implemented by programs proposed under the BDCP.

3.D.2 Effectiveness Monitoring Actions

Table 3.D-2 identifies effectiveness monitoring actions. These actions serve one of two purposes: to measure progress in attainment of one or more biological goals and objectives or to track population status and trends.

Precise details of each of the effectiveness monitoring actions are not presented here and will be developed and then periodically updated through the adaptive management and monitoring program (Chapter 3, Section 3.6). Where possible, existing protocols will be used so that results can be compared and integrated with those from other monitoring programs, such as those used in neighboring habitat conservation plans, natural community conservation plans, or other conservation efforts within the range of the covered species.

Progress toward meeting the biological goals and objectives, including results of effectiveness monitoring actions, will be presented in annual reporting as described in Chapter 6, Section 6.3.3, *Annual Progress Report.* That section states (in part) that the report will include an evaluation of the results of monitoring and research activities, including descriptions of ecosystem/landscape-scale, natural community, and species monitoring activities conducted during the reporting period, and a summary of monitoring results with appropriate assessment of population trends and status of covered species.

1 **Table 3.D-2. Effectiveness Monitoring Actions**

Conservation Measure	Effectiveness Monitoring Action(s)	Metric	Success Criteria	Timing and Duration
CM1 Water Facilities and Operation	Perform visual inspections (diver and/or camera) to evaluate effectiveness of cleaning mechanism and screen integrity. Determine whether cleaning mechanism is effective at protecting the structural integrity of the screen and maintaining uniform flow distribution through the screen. Adjust cleaning intervals as needed to meet requirements. (same as postconstruction study 3, *Periodic Visual Inspections* [Fish Facilities Technical Team 2013]).	To be determined	Cleaning mechanism is effective at protecting the structural integrity of the screen and maintaining uniform flow distribution through the screen	Initial study to occur during first year of facility operation with periodic reevaluation over life of project.
CM1 Water Facilities and Operation	Monitor refugia to evaluate effectiveness relative to design expectations. Method is likely to entail use of a Didson camera to observe fish behavior within refugia, but more specific monitoring protocols and performance metrics are to be developed once refugia design has been completed, and prior to facility operation. Monitoring will evaluate refugia operation at a range of river stages and with regard to target species or agreed proxies. Once compliance has been demonstrated, monitoring may cease. Monitoring will be repeated following any changes to the refugia that may be prescribed in the course of adaptive management (same as postconstruction study 5, *Refugia Effectiveness* [Fish Facilities Technical Team 2013]).	To be determined	To be determined	Approximately 6 months beginning with initial facility operations.

Conservation Measure	Effectiveness Monitoring Action(s)	Metric	Success Criteria	Timing and Duration
CM1 Water Facilities and Operation	Observe fish activity at screen face (using Didson cameras or other technology to be determined prior to facility operations) and use mark/recapture study of salmonid and smelt proxy fishes to evaluate impingement injury rate. Performance metrics to be determined prior to study initiation (same as postconstruction study 7, *Evaluation of Screen Impingement* [Fish Facilities Technical Team 2013]).	To be determined	To be determined	Study to be performed at varied river stages and diversion rates, during first 2 years of facility operation
CM1 Water Facilities and Operation	Determine overall impact on survival of juvenile salmonids throughout the diversion reach related to the operation of the new facilities. Use mark/ recapture and acoustic telemetry studies (or other technology to be determined prior to facility operations) to evaluate any impacts of facility operations on juvenile salmonids, under various pumping rates and flow conditions, to insure that the survival objectives for juvenile salmonids traversing the diversion reach are being met.	Survival through diversion reach	Survival of at least 95% of outmigrant juveniles entering the reach (0.25 mile upstream of the upstream intake), measured 0.25 mile downstream of the downstream intake	Study to be performed at varied river flows and diversion rates, during first 2 to 5 years of facility operation
CM1 Water Facilities and Operation	Measure entrainment rates at screens using fyke nets located behind screens. Identify species and size of entrained organisms. Use trawl surveys in channel to calibrate density of entrained organisms. Performance metrics to be determined prior to study initiation (same as postconstruction study 8, *Screen Entrainment* [Fish Facilities Technical Team 2013], but with addition of trawl surveys).	To be determined	To be determined	Study to be performed at varied river stages and diversion rates, during first 2 years of facility operation

Conservation Measure	Effectiveness Monitoring Action(s)	Metric	Success Criteria	Timing and Duration
CM2 Yolo Bypass Fisheries Enhancement	Measure passage delays in Yolo Bypass and other anthropogenic barriers and impediments (i.e., Sacramento and Stockton Deep Water Ship Channel, Delta Cross Channel) using methods such as Dual-Frequency Identification Sonar (DISDON) or other suitable method to observe fish behavior at barriers.	To be determined following selection of methodology	Reduced delay in Yolo Bypass and other anthropogenic barriers and impediments (i.e., Sacramento and Stockton Deep Water Ship Channel, Delta Cross Channel)	Annually through year 15
CM2 Yolo Bypass Fisheries Enhancement	Annually assess juvenile salmonid through-Delta survival and/or continue conducting studies assessing juvenile growth rates using hatchery origin juvenile salmonids. Begin monitoring upon final BDCP permit authorization and continue through year 15. Report results in annual progress report.	To be determined following selection of methodology	Performance consistent with juvenile steelhead survival target set by objective STHD1.1	Annually through year 15
CM2 Yolo Bypass Fisheries Enhancement	Assess the abundance of Sacramento splittail as part of the fall midwater trawl and evaluate the response of the population to habitat restoration actions, particularly CM2, *CM4 Tidal Natural Communities Restoration*, and *CM5 Seasonally Inundated Floodplain Restoration.*	To be determined following selection of methodology	Performance consistent with Sacramento splittail abundance target set by objective SAST1.1	Annually through year 15; at the 15-year milestone, assess whether the objective has been met and present the agencies with the plan for continued monitoring (annual, every-other-year, every 5 years)
CM3 Natural Communities Protection and Restoration	Record, quantify and delineate occurrences of covered plant species and rare alliances.	Location and numbers of plants, location and area of rare alliances	Presence of covered plant species and rare plant alliances	Every 5 years
CM3 Natural Communities Protection and Restoration	Document habitat connectivity among reserve units in the reserve system.	Reserve connectivity	Connection between BDCP reserves, or between existing conservation lands and BDCP reserves	Annual assessment of lands added to reserve system

Conservation Measure	Effectiveness Monitoring Action(s)	Metric	Success Criteria	Timing and Duration
CM4 Tidal Natural Communities Restoration	Conduct a site-level assessment of bathymetry and topography.	Tidal elevations and flooding frequency	Gradual transition in elevation and hydrology, from subtidal areas, to marsh plain, to ecotonal areas and adjacent uplands	Annually for first 5 years after restoration
CM4 Tidal Natural Communities Restoration	Conduct a site-level assessment of warm-season dissolved oxygen concentrations.	Water quality	Maintenance of high warm-weather dissolved oxygen concentrations and temperatures comparable to seasonal norms for the region.	Annually for first 5 years after restoration
CM4 Tidal Natural Communities Restoration	Conduct a site-level assessment of use by native and nonnative fishes.	Use of restoration sites by covered fish species	Detection of site use by Chinook salmon, splittail, and the following covered fish species: longfin smelt and delta smelt in the Suisun Marsh, West Delta and Cache Slough Restoration Opportunity Areas (ROAs); steelhead in the West Delta, Cache Slough and Cosumnes/Mokelumne ROAs	Monthly seine/net surveys during one water year between the second and fifth year following restoration site construction. Existing studies/ monitoring efforts (i.e., fall midwater trawl, zooplankton study) will be used to track larger, emergent trends in abundance of covered fish and important foodweb species, such as zooplankton.
CM4 Tidal Natural Communities Restoration	Conduct a site-level assessment of channel morphology.	Tidal natural community geomorphology	Presence of sinuous, high-density, dendritic networks of tidal channels through tidal areas	As specified in site-specific restoration plans

Conservation Measure	Effectiveness Monitoring Action(s)	Metric	Success Criteria	Timing and Duration
CM4 Tidal Natural Communities Restoration	Conduct plankton and invertebrate sampling in restored tidal natural communities.	Plankton and invertebrate abundance in restored floodplain	Presence within and transport from restored tidal natural communities to adjacent open-water habitat occupied by covered fish species	Every 5 years following floodplain restoration until end of permit term
CM4 Tidal Natural Communities Restoration	Vegetation sampling	Vegetation composition, diversity, and structural complexity	Reflective of historic conditions. Comparable to natural, undisturbed reference sites or based on historical ecology studies such as Beagle et al. 2012	As specified in site-specific restoration plans
CM4 Tidal Natural Communities Restoration	Population Sampling	Livetrap capture efficiency	Criteria provided under *Siting and Design Considerations for Covered Species, Salt Marsh Harvest Mouse*, in Chapter 3, Section 3.4.4.3.4	Every 5 years until capture efficiency targets have been met at least twice
CM4 Tidal Natural Communities Restoration	Vegetation Sampling	Salt marsh harvest mouse "Viable Habitat Areas," as defined in the final *Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California* (U.S. Fish and Wildlife Service in prep.)	Criteria to be provided in the final *Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California* (U.S. Fish and Wildlife Service in prep.)	Sampling prior to subsequent phasing to ensure initial or previous restoration is successful before initiating subsequent phases
CM4 Tidal Natural Communities Restoration	Site level assessments	Parameters described in Chapter 3, Section 3.4.4.3.4, *Siting and Design Considerations, Covered Species, Giant Garter Snake*	Criteria provided in Chapter 3, Section 3.4.4.3.4, *Siting and Design Considerations, Covered Species, Giant Garter Snake*	As specified in site-specific restoration plans
CM4 Tidal Natural Communities Restoration	Site-level assessments	Extent and population size of all Suisun thistle occurrences and those soft bird's-beak occurrences in proximity to tidal restoration sites	Stable or increasing	Every 3 years after tidal restoration or until success criterion is met if adaptive action is required

Conservation Measure	Effectiveness Monitoring Action(s)	Metric	Success Criteria	Timing and Duration
CM5 Seasonally Inundated Floodplain Restoration	Site-level assessment	Floodplain elevations and flooding frequency and duration	A range of elevations that transition from frequently flooded (e.g., every 1 to 2 years) to infrequently flooded (e.g., every 10 years or more)	Annually for first 5 years after floodplain restoration and every 5 years thereafter until the end of the permit term
CM5 Seasonally Inundated Floodplain Restoration	Site-level assessment	Lateral channel migration	Occurrence of lateral channel migration in restored floodplains	Every 5 years following floodplain restoration until end of permit term
CM5 Seasonally Inundated Floodplain Restoration	Site-level assessment	Hydrologic connectivity	As specified in site-specific restoration plan	As specified in site-specific management plan
CM5 Seasonally Inundated Floodplain Restoration	Plankton and invertebrate sampling in restored floodplain, at each restoration site	Plankton and invertebrate presence in restored floodplain (plankton and invertebrate abundance may fluctuate based on predation by juvenile fish, water temperature, and fluctuations in the duration, extent, and frequency of floodplain inundation)	Plankton and invertebrate presence, as well as presence of juvenile fishes that may feed upon them (presence of juvenile fishes may result in decreased plankton and invertebrate abundance [Grosholz and Gallo 2006])	Every 5 years following floodplain restoration until end of permit term
CM5 Seasonally Inundated Floodplain Restoration	Landscape-level assessment of restored floodplains throughout reserve system	Habitat connectivity for covered species	Increased connectivity between primary channels and seasonal floodplains, as well as use by covered species while avoiding stranding of covered fish species	Every 5 years following floodplain restoration until end of permit term

Conservation Measure	Effectiveness Monitoring Action(s)	Metric	Success Criteria	Timing and Duration
CM5 Seasonally Inundated Floodplain Restoration	Frequency, duration, and extent of inundation of restored floodplain in the South Delta	On average, 50 acres of floodplain will be inundated a minimum of every other year, 500 acres will be inundated a minimum of every 5 years, and all 1,000 acres will be inundated a minimum of once every 10 years, by year 15	Inundation for a period of 1 week between December and June	Annually, following floodplain restoration until end of permit term
CM6 Channel Margin Enhancement	Assess whether splittail spawn in enhanced channel margins.	Detection of evidence of splittail spawning	Occurrence of spawning splittail, particularly during dry years when seasonally inundated floodplain habitat may be functioning at capacity	Six times per year for first 5 years after site construction; three times per year every fifth year thereafter
CM6 Channel Margin Enhancement	Assess the extent to which juvenile salmon and splittail hold and forage in enhanced channel margins.	Catch per unit effort for covered fishes in enhanced channel margin sites	Occurrence of juvenile salmonids and splittail during periods of rearing and outmigration in the Plan Area	Up to three times per year for the 2 years prior to construction once a site is identified. Then six times per year for first 5 years after site construction; three times per year every fifth year thereafter
CM6 Channel Margin Enhancement	Assess whether piscivorous predators use woody debris associated with enhanced channel margins as ambush cover.	Catch per unit effort for predators in enhanced channel margin sites	Negligible use of woody debris in channel margins by predators (such as striped and largemouth bass)	Six times per year for first 5 years after site construction; three times per year every fifth year thereafter
CM6 Channel Margin Enhancement	Measure plankton and invertebrate abundance in aquatic habitat within and adjacent to enhanced channel margins.	Laboratory counts of water and seine samples taken in the field	Increased plankton and invertebrate abundance	Six times per year for first 5 years after site construction; three times per year every fifth year thereafter

Conservation Measure	Effectiveness Monitoring Action(s)	Metric	Success Criteria	Timing and Duration
CM6 Channel Margin Enhancement	Evaluate the distribution and abundance of covered fish species and predators at enhancement sites.	To be determined.	Increased distribution and abundance of covered fish species and decreased distribution and abundance of predators at enhancement sites	To be determined.
CM7 Riparian Natural Community Restoration	Conduct landscape-level assessment of restored riparian natural community throughout reserve system.	Covered species habitat connectivity	Increased connectivity between existing patches of riparian natural community	Every 5 years until end of permit term
CM7 Riparian Natural Community Restoration	Conduct vegetation sampling of herbaceous, shrub, and canopy layers for plant community structure.	Structural heterogeneity	As specified in site-specific restoration plan	As specified in site-specific restoration plan
CM7 Riparian Natural Community Restoration	Conduct vegetation sampling of herbaceous, shrub, and canopy layers in restored riparian vegetation for plant community structure in areas targeted for 1,000-acre minimum (locations may shift over time).	Amount of early- to mid-successional riparian vegetation	1,000 acres throughout reserve system	Every 5 years until end of permit term
CM7 Riparian Natural Community Restoration	Conduct vegetation sampling, mapping vegetation based on successional stage, in areas targeted for the 500-acre minimum (locations may shift over time).	Amount of mature riparian forest intermixed with early- to mid-successional riparian vegetation, patch size	500 acres of mature riparian intermixed with early- to mid-successional, in minimum 50-acre blocks	Every 5 years until end of permit term
CM7 Riparian Natural Community Restoration	Vegetation sampling and mapping rare vegetation alliances in representative locations	Amount of rare and uncommon riparian vegetation alliances in the reserve system	Increased acreage	Every 5 years until end of permit term
CM7 Riparian Natural Community Restoration	Vegetation sampling	Vegetation composition and structure	300 acres of suitable riparian brush rabbit habitat as specified in site-specific restoration plan	As specified in site-specific restoration plan
CM7 Riparian Natural Community Restoration	Site-specific assessment	Presence and location of suitable riparian brush rabbit refugia	Suitable refugia not further apart than 20 meters in riparian brush rabbit habitat	Annually for 5 years following creation (thereafter monitored under CM11)

Conservation Measure	Effectiveness Monitoring Action(s)	Metric	Success Criteria	Timing and Duration
CM7 Riparian Natural Community Restoration	Vegetation sampling	Vegetation composition and structure	300 acres of suitable riparian woodrat habitat as specified in site-specific restoration plan	Annually for 5 years following creation (thereafter monitored under CM11)
CM7 Riparian Natural Community Restoration	Site-specific assessment	Presence and location of suitable riparian woodrat refugia	Suitable refugia not further apart than 20 meters in riparian woodrat habitat	Annually for 5 years following creation (thereafter monitored under CM11)
CM8 Grassland Natural Community Restoration	GIS mapping and tracking acreages	Acres successfully restored	1,000 acres restored by year 10 and 2,000 acres (cumulative) restored by year 25	Update maps and acres successfully restored at least once every 5 years
CM8 Grassland Natural Community Restoration	GIS mapping and documenting location relative to reserve system	Location relative to fragmented grassland patches or adjacency to riparian or emergent wetland natural communities	Connectivity with grassland patches and provision of upland adjacent to riparian or emergent wetland natural communities	Update at least once every 5 years
CM8 Grassland Natural Community Restoration	Vegetation sampling	Percent cover of vegetation dominated by species that compose California annual grassland series or native grassland series, as defined by Sawyer and Keeler-Wolf (2009, or latest edition)	Minimum percent cover as defined in site-specific plan	Prior to restoration, and annually for first 5 years or until success criteria are met, whichever is longer
CM8 Grassland Natural Community Restoration	Vegetation sampling	Percent cover of noxious weeds and bare ground	Maximum percent cover as defined in site-specific plan	Prior to restoration, and annually for first 5 years or until success criteria are met, whichever is longer
CM8 Grassland Natural Community Restoration	Vegetation sampling, mapping and tracking acreages	Extent, distribution, and number of native vegetation alliances across the reserve system	Increase	Every 5 years throughout permit term

Conservation Measure	Effectiveness Monitoring Action(s)	Metric	Success Criteria	Timing and Duration
CM8 Grassland Natural Community Restoration	Vegetation sampling	Native species richness and species diversity	Maintain or increase	Every 5 years throughout permit term
CM9 Vernal Pool and Alkali Seasonal Wetland Complex Restoration	Vegetation sampling	Species dominance, percentage of relative cover attributable to native vernal pool species	Dominant species (with a Braun-Blanquet cover scale of 3 or greater) will be "vernal pool indicators," "vernal pool associates," or vernal pool generalists that occur in the reference pools[1] (as specified in site-specific restoration plan and comparable to reference pools)	Annually until success criteria are met, then once every 5 years for 10 years
CM9 Vernal Pool and Alkali Seasonal Wetland Complex Restoration	Monitor hydrology	Pool depth and duration	As specified in site-specific restoration plan and comparable to reference pools	Annually until success criteria are met, then once every 5 years for 10 years
CM9 Vernal Pool and Alkali Seasonal Wetland Complex Restoration	Plant count	Number of individuals	Annual average number of individuals measured over a 5-year period meets or exceeds number necessary for viable population based on best available scientific information	Annually for 10 years or until success criteria are met, whichever is longer
CM10 Nontidal Marsh Restoration	Site-level assessment	Total and relative cover of native, nontidal marsh vegetation within a mosaic of open water	As specified in site-specific restoration plan	As specified in site-specific restoration plan

[1] "Vernal pool indicators" and "vernal pool associates" as defined in CDFW's list: *Catalog of Plant Species Known to be Associated with Vernal Pools* (California Department of Fish and Game 1997) or as native species present in reference pools.

Conservation Measure	Effectiveness Monitoring Action(s)	Metric	Success Criteria	Timing and Duration
CM10 Nontidal Marsh Restoration	Monitor greater sandhill crane use of roost sites in vicinity of covered activities	Presence of roosting cranes	Cranes have not abandoned roost sites	During construction activities in vicinity of roost sites, annually for 3 years after construction is completed, and during the season of expected occupancy every 5 years thereafter
CM11 Natural Communities Enhancement and Management	Vegetation sampling, mapping invasive species infestations	Relative cover of invasive species, presence of infestations that threaten ecosystem and covered species habitat functions	As specified in reserve unit management plan	Within 6 months of site acquisition and every 5 years thereafter
CM11 Natural Communities Enhancement and Management	Site-level assessment	Presence of obstacles to wildlife movement	No significant obstacles to wildlife movement in reserve system	Within 6 months of site acquisition and every 5 years thereafter
CM11 Natural Communities Enhancement and Management	Freshwater emergent wetland vegetation sampling	Freshwater emergent wetland vegetation composition, diversity, and structural complexity	Reflective of historical conditions	Every 5 years after restoration is determined to be successful (See *CM4 Tidal Natural Communities Restoration* regarding restoration success criteria)

Conservation Measure	Effectiveness Monitoring Action(s)	Metric	Success Criteria	Timing and Duration
CM11 Natural Communities Enhancement and Management	Riparian natural community vegetation sampling	Structural heterogeneity, successional stage, patch size, presence of rare and uncommon vegetation alliances	To be determined regarding structural heterogeneity; 1,000 acres early- to mid-successional; 500 acres of mature riparian intermixed with early- to mid-successional, in minimum 50-acre blocks	For protected riparian natural community, within 6 months of site acquisition and every 5 years thereafter. For restoration of riparian natural community, every 5 years after successful restoration (See *CM7 Riparian Natural Community Restoration* regarding restoration success criteria)
CM11 Natural Communities Enhancement and Management	Hydrologic monitoring in alkali seasonal wetlands	Duration of wetland saturation or ponding	Hydrology characteristic of alkali seasonal wetlands supporting a diversity of endemic alkali seasonal wetland species, based on reference wetlands	Within 6 months of site acquisition and every 5 years thereafter
CM11 Natural Communities Enhancement and Management	Vegetation sampling in grasslands	Extent, distribution, and density of native perennial grasses intermingled with other native species, including annual grasses, geophytes, and other	Increase above baseline	Within 6 months of site acquisition and every 5 years thereafter
CM11 Natural Communities Enhancement and Management	Site-level assessment in grasslands	Burrow availability for burrow-dependent species	Increase above baseline	Within 6 months of site acquisition and every 5 years thereafter
CM11 Natural Communities Enhancement and Management	Rodent live trapping and insect sampling, site-level assessment in grasslands	Prey abundance and accessibility (especially small mammals and insects) for grassland-dependent species.	Increase above baseline	Within 6 months of site acquisition and every 5 years thereafter

Conservation Measure	Effectiveness Monitoring Action(s)	Metric	Success Criteria	Timing and Duration
CM11 Natural Communities Enhancement and Management	Hydrologic monitoring in vernal pools	Depth and duration of ponding	Hydrology characteristic of vernal pools supporting a diversity of endemic vernal pool species, based on reference wetlands	Within 6 months of site acquisition and every 5 years thereafter
CM11 Natural Communities Enhancement and Management	Insect sampling in vernal pool complexes	Abundance of native solitary bees and other pollinators	Equal to or greater than baseline	Within 6 months of site acquisition and every 5 years thereafter
CM11 Natural Communities Enhancement and Management	Survey foraging plant density and type	Food biomass density and energetic value	Equal to that which was lost	For 2 years prior to enhancement to determine baseline, for 3 years after enhancement to determine postrestoration condition; and once every 10 years thereafter
CM11 Natural Communities Enhancement and Management	Mapping native grassland vegetation alliances	Distribution and diversity of native grassland vegetation alliances	A mosaic of alliances with consideration of historical sites	Immediately after site acquisition and every 10 years thereafter
CM11 Natural Communities Enhancement and Management	Site-level assessment	Presence of suitable habitat features for riparian brush rabbit, including flood refugia	Meets habitat criteria as defined in *CM7 Riparian Natural Community Restoration* and Appendix 3.E, *Conservation Principles for the Riparian Brush Rabbit & Riparian Woodrat*	Within 6 months of site acquisition of protected habitat or after restoration is determined to be successful for restored habitat, and every 5 years thereafter
CM11 Natural Communities Enhancement and Management	Site level surveys	Presence of feral predators (cats and dogs)	Absent from occupied riparian brush rabbit habitat	Annually in occupied riparian brush rabbit habitat

Conservation Measure	Effectiveness Monitoring Action(s)	Metric	Success Criteria	Timing and Duration
CM11 Natural Communities Enhancement and Management	Site-level assessment	Presence of suitable habitat features for riparian woodrat, including flood refugia	Meets habitat criteria as defined in *CM7 Riparian Natural Community Restoration* and Appendix 3.E, *Conservation Principles for the Riparian Brush Rabbit & Riparian Woodrat*	Within 6 months of site acquisition and every 5 years thereafter
CM11 Natural Communities Enhancement and Management	Vegetation sampling in middle and high brackish marsh	Plant species composition and relative cover	Consistent with "Viable Habitat Areas" for salt marsh harvest mouse defined in the final *Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California* (U.S. Fish and Wildlife Service in prep.)	Within 6 months of successful restoration of tidal brackish emergent wetland or of acquisition of managed wetland for salt marsh harvest mouse, and every 5 years thereafter
CM11 Natural Communities Enhancement and Management	Small mammal live trapping	Salt marsh harvest mouse capture rate	Capture efficiency targets for salt marsh harvest mouse described in the final *Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California* (U.S. Fish and Wildlife Service in prep.)	Within 6 months of acquisition of managed wetland or after restoration of tidal brackish emergent wetland is determined to be successful, and every 5 years thereafter
CM11 Natural Communities Enhancement and Management	Site-level assessment in tricolored blackbird nesting habitat	Age of vegetation	Young, lush stands of emergent vegetation, rather than senescent vegetation	Within 6 months of site acquisition and every 5 years thereafter
CM11 Natural Communities Enhancement and Management	Site-level assessment in occupied Carquinez goldenbush habitat	Erosion and habitat degradation	Reverse any erosion or degradation trends	Within 6 months of site acquisition and every 5 years thereafter

Conservation Measure	Effectiveness Monitoring Action(s)	Metric	Success Criteria	Timing and Duration
CM11 Natural Communities Enhancement and Management	Estimate of delta button celery population size	Population size	Stable or increasing	Within 1 year of determining that each occurrence has been successfully established, and every 5 years thereafter
CM12 Methylmercury Management	Methylmercury	Methylmercury allocations per the Delta Mercury Control Program	Adhere to the numeric targets selected for the load allocation of methylmercury per Resolution No. R5-2010-0043 of the Delta Mercury Control Program.	Monitor methylmercury discharge from wetlands and other aquatic habitats restored as part of BDCP for the permit term.
CM13 Invasive Aquatic Vegetation Control	Delta-wide risk assessment	Substantial site-level impairment of natural community or covered species habitat	Identification of sites meeting metric	Once during first 3 years
CM13 Invasive Aquatic Vegetation Control	Site-level assessment	Amount of IAV	Removal effectiveness in accordance with site treatment plan	1 month, 3 months, and 12 months after treatment
CM13 Invasive Aquatic Vegetation Control	Determine the effectiveness of IAV control actions in reducing predation risk from nonnative predatory fish on covered fish species.	Catch per unit effort for predators in treatment areas before and after treatment	Significant reduction in predators	Twice in the month before and twice in the month after treatment
CM13 Invasive Aquatic Vegetation Control	Conduct surveys to assess new infestations of IAV throughout the Plan Area.	Aerial survey and ground surveys	Low detection rates	10% of aquatic habitat in the Plan Area surveyed each year
CM14 Stockton Deep Water Ship Channel Dissolved Oxygen Levels	Review/evaluate of dissolved oxygen levels at various distances from the diffuser(s).	Dissolved oxygen and possibly water temperature, pH, and oxygen-depleting substances (e.g., 5-day biochemical oxygen demand, volatile suspended solids, chlorophyll a)	Reduction in dissolved oxygen levels in the Stockton Deep Water Ship Channel and in San Joaquin River upstream of the Stockton Deep Water Ship Channel–San Joaquin River confluence	Continuous monitoring at five established water quality monitoring stations, including Turning Basin (TB) and R3 through R6 monitoring stations

Conservation Measure	Effectiveness Monitoring Action(s)	Metric	Success Criteria	Timing and Duration
CM14 Stockton Deep Water Ship Channel Dissolved Oxygen Levels	Site-level assessment of water quality	Dissolved oxygen (DO) concentrations	Achievement of DO concentrations consistent with the DWSC DO total maximum daily load of 6 mg/L from September 1 through November 30 and 5 mg/L at all other times on a year-round basis, particularly from May through October when DO levels have historically fallen below the target levels.	Year-round monitoring of DO concentrations, for the BDCP permit term
CM15 Localized Reduction of Predatory Fishes	Monitor predator distribution and abundance at known predator hotspots to determine effectiveness of implementation actions to reduce potential predation loss.	Catch per unit effort; additional metrics regarding juvenile salmonid survival to be identified during study design	Magnitude and duration of predator reduction	Annually in years 3 through 13; once every 3 years thereafter
CM16 Nonphysical Fish Barriers	Site-Level Assessment	Migration	Monitor the effectiveness of nonphysical fish barriers in deterring juvenile salmonids from migrating into interior Delta and other waterways known to result in reduced survival	Annually for 5 years beginning at permit authorization, reevaluating monitoring needs after year 5
CM17 Illegal Harvest Reduction	Illegal Harvest Tracking	Increase enforcement and track trends in number, types and distribution of citations and arrests associated with illegal harvest made by warden within the Plan Area.	An increase in the abundance of covered salmonids and green and white sturgeon over time.	Year-round enforcement and annual reporting, for the duration of the BDCP permit term.
CM18 Conservation Hatcheries	Monitor smelt genetic diversity to ensure that it is maintained at a level comparable to wild populations.	Methods to be developed in collaboration with fish agency and hatchery staff	Genetic diversity is maintained at a level comparable to wild populations	Ongoing

Conservation Measure	Effectiveness Monitoring Action(s)	Metric	Success Criteria	Timing and Duration
CM19 Urban Stormwater Treatment	Conduct ongoing review of monitoring, progress, and other relevant reports from the stormwater entities.	Decreases in stormwater constituents/pollutant loads such as total suspended sediment, oil and grease, total and dissolved metals (i.e., copper and zinc), pesticides and other toxic chemicals	Reductions in stormwater constituents and pollutant loads within the Plan Area over time	Annual effectiveness monitoring and reporting, performed by the individual stormwater entities, for the duration of the BDCP permit term
CM19 Urban Stormwater Treatment	Fund individual stormwater entities in the Plan Area to implement best management practices (BMPs).	Implement BMPs for urban stormwater runoff through local jurisdictions within the Plan Area (e.g., cities and towns) to achieve compliance with NPDES MS4 and Phase II NPDES MS4 permit conditions	Reductions in pollutant loads in urban stormwater effluent generated by local jurisdictions	Individual stormwater entities will be responsible for performing annual monitoring of BMPs implemented at the local level for the duration of the BDCP permit term.
CM20 Recreational Users Invasive Species Program	Identify the type, distribution, and abundance of aquatic invasive species detected during program implementation.	Lists of detected species, numbers, locations	Measure remains focused on the principal invasive species of concern	Annually
CM21 Nonproject Diversions	Postproject monitoring of active diversions (i.e., they had been screened or otherwise modified, rather than removed)	Estimate of incidental take	Remediated diversion functions as intended, resulting in fewer covered fish entrained at remediated diversions	Until functionality of diversion is verified
IAV = invasive aquatic vegetation				

3.D.3 Research Actions

Table 3.D-3 identifies research actions. Each of these actions serves to address a key uncertainty in the function of an ecosystem or supporting physical process identified in Chapter 3, *Conservation Strategy*, or Chapter 5, *Effects Analysis*.

This is a preliminary list of research actions. It is expected that additional key uncertainties will be identified during Plan implementation. Some are likely to emerge from developing scientific understanding of Bay-Delta ecosystems, while others are likely to emerge from changes in those ecosystems in response to forcing factors such as climate change or new invasive species. These uncertainties will be identified, prioritized, and addressed as described in Chapter 3, Section 3.6, *Adaptive Management and Monitoring Program*.

Activities of the research program will be presented in publications and reports of the program and summarized annually as described in Chapter 6, Section 6.3.3, *Annual Progress Report.* That section states (in part) that each annual progress report will include descriptions of all directed research conducted under the BDCP during the reporting period and a summary of research results to date.

Table 3.D-3. Key Uncertainties, Potential Research Actions, and Relevant Conservation Measures

Relevant Conservation Measure(s)	Key Uncertainty	Potential Research Actions
CM1 Water Facilities and Operation	Are the initial spring outflow criteria (listed in Table 3.4.1-1) necessary, in conjunction with other conservation measures in the Plan, to achieve the biological objectives for covered fish species?	• [Studies necessary to evaluate this uncertainty, which is the root of the spring outflow decision tree, have not yet been determined.]
CM1 Water Facilities and Operation	Is the U.S. Fish and Wildlife Service Reasonable and Prudent Alternative (RPA) for Fall X2 (listed in Table 3.4.1-1) necessary, in conjunction with other conservation measures in the Plan, to achieve the delta smelt biological objectives?	• [Studies necessary to evaluate this uncertainty, which is the root of the fall outflow decision tree, have not yet been determined.]
CM1 Water Facilities and Operation	Relationship between proposed intake design features and expected intake performance relative to minimization of entrainment and impingement risks.	• Develop physical hydraulic model(s). If intake screen locations differ significantly in terms of river flow conditions or structure geometry, then more than one physical model study is needed. A physical model provides the capability to optimize hydraulics and sedimentation in the chosen river reach. Differences between the average channel velocity in the river and sweeping velocity adjacent to the screen face will be identified. Neutrally buoyant particles will be tracked to provide information on larval fish movement (same as preconstruction study 1, *Site Locations Lab Study* [Fish Facilities Technical Team 2013]).
CM1 Water Facilities and Operation	Evaluation of tidal effects and withdrawals on flow conditions at screening locations	• Develop computational fluid dynamics model to provide information on how tidal changes and flow withdrawals affect flow conditions and sweeping velocities at screening locations. Results can be used in "Site Locations Lab Study" to set boundary conditions and validate physical model results (same as preconstruction study 2, *Site Locations Numerical Study* [Fish Facilities Technical Team 2013]).
CM1 Water Facilities and Operation	Design of refugia areas (macro, micro, and base refugia)	• Develop a physical hydraulic model to measure hydraulics and observe fish behavior in a controlled environment. Size/shape of refugia areas can be modified to optimize fish usage. Predators can be added to examine predation behavior near refugia (same as preconstruction study 3, *Refugia Lab Study* [Fish Facilities Technical Team 2013]).

Relevant Conservation Measure(s)	Key Uncertainty	Potential Research Actions
CM1 Water Facilities and Operation	Examination of refugia at future fish screens	• Perform field evaluation of one or more existing (or soon-to-be-completed) fish screening facilities using fish refugia. Use these data to develop understanding of expected effectiveness of fish refugia and to identify areas for improvement (same as preconstruction study 4, *Refugia Field Study* [Fish Facilities Technical Team 2013]).
CM1 Water Facilities and Operation	Characterize the water velocity distribution at river transects within the proposed intake reaches for differing river flow conditions.	• Perform field study to measure water velocity distribution across river transects using acoustic Doppler current profiler and to define velocity conditions at channel boundary. Differences between the average channel velocity in the river and sweeping velocity adjacent to the screen locations need to be identified to properly design the screen for sweeping velocity. Water velocity distributions in intake reaches will identify how hydraulics change with flow rate and tidal cycle (same as preconstruction study 7, *Flow Profiling Field Study* [Fish Facilities Technical Team 2013]).
CM1 Water Facilities and Operation	What are the effects of deep-water screens on hydraulic performance?	• Use computational fluid dynamics model to assist development of baffling systems or other elements to address vertical velocity variations at the screen face (same as preconstruction study 8, *Deep Water Screens Study* [Fish Facilities Technical Team 2013]).
CM1 Water Facilities and Operation	How will the new north Delta intakes affect survival of juvenile salmonids in the affected reach of the Sacramento River?	• Perform mark-and-recapture studies, acoustic telemetry studies, and/or fyke net studies in proposed intake river reaches and control river reaches. Need to collect baseline data at 2 to 3 proposed screen locations and 2 to 3 control reaches. Following initiation of project operations, continue studies using same methodology and same locations. Identify the change in survival rates due to construction/operation of the intakes (same as preconstruction study 10, *Baseline Juvenile Salmon Survival Rates*, and postconstruction study 10, *Post-Construction Juvenile Salmon Survival Rates* [Fish Facilities Technical Team 2013]).
CM1 Water Facilities and Operation	How will the new north Delta intakes affect delta and longfin smelt density and distribution in the affected reach of the Sacramento River?	• Use literature search, then trawling, trapping, and beach seining to collect data on delta and longfin smelt density and distribution within the intake reaches. Also collect data directly upstream and downstream of the intakes and in close proximity to sloughs and channels. Following initiation of diversion operations, continue sampling using same methods and at same locations. Compare to baseline catch data. Identify potential changes due to construction of intakes (same as preconstruction study 11, *Baseline Fish Surveys*, and postconstruction study 11, *Post-Construction Fish Surveys* [Fish Facilities Technical Team 2013]).

Relevant Conservation Measure(s)	Key Uncertainty	Potential Research Actions
CM1 Water Facilities and Operation	What is the relationship between Delta Cross Channel gates' operations, covered fish movement and survival, and tidal flows?	• Document effects of Delta Cross Channel gates' operations on hydrodynamics and fish migration.
CM2 Yolo Bypass Fisheries Enhancement	Do the modifications at Yolo Bypass function as expected, and if so, how effective are they?	• Evaluate the effectiveness of the fish passage gates at Fremont Weir. • Evaluate the effectiveness of the sturgeon ramps. • Determine whether stilling basin modification has reduced stranding risk for covered fishes. • Determine whether Sacramento Weir improvements have benefited fish passage and minimized stranding risk. • Determine effectiveness of Tule Canal/Toe Drain and Lisbon Weir improvements in reducing the delay, stranding, and loss of migrating salmon, steelhead, and sturgeon. • Determine growth rates of juvenile salmonids that have entered the Yolo Bypass during Fremont Weir operation. • Document Sacramento splittail spawning and spawning success in the Yolo Bypass during Fremont Weir operation. • Evaluate whether the Lower Putah Creek realignment has improved upstream and downstream passage by covered fish. • Determine severity of predation effects on covered fish using the Yolo Bypass. • Determine plankton and invertebrate production rates during periods the Fremont Weir is operated.
CM2 Yolo Bypass Fisheries Enhancement	Do increased frequency and duration of flooding in Yolo Bypass affect the health and vigor of elderberry shrubs and other valley/foothill riparian vegetation in the Yolo Bypass?	• Monitor key indices of plant health and vigor for elderberry shrubs and other riparian species at selected sites prior to implementation of CM2, and at regular intervals (to be determined) following Fremont Weir improvements.
CM4 Tidal Natural Communities Restoration	How does tidal marsh restoration affect production of food for covered fish and export of this food to suitable habitat?	• Quantify the primary and secondary production, including food suitable for covered species, both within restored tidal marsh natural communities and transported from restored areas to adjacent open-water habitat and its fate.

Relevant Conservation Measure(s)	Key Uncertainty	Potential Research Actions
CM4 Tidal Natural Communities Restoration	How have hydrodynamic changes associated with tidal restoration affected organic carbon transport and fate?	• Quantify the flux of organic carbon produced in restored tidal marsh plain into existing channels in the Plan Area.
CM4 Tidal Natural Communities Restoration	How has tidal marsh restoration affected benthic invertebrate communities?	• Determine the extent and patterns of establishment of nonnative clams in restored subtidal aquatic habitats. • Document and evaluate water quality conditions in restored subtidal aquatic habitats.
CM4 Tidal Natural Communities Restoration	How are invasive bivalves affecting zooplankton production in restored tidelands?	• Assess density and foraging effectiveness of Asian clams or other invasive species that colonize restoration sites. Periodically repeat surveys to determine if delayed colonization occurs.
CM4 Tidal Natural Communities Restoration	How is temporal habitat loss resulting from tidal natural communities restoration affecting saltmarsh harvest mouse and Suisun shrew?	• On restored tidal brackish marsh, perform a capture and release tagging study to determine colonization rate, abundance, and distribution of salt marsh harvest mouse. • On lands adjacent to planned tidal restoration sites, perform capture and release tagging study to determine whether a sufficient population of salt marsh harvest mouse exists to serve as a source population for recolonizing newly restored areas. • Conduct similar studies on Suisun shrew.
CM4 Tidal Natural Communities Restoration	How do nonnative species use restored tidal natural communities?	• Evaluate potential colonization of restored tidal natural communities by invasive flora and fauna. • Assess effects of nonnative species in restoration sites on covered species and natural communities. Identify ways to avoid and minimize those impacts.
CM5 Seasonally Inundated Floodplain Restoration	How is predation affecting covered fishes in restored natural communities?	• Evaluate the distribution and abundance of covered fish species and predators at restoration sites.
CM7 Riparian Natural Community Restoration	Are nonnative fishes using restored floodplains?	• Quantify abundance of nonnative fishes in restored floodplains.
CM11 Natural Communities Enhancement and Management	What is the status and trend of riparian brush rabbit populations in the Plan Area?	• Perform live-trapping of riparian brush rabbits biannually in suitable riparian brush rabbit habitat in Conservation Zone 7, using methods developed in coordination with the Endangered Species Recovery Program, to estimate status and trends of the riparian brush rabbit population in the Plan Area.

Relevant Conservation Measure(s)	Key Uncertainty	Potential Research Actions
CM11 Natural Communities Enhancement and Management	What management techniques will encourage colonization of riparian natural community by covered species?	• Conduct a variety of management techniques in experimental study plots and compare effectiveness in terms of encouraging colonization by covered riparian species.
CM11 Natural Communities Enhancement and Management	What techniques are effective for controlling exotic plants but safe for use on or near native plant and wildlife species?	• Conduct a variety of exotic plant control techniques in experimental study plots and compare effectiveness.
CM11 Natural Communities Enhancement and Management	What are the effects of various managed wetland management regimes on salt marsh harvest mouse habitat and populations?	• Establish experimental plots, apply varying managed wetland management techniques and compare results with best available information regarding suitable habitat characteristics for salt marsh harvest mouse. Also assess in terms of species occupation and numbers.
CM12 Methylmercury Management	How effectively does CM12 minimize production and mobilization of methylmercury from lands in the reserve system and the foodweb?	• Evaluate this question at selected restoration sites. • Evaluate wetland management strategies intended to minimize methylation. • Evaluate the ecological fate of wetland-generated methylmercury. • Evaluate the biological thresholds for mercury exposure for covered species to guide methylmercury objectives and Delta wetland management priorities. • Evaluate Plan Area–wide effectiveness of CM12 site screening
CM12 Methylmercury Management	Do measures implemented under CM12 to minimize microbial methylation of mercury interfere with the potential of a restoration project to meet its intended purpose?	• Comparatively evaluate conservation sites in different types of wetland natural communities.
CM13 Invasive Aquatic Vegetation Control	What are the most effective designs of tidal restoration sites to achieve tidal flow velocities that preclude rooting by IAV?	• Conduct empirical and lab studies to determine flow constraints on rooting of IAV species of concern. • Conduct model studies to assess velocity field for alternative restoration site design. • Conduct field tests in restoration site projects.
CM13 Invasive Aquatic Vegetation Control	How are restored natural communities being affected by IAV and have there been changes in existing areas?	• Evaluate the effect of tidal natural communities restoration on the establishment of IAV in subtidal aquatic habitats. • Evaluate whether there have been changes in IAV that could be related to water operations (e.g., changes in Delta hydrodynamics).

Relevant Conservation Measure(s)	Key Uncertainty	Potential Research Actions
CM13 Invasive Aquatic Vegetation Control	Is it feasible to create conditions that favor the growth of native pondweeds (*Stuckenia* spp.) rather than IAV?	• Evaluate environmental conditions that support pondweed beds, focusing on abiotic factors, particularly salinity, that determine growth and distribution of native pondweeds. • Evaluate how future salinity changes affect growth and distribution of pondweeds and Brazilian waterweed (*Egeria densa*, commonly referred to as *Egeria*). • Determine what differences in environmental conditions and abiotic factors favor Stuckenia over *Egeria*. • Evaluate to what extent restoration sites can be designed to encourage colonization and growth of native pondweeds while discouraging *Egeria*. • Determine the potential for native pondweed beds to contribute to restoration of native communities and ecosystem functions in the Delta. • Determine if the epifaunal invertebrate assemblages supported by pondweed beds provide substantial foraging and cover benefits in comparison to *Egeria*.
CM15 Localized Reduction of Predatory Fishes	Where is predation likely to occur in the vicinity of the new north Delta intakes?	• Perform field evaluation of similar facilities (e.g., Freeport, Reclamation District 108, Sutter Mutual, Patterson Irrigation District, and Glenn Colusa Irrigation District) and identify predator habitat areas at those facilities (same as preconstruction study 5, *Predator Habitat Locations* [Fish Facilities Technical Team 2013]).
CM15 Localized Reduction of Predatory Fishes	What are predator density and distribution in the intake reach of the Sacramento river?	• Use a Didson camera or other technology and/or acoustic telemetry at two to three proposed screen locations; perform velocity evaluation of eddy zones if needed. Collect baseline predator density and location data prior to facility operations; compare to density and location of predators near operational facility. Identify ways to reduce predation at the facilities (same as study 9. *Predator Density and Distribution*, both pre- and postconstruction [Fish Facilities Technical Team 2013]).
CM15 Localized Reduction of Predatory Fishes	Under what circumstances and to what degree does predation limit the productivity of covered fish species?	• Evaluate predation effect on productivity of covered fish species using life-cycle simulation models and bioenergetics modeling.
CM15 Localized Reduction of Predatory Fishes	Which predator species and life stages have the greatest potential impact on covered fish species?	• Determine whether large predators that are comparatively easy to target for reduction are the key predators of some or many covered fishes. • Conduct site-specific monitoring of predator abundance (by species and life stage) during periods when covered fish species are present (particularly juvenile salmonids). • Conduct surveys to determine site-specific diet composition of predators (at finer resolution than simply “fish”).

Relevant Conservation Measure(s)	Key Uncertainty	Potential Research Actions
CM15 Localized Reduction of Predatory Fishes	How should hotspots for localized predator reduction and/or habitat treatment be prioritized?	• Document the extent and locations of predator hotspots within the Delta, and evaluate relative intensity of predation and feasibility of treatment. • Use a habitat suitability approach at known hotspots to identify specific physical features and hydrodynamic conditions that facilitate elevated predation loss. • Continue with acoustic-tagging studies to identify areas that facilitate intense predation (e.g., Bowen et al. 2009; Vogel 2011).
CM15 Localized Reduction of Predatory Fishes	What are the best predator reduction techniques? Which are feasible, most effective, and best minimize potential impacts on covered species?	• Test and evaluate various reduction techniques with regards to efficacy, logistics, feasibility, cost and benefits, and public acceptance. • Determine if covered fish species are caught as by-catch during predator reduction efforts and assess ways to reduce such by-catch, if necessary. • Perform literature search and potentially field evaluations at similar facilities (e.g., Freeport, Reclamation District 108, Sutter Mutual, Patterson Irrigation District, and Glenn Colusa Irrigation District).
CM15 Localized Reduction of Predatory Fishes	What are the effects of localized predator reduction measures on predator fish and covered fish species?	• Conduct before and after studies (BACI design) to evaluate the distribution and abundance of predators and covered fish species at treatment location and nearby sites. Metrics include abundance, age classes, and distribution of predators such as striped bass, largemouth bass, and other smaller piscivorous fish. • Monitor recolonization rates of habitats by predators following reduction treatments to assess longevity of treatment effects.
CM15 Localized Reduction of Predatory Fishes	How have other conservation measures affected the distribution and intensity of predation in the Plan Area?	• Restoration actions are expected to create additional habitat for some species of predators along with covered species (e.g., *CM2 Yolo Bypass Fisheries Enhancement*, *CM4 Tidal Natural Communities Restoration*, *CM5 Seasonally Inundated Floodplain Restoration*, *CM6 Channel Margin Enhancement*, and *CM7 Riparian Natural Community Restoration*). Monitoring and potential active adaptive management studies will be developed, if increased predation is suspected or demonstrated in conjunction with restoration or enhancement projects.
CM15 Localized Reduction of Predatory Fishes	Is modification of sportfishing regulations a viable and effective means of achieving localized predator reduction?	• Perform literature review and interviews with qualified agency and independent scientists to summarize potential benefits, hazards, costs, and implementation issues associated with using modification of sportfishing regulations to manage predatory fish in the Delta.

Relevant Conservation Measure(s)	Key Uncertainty	Potential Research Actions
CM16 Nonphysical Fish Barriers	How effective are nonphysical barriers over a range of environmental conditions, such as a various flow conditions, tidal cycles, and channel bifurcations?	• Evaluate change in survivorship of covered species. • Evaluate effectiveness of barriers in high-flow areas. • Monitor changes in proportion of covered species distribution and abundance upstream and downstream of barrier. • Evaluate behavioral response of covered species to barriers. • Evaluate the effectiveness and permeability of nonphysical barriers with studies using tagged juvenile salmonids.
CM16 Nonphysical Fish Barriers	How do nonphysical barriers affect predators?	• Determine the abundance of predators within the area of the nonphysical barriers, both before and after installation, and evaluate the effect of the barriers on the survival of outmigrating juvenile salmonids. • Evaluate effectiveness of nonphysical barriers on green sturgeon, white sturgeon, and Chinook salmon and steelhead. • Evaluate potential attraction of fish predators to sites of nonphysical barriers (e.g., type of predators, number of predators). • Evaluate the extent of predator aggregation at nonphysical barriers before and after installation. • Evaluate predator composition before and after installation of nonphysical barriers. • Evaluate predator response to operation of nonphysical barriers.
CM17 Illegal Harvest Reduction	Has increased enforcement reduced the incidence of poaching?	• Evaluate incidence of illegal take of covered species, especially Chinook salmon, steelhead, and sturgeon.
CM17 Illegal Harvest Reduction	Has increased enforcement had beneficial effects on anadromous fish stocks?	• Evaluate whether changes in abundance and population dynamics can be attributed to reductions in illegal harvest.
CM18 Conservation Hatcheries	Can refugial populations of both delta and longfin smelt be maintained with little or no supplementation from wild stocks?	• Develop techniques for ensuring successful breeding and survivorship, so that refugial populations can be shown to increase without further supplementation from wild stocks.
CM19 Urban Stormwater Treatment	Does reducing stormwater pollution loads result in measurable benefits to covered fish species or their habitat?	• Evaluate results of effectiveness monitoring.

Relevant Conservation Measure(s)	Key Uncertainty	Potential Research Actions
CM20 Recreational Users Invasive Species Program	What are the principal invasive species threats in the Delta?	• Ensure through adaptive management that the measure remains focused on the principal invasive species of concern, as identified in the annual work plan for the Delta Recreational Users Invasive Species Program.
CM20 Recreational Users Invasive Species Program	Have existing invasive species proliferated since the prior year's work plan?	• Ensure through adaptive management that the measure remains focused on the principal invasive species of concern, as identified in the annual work plan for the Delta Recreational Users Invasive Species Program.
CM21 Nonproject Diversions	How can monitoring entrainment risk of covered species be made less time-consuming and expensive?	• Develop means of more quickly and effectively estimating preproject entrainment risk and project effectiveness in reducing entrainment risk.
IAV = invasive aquatic vegetation.		

3.D.4 References Cited

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