APPENDIX E-1

SUPPORTING DOCUMENTATION FOR DEVELOPMENTAL ANALYSIS, PREFERRED PLAN AND ALTERNATIVES PROPOSED BY OTHERS

ATTACHMENT C

PREDATOR CONTROL AND SUPPRESSION PLAN FOR THE LOWER TUOLUMNE RIVER

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DON PEDRO HYDROELECTRIC PROJECT
FERC NO. 2299

AMENDMENT OF APPLICATION

EXHIBIT E – ENVIRONMENTAL REPORT

APPENDIX E-1, ATTACHMENT C
PREDATOR CONTROL AND SUPPRESSION PLAN FOR THE LOWER TUOLUMNE RIVER



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September 2017

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List of Acronyms

AFLA..........................Amendment to the Final License Application
BA..............................Biological Assessment
CDFW........................California Department of Fish and Wildlife
CPUE.........................Catch per Unit Effort
Districts......................Turlock and Modesto Irrigation Districts
ESA............................Endangered Species Act of 1973
FERC..........................Federal Energy Regulatory Commission
hr................................hour
MID............................Modesto Irrigation District
mm.............................millimeter
NEPA.........................National Environmental Policy Act
NMFS.........................National Marine Fisheries Service
PM&E........................Protection, Mitigation, and Enhancement
RM.............................River Mile
RST............................Rotary Screw Trap
TID.............................Turlock Irrigation District
USACE......................U.S. Army Corps of Engineers

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PREFACE

On April 28, 2014, the co-licensees of the Don Pedro Hydroelectric Project, Turlock Irrigation District (TID) and Modesto Irrigation District (MID) (collectively, the Districts), timely filed with the Federal Energy Regulatory Commission (Commission or FERC) the Final License Application (FLA) for the Don Pedro Hydroelectric Project, FERC No. 2299. As noted in the filing and acknowledged by FERC at the time, several studies were ongoing which were likely to inform the development of additional protection, mitigation, and enhancement (PM&E) measures. The Districts have now completed these studies and herein submit this Amendment of Application (Amendment to the Final License Application or AFLA). For ease of review and reference, this AFLA replaces the Districts' April 2014 filing in its entirety.

The Don Pedro Project provides water storage for irrigation and municipal and industrial (M&I) use, flood control, hydroelectric generation, recreation, and natural resource protection (hereinafter, the "Don Pedro Project"). The environmental analysis contained in this AFLA considers all the components, facilities, operations, and maintenance that make up the Don Pedro Project and certain facilities proposed to be included under the new license. The Don Pedro Project is operated to fulfill the following primary purposes and needs: (1) to provide water supply for the Districts for irrigation of over 200,000 acres of Central Valley farmland and M&I use, (2) to provide flood control benefits along the Tuolumne and San Joaquin rivers, and (3) to provide a water banking arrangement for the benefit of the City and County of San Francisco (CCSF) and the 2.6 million people CCSF supplies in the Bay Area. The original license was issued in 1966. In 1995, the Districts entered into an agreement with a number of parties, which resulted in greater flows to the lower Tuolumne River for the protection of aquatic resources.

Hydroelectric generation is a secondary purpose of the Don Pedro Project. Hereinafter, the hydroelectric generation facilities, recreational facilities, and related operations will be referred to as the "Don Pedro Hydroelectric Project," or the "Project". With this AFLA to FERC, the Districts are seeking a new license to continue generating hydroelectric power and implement the Districts' proposed PM&E measures. Based on the information contained in this AFLA, and other sources of information on the record, FERC will consider whether, and under what conditions, to issue a new license for the continued generation of hydropower at the Districts' Don Pedro Project. The Districts are providing a complete description of the facilities and operation of the Don Pedro Project so the effects of the operation and maintenance of the hydroelectric facilities can be distinguished from the effects of the operation and maintenance activities of the overall Don Pedro Project's flood control and water supply/consumptive use purposes.

Being able to differentiate the effects of the hydropower operations from the effects of the flood control and consumptive use purposes and needs of the Don Pedro Project will aid in defining the scope and substance of reasonable PM&E alternatives. As FERC states in Scoping Document 2 in a discussion related to alternative project operation scenarios: "…alternatives that address the consumptive use of water in the Tuolumne River through construction of new structures or methods designed to alter or reduce consumptive use of water are…alternative mitigation strategies that could not replace the Don Pedro *hydroelectric* [emphasis added] project. As such, these recommended alternatives do not satisfy the National Environmental

Policy Act (NEPA) purpose and need for the proposed action and are not reasonable alternatives for the NEPA analysis."

1.0 INTRODUCTION

1.1 Background

Results of the Predation Study (TID/MID 2013) and earlier studies of Chinook salmon (*Oncorhynchus tshawytscha*) predation in the lower Tuolumne River (TID/MID 1992, Appendix 22) concluded that predation by non-native predatory fishes, most importantly largemouth bass (*Micropterus salmoides*), smallmouth bass (*M. dolomieu*), and striped bass (*Morone saxatilis*), is a significant factor limiting Chinook salmon outmigrant survival. Results of the Predation Study (TID/MID 2013) indicate that smallmouth and largemouth bass (members of the genus collectively called "black bass") are currently the most abundant predators in the lower Tuolumne River and, based on observed predation rates on juvenile salmonids, together account for 75-80 percent of the potential salmon predation between river mile (RM) 30.3 and RM 5.2 during the juvenile Chinook salmon outmigration period. Striped bass, though much less abundant, account for the remaining 20-25 percent of potential salmon predation due to their disproportionately high predation rate. Striped bass captured during the Predation Study were found to have consumed an average of 1.1 salmon per predator per day, a predation rate 10 times greater than that of either smallmouth or largemouth bass (TID/MID 2013). Recent relicensing studies indicate that striped bass forage throughout the entire 52 miles of the lower Tuolumne River, including in cold-weather conditions when largemouth bass are generally inactive (TID/MID 2017b). In comparison, the distribution of largemouth bass, especially during summer, is determined largely by environmental conditions related to longitudinal differences in habitat (i.e., more largemouth bass in lower gradient, warmer downstream reaches) (Brown and Ford 2002). Likewise, Sacramento pikeminnow (*Ptychocheilus grandis*), a species native to the Tuolumne River but also considered to be a potential salmonid predator, is expected to be largely confined to the middle and upper reaches of the river where water velocity is relatively high and water temperatures remain relatively low (Brown and Ford 2002). Sacramento pikeminnow have not been found to prey on juvenile salmonids in the lower Tuolumne River (TID/MID 1992, Appendix 22; TID/MID 2013).

In the reach between the Waterford (RM 29.8) and Grayson (RM 5.2) rotary screw traps (RSTs) used to monitor juvenile Chinook salmon production, expansion of observed predation rates by the corresponding predator abundance estimates suggests that predation mortality between the traps could equal or exceed the number of juveniles passing the Waterford trap during the outmigration season. Model simulations using the Tuolumne River Chinook Salmon Population Model (TID/MID 2017a), indicate that a reduction of smolt mortality rates by 20 percent upstream of RM 25.9 and by 10 percent downstream of RM 25.9 is accompanied by an increase of 69–72 percent in annual Chinook salmon smolt production.

In response to the substantial adverse effects of invasive predatory fish on native fish populations, predator control efforts have been implemented throughout the U.S. and elsewhere. Examples include programs to control smallmouth bass in Colorado (Burdick 2008, Hawkins et al. 2009), Maine (Kleinschmidt 2008), and New Brunswick, Canada (Halfyard 2010), northern pikeminnow and smallmouth bass in Utah (Skorupski and Breen 2013), northern pikeminnow in the Columbia River basin (Williams et al. 2017), and largemouth bass in Japan (Nakai et al. 2014). Predator control efforts in California have included Sacramento pikeminnow (formerly squawfish) removal in the Eel River (Downie 1992) as well as planning stages of a pilot predator removal program to control black bass and striped bass in the Stanislaus River (Water Infrastructure Improvements for the Nation [WIIN] Act 2016).

Recognizing the impact of predatory fishes on juvenile salmonid survival in the lower Tuolumne River and that exclusion or removal of a relatively small fraction of these fish is expected to reduce predation and considerably improve smolt production (TID/MID 1992, Appendix 22; TID/MID 2013), the Districts' Preferred Plan for Future Operations of the Don Pedro Project ("Preferred Plan") includes a robust predator control and suppression program to increase juvenile salmonid production from the lower Tuolumne River. This document, the Lower Tuolumne River Predator Control and Suppression Plan (Plan), describes that program and is intended to serve as a guidance document for actions to be implemented during the first five years of the program. Specific details of predator control efforts to be implemented annually will be detailed in an implementation plan prepared prior to sampling each year.

1.2 Goals and Objectives

The goal of the Plan is to reduce population-level impacts on juvenile Chinook salmon and *O. mykiss* production through a combination of predator exclusion, reduction, and removal or relocation efforts.

To achieve this goal, this Plan proposes the following objectives:

- Exclude striped bass from the reach upstream of RM 25.5;
- Reduce and eventually eliminate smallmouth bass upstream of RM 25.5; and
- Reduce black bass populations downstream of RM 25.5 by 10 percent.

The Districts have previously supported evaluation of direct removal of introduced predatory species as a strategy for reducing predator abundance and increasing survival of juvenile Chinook salmon and *O. mykiss* in the lower Tuolumne River (TID/MID 2005). Results from this evaluation have informed the likely effectiveness of removal approaches as components of an overall predator control program.

2.0 PREDATOR CONTROL PROGRAM

The predator control program described herein includes a description of the proposed actions to be implemented during the first five years (Years 1–5) of implementation, as well as removal targets and monitoring metrics for which success of the program will be evaluated. The program will include implementation of a suite of actions each year intended to meet program objectives and build a base of knowledge to inform annual implementation. After the first five years of implementation are complete, the program will be evaluated to assess the extent to which project goals and objectives are met, as well as the effects of the program on reducing predation on juvenile anadromous salmonids. Based on program effectiveness, a revised approach for implementing future actions to be implemented under the program would be developed and included in an updated plan.

2.1 Target Species

The Tuolumne River predator control and suppression program will target specific predator species and life stages, and/or groups of species with similar life history timing (e.g., black bass, genus *Micropterus*: smallmouth bass, largemouth bass, spotted bass, redeye bass), while reducing potential impacts on Chinook salmon and *O. mykiss*. Based on information from the Tuolumne River predation studies (TID/MID 2013; TID/MID 1992, Appendix 22) and other sources (e.g., Moyle 2002), key predators and secondary predators in the lower Tuolumne River have been identified. The following key predator species, which have been shown to impact salmon production the most, will be the primary focus of the Plan:

- striped bass
- smallmouth bass
- largemouth bass

In addition to the key predator species, other relatively abundant predators that will be targeted (i.e., secondary predators) may include the following:

- Sacramento pikeminnow
- spotted bass
- redeye bass
- black crappie
- channel catfish
- white catfish

With the exception of Sacramento pikeminnow, all predators targeted for control and suppression are non-native species. Although sampling activities for the Predation Study (TID/MID 2013) were confined to reaches downstream of RM 38.5, predation on salmon by Sacramento pikeminnow was not documented and pikeminnow were found at low abundance below RM 38.5.

2.2 Overview of Proposed Actions

A successful predator control program in the lower Tuolumne River will employ a combination of actions for targeting specific predator species and life stages to reduce potential impacts on Chinook salmon and *O. mykiss*. This section provides a brief overview of specific predator control actions. More detailed descriptions of the proposed actions are provided in Section 2.8. General considerations for implementing the predator control and suppression program in the lower Tuolumne River, including fish handling, permitting requirements, adaptive management, and uncertainties are described in Section 3. Additional detail on these and other methods, including those not proposed for this Plan, is provided in Attachment A along with an overview of permitting considerations.

Based a review of potential predator control methods (Attachment A) and the empirical data collected on the river, and in recognition of the importance of rapid implementation of predator control in the lower Tuolumne River, the Predator Control and Suppression Program will use multiple actions to leverage the strengths of particular methods, and is expected to have a more comprehensive effect than relying on a single method. Proposed predator control actions for Years 1–5 are presented below (Table 2.2-1).

Table 2.2-1. Predator control actions proposed for Years 1–5.

Control Action	Primary Target Species[1]	Target Life Stages	Recommended Timing
Primary Predator Control Actions			
Predator exclusion weir	STB	Adult	year-round
Boat electrofishing	LMB, SMB	Adult	spring, summer
Public sport fishing derby	LMB, SMB	Adult	early summer
Fyke trapping	STB	Adult	spring
Supplemental Actions			
Shoreline electrofishing	LMB, SMB	Adult, juvenile	spring, summer
Hook-and-line angling	LMB, SMB	Adult	spring, summer
Baited fish traps	LMB, SMB, STB	Adult	spring, summer
Minnow traps	LMB, SMB	Juvenile	summer
Beach seining	LMB, SMB	Juvenile	spring, summer
Public sport-reward fishery	LMB, SMB, STB	Adult	spring - winter

[1] LMB = largemouth bass; SMB = smallmouth bass; STB = striped bass.

In addition to these direct predator control and suppression actions, the Districts will undertake a public outreach program in local communities to promote fishing for black bass and striped bass, and provide educational programs on the effects of predation by these fishes on native salmonid populations.

Predator control actions proposed for Years 1–5 include predator removal and relocation approaches to deplete predator populations relatively quickly. These approaches generally require minimal planning and startup, and in most cases, can be initiated in Year 1. Because population-level effects of short-term removal are generally temporary, predator control efforts will be performed annually during Years 1–5. Other approaches that will require one year or more for planning, coordination, and/or construction prior to implementation (i.e., predator exclusion weir and sport-reward fishery) will also be pursued during Years 1–5. These actions are expected to be effective for reducing predators beyond the initial 5-year implementation period described in this Plan.

During the first five years of implementing the Plan, a series of field-based efforts will be carried out in the lower Tuolumne River. Results of these initial efforts will inform selection and refinement of the most efficient and cost-effective suite of approaches for achieving predator removal targets in subsequent five-year periods. Predator removal efforts during Years 1–5 will focus on the 25-mile reach between the RST at Waterford (RM 29.8) and Grayson (RM 5.2), where substantial predation on juvenile salmonids is expected to occur (TID/MID 2013). Focusing predator removal in this reach will also allow observed changes in smolt survival to be more readily correlated with predator removal actions. In addition, focusing predator removal within this 25-mile reach also avoids the primary spawning reaches used by Chinook salmon and *O. mykiss* upstream of RM 31.5. Based on the review of various predator removal approaches (Attachment A), a relatively broad suite of actions is included in the program proposed for Years 1–5.

The implementation approach for Years 1–5 integrates primary and supplemental actions described above to achieve predator removal targets. The approach is divided into separate strategies for removing black bass (largemouth and smallmouth) and striped bass. A brief description of the general schedule, duration, and composition of actions proposed for black bass and striped bass is provided below.

2.2.1 Black Bass

Boat electrofishing and sport fishing derbies are the primary actions proposed for removing piscivorous-sized black bass in Years 1–5. Supplemental actions to be implemented for removing adult and juvenile black bass include shoreline electrofishing, hook-and-line angling, fish traps, minnow traps, and beach seine. Boat electrofishing would be implemented during two five-day field efforts—one in the spring and one in the summer. One two-day public sport fishing derby would be held in the late spring or summer during Years 2–5. Hook-and-line angling will be used in conjunction with planned boat electrofishing efforts and during separate field efforts to test other supplemental actions. Shoreline electrofishing, baited fish traps, minnow traps, and beach seines, will be implemented separately during two additional five-day field efforts—one in the spring and one in the summer. The effectiveness of the predator exclusion and trapping weir at capturing black bass will also be evaluated as part of operations targeting striped bass described below.

2.2.2 Striped Bass

Fyke trapping and operation of a predator exclusion barrier weir are the primary actions proposed for removing striped bass. Supplemental actions to be evaluated for striped bass removal include boat electrofishing and baited fish traps. Fyke trapping will be implemented for approximately three weeks during the projected peak period of striped bass migration in the spring. A small barrier weir (less than 5 feet of head at normal flows), made of reinforced concrete, will be constructed at approximately RM 25.5, as presented in Exhibit F of this AFLA. The barrier weir will be built by Year 3 following license issuance, and operated year-round (at least initially) to evaluate run timing and capture of striped bass and other predators during different seasons.

Baited fish traps and boat electrofishing for striped bass would be implemented as part of the black bass effort described above.

2.3 Predator Removal Targets

Predator control actions will be designed to meet the initial project goals (i.e., reduce predator abundance, restrict upstream movement, and thereby increase salmon smolt survival) as efficiently and effectively as possible. Recent population estimates for adults of the three key predator species are provided in Table 2.3-1 (TID/MID 2013). Target numbers for removal of piscivorous-sized predators in the reach between the Grayson (RM 5.2) and Waterford (RM 29.8) RSTs in the first years of implementation of the Plan and associated reductions in salmon predation are provided in Table 2.3-2. The initial target for Years 1–5 is a reduction of 10–15 percent of the population of the piscivorous-sized component of each of the three key predator species. Removal targets for subsequent periods will be adjusted periodically based upon up-to-date salmon survival or predator population estimates.

Table 2.3-1. Estimated abundance of key predators >150 mm FL in the lower Tuolumne River.

Species	Estimated 2012 River Wide Abundance[1] (SE)	Estimated 2012 Abundance in RST Reach[2] (SE)
Largemouth bass	4,185 (± 261)	3,013 (± 156)
Smallmouth bass	6,764 (± 260)	3,626 (± 111)
Striped bass	588 (± 57)	235 (± 21)

Source: TID/MID 2013.
[1] Based on shoreline length between RM 0 and 39.4.
[2] Between Grayson (RM 5.2) and Waterford (RM 29.8) RSTs.

Table 2.3-2. Target removal numbers per year of piscivorous-size predators of each species between the Waterford (RM 29.8) and Grayson (RM 5.2) RSTs for the first year of implementation of removal efforts and estimated range in reduction of daily salmon predation following removal.

Species	10% Removal Target	15% Removal Target	2012 Predation Rate (Salmon/Day)	Potential Reduction in Predation (Salmon/Day)	
				10% removal	15% removal
Largemouth bass	301	452	0.1	30	45
Smallmouth bass	363	544	0.11	40	60
Striped bass	24	35	1.1	26	39
Total reduction in predation (salmon/day)				96	144

2.4 Schedule and Timing

Predator control actions will be implemented throughout the first five years beginning in Year 1 (Table 2.4-1). Actions such as electrofishing, trapping, seining, and angling will be performed during Year 1 as summarized above. The predator exclusion weir and sport-reward fishery actions will require additional planning and regulatory coordination before they can be implemented, and will be incorporated into the annual sampling approach as soon as each is available for implementation.

To maximize effects on predator abundance and reproductive success, predator removal actions should occur at least annually and would generally be timed to coincide with the spring–summer period of peak foraging and reproductive behaviors (e.g., spawning and nest guarding) that increase vulnerability of predators to removal. These behaviors are linked to water temperature; thus the seasonal timing of predator control actions will annually require continuous monitoring of water temperature at multiple locations in the lower Tuolumne River and mobilization of field crews once spring water temperatures reach levels that increase predator activity.

Largemouth bass begin foraging at 41°F (5°C) and activity increases until water temperatures reach 79–81°F (26–27°C) (Coutant 1975; Zweifel et al. 1999). Moyle (2002) reports that largemouth bass spawning begins when water temperature reaches 59–61°F (15–16°C) (usually in March or April in California) and continues through June at temperatures up to 75°F (24°C). For smallmouth bass, maximum prey consumption rate peaks at approximately 72°F (22°C) and declines at higher temperatures (Zweifel et al. 1999). Spawning by smallmouth bass begins when water temperatures reach 13–16°C (Moyle 2002). Striped bass can tolerate a wide range of water temperatures but temperatures over 25°C are considered stressful (Moyle 2002) and probably not conducive to feeding. Striped bass spawning occurs when water temperatures are between 14° and 20°C (Moyle 2002).

Timing considerations specific to each predator control method recommended for implementation are described in Table 2.2-1, and for all methods evaluated in Attachment A.

Prior to initiating sampling each year, an implementation plan will be prepared that details the specific actions to be implemented that year. The implementation plan will include details regarding the annual implementation schedule (e.g., sampling dates, fishing derby dates), site locations, sampling thresholds (e.g., flow and water temperature thresholds), and other considerations. Specific dates and locations for implementing are expected to be refined annually based on results of the previous year's predator control and suppression actions.

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Table 2.4-1. Anticipated schedule for implementing predator control actions during Years 1–5.

Measure	Year 1	Year 2	Year 3	Year 4	Year 5
Predator exclusion weir at RM 25.5[1] (striped bass)	Design and construction	Design and construction	Operate year-round	Operate year-round or during key migration periods	Operate year-round or during key migration periods
Boat electrofishing (black bass)	Spring and summer	Spring and summer	Spring and summer	Spring and summer	Spring and summer
Public sport fishing derby (black bass)	Planning	Spring or summer derby	Spring or summer derby	Spring or summer derby	Spring or summer derby
Fyke Trapping (striped bass)	Spring migration	Spring migration	Spring migration	Spring migration	Spring migration
Shoreline electrofishing (black bass)	Spring and summer	Spring and summer	Spring and summer	Spring and summer	Spring and summer
Hook-and-line angling (black bass)	Spring and summer	Spring and summer	Spring and summer	Spring and summer	Spring and summer
Trapping and netting (black bass and striped bass)	Spring and summer	Spring and summer	Spring and summer	Spring and summer	Spring and summer
Public sport-reward fishery[2] (black bass)	Planning and regulatory support	Planning and regulatory support	Implement reward/bounty	Implement reward/bounty	Implement reward/bounty
Public outreach program (supporting the predator control program)	Planning and outreach	Planning and outreach	Planning and outreach	Planning and outreach	Planning and outreach

[1] The predator exclusion weir is expected to be constructed and operational by Year 3.

[2] A longer period of planning and regulatory support is expected, since the sport-reward fishery will require changes to, or an exemption from, existing state regulations, which currently prohibit sale of fish taken with a sport fishing license (Fish and Game Code Section 7121).

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2.5 Predator Removal Estimates

Based on the proposed level of effort for each action and conservative (i.e., low-end) catch per unit effort (CPUE) estimates, removal of predators through primary actions is predicted to exceed 10 percent removal targets for piscivorous-size smallmouth bass and striped bass, and nearly meet the largemouth bass target (Table 2.5-1). Additional predator removal is expected to occur with supplemental actions for each species, ensuring that removal targets will be met or exceeded. For example, additional striped bass will likely be caught during boat electrofishing and additional black bass should be caught by baited fish traps. Although specific removal targets have not been established for predators <150 millimeters (mm) in length, substantial numbers of these younger age classes are expected to be removed by both supplemental actions targeting them (e.g., shoreline electrofishing, beach seining, minnow trapping) and primary actions targeting adults. Table 2.5-1 provides conservative estimates of numbers of predators of each species that could be captured if trapping were conducted at the barrier weir over an approximate three-month period.

Table 2.5-1. Anticipated catch and percentage of 10 percent adult removal targets met for each primary action, based on conservative CPUE estimates and proposed effort.

Primary Action	Species	CPUE (fish/hr)	Effort (hrs)	Catch	10% Removal Target	Percent of 10% Removal Target
Boat electrofishing	LMB	8.8[1]	30[5,6]	264	301	88%
	SMB	13.3[1]	30[5,6]	399	363	110%
Predator exclusion barrier weir	STB	0.002[4]	2,160	4	24	18%
	LMB, SMB	0.05[4]	2,160[9]	108	664	16%
Public sport fishing derby	LMB, SMB	0.10[2]	300[7]	30	664	5%
Fyke trapping	STB	0.04[3]	1,440[8]	58	24	240%

1 Mean CPUE for boat e-fishing in the lower Tuolumne River in 2012 (TID/MID 2013).
2 Lowest CPUE of approximately 60 water bodies in 2012 California bass fishing derbies (Krogman 2013).
3 Average CPUE of multiple traps at the location with lowest CPUE in a 2013 pilot study in the San Joaquin River (Ainsley et al. 2013).
4 Lowest annual CPUE reported for lower Tuolumne River weir operations during fall and winter operation period between 2009 and 2012 (FISHBIO 2010, 2013; TID/MID 2012).
5 Effort is based on number of hours voltage is applied.
6 Assumes both LMB and SMB captured during a combined effort of 30 hours.
7 Assumes a 2-day derby with 25 participants each fishing 6 hours/day.
8 Assumes 4 fyke traps are deployed for 3 5-day weeks and fished 24 hours/day.
9 Assumes weir is operational 24 hours/day for 90 consecutive days.

2.6 Monitoring Metrics

Monitoring and assessment of fish populations requires the use of metrics, also called indices, to describe and compare various population parameters. Metrics can be categorized according to the parameter of interest, each of which requires collection of specific types of data. Categories of metrics typically used for fish population investigations include population structure, population dynamics, abundance, density, and distribution (Pope et al. 2010). Studies of predator populations and predator-prey interactions in the lower Tuolumne River have relied on metrics that describe the predator population (e.g., abundance, age structure, recruitment, density, distribution) and how predators affect their prey (e.g., diet composition, rate of prey consumption, predator movement and habitat use) (TID/MID 2013; McBain & Trush and Stillwater Sciences 2006; TID/MID 1992, Appendix 22).

Evaluating the success of predator removal and control efforts in achieving desired targets (Section 2.1) requires metrics that describe predator populations before and after control methods are implemented, as well as metrics to assess effects on prey (i.e., salmon survival).

2.6.1 Predator Populations

The following metrics are proposed to evaluate predator populations and the effect of control methods on the populations:

- **Absolute abundance and density.** Absolute abundance is the total number of fish in a defined area. Density is the number of fish per unit area (e.g., fish per m^2), determined using abundance and sampled area. Density metrics normalize abundance and allow comparison among units of different size (area). Predators per unit of habitat area and predators per unit of bank length are the density metrics used in previous Tuolumne River predator studies (TID/MID 2013; McBain & Trush and Stillwater Sciences 2006; TID/MID 1992, Appendix 22). Methods used to collect absolute abundance and density data include depletion sampling (e.g., multi-pass electrofishing) and mark-recapture (Portt et al. 2006).
- **Relative abundance.** Relative abundance is the ratio between multiple species or locations. It is a commonly used descriptor of predator population size or density among species, reaches, or habitat types. Relative abundance can be calculated from CPUE if catchability is equal among species or locations (Portt et al. 2006).
- **Population demographics.** Demographic metrics include age class structure, size-at-age, and recruitment. These metrics are useful indicators of the response of predator populations to removal or control efforts. For example, an age class structure heavily skewed toward juveniles could indicate that predator control efforts are disproportionately removing adults from the population.

Each of these metrics will be evaluated every five years, through targeted field efforts that are separate from ongoing predator control efforts. However, data (e.g., CPUE) collected during predator control efforts may also be used to monitor and inform program effectiveness.

2.6.2 Salmon Survival

Paired RST monitoring will be used to evaluate changes in reach-specific salmon survival resulting from predator control. Survival during the fry, juvenile, and smolt emigration period (approximately January–May) will be evaluated based on the ratio of total seasonal RST passage at Grayson (RM 5.2) divided by passage at Waterford (RM 29.8). Survival should be assessed for at least one year prior to implementation of the Plan and annually beginning the year following implementation.

2.7 Adaptive Management

Adaptive management principles are included in the *Habitat Restoration Plan for the Lower Tuolumne River Corridor* (McBain & Trush 2000; hereafter, the Restoration Plan) and have been included in the Delta Reform Act (Water Code §85052) as a means of improving conditions for juvenile salmonids and other native species. The adaptive management approach for the lower Tuolumne River Predator Control and Suppression Program is based on general scientific principals where results from focused monitoring provides a progressive improvement in understanding the issue at hand (Figure 2.7-1). The resulting improved understanding is then used to refine predator control actions to improve effectiveness (e.g., the number of target predators removed) and efficiency (e.g., cost per predator removed) in meeting project targets (i.e., numbers of predators removed and effects on predator populations). For the lower Tuolumne River Predator Control and Suppression Plan, existing information is generally sufficient to support reasonable conclusions about likely outcomes; however increased knowledge of predator suppression methods will improve implementation design and the success of predator control efforts over time.

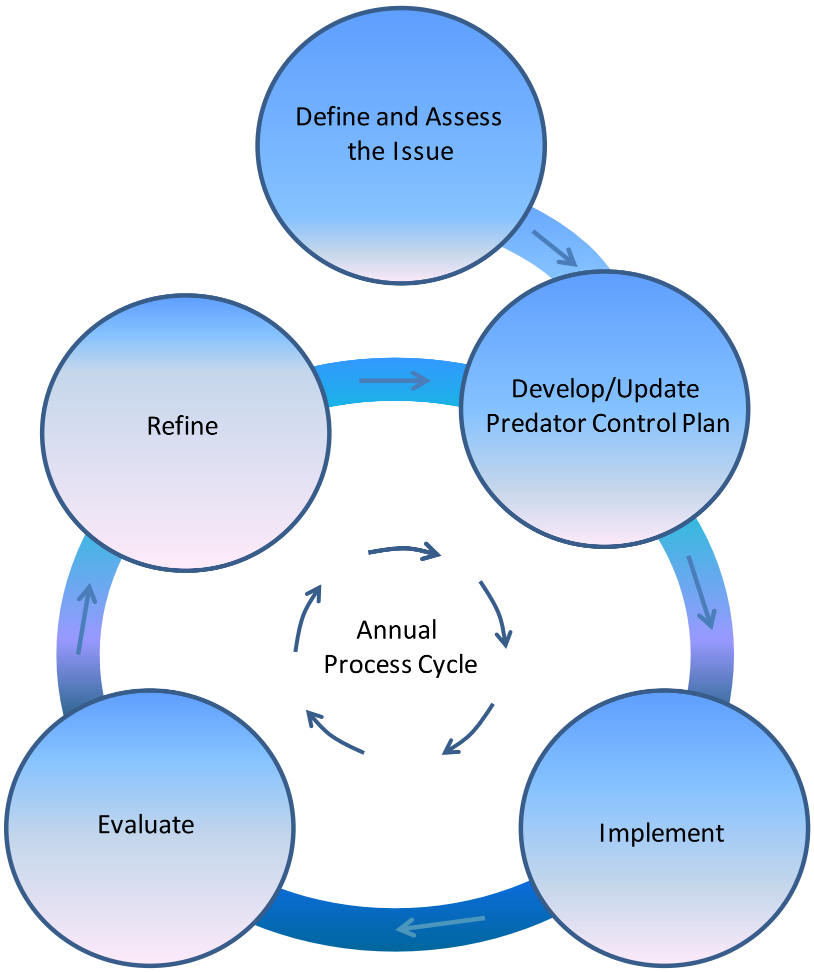

Figure 2.7-1. Adaptive management approach and process cycle for the lower Tuolumne River Predator Control and Suppression Program.

The adaptive management approach for the lower Tuolumne River includes feedback loops at both one-year and five-year intervals to apply knowledge gained to improve the efficiency and effectiveness of implementing the Plan. The annual process cycle is used to refine the implementation of predator control actions each year based on experience from implementing actions during previous years. The five-year adaptive management cycle is used to evaluate the program and assess the effectiveness regarding project goals and objectives. After the first five years of implementation are complete, the program will be evaluated to assess the extent to which project goals and objectives are met, as well as the effects of the program on reducing predation on juvenile anadromous salmonids. Based on program effectiveness at Year 5, a revised approach for implementing future predator control actions to be implemented under the program will be developed and included in an updated plan.

2.8 Description of Proposed Actions

Predator control efforts include both primary and supplemental actions. A primary action is one that is expected to be relatively efficient and effective, allocated a substantial level of effort, and result in a large proportion of target fish captured. A supplementary action is one that, if considered alone, may have relatively low efficiency and effectiveness for a given target species, but would: (1) be at least moderately efficient and/or effective to implement in combination with primary or other secondary actions; (2) be allocated a relatively low level of effort; and (3) result in a relatively small (but important) proportion of target fish captured. Supplementary actions may also target different habitats or life stages than the primary action, and thus prove useful as components of a comprehensive predator control approach.

Specific methods used during implementation of predator control actions will be refined over time through an adaptive management process (see Section 2.7). In addition to meeting predator removal targets through actions targeting piscivorous-sized (>150 mm) individuals of predator species, several approaches for removing smaller size classes of bass will be evaluated, which is an important part of the Plan. A program that targets adult fish only may result in reduced intraspecific competition, leading to increased abundance due to more rapid growth and maturation of juveniles (see Section 3.5).

A public outreach program will be developed and implemented to support implementation of predator control actions. The public outreach program will inform and educate local communities about the effects of predation by non-native fish species on native salmonid populations in the lower Tuolumne River. The program will promote local fishing opportunities for black bass and striped bass to encourage angling and support removal of these species from the lower Tuolumne River.

Below is a brief discussion of the recommended timing, logistics, and other considerations for implementing predator control actions during Year 1–5. Additional detail on methods, strengths, challenges, constraints, uncertainties, timing, relative effectiveness, and recommended next steps for each action are provided in Attachment A.

2.8.1 Primary Actions

2.8.1.1 Boat Electrofishing

Electrofishing is commonly used as a non-lethal method to capture a wide variety of fish species, and has proven successful as a predator capture method in the lower Tuolumne River (TID/MID 2013; McBain & Trush and Stillwater Sciences 2006; TID/MID 1992, Appendix 22) and elsewhere in the region (e.g., Cavallo et al. 2012). Boat-based electrofishing would likely be the preferred approach for targeting predators on the lower Tuolumne River; however, shoreline electrofishing using backpack or barge electrofishers may be more effective in certain locations or for targeting certain life stages (e.g., juvenile or spawning stage fish in shallow waters). Boat electrofishing efforts should be designed to target primarily piscivorous-sized (>150 mm FL) largemouth bass and smallmouth bass. However, incidental captures of smaller black bass, adult striped bass, or secondary predator species (e.g., catfish) will likely occur, which will help inform future efforts to target them.

Electrofishing will be timed to coincide with spawning (when predators are on nests at relatively shallow depth) and early rearing (when fry/juveniles are concentrated in shallow margin areas) to maximize population-level effects on predators (Loppnow et al. 2013). Year 1–5 boat electrofishing will be timed to occur during both the spring spawning and nest-guarding season, and again during the summer adult foraging and juvenile rearing period. Boat electrofishing will be conducted at night to maximize capture efficiency. Nighttime electrofishing, as used in previous predator capture efforts (TID/MID 1992, Appendix 22; McBain & Trush and Stillwater Sciences 2006; TID/MID 2013), is considered preferable due to higher capture rates than daytime electrofishing (Pierce et al. 2001).

In the spring, boat electrofishing will focus on areas that have high quality spawning habitat for bass (generally shallow water and low velocity). In the summer, boat electrofishing would focus on habitat shown to have high densities of adults of each species (TID/MID 2013). Within selected sites, predator removal efforts will focus on preferred habitat for each species, as determined by professional judgment and recent acoustic tagging studies documenting microhabitat scale distribution of each species (TID/MID 2013).

Electrofishing sampling will be performed during two five-day field efforts—one in the spring and one in the summer. Each effort will target approximately 1–3 sites per day that will be distributed throughout the 25-mile sampling reach. Sites will be selected based on habitat characteristics focusing on habitats where boat electrofishing sampling will be effective and where preferred bass habitat is abundant, which include slow water habitats with moderate nearshore depth. Access (proximity to boat ramp) will also be a consideration in site selection. The exact sites will be identified each year and detailed in the annual implementation plan. Sampling effort and shoreline length and/or sampling area will be recorded for each site to allow estimates of capture density and CPUE to assess efficiency and effectiveness.

Electrofishing is subject to special state and federal permitting requirements, as sampling can potentially affect non-target species, especially listed salmonids. Permitting requirements may also include agency participation and/or oversight during field sampling. Electrofishing sample locations, times, and methods will be selected to minimize impacts on salmonids and to comply with expected state and federal permitting conditions. Restricting electrofishing predator removal efforts to the 25-mile reach between Waterford and Grayson will minimize the likelihood for incidental take of juvenile Chinook and *O. mykiss*, which tend to rear in the cooler reaches upstream of RM 40 where their abundance is highest.

2.8.1.2 Predator Exclusion Weir

A channel-spanning predator exclusion weir will be constructed at approximately RM 25.5. The exclusion weir will be a reinforced concrete structure as presented in Exhibits E and F of this AFLA. The predator exclusion weir will be built by Year 3 following license issuance.

The predator exclusion weir will block adult striped bass attempting to pass upstream of the weir at any time of year. The structure will also replace the fish counting weir currently being operated at RM 24.5 to enumerate migrating adult salmonids. Exclusion of striped bass at the weir is expected to be highly effective at reducing or eliminating predation by striped bass upstream of the weir. The exclusion weir will also prevent successful reproduction by striped bass in the Tuolumne River upstream of the weir by preventing access to spawning habitat. Initially, the weir will be operated year-round to evaluate run timing and seasonal abundance of striped bass and other predators during different seasons. This information could be used to refine weir operations in subsequent years to maximize effectiveness at excluding and potentially removing striped bass and other predators, while minimizing impact on non-target species.

Based on the dates when striped bass are typically caught during fyke trapping conducted in the Sacramento River, weir operations for predator monitoring purposes would be conducted during the entire spring (March 20 – June 21) (DuBois et al. 2010, 2011, 2012; DuBois and Harris 2013).

2.8.1.3 Public Sport Fishing Derby

Sport fishing derbies are organized fishing contests open to the public, with awards and/or prizes offered as incentive to increase participation. This method is advantageous because it can selectively target key predators (e.g., smallmouth bass, largemouth bass, and striped bass) with little effect on other species. A sport fishing derby including predator relocation is proposed for implementation in Years 2–5, subject to California Department of Fish and Wildlife (CDFW) permit authorization (Fish and Game Code Section 2003) (See Section 1.3.5 in Attachment A).

Sport fishing derbies will be held in late spring or summer when water temperatures are relatively warm and catch rates are expected to be relatively high. Participation would likely be highest at this time of year. The derby will be held in a discrete river reach with good boat access and high-quality bass habitat. Ideally, the derby will be organized by an existing fishing group that can assist with event sponsorship and promotion. The derby will be designed to encourage participants to target both largemouth and smallmouth bass (e.g., category prizes for both species).

2.8.1.4 Fyke Trapping

Various netting and trapping methods are commonly used for a variety of fish capture applications in diverse habitats (Attachment A). The effectiveness of large diameter (8 feet) cylindrical fyke traps will be tested as a primary action for capturing adult striped bass migrating up the lower Tuolumne River. Ainsley et al. (2013) recommended reducing the diameter of fyke traps from 10 feet to 8 feet to better suit depth conditions in the San Joaquin River. Further reduction in fyke trap diameter may be warranted for use in the Tuolumne River where average depths of comparable habitats may be less than the San Joaquin River.

In Year 1, fyke traps would be deployed during the expected peak migration period to ensure removal targets are met, refine understanding of run timing, and inform timing of trapping in future years. Fyke traps should be fished from late May to early June based on timing of peak capture at traps fished at Sturgeon Bend on the San Joaquin River (just downstream of Stanislaus River) (Ainsley et al. 2013). During Year 1, traps should be deployed at several different locations in the lower Tuolumne River to help determine locations with highest catch rates. Locations will initially be selected based on ease of access and through consultation with individuals knowledgeable about factors impacting capture efficiency of these traps (DuBois and Harris 2013, Ainsley et al. 2013).

During Year 1, it may also be worth baiting a sub-set of traps with live forage species to determine whether live bait can increase capture efficiency for both striped bass, black basses, or secondary predator species such as channel catfish.

2.8.2 Supplemental Actions

In addition to the primary actions described above, supplemental actions including hook-and-line angling and various traps and nets to control predator populations in the lower Tuolumne River will occur. While these supplemental actions by themselves are not expected to meet removal targets, they are worth undertaking in conjunction with primary actions due to their relatively low cost. The use of supplemental actions that are proven effective may be expanded, whereas those with low effectiveness would be reduced or tested in different habitats or using a different approach. Additionally, if primary actions are not viable or effective for logistical or other reasons, supplemental actions may play a more prominent role in implementation of the Plan.

2.8.2.1 Shoreline Electrofishing

In addition to boat electrofishing, shoreline electrofishing (using a backpack or barge mounted electrofishing unit) should be evaluated as a means of capturing piscivorous-sized (>150 mm FL) largemouth and smallmouth bass that may be spawning, nest guarding, or feeding in shallow water habitats. Shoreline electrofishing should also be tested for effectiveness at capturing juvenile bass, which are expected to be concentrated in shallow margin areas.

Shoreline electrofishing should be conducted during the spring spawning and nest-guarding seasons, and again during the summer after young-of-the year bass have hatched and become established in shallow rearing habitats. Shoreline electrofishing should be tested during both daytime and nighttime to evaluate feasibility of nighttime sampling and determine the best approach for maximizing capture efficiency.

In the spring, sites should be selected in areas that have high quality spawning habitats for each species and good access for wading. In the summer, shoreline electrofishing should target sites with high quality juvenile rearing habitat.

Electrofishing is subject to special state and federal permitting requirements, as sampling can potentially affect non-target species, especially listed salmonids. Electrofishing sample locations, times, and methods will be selected to minimize impacts on salmonids and to comply with expected state and federal permitting conditions.

2.8.2.2 Hook-and-Line Angling

Hook-and-line capture (angling) involves the active use of lures or baits to capture fish. This method can selectively target key predators (e.g., smallmouth bass, largemouth bass, and striped bass) with little effect on other species. Various angling techniques may be evaluated as supplemental actions during Years 1–5. Angling will be conducted during the period immediately before dark, in conjunction with planned boat electrofishing efforts (e.g., while waiting for darkness). During the nest guarding period immediately after the peak bass spawning periods, anglers should also attempt to target nest guarding males. Various angling approaches (shore- and boat-based) and gear types (e.g., lures, bait) will be tested by experienced anglers for effectiveness in a variety of habitat types.

2.8.2.3 Baited Fish Traps

Baited fish traps have recently been shown to be effective for capturing adult striped bass in a laboratory environment, particularly when baited with live prey fish (Mortensen 2014). Traps would be deployed overnight in conjunction with other supplemental actions to maximize efficiency. Trap types, sizes, and openings should be selected to most effectively capture adult predators in a riverine environment. Fish captured using other supplemental actions under this Plan could potentially provide prey species used to bait traps.

2.8.2.4 Minnow Traps

Minnow traps will be tested as a relatively low-cost, low-effort approach for capturing juvenile bass. Minnow traps should be deployed in the summer after young-of-the-year bass have established in rearing habitat. Traps should be deployed both during the day and overnight in conjunction with other supplemental actions. Minnow traps should be baited with salmon roe or similar baits shown to be effective at capturing young bass.

2.8.2.5 Beach Seining

Beach seining will be tested as a supplemental method for removing juvenile bass, both in the spring and in summer after young-of-the-year bass have established in rearing areas. Spring seining will target all size classes and net mesh size will be selected accordingly. Summer netting will primarily target young-of-the-year bass before they grow too large to avoid the seine (approximately 60 mm; Jackson and Noble 1995). Beach seining should target high quality rearing habitat near areas known to contain considerable numbers of spawning bass.

2.8.2.6 Public Sport-Reward Fishery

Public sport-reward fisheries have been successful at reducing predators and associated predation on juvenile salmonids in the Columbia River and other locations (Attachment A). This type of fishery relies on the public anglers to capture target species and submit them for a cash reward. The reward is used to incentivize anglers to target, capture, and retain the species of interest. A public sport-reward program may only require a recreational fishing license subject to the daily bag limit, but could not be held as an organized contest under existing CDFW regulations due to prohibitions on selling fish taken with a sport fishing license. As a result, this method cannot be implemented until existing regulatory constraints are resolved. See Attachment A, Section 1.4 for a discussion of how such constraints have been resolved in Washington and Oregon to implement a sport-reward fishery for northern pikeminnow.

Implementing of this action includes working with state agencies to revise non-commercial sport fishing regulations to allow for a public sport-reward fishery in the lower Tuolumne River to reduce non-native predators and the effects of predation on native salmonids. Possible revisions include an exemption to allow a sport-reward fishery to be implemented, as well as adjustments existing bag and size limit regulations to improve program effectiveness.

2.8.3 Public Outreach Program

A public outreach program will be implemented to inform and educate local communities about the effects of non-native fish species on native salmonid populations in the lower Tuolumne River. The program will promote local fishing opportunities for black bass and striped bass to encourage angling and support removal of these species from the lower Tuolumne River. The program will also highlight Chinook salmon ecology and regional value of anadromous salmonid populations in the lower Tuolumne River. Outreach will be achieved through public events (e.g., site tours, seminars), articles and/or notifications of events in local publications (e.g., radio, newspapers), interpretive materials, and internet/web presence. Interpretive materials will be provided at public facilities such as boat ramps and parks where recreational angling opportunities are concentrated. Interpretive materials may include posters/pamphlets/flyers posted at key locations and distributed to local businesses, in addition to installation of more permanent signage at key locations. Topics covered by interpretive materials may include:

- Fishing access locations (parks, boat ramps, picnicking, public restrooms);
- Fishing regulations (seasons and gear restrictions), and species ID; and
- Salmon ecology and the effects of predation by non-native fish species.

3.0 PROGRAMMATIC CONSIDERATIONS FOR PREDATOR CONTROL

3.1 Feasibility, Effectiveness, and Cost

The Predator Control and Suppression Program for the lower Tuolumne River will include monitoring to compare relative feasibility, effectiveness, and cost of each predator control method implemented. Feasibility, effectiveness, and cost should be re-evaluated following each predator removal effort and results of the evaluation should be used to refine methods and level of effort, recommend new gear types or alternative methods, revise timing or duration of removal efforts, or identify other changes as part of the adaptive management framework (Section 3.5). Monitoring metrics for evaluating relative feasibility, effectiveness, and cost of actions will include:

- **Catch per unit effort**. CPUE is a measure of the relative success rate of a given method at capturing or excluding target predators. CPUE metrics vary by gear type and study type, and include fish captured per unit time (e.g., hour) or fish captured per unit of deployment (e.g., a seine haul).
- **Catch per unit cost**. Catch per unit cost—alternatively termed cost per unit catch—measures the monetary expense required to catch or exclude an individual or certain number of predators. Cost per unit catch should be calculated using total labor, equipment, permitting, and analysis expenditures using standardized accounting procedures to facilitate comparison among methods.

3.2 Fish Handling

Target predators captured during predator removal efforts would generally be killed, held temporarily (e.g., striped bass during pulse flows), or a portion may be relocated to nearby lakes or reservoirs (e.g., Turlock Lake, Modesto Reservoir) to provide anglers with future recreational opportunities. Transport and release of live fish would require holding facilities (e.g., live wells) and transport vehicles, as well as a CDFW permit. Target predators caught by anglers in a public sport-reward fishery would be killed rather than relocated. Fish removed using this method could be sold or donated for processing as food (human), livestock feed, fertilizer, fish meal, or pet food. If used for human consumption, additional handling considerations or permitting requirements may be required. Other fish captured during predator removal efforts, including key secondary predator fish listed above would be permanently removed from the Tuolumne River or killed.

3.3 Spatial Considerations

In the lower Tuolumne River, predation studies have identified the SRPs and run-pool habitats as primary predation hot spots for black bass (TID/MID 2013, 1992, Appendix 22). In addition, the reach from Waterford (RM 29.8) to Grayson (RM 5) has been identified as having a very high potential predation rate for outmigrating juvenile Chinook salmon based on RST monitoring and predation rate studies (TID/MID 2013). These predation "hot-spots" are considered as priority areas for implementing predator control actions; although additional work is needed to identify locations and times where each target predator and key prey species overlap the most during periods of maximum predator foraging activity.

3.4 Permitting Requirements

Adoption of PM&E measures, including this Predator Control and Suppression Plan, under the Don Pedro Project's FERC license will require NEPA review. Predator removal will require consultation and agreements for the activities conducted and methods used. For actions involving fish capture and removal, a CDFW Scientific Collecting Permit will be required. Pursuant to Fish and Game Code Section 1002 and Title 14 Sections 650 and 670.7, a Scientific Collecting Permit is required to take, collect, capture, or mark fish as part of a scientific study or research activity. Required federal permits may include either an Endangered Species Act (ESA) Section 10 permit (National Marine Fisheries Service [NMFS]) for incidental take in waters with listed anadromous salmonids (*O. mykiss*), or a permit under the ESA Section 4(d) rule. Estimates of *O. mykiss* take that may be requested under an NMFS Section 10 or Section 4(d) permit, based on previous permits for fish monitoring projects in the Tuolumne River and other Central Valley rivers, are provided in Table 3.4-1.

Table 3.4-1. Estimated annual take to be requested under a federal ESA Section 10 or Section 4(d) permit for Tuolumne River predator control activities.

Species and DPS[1]	ESA Listing Status	Take Activity/ Capture Method[2]	Adult		Juvenile		
			Non-lethal	Lethal[3]	Non-lethal	Lethal[3]: Number of Intentional	Lethal[3]: Percent Unintentional
Oncorhynchus mykiss (Central Valley steelhead)	Threatened	Encounter (boat electrofishing)	3	0	20	0	5% of CV steelhead captured
		Capture (boat/backpack electrofishing, seine, fyke or other traps, angling) handle, release	0	0	40	0	5% of CV steelhead captured

1 DPS = distinct population segment.
2 Boat and backpack electrofishing may not be conducted in the vicinity of redds of ESA-listed species. Site surveys shall be conducted and resource agency personnel consulted prior to electrofishing to verify that no redds are present at sampling sites. No boat electrofishing will be allowed upstream of RM 31.5 from September through March. No backpack electrofishing will be allowed upstream of RM 31.5 from September through January.
3 No intentional lethal take of ESA-listed salmonids is permitted using any method.

A public sport-reward program would require an exemption from existing CDFW regulations (Fish and Game Code Section 7121), which prohibit sale of fish taken with a sport fishing license. It is also unlawful to offer a prize as a reward for the taking of a fish in an individual contest, tournament, or derby unless CDFW issues a permit authorizing a prize to be offered after determining that there would be no detriment to the resources (Fish and Game Code Section 2003). Additionally, a CDFW bass tournament permit application (Permit to Offer Prizes for Taking of Game Fish; $60 application fee), would be required pursuant to Section 230, Title 14, California Code of Regulations.

Any fish relocation associated with predator control actions would be subject to Section 6400 of the Fish and Game Code, which states that it is unlawful to place, plant in waters of the state, any live fish, any fresh or salt water animal whether taken without or within the state, without first securing the written permission of the Department. Permits would require annual or semi-annual renewal and reporting of results (i.e., data on species captured, transported, and released).

Predator isolation projects initiated as part of a long-term predator control program (barrier weir) require California Environmental Quality Act and NEPA review, as well as permits from the U.S. Army Corps of Engineers (USACE) and CDFW, as described below.

- Section 404 of the Clean Water Act requires that project applicants seek a permit from the USACE prior to discharging dredge or fill material into waters of the U.S. It is anticipated that the barrier weir construction would require the placement of temporary or permanent fill in waters of the U.S. These activities would require application for a Clean Water Act Section 404 permit from USACE, thus necessitating NEPA review.
- CDFW Streambed Alteration Agreement. Pursuant to Fish and Game Code Section 1602, CDFW must be notified of any proposed activity that may substantially modify a river, stream, or lake. The applicant must submit a completed notification form and the corresponding fee. If CDFW determines that the activity may substantially adversely affect fish and wildlife resources, a Lake or Streambed Alteration Agreement will be prepared. The Agreement includes reasonable conditions necessary to protect those resources and must comply with California Environmental Quality Act.
- Section 10 of the Rivers and Harbors Act requires authorization from USACE for the construction of any structure in, under, or over navigable waters of the U.S., as well as for structures outside of the limits of the defined navigable water if the structure or work would affect the course, location, or condition of the water body. The lower Tuolumne River is considered navigable by USACE, so all work that may affect the channel would be regulated under Rivers and Harbors Act Section 10.

The AFLA is accompanied by an applicant-prepared Biological Assessment (BA) to assess potential impacts on species listed as threatened or endangered under the federal ESA. The analysis in the BA includes potential effects of the Plan and other proposed Protection, Mitigation and Enhancement (PM&E) measures. The BA will provide ESA Section 7 compliance and inform development by the federal resource agencies (NMFS and possibly USFWS) of a Biological Opinion. The Districts anticipate an incidental take permit would be issued, as appropriate, in conjunction with the new FERC license.

3.5 Uncertainties

Uncertainty exists regarding the response of predator populations, even to relatively smaller scale removal programs and the long-term effects on predators and other species that are ecologically closely linked with predators (e.g., Moyle and Bennett 2011). Potential ecological effects of predator removal may include:

- Replacement of one predator species with another. Depletion of black bass, for example, may create an "empty niche" leading to increased abundance and/or predation by striped bass or Sacramento pikeminnow. Burdick (2008) documented increased abundance of largemouth bass and several other non-native fish species following a focused smallmouth bass removal program in the Colorado River, although predation levels were not evaluated.
- Increases in prey species (non-salmonid) abundance leading to unknown food web effects. Key predators identified for this evaluation prey on a variety of species in addition to juvenile salmonids, such as crayfish and other fishes (TID/MID 2013). Potential effects may include increased abundance of these prey species and resultant reductions in their primary plant and animal food items.

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PREDATOR CONTROL AND SUPPRESSION PLAN FOR THE LOWER TUOLUMNE RIVER

ATTACHMENT A

REVIEW OF PREDATOR CONTROL METHODS

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1.0 REVIEW OF PREDATOR CONTROL METHODS

The following is a review of the predator control methods considered for implementation as part of the Lower Tuolumne River Predator Control and Suppression Plan. It includes information from published literature, unpublished reports, and other sources, including information on effort (CPUE) and cost where available. The methods reviewed here include those proposed for implementation on the lower Tuolumne River as well as several that are not proposed.

1.1 Electrofishing

Electrofishing is commonly used as a non-lethal method to capture a wide variety of fish species, including predatory fishes. Target predators captured could be killed or retained for relocation to Turlock Lake, Modesto Reservoir, or other nearby lakes or reservoirs to provide anglers with future recreational opportunities, depending on approval of a predator control plan with CDFW. Transport and release of live fish would require holding facilities (e.g., live wells) and transport vehicles, as well as a CDFW permit (see Permitting Requirements below). Electrofishing is recommended as the primary method of predator removal, while other gear types could be used as supplementary methods. It is generally an efficient capture method, compared with other non-lethal methods. Boat-based electrofishing would likely be the preferred approach for targeting predators on the lower Tuolumne River; however, shore-based electrofishing using backpack or barge electrofishers may be appropriate in certain locations or for targeting certain life stages (e.g., juvenile or spawning stage fish in shallow waters).

Boat-based electrofishing has proven successful as a predator capture method in the lower Tuolumne River (TID/MID 2013; McBain & Trush and Stillwater Sciences 2006; TID/MID 1992, Appendix 22) and elsewhere in the region (e.g., Cavallo et al. 2012). Its relative effectiveness is discussed in more detail below.

1.1.1 Strengths

- Efficient predator capture method.
- Can target all age classes (and thus maximize population-level effects).
- Proven to be effective in the lower Tuolumne River.

1.1.2 Challenges, Constraints, and Uncertainties

- Fish can be only be captured in limited depth range (not effective in deep water).
- Not highly selective for target species and can potentially affect non-target species, especially larger fish (adults).
- Permitting may be challenging, but feasible if sampling timing and locations are selected to avoid non-target species. Permits to sample predators in the lower Tuolumne River using electrofishing were successfully obtained for the 2012 predation study (TID/MID 2013).

1.1.3 Monitoring Metrics

The programmatic population and effectiveness metrics described in Section 2.3 are appropriate for this method. No additional monitoring is currently recommended for electrofishing.

1.1.4 Timing

Predator removal by electrofishing would likely be timed to coincide with spawning (when predators are on nests at relatively shallow depth) and early rearing (when fry/juveniles are concentrated in shallow margin areas) to maximize population-level effects on predators (Loppnow et al. 2013). Effectiveness (i.e., capture efficiency) of electrofishing is expected to be negatively correlated with river flow; i.e., effectiveness increases as flows decrease and the depth and area of the sampled aquatic habitat units decrease. Nighttime electrofishing, as used in previous predator capture efforts, is considered preferable due to higher capture rates than daytime electrofishing (Pierce et al. 2001; TID/MID 1992, Appendix 22; McBain & Trush and Stillwater Sciences 2006; TID/MID 2013).

1.1.5 Permitting Requirements

Electrofishing is subject to special state and federal permitting requirements, as sampling can potentially affect non-target species, especially larger fish (adults). Permitting requirements would likely include the following:

- CDFW Scientific Collecting Permit for electrofishing. Pursuant to Fish and Game Code Section 1002 and Title 14 Sections 650 and 670.7, a Scientific Collecting Permit is required to take, collect, capture, or mark fish as part of a scientific study or research activity.
- Either an ESA Section 10 permit (NMFS) for electrofishing, which could result in incidental take in waters with listed anadromous salmonids (*O. mykiss*) or a permit under the ESA Section 4(d) rule.
- A special state permit such as a Fish and Game Code Section 5501 permit may be required. Section 5501 of the Fish and Game Code states that the Fish and Game Commission may prescribe the terms of a permit to take any fish which, in the opinion of the department, is harmful to other species of fish and which should be reduced in numbers. A permit pursuant to Section 5501 would allow take (destruction) of predator fish captured as part of a predator control program. Although Section 226.5 of the Fish and Game Code provides for issuance of permits to destroy harmful species of fish in private waters for management purposes, the lower Tuolumne River is not privately owned, and paragraph (d) specifically states that no permits shall be issued for rivers or streams.
- Any fish relocation would be subject to Section 6400 of the Fish and Game Code, which states that it is unlawful to place, plant, or cause to be placed or planted, in any of the waters of this state, any live fish, any fresh or salt water animal, or any aquatic plant, whether taken without or within the state, without first submitting it for inspection to, and securing the written permission of, the Department (see Sections 12023 and 12024 of the Fish and Game Code for penalties).

1.1.6 Relative Effectiveness

Cost to implement would likely be **moderate-high** and cost per predator captured would likely be **moderate.**

Primary costs would be electrofishing and boat equipment, field staff, program administration, and analysis and reporting.

Mean CPUE for boat electrofishing conducted by FISHBIO in the lower Tuolumne River at all sites during three sampling efforts in 2012 (March 22–29, May 1–9, and July 25–August 8) was 0.164 adult largemouth bass per minute (8.8/hr) of electrofishing, 0.222 adult smallmouth bass per minute (13.3/hr), and 0.015 adult striped bass per minute (0.9/hr) (TID/MID 2013). Using these CPUE values, boat electrofishing could be used to achieve the 10 percent predator removal target in the reach between the Grayson and Waterford RSTs (RM 5.1–30.3) (Table 2.3-1 of the Predator Control Plan) with 1,835 minutes (31 hours) of sampling for largemouth bass, 1,653 minutes (27 hours) of sampling for smallmouth bass, and 1,600 minutes (27 hours) of sampling for striped bass. Assuming that CPUE for all three species can be achieved concurrently (as in the TID/MID [2013] study) and would not require separate survey efforts, 31 total hours of sampling would be required to meet the 10 percent removal target for all three species. The 15 percent predator removal target in this reach could be achieved by 2,756 minutes (46 hours) of boat electrofishing for largemouth bass, 2,450 minutes (41 hours) for smallmouth bass, and 2,333 minutes (39 hours) for striped bass. Assuming that CPUE for all three species can be achieved concurrently, 46 total hours of sampling would be required to meet the 15 percent removal target for the three key predator species. Note that sampling time estimates above are based on time electricity is applied, and do not include time for supporting activities (e.g., mobilizing/demobilizing, travel time between sites, fish processing). Based on the estimated effort for boat electrofishing, this predator control method would likely be highly effective and moderately cost efficient.

Because boat electrofishing would be most effective at capturing adult fish, a supplemental predator removal method (e.g., trapping, seining, shoreline backpack or barge electrofishing) should be used concurrently to ensure capture of younger year classes (see discussion of increased recruitment due to reduced intraspecific competition in Section 2.8).

Use of electrofishing in shallow water (either backpack, barge, or from a flat bottom boat) has potential to efficiently capturing large numbers of younger age classes, particularly in areas with high densities of aquatic vegetation that hinder or preclude netting (McInerny and Cross 2004). For example, in a North Carolina reservoir, Jackson and Noble (1995) reported a CPUE for age-0 largemouth bass of 0.2–2.2 fish/min (12–132 fish/hr) using a handheld electrofisher from a flat-bottomed boat.

See Table 1.1-1 below for a summary of CPUE for this method reported in the literature.

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Table 1.1-1. Catch per unit effort (CPUE) for predator removal methods.

Reference	Location	Gear	Species[1]	Life Stage	CPUE (units)	Notes
Electrofishing						
Jackson and Noble (1995)	Jordan Lake, NC	E-fishing (boat, handheld)	LMB	Juvenile/YOY	12–132 (fish/hr)	Study reported catch rates as *fish/min* e-fished (converted to fish/hr). They also tested a boom-mounted e-fisher, but did not provide CPUE. Hand-held electrofisher was effective for sampling all lengths of fish < 200 mm total length and more effective for smaller fish than boom-mounted unit. Boom-mounted unit was effective at sampling fish longer > 150 mm, but underestimated smaller fish. Boom-mounted unit collected fish from two larger size-classes not represented in the sample from the hand-held unit.
Bacula et al. (2011)	4 glacial lakes, SD	E-fishing	SMB	Adult, YOY	99.7–771.8 (fish/hr)	Includes all sizes; range = monthly means
Skorupski and Breen (2013)	Green River, UT	E-fishing	SMB	Adult, Juvenile	4–34 (fish/hr)	Range = annual CPUE 2004–2012 (all sizes) CPUE highest in 2012, when 15,624 SMB were removed over 458 hours of e-fishing (> 50% were < 100-mm long; see Fig. 5)
Boucher (2006, as cited in Loppnow et al. 2013)	pond, ME	E-fishing	SMB	Adult	23.2 (fish/hr)	Only 7 fish captured in 70-ha pond in 2,103 trap net hrs (0.003 fish/hr), as compared to 200 in 8.62 hours of e-fishing (23.2 fish/hr)
McInerny and Cross (2004)	lakes, MN	E-fishing	SMB, LMB	Adult, Juvenile	Not reported	E-fishing generally resulted in higher CPUEs during late summer or fall when submergent aquatic macrophyte densities were highest; however, e-fishing CPUEs of larger LMB are higher if conducted during spawning.
TID/MID (2013)	Tuolumne River, CA	E-fishing	LMB, SMB, STB	Adult	LMB = 0.164/min (8.8/hr) SMB = 0.222/min (13.3/hr) STB = 0.015/min (0.9/hr)	Mean CPUE for boat e-fishing conducted by FISHBIO in the lower Tuolumne River at all sites during 3 sampling efforts in 2012 (March 22–29, May 1–9, and July 25–August 8).
North Carolina WRC (2011)	Cape Fear River, NC	E-fishing (boat)	LMB, Spotted bass	Adult (>8")	17.2 (fish/hr)	2011 sampling CPUEs: largemouth bass > 14" = 4.0 fish/hr spotted bass > 8" = 4.0 fish/hr

Reference	Location	Gear	Species[1]	Life Stage	CPUE (units)	Notes
Dieterman (2008)	Upper Mississippi River, MN	E-fishing (boat)	LMB	Adult	14–98 (fish/hr)	Range = mean of 7 sites from 1994–2008 (Tables 2.3-2 and 2.4-1 of the Predator Control Plan).
Hawkins et al. (2009)	Yampa River, CO	E-fishing (boat)	SMB	Adult, Juvenile	8–40 (fish/hr)	Range from annual CPUE for smallmouth bass > 150–mm TL at two study sites, 2004–2007. CPUE was higher at sites with higher fish density (as estimated from mark-recapture). Removed 15,190 SMB and tagged and released 4,876 in 5 years at 2 study sites. Estimated that they removed 40–83% of fish present at study sites (depending on year). Removal rates improved with increased effort.
Louisiana DWF (2011)	Blind River, LA	E-fishing (boat)	LMB	Adult, Juvenile	~5–50 (fish/hr)	CPUE from figures for fish > 8". Range = annual means for 6 years of spring e-fishing.
Fewlass (1985)	Chesapeake Bay tribs, MD	E-fishing (boat)	LMB	Adult, Juvenile	~6–56 (fish/hr)	Range from several rivers over 2 years (appears to be age 1 and older only; see Table 2.2.-1 of the Predator Control Plan); mean CPUE was 23.
Frederick County (2005)	Monacy R, MD	E-fishing (boat)	SMB	YOY	0–26 (fish/hr)	Range from 5 sites sampled in 2005; YOY only.
Pierce et al. (2001)	lakes, IA	E- fishing (boat)	LMB, SMB	Unknown	SMB (fish/hr) day = 1.00; night = 8.74 LMB (fish/hr) day = 1.90; night = 5.37	Total CPUE for electrofishing was significantly greater for night than for day sampling. Diel differences in CPUE were more prevalent for electrofishing than seining.
Hook-and-Line						
TID/MID (2013)	Lower Tuolumne River, CA	Hook-and-line	LMB, SMB, STB	Adult (> 150 mm FL)	0.15 fish/hr	Angling conducted in 2012 in lower Tuolumne River. Date not specified. Total angling time of 112 hrs split equally between SRP 6 and SRP 10. CPUE for individual species not specified.
Krogman (2013)	Various, CA	Hook-and-line (derbies)	LMB, SMB, spotted bass	Adult	0.17–0.34 (fish/contest-hr)	Range = mean "catch rate" (fish/contest hr) of all contests held each year from 1985 to 2012. Contest hours assume that each participant fishes every eligible hour through total duration of contest. In 2012, catch rates for ~60 different water bodies ranged from

Reference	Location	Gear	Species[1]	Life Stage	CPUE (units)	Notes
						0.10 to 0.53. (App. 1)
DuBois and Gingras (2013)	Lower Sacramento and San Joaquin rivers, CA	Hook-and-line (party boat)	STB	Adult	~5–15 (fish /100 angler-hrs)	Range from 1980–2009; values taken from Fig. 3 appear to be all locations combined.
Porter (2013)	Columbia River, OR/WA	Hook-and-line (sport reward)	Pikeminnow	Adult	2.09–7.59 (fish/angler-day)	Range = mean annual from 1991 to 2012. CPUE increased steadily over period (Fig. 16). CPUE was cost/angler-day. One registration form represented one angler-day.
Boucher (2006, as cited in Loppnow et al. 2013)	Pond, ME	Hook-and-line	SMB	Adult	0.31 (fish/angler-hr)	Anglers removed *M. dolomieu* from 70-ha pond in Maine at rate of 0.31 fish/hr as compared to 23.2 fish/hr for electrofishing; author did not believe angling was appropriate control measure for that system.
Gomez and Wilkinson (2008, as cited in Loppnow et al. 2013)	Beaver Cr., British Columbia	Hook-and-line	SMB	Adult	0.50 (fish/angler-hr)	Nearly 300 angler hours over two years resulted in the removal of just 150 *M. dolomieu.*
Nets and Traps						
Hawkins et al. (2009)	Yampa River, CO	Electric Seine	SMB	YOY and juvenile	159–262 (fish/hr)	Range = annual CPUE for 3 years. Mostly YOY. Fish captured with 10-m-long electric seine powered by 2,000-watt generator. Removed 18,166 small, mostly YOY SMB with e-seine from 2005–2007.
Wisconsin DNR (2013)	Menominee River, WI	Fyke net	SMB	Age-1 and older	0.39–0.59 (fish/net-night)	Range for 2 years of sampling while targeting muskellunge (see Table 2.3-1 of the Predator Control Plan). No LMB caught.
Bacula et al. (2011)	4 glacial lakes, SD	Fyke net-modified	SMB	Adult, YOY	0.2–4.7 (fish/net-night)	Range reported in abstract is for monthly means.
Ainsley et al. (2013)	San Joaquin River, CA	Fyke trap	STB	Adult	0–0.94 (fish/trap-hr)	Varied by location and day with mean of 0.04 at one location; 0.14 at another.
DuBois and Mayfield (2009), DuBois et al. (2010, 2011, 2012), DuBois	Sacramento River, CA	Fyke trap	STB	Adult	0– >5 (fish/trap-hr)	Varied by day, year, and trap, with some individual traps having much higher CPUE (> 40 fish/hr in a day). Annual mean of all traps ranged from 0.22 to 1.50 (fish/hr). Up to 10 traps were fished simultaneously in area; thus

Reference	Location	Gear	Species[1]	Life Stage	CPUE (units)	Notes
and Harris (2013)						total annual catches for the ~2-month spring season were large (~2,000–7,000 fish)
Klumb (2007)	Missouri River, SD	Fyke trap (mini)	SMB	Juvenile/YOY	1–25 (fish/net-night)	Range from mean monthly CPUEs for multiple locations and months (all fish caught were < ~110 mm)
Fewlass (1985)	Chesapeake Bay tribs, MD	Seine	LMB	YOY	0.05–11.25 (fish/haul)	Range from stocked and unstocked sites; YOY only.
Frederick County (2005)	Monacy R, MD	Seine	SMB	YOY	1.4–8.4 (fish/haul)	Range is from 9 years of YOY data; geometric mean from ~20 hauls per year.
Jackson and Noble (1995)	Jordan Lake, NC	Seine	LMB	Juvenile/YOY	0.4–4.9 (fish/haul)	Seine was ineffective at capturing fish larger than 60 mm. There was a rapid decline in relative efficiency of seine for 30-60-mm lengths and consistently low efficiency (<1.0) for all length classes greater than 60 mm [9-m bag seine with 0.9-cm-bar mesh in the wings and 0.6-cm bar mesh in the bag].
Tuomikoski (2004)	Albemarle Sound, NC	Beach seine; purse seine	STB	Age-1	0.09–0.67 (fish/haul)	Range for 2 years for age-1 striped bass. Beach seine had higher CPUE than purse seine.
Boucher (2006, as cited in Loppnow et al. 2013)	Pond, ME	Trap net	SMB	Adult	0.003 (fish/hr)	Only 7 fish captured in 70-ha pond in 2,103 trap net-hours (0.003 fish/hour), as compared to 200 in 8.62 hours of electrofishing (23.2 fish/hour)
McInerny and Cross (2004)	Lakes, MN	Trap net	SMB	Adult, juvenile	<180 mm = 0.07 >180 mm = 0.00 (fish/hr)	Value estimated from Fig. 16 and methods indicating nets set for 24 hrs. Trap nets not effective for black bass compared with E-fishing. Trap nets did not capture SMB > 180 mm. Document also provides some information on day vs. night e-fishing and other considerations that may inform e-fishing capture efficiency.
			LMB	Adult, juvenile	<200 mm = 0.000–0.04 >200 mm = 0.004–0.017 (fish/hr)	Range of values estimated from Figs. 16 & 17 and methods indicating nets set for 24 hrs. Trap nets not effective for black bass compared with e-fishing. Document also provides some information on day vs. night e-fishing and other considerations that may inform e-fishing capture efficiency.

Reference	Location	Gear	Species[1]	Life Stage	CPUE (units)	Notes
Portt et al. (2006)	Various	various (review)	Multiple	Adult, juvenile	n/a	Literature review discussing various gear, CPUE concepts, considerations, and examples.
Loppnow et al. (2013)	Various	various (review)	SMB	Adult, juvenile	Review paper	Review discussing various control options and provides CPUE data for some approaches. Authors state that, in general, nets are much less effective at catching *M. dolomieu* than e-fishing. Also indicates that minnow traps have been used effectively for YOY SMB. Population modeling suggests that smallmouth bass population growth rate is most sensitive to survival in the first 1–4 years of life. Therefore, targeting eggs, larvae, and juveniles is the most efficient approach to controlling the species. Additionally, targeting these early life stages alone or in concert with management of adults could potentially prevent overcompensation.
Weirs						
FISHBIO (2010, 2013); TID/MID (2011, 2012)	Tuolumne River, CA	Weir	All black bass combined	adult (primarily)	0.050–0.537 (fish/hr)	Calculated CPUE based on count data provided in FISHBIO annual reports; reported data is for LMB, SMB, and unknown black bass combined. Weir only operated from Sept-Dec. CPUE may be higher in spring.
			STB	adult (primarily)	0.002–0.019 (fish/hr)	Calculated CPUE based on count data provided in FISHBIO annual reports. Weir only operated from Sept-Dec. CPUE would likely be higher during spring migration.

[1] LMB – Largemouth Bass; SMB = Smallmouth Bass; STB = Striped Bass.

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1.2 Predator Exclusion Weir

A channel-spanning weir that blocks the movement of large predators while allowing emigration of juvenile salmonids may be considered for future implementation in the lower Tuolumne River. This method may be highly effective at reducing or eliminating river spawning by large, migratory predators (e.g., striped bass) but may be less effective on resident predators such as largemouth and smallmouth bass that are abundant in multiple habitat types throughout much of the lower Tuolumne River but are not generally considered migratory. Notably however, significant numbers of black basses have been counted passing the existing lower Tuolumne River counting weir (RM 24) during its fall operation period (FISHBIO 2010, 2013; TID/MID 2012).

Implementation of this approach is dependent upon gaining additional information regarding migratory timing of striped bass in the lower Tuolumne River. To accomplish this, a weir fixed with a passive video monitoring system (e.g., the existing counting weir at RM 24.5) could be used to assess numbers of striped bass and their migration timing relative to other (sensitive) fish species, or target predators. In addition, an exclusion weir would likely need to be monitored intensively during initial years to determine effectiveness and impacts to non-target species. If significant numbers of non-target, migratory fish are being blocked, it may be necessary to actively trap fish approaching the weir to allow selective passage of native species. Trapping would also allow collection of biological data from striped bass and other predators and removal if warranted/specified in the Plan.

1.2.1 Strengths

- Prevents entry of large predatory striped bass into the Tuolumne River, minimizing predation on juvenile salmonids in upstream reaches.
- Non-lethal approach would be more accepted by public and sport fisherman.
- Labor associated with passive predator exclusion could be relatively minimal, particularly after initial intensive effectiveness monitoring was complete.

1.2.2 Challenges, Constraints, and Uncertainties

- Could block/disrupt native migratory species that have overlapping migratory timing with spawning striped-bass such as *O. mykiss*, non-typical Chinook salmon migrants, and Pacific lampreys (*Entosphenus tridentatus*).
- Unknown impact on striped bass behavior, including factors such as spawning site selection.
- Could be a navigation barrier to recreational watercraft.
- Could promote poaching if fish were to “stack-up” below the weir.
- Weirs have a tendency to clog with debris, therefore, may require regular monitoring and maintenance during certain times.
- Vandalism could be an issue.

1.2.3 Timing

The existing counting weir is currently permitted for year-round operations. Timing of weir placement would likely occur in spring, when most striped bass are thought to move from saltwater into the lower reaches San Joaquin River and tributaries to spawn. However, striped bass have also been observed moving during the fall (FISHBIO 2010, 2013; TID/MID 2012) and more information on timing of entry into and migration in the Tuolumne River is needed to refine timing of weir placement. Evidence from weir operations on the lower Tuolumne River indicates that striped bass may be most active during changes in flow (FISHBIO 2013); therefore, deployment of an exclusion weir may be strategically timed to coincide with planned or expected flow fluctuations. Weir placement should be planned to minimize interference with native migratory species, such as fall-run Chinook salmon, which migrate primarily between September and January (FISHBIO 2010, 2013; TID/MID 2012).

1.2.4 Monitoring Metrics

In addition to the longer-term effectiveness monitoring described in Section 2.3, during initial years monitoring effectiveness of the exclusion weir would include intensive on-site monitoring (either by active trapping or video monitoring) to determine how many target predators are being excluded and impacts to non-target species.

1.2.5 Permitting Requirements

Operating a weir would be subject to special state and federal permitting requirements, as it would potentially affect non-target species. Permitting requirements would likely include the following:

- CDFW Scientific Collecting Permit. Pursuant to Fish and Game Code Section 1002 and Title 14 Sections 650 and 670.7, a Scientific Collecting Permit is required to take, collect, capture, or mark fish as part of a scientific study or research activity.
- Either an ESA Section 10 permit (NMFS) for weir operation, which could result in incidental take in waters with listed anadromous salmonids (*O. mykiss*), or a permit under the ESA Section 4(d) rule.

A barrier weir would also require California Environmental Quality Act (CEQA) and NEPA review, as well as permits from the U.S. Army Corps of Engineers (USACE), CDFW, and the CVRWQCB as described below.

- Section 404 of the Clean Water Act (CWA) requires that project applicants seek a permit from the USACE prior to discharging dredge or fill material into waters of the U.S. It is anticipated that the barrier weir construction would require the placement of temporary or permanent fill in waters of the U.S. These activities would require application for a CWA Section 404 permit from USACE, thus necessitating NEPA review.
- CDFW Streambed Alteration Agreement. Pursuant to Fish and Game Code Section 1602, CDFW must be notified of any proposed activity that may substantially modify a river, stream, or lake. The applicant must submit a completed notification form and the

corresponding fee. If CDFW determines that the activity may substantially adversely affect fish and wildlife resources, a Lake or Streambed Alteration Agreement will be prepared. The Agreement includes reasonable conditions necessary to protect those resources and must comply with CEQA.

- Section 10 of the Rivers and Harbors Act (RHA) requires authorization from USACE for the construction of any structure in, under, or over navigable waters of the U.S., as well as for structures outside of the limits of the defined navigable water if the structure or work would affect the course, location, or condition of the water body. The lower Tuolumne River is considered navigable by USACE, so all work that may affect the channel would be regulated under RHA Section 10.
- Section 401 of the Clean Water Act requires that every applicant for a federal permit or license for an activity that may result in a discharge into a water body must request state certification that the proposed activity will not violate state and federal water quality standards. The Central Valley Regional Water Quality Control Board would be the state agency responsible for issuing the certification.

1.2.6 Relative Effectiveness

Cost to implement would likely be **moderate**, and cost per predator excluded would likely be **moderate–high**.

Implementation would likely require periodic (e.g., daily) monitoring of the weir during periods of seasonal deployment. Costs may be reduced following initial years with increased understanding of run timing, impacts to non-target species, and level of debris accumulation.

A properly installed, channel-spanning exclusion weir could theoretically block migration of 100 percent of the striped bass attempting to enter the lower Tuolumne River in the spring. During September – December operation of a resistance board weir equipped with a Vaki Riverwatcher fish counting system in the Tuolumne River at RM 24.5, between 5 and 38 adult striped bass were counted annually from 2009 through 2012 (FISHBIO 2010, 2013; TID/MID 2012). These counts equate to 0.002–0.019 fish/hr assuming the weir was operated 24 hr / day during period of operation. If fish were excluded or trapped and removed at the weir, striped bass removal targets (Table 2.3-1 of the Predator Control Plan) could be reached during the current fall to early winter operation period in some years. Since significantly more striped bass are expected to migrate into the lower Tuolumne River during the spring, these targets would almost certainly be met (and likely exceeded) if such a weir were operated during peak migration in the spring.

Counts of black bass at the existing fall-operated weir also indicate that a weir and trap system could be a viable option for meeting predator removal targets for smallmouth and largemouth bass in some years. From 2009–2012, counts of bass (all species combined, including upstream and downstream counts) at the weir ranged from 128–1,275 fish (mean total length >200 mm in all years) (FISHBIO 2010, 2013; TID/MID 2012). These counts equate to 0.050–0.537 fish/hr assuming the weir was operated 24 hr/day during period of operation. It is possible that even more black bass per unit effort could be captured if a weir were operated during the spring and summer.

See Table 1.1-1 above for a summary of CPUE for this method reported in the literature.

1.3 Public Sport Fishing Derbies

Bass derbies are common and widespread, with over 1,400 derbies held in California in 2012 (Krogman 2013). Sport fishing derbies have been used successfully to help control northern pikeminnow populations in several Columbia River Basin reservoirs, but it is unknown whether bass fishing derbies have previously been used as part of a predator control program.

Lower Tuolumne River sport fishing derbies would be categorized by CDFW as "Event" type contests and subject to applicable regulations, including release of fish live and unharmed. Transport and release of live fish would require holding facilities (e.g., live wells) and transport vehicles, as well as a CDFW permit (see Permitting Requirements below).

1.3.1 Strengths

- This method is advantageous because it can selectively target key predators (e.g., smallmouth bass, largemouth bass, striped bass) with little effect on other species.
- Requires low–medium cost and effort to implement since fish capture would be conducted by public.
- There are numerous existing fishing clubs and bass fishing tournaments; therefore, it may be relatively easy to identify a group with tournament organizing experience that is willing to assist with event sponsorship and promotion.

1.3.2 Challenges, Constraints, and Uncertainties

- Only one of over 1,400 bass events held in California in 2012 was held in a river reach (i.e., such events are typical on lakes/reservoirs). Therefore, it would be important to evaluate why this is, what the level of interest is for holding an event on a river reach, and whether it would garner enough interest to be effective since it would be competing with many events held in reservoirs. Note: this does not consider the Sacramento-San Joaquin Delta as a river, and there are numerous events held in the Delta annually.
- One possible reason for few events on rivers is that few bass fishing boats (i.e., “bass boats”) are equipped with jet propulsion or have shallow-running hulls designed to run in riverine environments. Rather, bass boats typically have a v-hull design and are driven by propeller, making it difficult or infeasible to operate in shallow water or areas with abundant debris.
- Jet boats are not typically equipped with live wells, which would be desirable, but not required, to keep fish in good condition for relocation.
- It is possible that devoted bass fisherman would be unwilling to participate in a derby designed to reduce the bass population.
- A predator removal approach such as a fishing derby that targets adult fish only may result in reduced intraspecific competition, leading to increased abundance due to more rapid growth and maturation of juveniles (Zipkin et al. 2009; Zipkin et al. 2008; Weidel et al. 2007;

Ridgway et al. 2002; all as cited in Loppnow et al. 2013). For this reason, a derby should be conducted in conjunction with methods that also target smaller size classes.

- There is some uncertainty on the extent to which a fishing derby would result in capture of significant numbers of striped bass. Most existing tournaments are set up for and focused on largemouth, but a derby could be geared towards all three species.
- Possible approaches to increase participation and success:
  - Consider trying to promote the river tournament as challenging and different from lake-based tournaments.
  - Consider promoting as "Derby" to encourage more widespread public participation, versus a "tournament" that may imply "professional" participation.
  - Consider promoting to river anglers in the upper Sacramento valley and elsewhere who generally fish for salmon and steelhead and are more likely to own a jet boat.
  - Limit event location to specified habitat units or reaches (e.g., SRPs) known to have high bass densities and sufficient depth to enable use of typical bass boats, as well as easier entry and exit points. This would improve angler participation and success, maximize predator removal, and reduce logistical constraints for organizers.
  - Offer cash awards for catching all three species and have award categories for largest fish of each species, etc.

1.3.3 Monitoring Metrics

The programmatic effectiveness metrics (e.g., CPUE) described in Section 2.3 are appropriate for this method. Additional monitoring for a public sport fishing derby would include surveys to document level of participation and demographic information of participants, which could inform marketing, timing, and success of future events (adaptive management).

1.3.4 Timing

Public sport fishing derbies for bass are held year-round in California, however, public participation would likely be highest during spring and summer, and catch rates would likely improve when water temperatures are relatively warm. Periods around spawning (pre-spawn, spawn, post-spawn) can be especially effective for capturing bass, particularly larger fish, due to territorial and defense behaviors to protect eggs and fry at shallow-water nesting sites. However, there may also be increased competition with other bass fishing tournaments during this time.

1.3.5 Permitting Requirements

- Section 2003 of the Fish and Game Code states that it is unlawful to offer a prize as a reward for the taking of a fish in an individual contest, tournament or derby unless CDFW issues a permit authorizing a prize to be offered after determining that there would be no detriment to the resources.
- CDFW bass tournament permit application (*Permit to Offer Prizes for Taking of Game Fish*; $60 application fee), pursuant to Section 230, Title 14, California Code of Regulations.

- CDFW exemption for regulations prohibiting transport of fish caught in fishing tournaments, and/or a Section 5501 permit.
- Section 230 of the Fish and Game Code prohibits the relocation of live fish caught in fishing tournaments unless by special exception. Such an exception would be required to transport predator fish caught in the Tuolumne River to a nearby reservoir or lake.
- Section 5501 of the Fish and Game Code states that the Fish and Game Commission may prescribe the terms of a permit to take any fish which, in the opinion of the department, is harmful to other species of fish and which should be reduced in numbers. A permit pursuant to Section 5501 would allow take (destruction) of predator fish captured as part of a predator control program. Although Section 226.5 of the Fish and Game Code provides for issuance of permits to destroy harmful species of fish in private waters for management purposes, the lower Tuolumne River is not privately owned, and paragraph (d) specifically states that no permits shall be issued for rivers or streams.
- Any fish relocation would be subject to Section 6400 of the Fish and Game Code, which states that it is unlawful to place, plant, or cause to be placed or planted, in any of the waters of this state, any live fish, any fresh or salt water animal, or any aquatic plant, whether taken without or within the state, without first submitting it for inspection to, and securing the written permission of, the Department (see Sections 12023 and 12024 of the Fish and Game Code for penalties).

1.3.6 Relative Effectiveness

Cost to implement and cost per predator captured would likely be **low-moderate**.

Costs could be reduced if an existing sport fishing or other organization took the lead in promotion and organization of the event.

Effectiveness (catch per unit effort, or CPUE), can be expected to range from 0.17–0.34 black bass/contest hour based on average CPUE from bass sport fishing derbies in California from 1985–2012 (Krogman 2013). However, these data primarily represent CPUE for lake and reservoir derbies; CPUE for sport fishing derbies in the Tuolumne River may differ. CPUE for the only reported California black bass sport fishing derby held in a river in 2012 (Colorado River) was 0.58 black bass/contest hour (Krogman 2013), suggesting that CPUE for a river derby could be higher than the average CPUE for lake and reservoir derbies.

For a hypothetical 5-day derby on the lower Tuolumne River with 8 hours of eligible fishing time per day (40 total contest hours) and 30 participants assumed to fish all eligible hours[1], the total fishing effort would be 1,200 hours. Assuming the minimum CPUE for a Tuolumne River sport fishing derby would equal the minimum reported by Krogman (2013) for all California derbies in 2012 (0.10 bass/hour) and the maximum would equal the CPUE reported for the 2012 Colorado River derby (0.58 bass/hour), 120–696 black bass could theoretically be caught in a 5-day lower Tuolumne River derby. The maximum estimate (696 black bass) exceeds the 10

[1] This assumption was used by Krogman (2013) to calculate CPUE for California black bass contests. Although we recognize it is not realistic to assume each participant will fish all eligible hours, we use this assumption to calculate a comparable estimate of effort for this hypothetical example.

percent removal target for largemouth and smallmouth bass combined (664) for the reach between the Grayson and Waterford RSTs (RM 5–30) (Table 2.3-1 of the Predator Control Plan).

Based on these estimates for a single 5-day bass derby in the lower Tuolumne River, this predator control method would likely be highly effective. Multiple derbies each year would increase effectiveness, potentially meeting the 10 percent and 15 percent removal targets using this method alone.

Because a bass derby would target only adult fish greater than a specified minimum length (e.g., 150 mm), a derby should be used in conjunction with a supplemental predator removal method (e.g., trapping, seining) that would ensure capture of younger year classes (see discussion of increased recruitment due to reduced intraspecific competition in Section 2.8).

See Table 1.1-1 above for a summary of CPUE for this method reported in the literature.

1.4 Public Sport-Reward Fisheries

A public sport-reward fishery offers a bounty or reward to members of the public for each fish caught as an incentive for fish to be captured and removed (killed). Implementation of such a program in the lower Tuolumne River would likely require a full-time, temporary CDFW/District position to register anglers, process fish, and manage data.

This type of program has been used successfully for removal of northern pikeminnow, an important predator on juvenile salmonids, in the Columbia River basin since 1991 (Porter 2013). The 2012 sport-reward pikeminnow program in the Columbia and Snake rivers paid citizen anglers $4, $5, and $8 per fish for the three payment tiers (up to 100 fish, 101–400 fish and 401 and up) for fish > 9 inches (Porter 2013). A bounty of $500 was paid for special tagged fish. In 2012, 156,837 non-tagged fish and 188 tagged fish were caught for a total payout of $1.1 million, an average of $7 per fish (Porter 2013).

1.4.1 Strengths

- Like sport fishing derbies, this method is advantageous because it can selectively target key predators (e.g., smallmouth bass, largemouth bass, striped bass) with little effect on other species.
- It may be possible to collect useful data, such as length frequency and diet composition, from removed fish.
- Once initial regulatory and logistical hurdles are addressed, such a bounty program would be relatively easy to implement.
- Cost per predator removed by the public would likely be less than many non-public approaches.

1.4.2 Challenges, Constraints, and Uncertainties

- Public opposition. Because this method is lethal to captured fish, opposition can be expected from anglers, sport fishing groups, and other individuals and organizations.
- Verification. This method requires verification that reward fish were in fact removed from the lower Tuolumne River and not taken from other water bodies.
- Disposition of removed fish. Possibly use as livestock feed, fertilizer, fish meal, or pet food. If donated for human consumption, may require additional handling considerations or permitting requirements.
- Regulatory constraints. Existing CDFW regulations (12-inch minimum size limit and a five-fish daily bag) and various permitting/legal challenges (see below) may delay or prevent implementation or limit effectiveness of this type of program.

1.4.3 Monitoring Metrics

The programmatic effectiveness metrics (e.g., CPUE) described in Section 2.3 are recommended. Additional monitoring for a public sport-reward fishery would include surveys to document level of participation and demographic information of participants, which could inform improvements to implementation in future years.

1.4.4 Timing

Bass fishing is open all year. A public sport-reward program could be open year-round or some portion of a year, depending on participation, logistical, and budgetary considerations.

1.4.5 Permitting Requirements

- A sport-reward program in the lower Tuolumne River would require collection and verification of fish by an official such as a CDFW warden or other employee.
- A public sport-reward program may only require a recreational fishing license subject to the daily bag limit, but could not be held as an organized contest under existing CDFW regulations, which prohibit sale of fish taken with a sport fishing license (FGC 7121; http://ca.regstoday.com/law/fgc/ca.regstoday.com/laws/fgc/calaw-fgc_DIVISION6_PART2_CHAPTER1.aspx). In order to allow payments to anglers for sport-captured Northern pikeminnow as part of sport-reward predator control program on the Columbia River, Oregon and Washington wrote specific exemptions for the Northern Pikeminnow Sport Reward Fishery into their state wildlife laws, which previously prohibited payments for all sport-captured fish (Washington: WAC 232-12-019, http://app.leg.wa.gov/wac/default.aspx?cite=232-12-019; Oregon: OAR 635-011-0175, http://arcweb.sos.state.or.us/pages/rules/oars_600/oar_635/635_011.html). A similar approach could be pursued for allowing payments of predators captured in a sport-reward fishery in the lower Tuolumne River. In addition, the success of a sport reward program may benefit warrant increased bag limits for target fish species that are subject to Fish and Game Commission regulations, which may need to be modified to allow increased take of predatory fish.

- A special state permit such as a Fish and Game Code Section 5501 permit may be required. Section 5501 of the Fish and Game Code states that the Fish and Game Commission may prescribe the terms of a permit to take any fish which, in the opinion of the department, is harmful to other species of fish and which should be reduced in numbers. A permit pursuant to Section 5501 would allow take (destruction) of predator fish captured as part of a predator control program. Although Section 226.5 of the Fish and Game Code provides for issuance of permits to destroy harmful species of fish in private waters for management purposes, the lower Tuolumne River is not privately owned, and paragraph (d) specifically states that no permits shall be issued for rivers or streams.

1.4.6 Relative Effectiveness

Cost to implement would likely be **moderate** and cost per predator captured would likely be **low–moderate.**

Because the public would be doing much of the work at relatively low cost per fish, and fish do not need to be relocated, the majority of cost would be related to rewards and management of the program. Based on Columbia River examples (e.g., reports in Willis and Ward 1995), cost considerations (in addition to reward payouts) include: (1) advertising and permitting (2) developing, tracking, and processing vouchers and payments, (3) providing IRS Form 1099-Misc statements to payees, (4) creating and maintaining database records, and (5) funding a full-time, temporary (spring-summer) CDFW position to register anglers and process fish.

Assuming an average payment of $7 (similar to the sport-reward pikeminnow program in the Columbia River) would be paid per fish in a Tuolumne River sport-reward program targeting black bass, achieving the 10 percent (664 fish) and 15 percent (996 fish) removal targets for largemouth and smallmouth bass combined would cost $4,648 and $6,972, respectively. This cost does not include the more substantial start-up, promotional, permitting, data management, and staffing costs listed above.

As reported by Porter (2013) for the Columbia River pikeminnow sport-reward fishery, average annual CPUE from 1991–2012 was 2.1–7.6 fish/angler day. An angler day was represented by submittal of one (required) daily registration form for the program, although actual angling time spent by an angler in each angler day presumably varied.

For a hypothetical 6-month (April–September) sport-reward fishery on the lower Tuolumne River with 5 registered anglers per day, there would be a total of 900 angler days annually. Assuming each angler fished an average of 8 hours per day, there would be total effort of 7,200 hours. If the minimum CPUE for a Tuolumne River sport-reward program equaled the minimum reported by Krogman (2013) for all California bass fishing derbies in 2012 (0.10 bass/hour), and the maximum equaled the CPUE reported for the 2012 Colorado River derby (0.58 bass/hour), between 720 and 4,176 black bass could theoretically be caught annually during a 6-month sport-reward fishery. On the lower end, predicted capture exceeds the 10 percent removal target for smallmouth and largemouth bass combined (664) (Table 2.3-1 of the Predator Control Plan). On the upper end, predicted capture is 38 percent of the total estimated 2012 population of smallmouth and largemouth bass combined in the entire lower Tuolumne River (Table 2.2-1 of the Predator Control Plan).

Based on the estimate for a six-month bass sport-reward fishery in the lower Tuolumne River, this predator control method would likely be highly effective and relatively cost efficient.

Because a sport-reward fishery would preferentially target adult fish greater than a specified minimum length (e.g., 150 mm), a supplemental predator removal method (e.g., trapping, seining) should be used concurrently to ensure capture of younger year classes (see discussion of increased recruitment due to reduced intraspecific competition in Section 2.8).

See Table 1.1-1 above for a summary of CPUE for angling reported in the literature.

1.5 Hook-and-Line Removal (Non-Public)

Hook-and-line capture (angling) involves the active use of lures or baits to capture fish. Target predators captured could be killed or retained for relocation to Turlock Lake, Modesto Reservoir, or other nearby lakes or reservoirs to provide anglers with future recreational opportunities, depending on approval of a predator control plan with CDFW. Transport and release of live fish would require holding facilities (e.g., live wells) and transport vehicles, as well as a CDFW permit (see Permitting Requirements below). This method would be used by biologists or fisheries technicians who are experienced anglers rather than by members of the public. This approach would be used primarily to target largemouth and smallmouth bass in conjunction with electrofishing or other planned predator removal efforts. However, angling may be considered for removing striped bass, or as a stand-alone method if pilot efforts determine that these applications can be relatively cost-effective and efficient.

1.5.1 Strengths

- Hook-and-line angling can selectively target key predators (e.g., smallmouth bass, largemouth bass, striped bass) with little effect on other species.
- Although by itself angling is generally not an efficient predator removal method (Boucher 2006), it may be an effective way to induce bass nest failure (Loppnow et al. 2013). By removing the guarding male from the nest, the eggs become highly susceptible to mortality by predation and physical disturbance.
- Angling can be implemented opportunistically by field crews before or during other planned methods such as electrofishing, as a way to minimize cost.
- Permitting restrictions may be minimal compared with other approaches (e.g., electrofishing or netting).

1.5.2 Challenges, Constraints, and Uncertainties

- Angling can be relatively inefficient for capturing predators compared with other gear types.
- Cost per fish captured could be relatively high compared with other approaches.

1.5.3 Monitoring Metrics

The programmatic effectiveness monitoring metrics (e.g., CPUE) described in Section 2.3 are recommended. No additional monitoring is currently recommended for hook-and-line removal.

1.5.4 Timing

Angling would be used as a supplemental method that would be implemented in conjunction with electrofishing and/or other efforts. Capture efficiency and population-level effectiveness can be maximized by angling for several hours prior to electrofishing events using the same fisheries crew, and by targeting adult bass during the spawning and nest guarding periods. As discussed in Section 2.4, timing for initiating angling effort could be informed by water temperature data (i.e., temperatures at which bass become most active). This timing would also maximize population-level impacts by increasing the likelihood of removing nest-guarding males and inducing nest failure.

1.5.5 Permitting Requirements

- CDFW Scientific Collecting Permit for angling. Pursuant to Fish and Game Code Section 1002 and Title 14 Sections 650 and 670.7, a Scientific Collecting Permit is required to take, collect, capture, or mark fish as part of a scientific study or research activity.
- Either an ESA Section 10 permit (NMFS) for scientific sampling activities that could result in incidental take in waters with listed anadromous salmonids (*O. mykiss*) or a permit for scientific research activities under the ESA Section 4(d) rule.
- A special state permit such as a Fish and Game Code Section 5501 permit may be required. Section 5501 of the Fish and Game Code states that the Fish and Game Commission may prescribe the terms of a permit to take any fish which, in the opinion of the department, is harmful to other species of fish and which should be reduced in numbers. A permit pursuant to Section 5501 would allow take (destruction) of predator fish captured as part of a predator control program. Although Section 226.5 of the Fish and Game Code provides for issuance of permits to destroy harmful species of fish in private waters for management purposes, the lower Tuolumne River is not privately owned, and paragraph (d) specifically states that no permits shall be issued for rivers or streams.
- Any fish relocation would be subject to Section 6400 of the Fish and Game Code, which states that it is unlawful to place, plant, or cause to be placed or planted, in any of the waters of this state, any live fish, any fresh or salt water animal, or any aquatic plant, whether taken without or within the state, without first submitting it for inspection to, and securing the written permission of, the Department (see Sections 12023 and 12024 of the Fish and Game Code for penalties).

1.5.6 Relative Effectiveness

Cost to implement non-public angling would likely be **low** and cost per predator captured would likely be **moderate–high**.

Angling generally requires a relatively high level of effort per fish captured; however, cost may be relatively low if only used as a supplementary method. The primary expenses for non-public angling would be salaries for seasonal staff (likely six month positions), fishing equipment, program administration, and analysis and reporting.

Angling and set-lines were used by crews of three to five in a northern pikeminnow control program in reservoirs in central Washington, with an overall catch per unit effort (CPUE) of 0.0014 fish per hook hour (Jerald 2013). Angling was used to capture adult smallmouth bass in a 173-acre pond in Maine with a CPUE of 0.3 fish/angler hour, compared with 23.2 fish/hour for electrofishing (Boucher 2006). In Beaver Creek, British Columbia an angling CPUE of 0.5 fish/angler hour was reported (Gomez and Wilkinson 2008, as cited in Loppnow et al. 2013). In the lower Tuolumne River, 112 hours of angling resulted in capture 17 piscivorous-sized predators (black bass and striped bass combined) at two sites in 2012, a CPUE of 0.15 fish/hour (TID/MID 2013). These CPUEs are in the range of those reported for public sport fishing derbies in California (Krogman 2013; Appendix A, Section B.1).

Using the CPUE reported by TID/MID 2013 and Gomez and Wilkinson (2008) (0.15 and 0.5 fish/angler hour, respectively) as low-end and high-end estimates, an effort of 1,328–4,426 angler hours would be required annually to remove 10 percent of the combined 2012 population of largemouth and smallmouth bass (664) estimated in the reach between the Grayson and Waterford RSTs (RM 5.1–30.3) (Table 2.3-1 of the Predator Control Plan). With a crew of two anglers fishing 8 hours/day, it would take 83–277 days to meet the 10 percent removal target for smallmouth and largemouth bass in this reach, based on the 2012 population estimate. Due to lack of CPUE data, we make no estimate of required effort for removal of striped bass by angling. Catch rates for striped bass may vary substantially from those reported for black bass.

Based on the above estimates, predator removal through angling by fisheries technicians would likely be inefficient and costly compared with other methods. However, angling may be useful for supplementing other more effective approaches when it can be done concurrently (e.g., when waiting to check passive traps) or at times (peak spawning season) or locations (known spawn aggregations) that maximize effectiveness.

See Table 1.1-1 above for a summary of CPUE for this method reported in the literature.

1.6 Netting and Trapping

Netting and trapping are recommended for potential inclusion in a predator control program in combination with other methods such as electrofishing. Target predators captured could be killed or retained for relocation to Turlock Lake, Modesto Reservoir, or other nearby lakes or reservoirs to provide anglers with future recreational opportunities, depending on approval of a predator control plan with CDFW. Transport and release of live fish would require holding facilities (e.g., live wells) and transport vehicles, as well as a CDFW permit (see Permitting Requirements below).

Various netting and trapping methods are commonly used for a variety of fish capture applications in a diversity of habitats (Hahn et al. 2007). Potential methods include gill, seine, trap, and fyke nets, and minnow, fish, and fyke traps. Although familiar and easy to implement, some of these methods can be relatively labor-intensive and moderately expensive. Some netting methods such as gill netting can result in the indiscriminant capture and mortality of multiple fish species. However, if gill net mesh size and deployment times and locations (habitat and reach scale) are strategically selected, impacts to non-target species can be minimized. For example, gill nets could be set at times and locations when water temperatures exceed values used by native salmonids. Other netting and trapping methods such as seining are non-lethal and can be used to selectively remove target fish species and sizes. Beach seining is among the most feasible and effective netting method for riverine fish capture, and is used annually to sample juvenile Chinook salmon in the lower Tuolumne River. Whereas gill nets and some kinds of traps can be deployed in a range of water depths, beach seining is best suited for shallow (wadeable) shoreline areas. Fish traps, either baited or non-baited, may be effective methods of fish capture, especially in conjunction with other methods or where other methods are not feasible (e.g., locations with large amounts of aquatic vegetation or debris).

Recent laboratory studies indicate that fish traps baited with live prey fish may be an effective capture method for striped bass (Mortensen 2014). This method is being tested as a possible strategy to reduce predation within the Bureau of Reclamation’s Tracy Fish Collection Facility, part of the Central Valley Project’s Delta Division.

1.6.1 Strengths

- Netting and trapping are versatile techniques, well suited for a variety of habitats and conditions, are generally not controversial (with the exception of gillnetting), and some gear types are subject to relatively few permitting requirements.
- Despite their relative inefficiency, netting and trapping may prove effective for capturing small (i.e., larval and juvenile) predators in certain habitats such as shallow shorelines and areas with dense instream cover that are not easily sampled with electrofishing. As described previously, targeting smaller size classes will maximize population-level impacts by reducing the potential for unintended increases in juvenile growth and abundance due to reduced intraspecific competition resulting from removal of adult predators only.

1.6.2 Challenges, Constraints, and Uncertainties

- These approaches can be labor-intensive and are much less effective at catching predators than electrofishing (Loppnow et al. 2013).
- Some netting methods such as gill netting may result in capture and mortality of non-target species and therefore be subject to more restrictive permitting and stakeholder opposition.

1.6.3 Monitoring Metrics

The programmatic effectiveness monitoring metrics (e.g., CPUE) described in Section 2.3 are recommended. No additional monitoring is currently recommended for netting and trapping.

1.6.4 Timing

Timing should be selected to maximize effectiveness of a specific gear type in capturing target predators while avoiding impacts to native species. For example, since beach seines are only effective in shallow water, to target adult bass it would be necessary to employ beach seines during the spawning season when reproductive bass are in relatively shallow water for nest building, spawning, and nest defense. Young-of-the-year bass, which are slower swimmers and more susceptible to seining than adults, should be targeted in the relatively shallow, near-shore areas they favor. In addition, sampling may be timed to allow most efficient use of field crews, such as immediately before or after an electrofishing effort. Timing of implementation would be refined through pilot studies and an adaptive management process.

1.6.5 Permitting Requirements

- CDFW Scientific Collecting Permit for trapping and netting. Pursuant to Fish and Game Code Section 1002 and Title 14 Sections 650 and 670.7, a Scientific Collecting Permit is required to take, collect, capture, or mark fish as part of a scientific study or research activity.
- Either an ESA Section 10 permit (NMFS) for netting and trapping, which could result in incidental take in waters with listed anadromous salmonids (*O. mykiss*), or a permit under the ESA Section 4(d) rule.
- A special state permit such as a Fish and Game Code Section 5501 permit may be required. Section 5501 of the Fish and Game Code states that the Fish and Game Commission may prescribe the terms of a permit to take any fish which, in the opinion of the department, is harmful to other species of fish and which should be reduced in numbers. A permit pursuant to Section 5501 would allow take (destruction) of predator fish captured as part of a predator control program. Although Section 226.5 of the Fish and Game Code provides for issuance of permits to destroy harmful species of fish in private waters for management purposes, the lower Tuolumne River is not privately owned, and paragraph (d) specifically states that no permits shall be issued for rivers or streams.
- Any fish relocation would be subject to Section 6400 of the Fish and Game Code, which states that it is unlawful to place, plant, or cause to be placed or planted, in any of the waters of this state, any live fish, any fresh or salt water animal, or any aquatic plant, whether taken without or within the state, without first submitting it for inspection to, and securing the written permission of, the Department (see Sections 12023 and 12024 of the Fish and Game Code for penalties).

1.6.6 Relative Effectiveness

Cost to implement would likely be **low–moderate** and cost per predator captured would likely be **moderate** (depending on the specific gear type and methods employed).

Cost for implementing traps or nets would vary substantially by gear type, methods, number deployed, and whether a particular gear was deployed as a primary removal method or as a supplementary method (e.g., deployed concurrently with other planned removal efforts). Equipment costs for most nets and traps are generally expected to be relatively low compared with electrofishing equipment. Labor costs, particularly for passively fished gear that is left unattended (e.g., most traps), is expected to be relatively low compared with electrofishing or actively fished gears such as seining.

In most cases, nets and traps are not effective at capturing piscivorous-sized black bass compared with electrofishing. In an extensive review of various control options for invasive smallmouth bass, Loppnow et al. (2013) state:

> "In general, nets are much less effective at catching *M. dolomieu* than electrofishing. Therefore, although netting is a familiar, available, and uncontroversial control option that can be both size- and species-selective and deployed at most depths, the inability of nets to catch large numbers of *M. dolomieu*, even when effort is high, is a significant shortcoming that precludes the use of nets for control, even in combination with other methods."

Despite this generality, netting and/or trapping may play an important role in targeting younger age classes or for supplementing more effective approaches without adding significant cost. Examples of reported effectiveness (CPUE) of various nets and traps are presented below. CPUE for nets and traps is generally reported as fish per trap hour, fish per net night, or fish per seine haul. CPUEs reported in the literature vary substantially depending on gear type, species, life stage, location, predator abundance, and other factors.

Annual CPUE of age-1 and older smallmouth bass (no YOY smallmouth were captured) in a Wisconsin river using fyke nets ranged from 0.4 to 0.6 fish per net night (Uvaas 2013). Assuming similar CPUE for catching adult black bass with fyke nets in the Tuolumne River, it would take over 1,000 net nights to reach the 10 percent removal target (664 for largemouth and smallmouth combined; Table 2.3-1 of the Predator Control Plan). Similarly, low CPUEs have been reported for capture of adult basses with trap nets and gill nets and (McInery and Cross 2004; Boucher 2006, as cited in Loppnow et al. 2013). Boucher (2006) as cited in Loppnow et al. (2013) only captured 7 adult smallmouth bass in 2,103 trap net hours (0.003 fish/hour), as compared to 200 captured in 8.62 hours of electrofishing effort (23.2 fish/hour). In a study evaluating use of nets to remove bass, less than 1 percent of 3,083 fish captured in gill nets were smallmouth bass (Gomez and Wilkinson 2008 as cited in Loppnow et al. 2013). These studies suggest fyke, trap, and gill nets are unlikely to efficiently meet program predator removal targets for adult black bass.

Fyke nets and trap nets as well as minnow traps, however, are generally more effective for targeting smaller size classes of bass (McInerny and Cross 2004; Loppnow et al. 2013) and therefore may be worth evaluating in the lower Tuolumne for use in conjunction with methods targeting adults. In the Missouri River, South Dakota, mean monthly CPUE of YOY and juvenile smallmouth bass using a "mini-fyke" net ranged from 1 to 25 fish per net night (Klumb 2007).

While not effective for black bass, large (10 ft diameter) cylindrical fyke traps have been used to successfully capture considerable numbers of adult striped bass. In a 2013 pilot study on the San Joaquin River, fyke trap CPUEs ranged from 0–0.94 fish per trap hour (depending on location and day) and averaging 0.04 fish per trap hour at one location and 0.14 fish per trap hour at another (Ainsley et al. 2013). On the Sacramento River, fyke traps resulted in annual mean CPUEs (from multiple traps and locations) ranging from 0.22 to 1.50 (fish/hr), with some individual trap locations and times having much higher CPUEs (>40 fish/hour in a day) (DuBois and Mayfield 2009; DuBois et al. 2010, 2011, 2012; DuBois and Harris 2013). In the Sacramento River study, up to 10 traps were fished simultaneously at numerous locations, allowing capture of large numbers of adult striped bass annually (e.g., 6,671 were captured in 25 days of trapping in 2011). Conservatively assuming an average of 0.1 adult striped bass per trap hour couple be captured using fyke trapping in the Tuolumne River during the spring migration period, it would take approximately 15 trap days to reach the 15 percent removal target of 35 striped bass (Table 2.3-1 of the Predator Control Plan). Notably, zero to only a few smallmouth and largemouth bass were captured during fyke trapping in both studies discussed above (Ainsley et al. 2013; DuBois and Harris 2013), suggesting it is not a viable option for achieving removal targets for these species.

Seine nets are generally not an effective gear for catching adult bass (Loppnow et al. 2013), but have potential to capture relatively large numbers of age-0 bass with moderate effort. Jackson and Noble (1995) caught 0.4–4.9 age-0 largemouth bass per seine haul using a 9-m bag seine with 0.9-cm-bar mesh in the wings and 0.6-cm bar mesh in the bag. However, they reported seining was ineffective at capturing fish larger than 60 mm and that there was a rapid decline in efficiency with increasing size between 30 mm and 60 mm. The authors also reported that electrofishing was more effective at catching a wider size range of juvenile bass compared with seining. CPUEs for seining age-0 bass in other locations have been reported as averaging 0.05–11.25 fish/seine haul for largemouth bass in Chesapeake Bay tributaries (Fewlass 1985) and 1.4–8.4 fish/seine haul for smallmouth bass in another Maryland river (Frederick County 2005).

One variation of seining that warrants consideration is the electric seine. In three years of efforts to control invasive smallmouth bass in the Yampa River, CO, Hawkins et al. (2009) reported annual mean CPUE ranging from 159–262 (fish/hr) using a 10 m-long electric seine powered by a generator. They removed 18,166 juvenile smallmouth bass with this gear.

See Table 1.1-1 above for a summary of CPUE for these methods reported in the literature.

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