Public Comment
303(d) List of 2014 & 2016 CA Integrated Report
Deadline: 7/10/17 by 12 noon

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Comment #1

VIA U.S. MAIL, EMAIL AND FACSIMILE
email: commentletters@waterboards.ca.gov
Fax No.: (916) 341-5620

Jeanine Townsend, Clerk to the Board
State Water Resources Control Board
P.O. Box 100
Sacramento, CA 95812-2000

Re: Comment Letter – 303(d) List portion of the 2014 and 2016 California Integrated Report

Dear Ms. Townsend:

On behalf of the Pacific Coast Federation of Fishermen's Associations, San Francisco Crab Boat Owners Association, Institute for Fisheries Resources and North Coast Rivers Alliance (collectively, "Conservation Groups"), we submit the following comments on the Clean Water Act ("CWA") section 303(d) List portion of the State Water Board's draft 2014 and 2016 California Integrated Report. Please include these comments in the public record on this matter.

I. INTRODUCTION

Congress adopted the Clean Water Act ("CWA") "to restore and maintain the chemical, physical and biological integrity of the Nation's waters." 33 U.S.C. § 1251(a). Under CWA section 303(d) (33 U.S.C. § 1313(d)), California is required to report to the U.S. Environmental Protection Agency ("EPA") on the quality of the waters of the United States within California's boundaries every two years. Known as the "section 303(d) list," this report identifies water bodies not meeting federal water quality standards and the specific water quality parameters that are not being met. 40 C.F.R. § 130.7(d). The section 303(d) list is combined with a report of the water quality conditions of the surface waters within the state prepared under CWA section 305(b) (33 U.S.C. § 1315(b)) into a single report known as the "California Integrated Report."

1.01 Pursuant to this statutory and regulatory regime, the State Water Resources Control Board ("State Water Board") is belatedly preparing the California Integrated Reports that were due in 2014 and 2016 for submission as a single document to EPA in late 2017. The State Water Board staff has made recommendations in its proposed combined 2014 and 2016 California Integrated

Report for the State Water Board to use the 2012 California Integrated Report with certain changes. The draft changes, as summarized in the Staff Report dated June 9, 2017, Table 4, largely recommend approval of the section 303(d) lists submitted by the five regional boards that are reporting. *Id.* at p. 17 and Appendices A-G and I-K. Only modest adjustments to the
1.02 Regional Board lists are proposed. Of particular concern to the four Conservation Groups we represent, the section 303(d) lists proposed for Region 2 (San Francisco Bay) and Region 5 (Central Valley) are flawed in a number of significant respects, resulting in less protection for California waterways than is required under the CWA. Coupled with the ongoing ecological collapse of the Bay-Delta and its tributary rivers, these deficiencies threaten to drive another nail in the coffin of California's sport and commercial fisheries, and the ecosystems that support them.

Our concerns are shared by state and federal agencies with expertise in the management of California's fisheries, and by independent experts within the mainstream scientific community. We detail below our primary concerns.

II. CONSERVATION GROUPS ARE VITALLY INTERESTED.

This letter is submitted on behalf of the Pacific Coast Federation of Fishermen's Associations ("PCFFA"), the San Francisco Crab Boat Owners Association, Inc. ("SFCBOA"), the Institute for Fisheries Resources ("IFR") and the North Coast Rivers Alliance ("NCRA") (collectively, "Conservation Groups"). PCFFA is a coalition of fourteen fishermen's organizations in California, Oregon and Washington with a combined membership of approximately 750 fishing men and women. The SFCBOA is a San Francisco-based organization of fishermen that has been protecting the seafood fisheries of San Francisco Bay and the Pacific Ocean since 1913. IFR has been engaged in fishery research and conservation activities since 1993. NCRA is a conservation organization working to protect California's rivers and their watersheds from pesticides, harmful agricultural runoff, excessive water diversions and other forms of degradation.

III. THE DELTA IS IN ECOLOGICAL CRISIS.

The largest and most productive estuary system on the west coast of North and South America – the Sacramento-San Joaquin River Delta – is collapsing for two principal reasons.
1.03 First, the Central Valley Project ("CVP") and the State Water Project ("SWP") have diverted too much of the Delta's fresh water flows. Second, agricultural diverters have discharged and
1.04 continue to discharge too much contaminated agricultural run-off and return flows into the Delta.
1.05 These unsustainable levels of diversions and polluted discharges greatly decrease fresh water flows while increasing water temperature and salinity and the concentration of herbicides, pesticides, and toxic agricultural run-off in the Delta.

1.06 These two threats to the Delta's health have grown steadily over the past five decades, and the resulting environmental devastation has pushed the Delta's imperiled fisheries to the brink of extinction. Several species of fish endemic to the Delta have already gone extinct; just twelve indigenous species remain. Critical habitat for the endangered Sacramento River winter run chinook salmon, Central Valley steelhead and spring run chinook, the Delta smelt, and the Southern Distinct Population Segment ("DPS") of the Northern American green sturgeon suffers progressively accelerating degradation.

As a consequence of worsening habitat degradation, winter run chinook salmon were declared threatened under the federal Endangered Species Act ("ESA") in 1990 (55 Fed.Reg 46515). Due to continuing population declines, they were declared endangered in 2005 (70 Fed.Reg 37160). Their critical habitat in the Sacramento River and its tributaries was designated in 1993. 58 Fed.Reg. 33212. Spring run chinook salmon were declared threatened, and their critical habitat was designated under the ESA, in 2005. 70 Fed.Reg. 37160, 52488. Central Valley steelhead were declared threatened in 2000 (65 Fed.Reg. 52084) and their critical habitat was designated in 2005 (70 Fed.Reg 52488). The Southern DPS of North American green sturgeon was declared threatened in 2006 (71 Fed.Reg 17757) and its critical habitat was designated in 2008 (73 Fed.Reg 52084). Delta smelt were declared endangered in 1993 (58 Fed.Reg. 12854) and their critical habitat was designated in 1994 (59 Fed.Reg. 65256).

1.07 The State Water Board's proposed 2014-2016 Integrated Report ignores or understates many of the causes of the habitat degradation that was caused these precipitous declines in the Delta's fisheries. Consequently, as discussed below it will worsen rather than improve the Delta ecosystem, and further imperil these fish species.

IV. TEMPERATURE-IMPAIRED WATERS ARE NOT LISTED.

1.08 The Staff Report proposes 269 listings of water bodies within Region 5. Of these, the Regional Board Staff Report dated September 2016 identified 189 new water body evaluations for temperature, and confirmed that excessive temperatures were found in 39 of these water bodies. Yet *only one of these 39 impaired water segments was recommended for listing*. The Draft California Integrated Report fails to correct this oversight.

1.09 The Regional Board Staff attempted to excuse this omission by claiming that the surface grab samples revealing excessive temperatures were not representative of temperature conditions throughout these water bodies. Consequently it ignored virtually all of these elevated temperatures. 1.10 However, when EPA reviewed the underlying lines of evidence, it concluded to the contrary that "there are many water bodies that are well mixed lotic systems where a surface grab sample showing exceedances of temperature thresholds *would still be representative of most of the water column* and suggest a temperature *impairment for the water body as a whole*." EPA letter dated November 3, 2016 to Central Valley Regional Water Board, copy attached as Exhibit

1 hereto (emphasis added), at p. 1. EPA pointed out that its criticism was supported by overwhelming documentary evidence. For example, "[t]here are several water bodies, such as segments of the Sacramento River that have substantial data collected under the Irrigated Lands Regulatory Program indicating impairment," and that "[a]dditionally, for many of these water bodies continuous monitoring stations with existing data published by [the California] Department of Water Resources in publicly available databases (e.g., California Data Exchange Center ("CDEC") . . . and the California Water Data Library . . . are available to *confirm impairments initially identified by the already analyzed grab sample data*." *Id*. at p. 1 (emphasis added).

EPA also pointed out, correctly, that "the thresholds selected in the [Regional Board's]
1.11 Staff Report for this [section 303(d)] listing cycle, 21°C and 24°C for rainbow trout and steelhead respectively, are *much warmer* than the temperatures recommended in EPA's *2003 Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards*." *Id*. (emphasis added). This means that river segments with temperatures too high to support salmonid survival were omitted from the list of impaired waterways. As EPA explained,
1.12 the Regional Board failed to identify numerous river segments as temperature impaired *even though existing numeric temperature criteria are clearly exceeded for these river segments*, many of which are salmon spawning and rearing waterways. Tables III-IV and III-IVA in the Sacramento and San Joaquin River Basin Plan for example, identify specific objectives for Deer Creek and the Sacramento River – major salmon spawning waterways – that were ignored by the Regional Board in its section 303(d) list. *Id.* at p. 2.

There is simply no excuse for the Regional Board's omission. According to the Central
1.13 Valley Basin Plan, 56°F (13.3°C) is the numeric objective for the Sacramento River between Keswick Dam and Hamilton City. But in direct defiance of this clear water quality standard, the Regional Board's section 303(d) list is based on a line of evidence for this segment that erroneously utilizes a 21°C threshold for salmonid protection – *nearly 8°C* (*14°F*) *too high*. As a consequence, significant segments of the Sacramento River and its tributaries that are essential for spawning and rearing of chinook salmon are excluded from the Regional Board's section 303(d) list – and from the State Water Board's proposed California Integrated Report – even though these river segments currently have excessive temperatures for salmon spawning and rearing, rendering them "impaired" as a matter of law under the CWA. This omission must be rectified.

V. THE INTEGRATED REPORT IGNORES READILY AVAILABLE CONTINUOUS MONITORING DATA IN THE DELTA.

1.14 The Integrated Report fails to remedy the Region 5 Board's omission of reliable and available data that reveal impairment due to excessive temperature, salinity and other pollutants.
1.15 EPA was particularly critical of the Region 5 Board's "inconsistent assessments for dissolved

oxygen and salinity" as required to be measured under the 2006 Bay-Delta Plan despite the fact that "there is an abundance of publicly available data *identifying broader impairments*." *Id.* at p. 2 (emphasis added). As EPA noted, "[t]hese data should be assessed and incorporated into the final Staff Report." *Id.* EPA pointed out that the Regional Board's "omission of continuous monitoring information is particularly notable in the Delta where 24 continuous monitoring stations are identified in Table 7 of the 2006 Bay-Delta Plan as stations to assess compliance with water quality objectives," yet this information is "not assessed for this Integrated Report." *Id.* The omission of this critical information has, according to EPA, "resulted in illogical [waterway] listing decisions [by the Regional Board] such as the listing of the Stockton Deep Water Ship Channel for temperatures unsuitable to support migration of cold water species, but none of the surrounding waters are listed as impaired." *Id.* (emphasis added).

1.16

These glaring omissions from the California Integrated Report violate the CWA and must be rectified. Under the CWA,

> "[i]n developing Section 303(d) lists, states are required to assemble and evaluate all existing and readily available water quality-related data and information, including, at a minimum, consideration of existing and readily available water quality-related data and information about the following categories of waters: (1) waters identified as partially meeting or not meeting designated uses, or as threatened, in the state's most recent CWA section 305(b) report; (2) waters for which dilution calculations or predictive modeling indicate non-attainment of applicable standards; (3) waters for which water quality problems have been reported by governmental agencies, members of the public, or academic institutions; and (4) waters identified as impaired or threatened in any CWA Section 319 non-point assessment submitted to EPA."

Id. at p. 2, n. 1, citing 40 C.F.R. § 130.7(b)(5).

VI. THE 2006 BAY-DELTA PLAN'S SALMON-DOUBLING OBJECTIVE IS IGNORED.

1.17

Table 3 of the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary ("2006 Bay-Delta Plan") reiterates the salmon-doubling water quality objective set forth in the 1995 Bay-Delta Plan, as follows:

> Water quality conditions shall be maintained, together with other measures in the watershed, sufficient to achieve a doubling of natural production of chinook salmon from the average production of 1967-1991, consistent with the provisions of State and federal law.

Id.

The salmon-doubling standard of the 2006 Bay-Delta Plan constitutes a water quality standard under the CWA with which the State Water Board section 303(d) list must be consistent. Yet both the Regional Board's list of impaired waterways and the State Water Board's proposed Integrated Report make no effort to implement this water quality objective. As a consequence, the Integrated Report conflicts with the 2006 Bay-Delta Plan, and the beleaguered populations of chinook salmon will continue their rapid decline, leading potentially to their extinction.

VII. MONITORING DATA COLLECTED BY CDFW FOR SAN JOAQUIN RIVER RESTORATION HAS BEEN OVERLOOKED.

1.18 Since 2008, numerous state and federal agencies have been engaged in a comprehensive effort to restore the San Joaquin River. As a result of these efforts, the upper restoration reaches have had temperature data collected for at least 8 years by the California Department of Fish and Wildlife ("CDFW"). According to EPA, these data show impairment of the upper San Joaquin River for salmonid reintroduction, and should be utilized in the Integrated Report as required by the CWA. *Id.* at p. 3.

VIII. THE INTEGRATED REPORT FAILS TO PROPERLY ACCOUNT FOR THE DISCHARGE OF PYRETHROID PESTICIDES.

CDFW is California's Trustee Agency for fish and wildlife resources, and has jurisdiction over and possesses specific expertise in the conservation, protection, and management of fish, wildlife, native plants, and habitat necessary for biologically sustainable populations of those
1.19 species. Fish and Game Code §§ 711.7(a), 1802. CDFW has long recognized that "[t]he San Francisco Bay/Sacramento-San Joaquin River Estuary (Delta) is in a state of ecological crisis, with many native fish species populations at all time low abundances." Letter from CDFW, ECD/Water Branch, to Central Valley Regional Board, dated March 24, 2017, at p. 1, attached as Exhibit 2 hereto. "In recent years, the poor water quality conditions in the Delta and Sacramento and San Joaquin River watersheds, exacerbated by drought, have brought fish species listed under the protection of the state or federal Endangered Species Acts to levels *near extinction* or extirpation." *Id.* (emphasis added).

1.20 Based on overwhelming data and careful review in numerous recent studies, CDFW has pinpointed the discharge of pyrethroids as a key factor in the collapse of the Delta's fisheries: "'The trend toward greater pyrethroid use has coincided with abrupt declines in abundances of pelagic fishes.'" CDFW, March 24, 2017 letter to Central Valley Regional Board, at p. 3, quoting from Brooks, et al. (2012). CDFW concluded that "[c]ontaminants, including pyrethroids, in Delta waters have likely contributed to ecological degradation and should be considered along with other stressors in Delta management." *Id.* CDFW has noted in particular that the increasing use of pyrethroid pesticides has been implicated in the dramatic loss of Delta fisheries known as the "pelagic organism decline," or POD. *Id.* at pp. 2-3, citing Healy, et al. 2016.

1.21 In its comments to the Region 5 Board, CDFW pointed to "multiple lines of evidence" that confirm that pyrethroids are a principal factor in the ongoing ecological collapse of the Delta, including in particular, the imperiled Delta smelt and longfin smelt. According to CDFW, pyrethroids are particularly harmful to zooplankton, which in turn, "are important prey for larval and juvenile salmon; splittail; Delta smelt, longfin smelt; and other estuarine fish species . . . ." *Id.* at p. 4. For example, "[t]he decline in mysid [shrimp] abundances have coincided with increased pyrethroid uses." *Id.* For these reasons, CDFW has recommended that the Regional Board employ a rigorous, scientifically-based methodology for identifying water quality impairment by pyrethroids. *Id.* at pp. 5-7.

1.22 Of particular relevance here, CDFW has pointed out that the Regional Board's use of bioavailability calculations for predicting toxicity ignores many pathways by which pyrethroids and other pesticides harm fishes and their prey, particularly zooplankton. *Id.* at 5-7. For example, CDFW has stressed that the Regional Board's "regulation of pyrethroids using [only] the dissolved fraction does not account for the fate and transport of sediment-bound pyrethroids." *Id.* at p. 5. Accordingly, CDFW recommends that the Regional Board consider sediment-bound pyrethroids in calculating impairment of waterways, noting that "[r]egulating sediment-bound pyrethroids at the source would be feasible." *Id.* at p. 5. CDFW "has invested great efforts to restore Delta habitats for the benefit of imperiled native species, which may be jeopardized by continued inputs of pyrethroid-contaminated sediments." *Id.*

CDFW's criticism of the Regional Board's failure to include the entirety of pathways by which pyrethroid pesticides harm fishes and their prey has been echoed and amplified in the leading studies on this issue conducted by University of California, Berkeley Professor Donald P. Weston. Professor Weston is widely considered California's premier expert on pyrethroid toxicology, having worked almost exclusively in this field since 2003, and on other related compounds with similar chemical properties for 20 years before that. Professor Weston has long recognized the widespread and pernicious impact of pyrethroid contamination of California's
1.23 waterways. As Dr. Weston pointed out in his comments to the Central Valley Regional Board dated March 24, 2017 (attached as Exhibit 3 hereto), "[p]yrethroid contamination, and its associated toxicity, is so pervasive that it exists in nearly all urban run-off and a substantial fraction of agricultural and POTW discharges." *Id.* at p. 1. Yet, notwithstanding the massive adverse impact of pyrethroid discharges on ecological health in the Delta and its tributary rivers, in evaluating impairment of waterways, the Regional Board has chosen to "regulate only what they view as the bioavailable fraction," *excluding approximately 90 percent of the harmful pyrethroids present in these waterways*. *Id.*

1.24 The proposed California Integrated Report likewise ignores 90 percent of the pyrethroids present in California waterways. Although the Staff Report confusingly states that "the use of whole water concentrations" – rather than only the "dissolved concentration" of the pyrethroids – "is also valid," it does not appear that the State Water Board's staff has made any effort to correct the Regional Board's exclusion of 90 percent of the harmful pyrethroids from its list of impaired waterways. *Id.* at p. 7. As Professor Weston pointed out in his recent letter to the Regional Board, "*despite overwhelming scientific evidence to the contrary*, the [Regional Board] staff report assumes biological uptake from particle-bound pyrethroids to be zero, or at least negligible, and therefore in no need of regulatory control." Professor Weston's March 24, 2017 letter to the Central Valley Regional Board at p. 2 (emphasis added). But the Regional Board's "[c]haracterization of the particle-bound fraction as non-bioavailable, as done in the staff report, is indefensible." *Id.* Excluding particle-bound pyrethroids from regulation based on the premise that they are not bioavailable "is not an accurate characterization for countless filter-feeding and deposit-feeding aquatic species," which ingest pyrethroids in sediments. *Id.* at p. 3.

1.25 The Regional Board's – and now, the State Water Board's – "exclusion of particle-bound pyrethroids from regulatory limits is likely to be of greatest significance with respect to agricultural discharges, since they often have the highest suspended sediment loads." *Id.* This scientifically unsound approach not only ignores the obvious, well-documented impact upon filter-feeding and deposit-feeding aquatic species on which higher-trophic level fishes such as salmonids feed, it wrongfully "provides a disincentive for growers to control release of suspended sediments." *Id.* As Professor Weston explained, "[t]he potential to manipulate suspended sediment so as to avoid a pyrethroid exceedance is akin to simply diluting to meet a treatment standard; neither should be acceptable practice to avoid regulatory limits." *Id.*

1.26 In summary, the Regional Board's – and now, the State Water Board's – refusal to recognize waterway impairment by the 90 percent of pyrethroid contamination that is not dissolved, has no basis in science. *Id.* at p. 4. To the contrary, as Dr. Weston pointedly observes, this is a "head-in-the-sand" approach:

> "1) never before used anywhere in the world, 2) that disregards 90% of the pollutant, 3) that incorporates numerical values that have never been shown to be generally applicable or field-verified, and 4) that is not scheduled to be re-assessed by the Board for 15 years . . . ."

1.27 *Id.* Rather than perpetuate this evasion of proper scientific methodology and analysis, this Board should recognize, consistent with these criticisms by CDFW and Professor Weston, that pyrethroid poisoning of our waterways is a significant cause of the ongoing ecological collapse of the Delta and its tributary rivers, and that ignoring the impact of 90 percent of the pyrethroids that are not "dissolved" is an evasion of the letter and spirit of the Clean Water Act.

IX. THE STAFF REPORT SHOULD BE REVIEWED AND REVISED TO CLARIFY CONFUSING PASSAGES.

1.28 The Staff Report contains several passages that are confusing to the lay reader, and may betray logical errors. For example, under "Sediment Matrix Analyses" the Staff Report states that "[i]n the event that the OC [organic carbon]-normalized MDL result was above the evaluation guideline, the sample was not included in the analysis. However, if the OC-normalized MDL was below the guideline the result was counted as a non-exceeding sample." *Id*. at p. 4. It is not clear from this passage whether Staff's analysis of pyrethroids and other toxics excluded samples that exceeded applicable limits, including only those that did not. Although this may not be the intent (or substance) of Staff's approach, the language used to describe Staff's analysis is at minimum confusing and should be restated. If, on the other hand, Staff did intend to exclude samples that exceeded applicable standards, this would not be appropriate and should be corrected.

1.29 Second, when discussing Staff's "Indicator Bacteria Assessment Approach," the Staff Report states that Staff would not update an analysis that was outdated because it used EPA's 1986 Ambient Water Quality Criteria for Bacteria, rather than EPA's 2012 criteria that are now available and should be used instead. Staff Report at p. 8. Utilizing 30-year old water quality criteria instead of current criteria does not reflect the best science available, and deviates from EPA's adopted protocol. This should be rectified.

1.30 Third, in discussing "Toxicity Assessments," the Staff Report states that it "determined, for 303(d) assessment purposes, only the SL [i.e., "Significantly Lower"] code should be used to determine whether a sample is considered to have a toxic effect and thereby an exceedance." Staff Report at p. 9. It is not clear why toxicity data associated with the "Significantly Greater" result code was not likewise considered in determining whether there is "an exceedance." *Id.* This discussion should be revised and clarified. And, of course, if Staff's approach ignores toxicity data indicating a "significantly greater" impact on toxicity, improperly excluding such data from the analysis and thereby leading to an inappropriately low recognition of exceedances, then the methodology should be revisited and, where appropriate, corrected.

X. CONCLUSION

For the foregoing reasons, the State Water Board's proposed 2014 and 2016 California Integrated Report" departs from the requirements of the Clean Water Act, and should be rejected and revised in accordance with the foregoing comments.

Thank you for considering our comments on this important matter.

Very truly yours,

Stephan C. Volker
Attorney for Pacific Coast Federation of Fishermen's Associations, San Francisco Crab Boat Owners Association, Institute for Fisheries Resources and North Coast Rivers Alliance

SCV:taf

Attachments: Exhibit 1: Letter from U.S. Environmental Protection Agency to Central Valley Regional Water Board, dated November 3, 2016

Exhibit 2: Letter from California Department of Fish and Wildlife, ECD/Water Branch, to Central Valley Regional Board, dated March 24, 2017

Exhibit 3: Letter from Professor Donald P. Weston, UC Berkeley to Central Valley Regional Board, dated March 24, 2017,

EXHIBIT

1

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105

November 3, 2016

Joseph Simi
Central Valley Regional Water Quality Control Board
11020 Sun Center Drive, #200
Rancho Cordova, CA 95670

Re: Proposed Revisions to the 303(d) List of Impaired Water Bodies and Integrated Assessment Report for the Central Valley Region

Dear Mr. Simi:

EPA reviewed the Clean Water Act Sections 305(b) and 303(d) 2014 Integrated Report for the Central Valley Region Draft Staff Report, dated September 2016 and have a few comments. We request the State consider further analysis of several waterbodies and additional listings where data show impairment.

Temperature Assessments Discard Many Impaired Waters

The Staff Report indicates that of 189 new waterbody evaluations for temperature, elevated temperatures were found in 39 yet only one was recommended for listing. The State states in the Staff Report that most of these were waterbodies that had surface grab samples only in summer months at the edges of swimming holes and would be unrepresentative of temperature conditions. However, in reviewing the lines of evidence, there are many waterbodies that are well mixed lotic systems where a surface grab sample showing exceedances of temperature thresholds would still be representative of most of the water column and suggest a temperature impairment for the waterbody as a whole. There are several waterbodies, such as segments of the Sacramento River that have substantial data collected under the Irrigated Lands Regulatory Program indicating impairment. Additionally, for many of these waterbodies continuous monitoring stations with existing data published by a sister State Agency, Department of Water Resources in publically available databases (e.g. California Data Exchange Center (CDEC) found at www.cdec.water.ca.gov and the California Water Data Library http://www.water.ca.gov/waterdatalibrary/) are available to confirm impairments initially identified by the already analyzed grab sample data.

EPA also notes that the thresholds selected in the Staff Report for this listing cycle, 21°C and 24°C for rainbow trout and steelhead respectively, are much warmer than the temperatures recommended in EPA's *2003 Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards.*

Existing Numeric Temperature Criteria Do Not Appear to be Utilized as Thresholds

EPA notes that in the Lines of Evidence for river segments that have more protective numeric standards than the thresholds utilized for comparison to the narrative objective, the more protective numeric standard was not used. Table III-4 and III-4A in the Sacramento and San Joaquin River Basin Plan identifies specific objectives for Deer Creek and the Sacramento River. As an example, 56°F (13.3°C) is a numeric objective for Sacramento River between Keswick Dam and Hamilton City but the line of evidence for this segment appears to have been compared to a 21°C threshold.

Continuous Monitoring Data in the Delta is "Readily Available Information"

In implementing section 303(d) of the Clean Water Act the State is required to assess all "readily available data and information"[1] when putting together a list of impaired waters. Federal policy[2] does not define this as narrowly as California has chosen to interpret it. EPA does not believe all readily available information were included in the development of the proposed list of impaired waters. California appears to have discarded all the continuous data reported in CDEC and the California Water Data Library. However, EPA notes this data is used by the State Board to implement water management decisions and is used by the Central Valley Regional Board in developing TMDLs.

The omission of continuous monitoring information is particularly notable in the Delta where 24 continuous monitoring stations are identified in Table 7 of the 2006 Bay-Delta Plan as stations to assess compliance with water quality objectives[3] and are not assessed for this Integrated Report. It has resulted in illogical listing decisions such as the listing of the Stockton Deep Water Ship Channel for temperatures unsuitable to support migration of cold water species, but none of the surrounding waters are listed as impaired. The Draft Staff Report also has inconsistent assessments for dissolved oxygen and salinity in the 2006 Bay-Delta Plan when there is an abundance of publically available data identifying broader impairments. These data should be assessed and incorporated into the final Staff Report.

The broader issue of incorporating readily available continuous monitoring data, not just from the Delta but across the State, should be addressed in the next listing cycle. These data are not readily incorporated into the California Environmental Data Exchange Network (CEDEN) but are collected at a great cost and effort by the State and other agencies and should be assessed against water quality objectives to accurately report the condition of California's waters to the public.

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[1] In developing Section 303(d) lists, states are required to assemble and evaluate all existing and readily available water quality-related data and information, including, at a minimum, consideration of existing and readily available data and information about the following categories of waters: (1) waters identified as partially meeting or not meeting designated uses, or as threatened, in the state's most recent CWA Section 305(b) report; (2) waters for which dilution calculations or predictive modeling indicate nonattainment of applicable standards; (3) waters for which water quality problems have been reported by governmental agencies, members of the public, or academic institutions; and (4) waters identified as impaired or threatened in any CWA Section 319 nonpoint assessment submitted to EPA. See 40 CFR § 130.7(b)(5).

[2] See pp. 30-32 of the Guidance for 2006 Assessment, Listing and Reporting Requirements Pursuant to Sections 303(d), 305(b) and 314 of the Clean Water Act (IRG). https://www.epa.gov/sites/production/files/2015-10/documents/2006irg-report.pdf

[3] "This Plan requires, and the permits and license of the DWR and the USBR include conditions for, a monitoring program to provide baseline information and determine compliance with water quality objectives." pp 41 of the 2006 Bay-Delta Plan

Monitoring Data Collected by CDFW for San Joaquin River Restoration Has been Overlooked

A multi-agency effort has been underway to restore the San Joaquin River since 2008. The upper restoration reaches have had temperature data collected since well before the data cutoff of 2010 and continue to be intensely scrutinized for suitability for salmonid reintroduction. These data are collected by the California Department of Fish and Wildlife (CDFW) and are an attachment to this letter.

The Salmon Protection Objective Should be Assessed

EPA notes that despite readily available data and information the Staff Report does not assess the Salmon Protection Objective found in Table 3 of the *Water Quality Control Plan for the San Francisco Bay/Sacramento- San Joaquin Delta Estuary* (2006 Bay-Delta Plan)

> Water quality conditions shall be maintained, together with other measures in the watershed, sufficient to achieve a doubling of natural production of chinook salmon from the average production of 1967-1991, consistent with the provisions of State and federal law.

This objective was adopted in the Water Quality Control Plan due to its inclusion in the Central Valley Project Improvement Act (CVPIA). Pursuant to CVPIA, US Fish and Wildlife Service has developed numeric targets to achieve this goal that are included in Table 1 and Appendix B-1 of the Restoration Plan for the Anadromous Fish Recovery Program. These can be accessed at the following website and are also included as an Appendix to this letter:
https://www.fws.gov/cno/fisheries/CAMP/Documents/Final_Restoration_Plan_for_the_AFRP.pdf

California collects the data used to assess progress towards these targets for many of these tributaries. CDFW publishes this information at this website:
https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=84381&inline=1

And existing program summary describing how all of the data are collected can be found here:
https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=3491&inline

The listing for Salmon Protection would be consistent with the Water Quality Control Policy for Developing California's Clean Water Act Section 303(d) List. Section 3.9 states that a water segment should be listed "if the water segment exhibits significant degradation of biological populations as compared to reference site(s) and is associated with water or sediment concentration of pollutants including but not limited to chemical concentrations, temperature, dissolved oxygen or trash". There are readily available data collected by a sister State agency (CDFW) to assess the Salmon Protection objective.

If you have any questions, please contact Valentina Cabrera at 415-972-3434 or cabrera-stagno.valentina@epa.gov or Terry Fleming at 415-972-3462 or fleming.terrence@epa.gov.

Sincerely,

Janet Hashimoto

Janet Hashimoto
Chief, Water Quality Assessment Section

Appendix: Table 1 and Appendix B-1 from the Restoration Plan for the Anadromous Fish Recovery Program

Table 1. Target production levels for anadromous fish in Central Valley rivers and streams.

Species	Target
Chinook salmon, all races[a]	990,000
Fall run	750,000
Late-fall run	68,000
Winter run	110,000
Spring run	68,000
Steelhead[b]	13,000
Striped bass[c]	2,500,000
American shad[d]	4,300
White sturgeon	11,000
Green sturgeon	2,000

Preliminary estimated production targets for chinook salmon. Data for rivers without a race designatio are for fall-run chinook salmon.

Race and river	Production targets
All races combined[a]	990,000
Fall run	750,000
Late-fall run	68,000
Winter run	110,000
Spring run	68,000
Sacramento River	
Fall run	230,000
Late-fall run	44,000
Winter run	110,000
Spring run	59,000
Clear Creek	7,100
Cow Creek	4,600
Cottonwood Creek	5,900
Battle Creek	
Fall run	10,000
Late-fall run	550
Paynes Creek	330
Antelope Creek	720
Mill Creek	
Fall run	4,200
Spring run	4,400
Deer Creek	
Fall run	1,500
Spring run	6,500
Miscellaneous creeks	1,100
Butte Creek	
Fall run	1,500
Spring run	2,000
Big Chico Creek	800
Feather River	170,000
Yuba River	66,000
Bear River	450
American River	160,000
Mokelumne River	9,300
Cosumnes River	3,300
Calaveras River Winter run	2,200*
Stanislaus River	22,000
Tuolumne River	38,000
Merced River	18,000

EXHIBIT
2

State of California – Natural Resources Agency
DEPARTMENT OF FISH AND WILDLIFE
ECD/Water Branch
830 S Street
Sacramento, CA 95811
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EDMUND G. BROWN JR., Governor
CHARLTON H. BONHAM, Director

March 24, 2017

Via Electronic Mail Only

Mr. Daniel McClure
California Regional Water Quality Control Board,
Central Valley Region
11020 Sun Center Drive, Suite 200
Rancho Cordova, CA 95670
Daniel.McClure@waterboards.ca.gov

Dear Mr. McClure:

Subject: Comments regarding the Proposed Amendments to the Water Quality Control Plan for the Sacramento River and San Joaquin River Basins for the Control of Pyrethroid Pesticides Discharges

The California Department of Fish and Wildlife (Department) appreciates the opportunity to review and comment on the California Regional Water Quality Control Board, Central Valley Region's (Regional Board) "Proposed Amendments to the Water Quality Control Plan for the Sacramento River and San Joaquin River Basins for the Control of Pyrethroid Pesticides Discharges" Draft Staff Report (Staff Report). The San Francisco Bay/Sacramento-San Joaquin River Estuary (Delta) is in a state of ecological crisis, with many native fish species populations at all time low abundances (SWRCB 2016a and 2016b). In recent years, the poor water quality conditions in the Delta and Sacramento and San Joaquin river watersheds, exacerbated by drought, have brought fish species listed under the protection of the state or federal Endangered Species Acts to levels near extinction or extirpation.

The Department is California's Trustee Agency for fish and wildlife resources, and holds those resources in trust by statute for all the people of the state. (Fish & G. Code, §§ 711.7, subd. (a) & 1802; Pub. Resources Code, § 21070; CEQA Guidelines § 15386, subd. (a).) The Department, in its trustee capacity, has jurisdiction over the conservation, protection, and management of fish, wildlife, native plants, and habitat necessary for biologically sustainable populations of those species. (Id., § 1802.) Similarly for purposes of CEQA, the Department is charged with providing, as available, biological expertise during public agency environmental review efforts, focusing specifically on projects and related activities that have the potential to adversely affect fish and wildlife resources.

The California Endangered Species Act (Fish & G. Code, §§ 2050-2069) states "that it is the policy of the state that state agencies should not approve projects as proposed which would jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of habitat essential to the continued existence of those species, if there are reasonable and prudent alternatives available consistent with conserving the species or its habitat which would prevent jeopardy." The Regional Board policies should be consistent with conserving any endangered or threatened species. The Department recognizes the tremendous effort the Regional Board and staff have put into developing this environmental document and associated amendments for the control of pyrethroid pesticides and their deleterious environmental impacts. Below are the Department's comments regarding the Staff Report to assist the Regional Board in this process.

There is ample scientific evidence to support that the use and discharge of pyrethroid pesticides have adversely impacted the aquatic ecosystem in the Central Valley. Regional Board staff identified that the six pyrethroids included in this control program were among the top thirty-eight pesticides that posed the greatest risk to aquatic life beneficial uses in the Sacramento River, San Joaquin River, and Delta watersheds below major dams (Lu and Davis 2009). The California Department of Pesticide Regulation (DPR) Surface Water Protection Program developed computer models to predict priorities for surface water monitoring based on the chemicals' potential to cause surface water toxicity (Lou et al. 2013; Lou et al. 2014). Five of the pyrethroids included in this control program were predicted to be in the top 20 priorities for urban uses in Sacramento and Placer Counties, and three of the included pyrethroids were in the top 20 priorities for statewide agricultural uses. United States Environmental Protection Agency's (USEPA) risk assessment pesticide effects determinations concluded that bifenthrin and cyfluthrin were "Likely to Adversely Affect" Delta smelt and its habitat (Melendez et al. 2012; Pranger and Hetrick 2013).

These predicted risks of pyrethroids to aquatic life beneficial uses are confirmed by the fifteen documented surface water body impairments by pyrethroids. As well, the addition of the forty-two more impairments by pyrethroids identified in the most recent update to the Regional Board's impaired waters list (Resolution No. R5-2016-0083) suggests that pyrethroid use and discharge continues to adversely impact aquatic resources. Based on the uncertainty around the characterization of pyrethroid discharges described in the Staff Report, the availability of robust monitoring to assess impairments by pyrethroids may be the limiting factor on the number of identified impairments. The current increasing trend of pyrethroid use in the Central Valley suggests that their environmental impact may increase accordingly. Statewide assessments of pollution trends identified trends of increasing sediment pyrethroid concentrations and toxicity attributed to pyrethroids (Phillips et al. 2016).

The recent update to the "State of the Bay-Delta Science" Report (SBDS), sponsored by the Delta Stewardship Council, reiterated the role of contaminants in the pelagic organism decline (POD) (Healy et al. 2016)[1]. Two of the new perspectives highlighted in the report were “1. Nutrients are important.” and “2. Delta waters are contaminated.” Healy et al. (2016) summarized the collection of papers which made up the SBDS report, which included topics such as flow dynamics, contaminants, primary and secondary production, food webs, fish populations, and predation. Early investigations into the POD suggested that contaminants likely played a role in the decline (Sommer et al. 2007). Brooks et al. (2012) developed conceptual models which linked the contaminant impacts to Delta fish declines. They identified pyrethroids of concern and stated, “The trend toward greater pyrethroid use has coincided with abrupt declines in abundances of pelagic fishes.” Contaminants, including pyrethroids, in Delta waters have likely contributed to ecological degradation and should be considered along with the other stressors in Delta management.

The contaminants chapter of the SBDS report presented an analysis which quantified the relationship between pyrethroid use and fish abundances hypothesized in these earlier works (Fong et al. 2016). Pyrethroid use in the counties of the Delta explained 24% to 73% of the variability in five Interagency Ecological Program (IEP) fall midwater trawl species abundance indices from 1978 to 2014, including the federally and State listed threatened or endangered species, Delta smelt and longfin smelt (see Fong et al. 2016, Figure 1). “Pyrethroid use exhibited statistically significant negative correlations (i.e., increased pyrethroid uses were associated with decreased abundances) with all species abundance indices.” Furthermore, a multi-factorial analysis showed that pyrethroid use was as strong as a determinant of abundance index variability as flow (Fong et al. 2016, Table 3). Overall, the analysis suggested that pyrethroid use may have played a comparable role in the POD.

Fong et al. (2016) also presented a synthesis of biological mechanisms which linked pyrethroid toxicity to Delta species, Delta waters, or ambient Delta pyrethroid concentrations (Fong et al. 2016, Table 1). These biological mechanisms along with the conceptual models help support the possible “causal” linkages between pyrethroid uses and fish abundance correlations. Overall, these examples add to the multiple lines of evidence that pyrethroids have played a part in the degradation of the Delta ecosystem. Delta smelt and longfin smelt, as well as other native and non-native fish species, are at record low abundances. The immediacy to implement actions to address the multiple stressors which degrade the Delta ecosystem is paramount.

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[1] The State of the Bay-Delta Science report was published in multiple issues of the San Francisco Estuary and Watershed Science Journal and can be found: http://escholarship.org/uc/search?entity=jmie_sfews;volume=14;issue=4

The preferred pyrethroid concentration goals using the 5th percentile of the species sensitivity distributions do not appear to be protective of aquatic beneficial uses. First, the chronic goal for lambda-cyhalothrin is at a concentration equal to the 96-hour LC_{50} for known sensitive species. Other goals are within 2 to 3-fold of the LC_{50} values. LC_{50} values may seem like arbitrary numbers, but setting a concentration goal equal to the LC_{50} value is essentially stating that mortality to ½ of the sensitive organisms is protective. In addition, the surviving organisms are not expected to prosper. Most likely, the remaining organisms will die days after the test exposure period, or they will exhibit severe chronic adverse impacts (e.g., reduce growth or failure to reproduce). Pyrethroid concentrations within 2 to 3 fold of LC_{50} values are expected to kill some portion of the population of sensitive organisms present or cause sub-lethal chronic toxicity.

Zooplankton are important prey for larval and juvenile salmon; splittail; Delta smelt; longfin smelt; and other estuarine fish species, and zooplankton are an important trophic link in estuarine ecosystems (Winder and Jassby 2010; CDWR 2011). IEP monitoring has shown substantial reductions in zooplankton prey availability in the Delta the last few decades, and multiple stressors have been linked to their decline (Winder and Jassby 2011; Hennessy 2011). Declined zooplankton species include mysid shrimp, which were once one of the most abundant and important prey items for estuarine species.

Mysid shrimps include multiple native and introduced species, which reside in the freshwater and saline Delta. One native mysid, *Neomysis mercedis*, is a filter feeding omnivore (i.e., they consume other zooplankton (e.g., rotifers and copepods) in addition to diatoms and detritus), which reside primarily in the brackish and freshwater Delta (Hiebert 2015). As the Staff Report states, the standard test organism *Americamysis bahia*, is a surrogate mysid which has been found to have similar sensitivities to pyrethroid as *H. azteca*. The decline in mysid abundances have coincided with increased pyrethroid uses. Based on the sensitivity of mysids to pyrethroids and possible impacts of pyrethroids to mysid prey, it is possible that pyrethroids may have also contributed to mysid abundance declines. Unfortunately, the University of California, Davis (UC Davis) criteria derivation does not incorporate mysid toxicity tests because they were performed in saline water. The sensitivity of mysids and its importance to the estuarine food web are additional evidence that the goals should be lower than the preferred 5th percentile goal.

Food limitations in the Delta estuary likely played a significant role in estuarine fish declines (Winder and Jassby 2011). Both Delta smelt and longfin smelt have been found to be food limited (Hammock et al. 2015; Burris 2017). Mysids are the preferred and a positively selected prey item for the threatened juvenile longfin smelt during most years (i.e., mysids make up greater proportions of juvenile longfin smelt diets than one would expect by considering the abundance in the environment (Burris 2017)). A study of the gut content of Delta smelt found that amphipods may make up a large portion of the mass of their diet, and *H. azteca* alone may comprise

10-15% of Delta smelt diets (Hilton et al. 2013). Other prey that have been identified as important to Delta smelt and longfin smelt diets, *Eurytemora spp.* and *Pseudodiaptomus spp.,* have been found to exhibit acute toxicity at environmentally relevant concentrations of bifenthrin and lambda-cyhalothrin (Teh et al. 2013). Any reduction in food availability could be a threat to Delta smelt, longfin smelt, and other estuarine species recoveries.

There is still significant uncertainty around the use of bioavailability calculations for predicting toxicity. A recent review concluded that the bioavailability and toxicity of pesticides to aquatic organisms in the presence of particles cannot simply be predicted by partitioning of particles between water and particles using K_{oc} (Knauer et al. 2017). In addition, the review found that the physiology of aquatic organisms, e.g., feeding behavior and digestion, influence both bioaccumulation and toxicity of pesticides. The exposure of aquatic organisms to pesticides and the environmental risks of many pesticides might be underestimated in prospective risk assessments, when predicted environmental concentrations are estimated based on the K_{oc} of a compound. This is consistent with research that showed mortality to filter-feeding calanoid copepods (*Eurytemora affinis* and *Pseudodiaptomus forbesi*) was higher than what would be predicted from dissolved concentrations of bifenthrin alone (Parry et al. 2015). The researcher suggested that toxicity could have been from the direct ingestion of bifenthrin-bound particles.

Furthermore, the regulation of pyrethroids using the dissolved fraction does not account for the fate and transport of sediment bound pyrethroids. Regional Board staff estimated that the sediment bound pyrethroid concentrations will equal or exceed the LC_{50} values for four out of the six pyrethroids, even if the 5^{th} percentile dissolved pyrethroid concentration goals are being attained. Regional Board studies estimate that 30% to 60% of the suspended sediment that flows into the Delta is deposited in the Delta (Louie et al. 2008; Wood et al. 2010). A large portion of suspended sediment will likely deposit in wetland, marsh, and floodplain habitats. Pyrethroid contaminated sediments deposited in these habitats will likely reduce their benefits. Wetland, marsh, and floodplain habitats have been found to be zones of high primary and secondary productivity that provide important prey (e.g., zooplankton) for estuarine fish species. Regulating sediment bound pyrethroids at the source would be feasible, whereas attempting to characterize the transport, the environmental impacts in the Delta, and the initial source of the pyrethroids in the watersheds are less likely. The Department has invested great efforts to restore Delta habitats for the benefit of imperiled native species, which may be jeopardized by continued inputs of pyrethroid contaminated sediments.

In environmental samples, evidence suggests that fish species may be more sensitive to environmental insults than invertebrate species. In a State Water Resources Control Board (State Water Board) SWAMP review of toxicity in Central Valley waters, researchers found that toxicity to fish occurred at a higher frequency than to either the invertebrate or algal species. Where studies were able to evaluate the cause of toxicity, insecticides, primarily pyrethroids singularly and in combination with other pesticides, were found to be the cause of toxicity. This suggest that detrimental effects may be occurring to fish species populations from chronic sub-lethal impacts, which may not be reflected by the acute mortality studies used to develop species sensitivity distribution. For example, Brander et al. (2016) found chronic reproductive impairments to the resident *Menidia beryllina* occurred at ratios extremely larger than the default acute to chronic ratio (ACR) for bifenthrin (11.4) used for the chronic criteria calculations (e.g., LC_{50} = 2100 ng/L and reduced fertilized eggs at 0.5 ng/L). The approximate ACR in this study using the LC_{50} and LOEC is 4,200. A calculation using an maximum acceptable toxicant concentration (MATC) would yield a larger ACR.

The federally listed threatened *Oncorhynchus mykiss* is far more acutely sensitive to bifenthrin toxicity than *Menidia beryllina* (e.g., 96-hour LC_{50} 150 ng/L versus 2100 ng/L, respectively). If an ACR of 4,200 was used to estimate the concentration at which chronic concentrations would impair *O. mykiss* reproduction, then it is estimated that *O. mykiss* reproduction could be impaired at concentrations as low as 0.04 ng/L bifenthrin. ACRs are typically higher in higher trophic level organisms (May et al. 2016). Default ACRs may underestimate the long-term chronic toxicity in fish species. Unfortunately, there is limited or no data available for direct effects to other listed species like Delta smelt and longfin smelt.

Based on the known toxicological effects predicted to occur in the aqueous and sediment phases of the aquatic environment using the 5^{th} percentile UC Davis criteria goal, the Department recommends that a more protective goal be adopted (e.g., the 1^{st} or 2.5 percentile UC Davis criteria) considering the current imperiled status of threatened or endangered species which rely on the Delta ecosystem. An alternative approach would be to apply the 5^{th} percentile UC Davis criteria goal to whole water samples, which would likely protect the local aqueous phases as well as the downstream Delta. The downward adjustment of the criteria to lower species sensitivity percentiles is consistent with the peer-reviewed literature, USEPA methodology, and the current revisions of the 2015 UC Davis methods (Tenbrook et al. 2010, USEPA 1985).

The assumption that the UC Davis 5^{th} percentile criteria is consistent with the USEPA's guidance because 0.05 is used to calculate a Final Acute Value has some uncertainty. First, the distribution calculations for the UC Davis method and the USEPA (1985) methods are different. For example, where the Staff Report presents values for the water quality criteria following the USEPA guidelines (Table 5-11) the values are below what the UC Davis 5^{th} percentile criteria predicts would be necessary to be protective, and the criteria for bifenthrin, cypermethrin, and lambda-cyhalothrin are more consistent with the UC Davis method 1^{st} and 2.5 percentile criteria. Second, the USEPA (1985) guidelines recommend that:

"To be acceptable to the public and useful in field situations, protection of aquatic organisms and their uses should be defined as prevention of unacceptable long-term short-term effects on (1) commercially, recreationally, and other important species and (2) (a) fish and benthic invertebrate assemblages in rivers and streams, and (b) fish, benthic invertebrate, and zooplankton assemblages in lakes, reservoirs, estuaries, and oceans."

The protection, restoration, and enhancement of a vibrant and healthy Delta ecosystem are clearly of State importance (DSC 2013). Adjustments to the percentile of the species sensitivity distribution are justified.

The 2.5 percentile UC Davis criteria was not considered by the independent science peer review. It is also unclear, whether the peer reviewers were made aware of the importance of mysid shrimp to the Delta ecology and threatened fish or their sensitivity to pyrethroids. There was no discussion of the current state of the native fish in the Delta or the indirect impact from a reduction in the major food groups in any of the peer review comments. As well, the peer reviews occurred prior to Brander et al. (2016) which demonstrated reproductive impairments to fish at 0.5 ng/L. Not all of the peer reviewers suggested that the 1st percentile criteria might be overprotective. Given the option of the 2.5 percentile criteria, the 5th percentile criteria may not have been preferred given its predicted toxicity in the water and sediment phases or the considerations of current local conditions.

The concentration goals should reflect the levels to protect beneficial uses, and not what might be closer to current analytical methods. The goals should be consistent with the current Basin Plan e.g., "All waters shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses in human, plant, animal, or aquatic life." Both the 2.5 and 5th percentile chronic criteria goals are well below analytical detection limits, so compliance assessments for either goal will be limited to the same commercially available analytical methods for, most likely, years. As well, the focus of moving toward improved water quality improvements while gathering additional information will be limited by analytical methods for both options.

As described in the Staff Report, the majority of the science shows that toxicity testing methods are demonstrating adverse impacts to aquatic life at levels below detection limits. Both percentile options will have to rely largely on toxicity testing for assessments of aquatic life protections, since toxicity tests appear to be the most sensitive means of assessing pyrethroid impacts to aquatic life. In addition, toxicity tests automatically address the question of bioavailabilty. As well, because this pyrethroid control program is proposing to adopt goals versus water quality objectives, many of the unintended regulatory consequences and restrictions under 40 CFR 136 may be avoided, even using the 2.5 percentile criteria.

The use of goals below detection and quantification limits is appropriate, when there is scientific evidence supporting its need to protect beneficial uses. The use of criteria below quantification limits is consistent with other State Water Board proposed policies. For example, the Proposed Statewide Mercury Control Program for Reservoirs sets load allocations for in-reservoir methylmercury production at no detectable methylmercury in reservoir water with a detection limit of 0.009 ng/L (SWRCB 2016c). Current common method detection and quantification limits for aqueous methylmercury are 0.02 ng/L and 0.04-0.06 ng/L, respectively (SWRCB 2017). Similar to this current project, the Statewide Mercury Control Program recognizes that adverse environmental impacts occur below common analytical detection limits, and protection goals and criteria should not be limited by what is currently “quantifiable”. Adjusting water quality goals and criteria to be similar to current quantification limits will likely underestimate impairments to beneficial uses.

Non-detect measurements and “J-flag” data are real data, and the use of these measurements is useful for environmental assessments. For example, the Sacramento-San Joaquin Delta Estuary TMDL for Methylmercury and the Proposed Statewide Mercury Control Program for Reservoirs rely heavily on the use of data that includes measurements below the detection and quantification limits for total mercury, methylmercury, and other constituents for the development of the linkage analyses, allocations, water quality goals, etc. (Wood et al. 2010; SWRCB 2016c). The pyrethroids that have been reported as above the method detection limit are defined as the minimum concentration of a substance that can be measured and reported with 99% confidence that the value is above zero (40 CFR Part 136). So, the confidence that the pyrethroid is present when detected above “detection limits” is very high. This information is indispensable, for example, when there is additional evidence that beneficial uses are being impaired, e.g., occurrence of toxicity or population impacts.

In regards to previous testimony provided during Regional Board workshops and hearings, the use of correlations and regressions as exploratory approaches to describe the possible factors contributing to abundance variability is consistent with current state of the science and methods employed in Delta, including Thomson and other’s (2010) use of log-linear models to describe relationships between species abundance and environmental variables. Kimmerer (2002) used similar regression models to describe fish and zooplankton species abundances interactions with X_2 location over time. As well, the use of regression analyses is consistent with methods used by the State Water Board to develop flow versus abundance relationships in the development of flow criteria for Phase 2 Bay-Delta Water Quality Control Plan update (SWRCB 2016b):

“State Water Board staff conducted a logistic regression analysis to estimate the magnitude of flow required to grow the longfin smelt population using data from 1967 to 2015 (Figure 3.5-3). A similar approach was used by The Bay Institute (TBI) (2010) in analyses submitted for the 2010 Flow Criteria Report with data from 1988-2007 (SWRCB 2010).”

Previous statements citing Nichols (2000) regarding correlation and regression analyses appears to be taken out of context. Nichols (2000) describes the limitation of monitoring and retrospective analyses in regards to migratory bird management and not specifically the statistical methods to describe associations between environmental factors and populations. The pyrethroid analyses in Fong et al. (2016) as well as the analyses in Thomson et al (2010), Kimmerer (2002), SWRCB (2016b), and the majority of Delta species abundance analyses use retrospective analyses of monitoring data to describe the possible environmental factors that may be driving species abundance. Nichols (2000) states that "retrospective analyses of monitoring data can be used to develop hypotheses and models of animal populations and management responses", which all these studies have attempted to do. The studies hypothesize the important environmental factors for population abundances; however, very few studies have tested the cause and effect natures of the environmental variables. The testing of cause and effect relationships would require the Regional Board or other management agencies to implement a change (e.g., regulation on pesticide discharges with confirmed reductions in loads, change in Delta flow requirements, or change in species take management), and then monitor the response of the populations.

The statistical analyses in Fong et al. (2016) were consistent with the methods used to develop the linkage analyses to support the State Water Board's Proposed Statewide Mercury Control Program for Reservoirs (SWRCB 2016c). Regional Board staff should review the methodology and the statistical review by the UC Davis Statistics Laboratory for the efficacy of methods for describing the associations of environmental factors. Clearly, the pyrethroid and species abundance correlations and regressions don't prove cause and effect relations, nor did they attempt to; however, based on the overwhelming evidence of pyrethroid use; discharge; presence in surface water bodies; direct link to toxicology; important food web species sensitivities to pyrethroids; and direct impacts to the food web presented here, in the Staff Report, and elsewhere in the literature, the linkage between pyrethroid use and species abundance declines is supported.

The Department appreciates the opportunity to provide comments on the draft Basin Plan Amendment and TMDL. Enclosed with this letter are more detailed comments and supplemental attachments to support the Department's comments. If you have any questions, please feel free to contact Stephen Louie at (916) 327-8758 or at Stephen.Louie@wildlife.ca.gov.

Sincerely,

Stephen Louie
Senior Environmental Scientist, Water Branch

Enclosures

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SED Chapter	Page #	SED Text, Paragraph, Sentence in Question	Staff Comment or Suggested Edits
BPA	xxx	The pyrethroid pesticides numeric triggers represent maximum allowable levels above which additional management actions may be required. The Regional Water Board may seek additional reductions in pyrethroid pesticides concentrations and exceedance frequencies if such reductions are necessary to account for additive effects with pyrethroids not identified in Table IV-Z or synergistic effects with other chemicals or to protect beneficial uses.	There is ample evidence in the literature that supports the concept that pyrethroids as well as other classes of pesticides have the potential to work in conjunction to adversely impact water quality and impair beneficial uses. For example, in California Stormwater Quality Association's review of pyrethroid and toxicity monitoring data from California urban watersheds, a key conclusion was that "Because pyrethroid toxicity is generally considered to be additive, the level of toxicity estimated from chemistry results must account for the mixtures of pyrethroids and other pesticides found, including fipronil" (Ruby 2013). In addition, the author found that pesticide mixtures were likely a significant factor in contributing to the observed toxicity in urban creeks. Furthermore, mixtures of pesticides in surface waters are a true concern. For example, in the National Water-Quality Assessment (NAWQA) Program's monitoring of pesticides, they found that more than 90% of the streams located in developed areas contained two or more pesticides or degradates (Gilliom et al. 2006). In addition, more than 50% of the streams had five or more pesticides or degradates. More recently, USGS monitoring of Sacramento and San Joaquin River inputs to the Delta found that all filtered samples contained mixtures of 3 to 14 pesticides (Orlando 2014). These are the major migratory and rearing habitats for threatened or endangered Central Valley anadromous salmonid species, Delta smelt, and longfin smelt, and green sturgeon. Not only do pesticide of similar classes or mechanisms of action (e.g., pyrethroids with pyrethroids or organophosphates with carbamates) work additively to adversely impact water quality, but pesticides with different mechanisms of action have been shown to work additively and synergistically to cause toxicity. For example, Denton and others (2003) observed synergistic toxicity and increased mortality to fathead minnows exposed to mixtures of

			esfenvalerate and diazinon. In addition, Westergaard and others (2012) observed "more-than-additive mixture toxicity" to the mobilization of Daphnia magna using copper and cypermethrin. Furthermore, even though they have different mechanisms of action at the cellular level (e.g., cholinesterase (ChE) inhibition or voltage-gated sodium channels), pyrethroids, organophosphates, carbamates, and metals have all been found to disrupt olfaction in salmonids (Scott and Sloman 2004; Scholz et al. 2000; Moore and Waring 2001; Hecht et al. 2007; NMFS 2008; NMFS 2009). Olfaction inhibition and other sub-lethal effects of pesticides often eliminates the performance of fish behaviors, such as predator avoidance, orientation, reproduction, kin recognition, etc. that are essential to fitness and survival in natural ecosystems (Potter and Dare 2003; Scott and Sloman 2004). It is reasonable to assume that pyrethroid pesticides can work additively with other classes of pollutants to cause sub-lethal toxicological effects. The proposed surveillance and monitoring program does not appear to include requirements to assess additive or synergistic effects with other chemicals. The evidence provided suggests that additive toxicity currently occurs in Central Valley water ways. The Department recommends that the impact of these additive effects are evaluated during the phased control program.
4	50	Beneficial Use discussion	There is data that suggests that impairments to MIGR and SPWN through olfactory impairments may be more sensitive than WARM and COLD. Moore and Waring (2001) found significant reductions to salmonid reproduction (e.g., reduced sex hormones and reduced milt production) at levels <4 ng/L. The nominal concentrations that exhibited impairments to reproduction were 0.1 and 1.0 ng/L. The measured concentrations of cypermethrin that were above detection limits ranged between 33% and 150% of nomimal concentrations, but measured concentrations averaged less than 100% of nominal concentrations. Accordingly, impairments to olfaction are likely occurring in the range of 0.033 to 0.15 ng/L

			cypermethrin. This range is below all acute and chronic effect concentrations used to develop the criteria for cypermethrin. As well, these effect concentrations are 2 to 9-fold lower than the preferred 5th percentile chronic UC Davis criteria for cypermethrin. As mentioned earlier, olfaction is important to many necessary behavior responses for reproduction and migration. Reduced milt production could result in the same adverse consequences as reduced egg production in sexually reproductive organisms. Studies to investigate MIGR & SPWN impairments would likely require different methods than those to evaluate WARM and COLD. Including MIGR and SPWN as designated beneficial uses needing protection could ensure that these uses will be assessed in surveillance and monitoring programs.
5	100	WWTP feasibility and Table 5-14 and 5-15	Because the report states that WWTP dissolved pyrethroid concentrations range between 1-6% of whole water samples, then it is reasonable to assume that current dissolved concentrations would be equivalent to a 94-99% reduction in concentrations for meeting the preferred 5th percentile goals for freely dissolved concentrations. It appears that very little reductions would be necessary to attain the preferred goals, thus attainable. Table 5-14 and 5-15 present reductions necessary for whole water concentrations to meet criteria. The preferred trigger concentrations are in terms of freely dissolved concentrations. Reductions presented as reductions from whole water samples to meet dissolved concentration triggers don't exhibit the true nature of the feasibility of necessary reductions for the program. Recommend that additional tables displaying reductions necessary from current dissolved concentrations to dissolved goals are provided.
5	103	Table 5-16	According to the data presented in the table, current peak dissolved pyrethroid concentrations in storm water samples are 71-99.5% lower than whole water concentrations. The dissolved concentrations for the impaired Pleasant Grove Creek are currently

			meeting the preferred 5th percentile chronic goal for cyfluthrin and slightly above the goal for bifenthrin. The source control program of the STORMS or other CDPR programs should reduce concentrations further, which is supported by testimony provided by stakeholders at the Feb. 24, 2017 Hearing (e.g., statistically significant decline in Pleasant Grove Creek sediment pyrethroid concentrations over time). The data suggests that some storm water programs currently, or in the near future, have the ability to attain dissolved goals, thus attainable and technologically feasible.
5.6.7.2	107		As described previously, the preferred goals are predicted to impair olfaction in salmonids, which is important for essential behavior responses. Salmonids use olfactory cues to home to natal streams. The disruption of olfaction in salmonids by other pesticides has been shown to likely increase straying in Chinook salmon (Scholz et al. 2000). A high occurrence of straying of fall-run Chinook salmon occurs between the Sacramento and San Joaquin river basins. The analysis for the protection of endangered and threatened species does not appear to include the cumulative impacts of pyrethroid pesticides, alone and in combination of other stressors, on the chronic long-term direct impacts to endangered species, or the indirect impacts from the reduction of the quantity or quality of food. Predicting the response of different fish species to contaminants requires considering the sensitivity and exposure of different life stages, the energy deficits due to multiple stressors, and the joint effects of temperature on metabolic rate and chemical elimination (Brooks et al. 2012). The list of federally and state listed threatened or endangered species that may be affected by the discharge of pyrethroids is incomplete. A few examples of missing species include: longfin smelt (*Spirinchus thaleichthys*), California Tiger Salamander (*Ambystoma californiense*), and Clapper Rail (*Rallus longirostris obsoletus*). The most recent list of threatened or endangered animal

			species can be found: https://www.wildlife.ca.gov/Conservation.
5	67	Sublethal effects on resident fish have been demonstrated at very low levels. Cole et al. (2016) reported reproductive effects on longfin smelt, which reside in the Delta, at 0.5 ng/L bifenthrin, which is equal to the H. azteca LC50 for bifenthrin. Other sublethal effects have been documented in resident fish (Fong et al. 2016), but if effects were not directly linked to survival, growth or reproduction they were not included in criteria derivation.	It appears that the report may have incorrectly cited Cole et al. (2016). Brander et al. (2016) found reproductive impairments in *Menidia beryllina* at 0.5 ng/L bifentrhin. In addition, the citation for Cole et al. (2016) references *Menidia beryllina* as well, and not longfin smelt. Brander et al. (2016) demonstrated clear reductions in egg fertilization for 0.5 ng/L bifenthrin exposures (approximately 30% reduction). As well, the study demonstrated that the likely mechanism for the reduced reproductive success, a trend in reduced choriogenein per total protein content, started at fish exposures to 0.5 ng/L bifenthrin. The report is unclear how Staff concluded that effects were not linked to reproduction and not included in the criteria derivation. This study is an additional line of evidence that the 5th percentile criteria goal is not protective of supporting aquatic life beneficial uses.
5	68	Studies on some non-resident species such as the amphipod Gammarus species and Atlantic salmon have documented sublethal effects at low concentrations, but these effects were not included in criteria derivation in several cases if they were not directly linked to survival, growth or reproduction or if effect concentrations were not quantified due to detection limits.	First, the non-native species tests are relevant as surrogate species, when available data are not available for species of concern. For example, the non-native *Ceriodaphnia dubia* was a surrogate species that was used extensively to demonstrate adverse effects from the use of organophosphate pesticides, as well as, to develop criteria for this class of pesticides. Second, the concentrations that caused measured impairments (e.g., reduced milt production and reduced egg fertilization) may have been below detection limits, but the nominal and predicted concentrations were below concentrations found to impair other sensitive species, including *H.*

			azteca. As well, the concentrations were predicted to be below the preferred 5th percentile chronic UC Davis criteria for cypermethrin. This evidence supports the need to use a goal that is more protective.
5	72	The UC Davis method also includes an exceedance frequency of not more than once every 3 years. This means that if there are two or more exceedances of the concentration goal in a 3 year period, then the concentration goals would not be achieved…	Caution should be used for the exceedance frequency of not more than once every 3 years as a conservative measure. Delta smelt abundances are at an all-time low. Delta smelt are an annual species, meaning the current stock gives rise to the next year's stock. Direct toxicity to Delta smelt populations or a crash in zooplankton prey which prevents Delta smelt from succeeding in any given year has the potential to extirpate the species.
6.2	121	Category 4b for Agricultural Waters	The Staff Report is inconsistent in its description of uncertainty around attaining standards. The Staff Report proposes to make use of goals and triggers due to the uncertainty around the feasibility of attaining water quality standards. However, Section 6.2 suggests that impairments in agricultural watersheds can be addressed through Category 4b of the 303(d)/305(b) Integrated Report as an alternative to TMDLs. If it is predicted that "water quality standards can be attained in the impaired agricultural water bodies in a specified time period", then it appears that pyrethroid water quality objectives specific to agricultural discharges may be feasible and warranted. The Department suggests that the Staff Report clarify the current and predicted feasibility of controlling pyrethroid discharges in the agricultural watersheds.

ES	xviii	Therefore additional dilution will likely be available in most receiving waters and resulting pyrethroid concentrations in receiving waters will likely be significantly less, thus providing an additional margin of safety.	This statement assumes that there are no pyrethroid discharges upstream, as well as any other constituents that could interact with pyrethroids in receiving waters. Without an analysis to predict whether receiving waters have the assimilative capacity to receive pyrethroids, there's no assurance that dilution is available. Considering the large number water bodies included on the 303(d) list for pollutants, including pesticides known to interact with pyrethroids, there is likely no assimilative capacity in many receiving waters to allow for dilution as a safety factor.
ES	xix	A **conditional prohibition** of pyrethroid discharges to all water bodies with aquatic life beneficial uses in the Sacramento River and San Joaquin River basins. Discharge above concentration triggers would be prohibited unless management practices to reduce discharges of pyrethroids are being implemented.	The report states numerous times that there is great uncertainty around dischargers' ability to control pyrethroids in their discharge (i.e., management practices are likely ineffective). It is unclear whether a reduction in pyrethroids in surface waters is expected or will be protective because dischargers will be allowed to discharge pyrethroids above goals (triggers) if they implement management practices, which may or may not be effective at reducing pyrethroid concentrations. Please clarify what the expected reductions in pyrethroid concentrations are, and whether the concentrations are predicted to be protective of beneficial uses.
5	65	Pyrethroid resistance	Artificial selection for pyrethroid resistant genes is a population effect. As stated in the Staff Report and supported by the literature, there are many fitness consequences of reduced genetic and biological diversity to populations. In addition to resistance by gene mutation, there are adverse costs to tolerance by acclimation. For example, fish species have been shown to be able to tolerate xenobiotic exposures, but the tolerance resulted in metabolic costs and reduced growth (Beyers et al. 1999). Reduced growth rates throughout the food web can exacerbate mercury contamination (Foe and Louie 2014). These cumulative impacts through the food web do not appear to be accounted for in the calculation of protective goals.

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Many contaminants in the California Bay–Delta (Bay–Delta) exceed regulatory standards, affect aquatic species, and potentially affect human health. Recent studies provide multiple lines of evidence that contaminants affect species of concern in the Bay–Delta (e.g., the decline of several important fish species referred to as the "Pelagic Organism Decline" or POD). Contaminants occur as dynamic complex mixtures and exert effects at multiple levels of biological organization. Multiple chemicals impair processes at cellular and physiological levels (measured as growth, development, and behavior abnormalities), and when viability and reproductive output are affected, populations are affected. As an important example, the population decline of the endangered Delta Smelt (*Hypomesus transpacificus*) is significantly associated with multiple stressors, including insecticide use. New analyses presented in this paper show significant correlations between pyrethroid use and declining abundance of POD fish species. Water sampled from the Bay–Delta causes multiple deleterious effects in fish, and Delta Smelt collected from

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the Bay–Delta exhibit contaminant effects. Fish prey items are also affected by contaminants; this may have an indirect effect on their populations. Co-occurrence with thermal changes or disease can exacerbate contaminant effects. Contaminants also pose threats to human health via consumption of fish and shellfish, drinking water, and contact recreation, in particular, mercury, cyanobacteria toxins, disinfection byproducts, pathogens, pesticides, and pharmaceuticals and personal care products. The role of contaminants in the decline of Bay–Delta species is difficult to accurately assess in a complex, dynamic system. However, tools and approaches are available to evaluate contaminant effects on Bay–Delta species, and separate the effects of multiple stressors. Integrated monitoring and focused mechanistic studies are instrumental for addressing management needs. Effect and risk assessments should be conducted for different species across multiple life stages, with emphasis on early life stages of high-priority Bay–Delta species.

Supporting material:

Appendix A: Potential Contribution of Pyrethroid Insecticides to the Pelagic Organism Decline

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SPECIAL ISSUE: THE STATE OF BAY–DELTA SCIENCE 2016, PART 3

Contaminant Effects on California Bay–Delta Species and Human Health

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ABSTRACT

Many contaminants in the California Bay–Delta (Bay–Delta) exceed regulatory standards, affect aquatic species, and potentially affect human health. Recent studies provide multiple lines of evidence that contaminants affect species of concern in the Bay–Delta (e.g., the decline of several important fish species referred to as the "Pelagic Organism Decline" or POD). Contaminants occur as dynamic complex mixtures and exert effects at multiple levels of biological organization. Multiple chemicals impair processes at cellular and physiological levels (measured as growth, development, and behavior abnormalities), and when viability and reproductive output are affected, populations are affected. As an important example, the population decline of the endangered Delta Smelt (*Hypomesus transpacificus*) is significantly associated with multiple stressors, including insecticide use. New analyses presented in this paper show significant correlations between pyrethroid use and declining abundance of POD fish species. Water sampled from the Bay–Delta causes multiple deleterious effects in fish, and Delta Smelt collected from the Bay–Delta exhibit contaminant effects. Fish prey items are also affected by contaminants; this may have an indirect effect on their populations. Co-occurrence with thermal changes or disease can exacerbate contaminant effects. Contaminants also pose threats to human health via consumption of fish and shellfish, drinking water, and contact recreation, in particular, mercury, cyanobacteria toxins, disinfection byproducts, pathogens, pesticides, and pharmaceuticals and personal care products. The role of contaminants in the decline of Bay–Delta species is difficult to accurately assess in a complex, dynamic system. However, tools and approaches are available to evaluate contaminant effects on Bay–Delta species, and separate the effects of multiple stressors. Integrated monitoring and focused mechanistic studies are instrumental for addressing management needs. Effect and risk assessments should be conducted for different species across multiple life stages, with emphasis on early life stages of high-priority Bay–Delta species.

INTRODUCTION

The term contaminant refers broadly to a large number of substances from distributed and diverse sources that include urban and agricultural runoff, treated industrial and municipal wastewater, atmospheric deposition, and chemicals applied directly to surface waters for invasive plant and pest control.

The San Francisco Bay and Sacramento–San Joaquin Delta (Bay–Delta) has been identified as impaired for aquatic life by several specific contaminants on the Environmental Protection Agency 2010 List of Impaired Water Bodies (SWRCB 2010). The 2010 list of contaminants includes metals (copper, cadmium, mercury, and zinc), pesticides (chlordane, chlorpyrifos, DDE, DDT, diazinon, dieldrin, organophosphate insecticides, and toxaphene), and chlorinated compounds (dioxins, furans, and polychlorinated biphenyls [PCBs]). The Delta is also listed for sediment toxicity and unknown toxicity[1]. An unknown toxicity listing results from toxicity being detected in lab or field studies, but not yet being linked to a specific chemical. Since the 2010 list was adopted, additional contaminants of concern have been identified including additional pesticides, flame retardants, nutrients, naturally occurring toxins, micro-plastics (e.g., from synthetic clothing), and pharmaceuticals and personal care products (PPCPs). Essential elements (e.g., selenium) and nutrients, when outside the beneficial ranges, may negatively affect organism or community health. A legacy of contaminants in the Bay–Delta, such as persistent organic chemicals and mercury, can, in addition to affecting aquatic life, accumulate through the food web, leading to health risks for humans and wildlife.

Although many contaminants have been identified as impairing aquatic life, it is unknown how many other contaminants may exert toxic effects. Compared to other biotic and abiotic factors that cause aquatic ecosystem degradation worldwide, the role of contaminants is often under-estimated because of a lack of comprehensive, quantitative, and effect-based analyses (Stehle and Schulz 2015). Contaminants affect populations and communities at concentrations detected in the Delta (Hasenbein et al. 2015c), but first exert their effects at the organism level by altering gene expression, physiological processes, and behavior. Historically, contaminant assessments focused predominantly on acute effects, but sublethal toxic effects can occur at exposure levels far below the concentrations that cause lethality. This does not imply that acute effects are no longer observed, but simply that there is greater awareness of the consequences of sublethal effects. Over the past decade, multiple lines of evidence demonstrate that contaminants, either singly or as mixtures, directly affect the health of Bay–Delta species (Table 1). These studies have provided much information about the risk of exposure to contaminants, and have also highlighted important knowledge gaps, including the significance of combined effects of chemical and other biotic and abiotic stressors.

Water quality standards are generally designed to be protective of 95% of aquatic life (i.e., of species for which we have toxicity data). Contaminant monitoring, coupled with toxicity testing that uses standard test species and methods, are also used as reliable indicators of "instream" threats to aquatic organisms (Grothe 1996; De Vlaming and Norberg–King 2000). In the past, contaminants were identified as impairing aquatic life primarily when chemical concentrations detected in Bay–Delta waters, sediment, or biota exceeded known water quality standards or caused toxicity. Although these tools are highly predictive of instream effects, they need to be paired with additional contaminant effect studies of resident or migratory species, whenever the abundance of these key species is linked to multiple stressors. It is noteworthy that when these standard regulatory tools were applied to the Bay–Delta and its tributaries, and the identified contaminants were examined in studies of resident species, effects were consistently confirmed.

The topic of Bay–Delta contaminants is broad, and by necessity a synthesis must focus on a subset of available information. In this paper we summarize new information which has become available since the State of Bay–Delta Science 2008 was published (Luoma et al. 2008). This synthesis emphasizes four topics:

1 *http://www.waterboards.ca.gov/water_issues/programs/tmdl/2010state_ir_reports/table_of_contents.shtml#r5*

1. The application of a weight-of-evidence approach to improve our ability to assess contaminant effects on Bay–Delta fish species that are experiencing significant population declines.
2. A synthesis of knowledge on known and emerging contaminants (not addressed in the weight-of-evidence examples).
3. An update on human health risks through fish consumption and drinking water from the Delta.
4. Recommendations on science priorities to address the current challenges in precisely defining the role of contaminants as one of many stressors.

APPLICATION OF A WEIGHT OF EVIDENCE APPROACH— CONTAMINANT EFFECTS ON DECLINING BAY–DELTA FISH SPECIES

One outstanding management challenge is that the role of contaminants in the decline of several Bay–Delta native and migratory species is not well understood. Even though the ecological effects of contaminants have been incorporated into Bay–Delta conceptual models, they have not been effectively quantified in terms of population declines. In recent years, a number of expert panels were convened to evaluate multiple stressors involved in the decline of Bay–Delta species. These expert panels identified contaminants as a stressor that warrants extensive investigation (Johnson et al. 2010; Mount et al. 2012; NRC 2013; IEP MAST 2015; Luoma et al. 2015), yet specific contaminants were not linked to the decline. Although several contaminants occur above their regulatory threshold concentration, we do not clearly understand the effect of these known contaminants on Bay–Delta species declines. Unknown contaminants could also be having an effect. Unequivocal identification of a specific contaminant as a cause of a species decline will continue to be a challenge, but recent research has generated multiple lines of evidence, which, when considered together, can be used to generate a weight of evidence that is more conclusive in identifying contaminants as an influential factor.

Quantifying the role of contaminants in observed Bay–Delta fish declines requires multiple approaches. For each species in decline, individual studies, or lines of evidence, can be synthesized to see if the weight of evidence supports that a contaminant is influencing species abundance. Some individual lines of evidence may determine that there is potential risk, but are clearly not definitive. For example, contaminants may be detected in the Bay–Delta at concentrations that exceed water quality standards, but these may not be adversely affecting the abundance of a particular species. Other lines of evidence may show species effects, but this is not enough to demonstrate that a contaminant is affecting the population as a whole. However, as we obtain multiple lines of evidence, it becomes more likely that effects are occurring, and that management action–or at least intensified studies–should be initiated. Potential lines of evidence include:

- major risk factors, such as:
  - declining species abundance not fully explained by other stressors
  - a statistical relationship between fish abundance and contaminant use
  - contaminants detected in fish habitats at levels of concern
- significant organism effects, such as:
  - effects detected in Bay–Delta waters or sediment on surrogate species
  - effects detected in Bay–Delta waters or sediment on the species of concern
  - effects detected in field-collected organisms
  - effects detected in laboratory and mesocosm studies conducted at contaminant levels detected in the Bay–Delta
- indirect effects of a contaminant, for example, on the food supply of a species known to be food limited

This synthesis focuses on the research conducted since 2005 that used field, mesocosm, and laboratory studies to evaluate the effects of contaminants on declining fish species including Delta Smelt (*Hypomesus transpacificus*), Longfin Smelt (*Spirinchus thaleichthys*), Threadfin Shad (*Dorosoma petenense*), juvenile Striped Bass (*Morone saxatilis*) and salmonids. We present available lines

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Table 1 Sublethal effect-based assessments of contaminant impacts of contaminants present in the Bay-Delta

DELTA SPECIFIC SUBLETHAL EFFECTS STUDIES FROM 2005 TO PRESENT	General Stress	Immune System	Osmoregulation	Nervous system	Muscular system	Endocrine system (reproductive)	Tissue effects / Histopathology	Necrosis / Apoptosis	Low Nutritional Status	Growth	Development	Deformities	Behavior	Reproductive Output
Pyrethroid insecticides	Ch[1-3] Sb[4] Sp[5] Ds[6]	Ch[1-3] Sb[4] Ds[6,7] Is[8]	Ds[6,7] Rt[9]	Ds[7] Fm[10,11]	Ds[7] Fm[10,11]	Fm[11] Is[8,12-15] Rt[16] Jm[17]	Sp[5]	Sp[5] Ds[6,7]		Sb[4] Sp[5] Ds[6,7] Cd[18,19] Ha[18,20]	Ds[6,7] Rt[16]	Sp[5]	Sb[4] Ds[7] Fm[10,11] Cd[18,19] Ce[21] Ha[20]	Is[8,12,14]
Organophosphate insecticides	Ch[1-3] Sp[5]	Ch[1-3]		Ch[22] Rt[23]			Sp[5]	Sp[5]		Sp[5] Cd[18,19] Ch[22]		Sp[5]	Cd[18,19] Ha[20] Ch[22] Rt[24]	
Phenylpyrazole insecticides				Fm[11,25]	Fm[11,25]	Fm[11,25]						Fm[11]	Fm[11,25]	
Pharmaceuticals and Personal Care Products	Is[26]	Is[26]	Is[26]	Fm[27]	Fm[27]						Is[26]		Fm[27]	
Metals and Metalloids	Sb[4] Lmb[28]	Sb[4] Ds[29] Lmb[28]		Ds[29]	Ds[29]		Sp[30] Lmb[28]	Ds[29]	Sp[30]	Sb[4] Ds[29] Ha[20] Sp[30]	Ds[29]	Sp[30,31]	Sb[4] Ds[29] Ha[20]	
Persistent Organic Pollutants	Sb[32,33]						Sb[34]			Sb[34]	Sb[34]			
Ammonia and Ammonium	Ds[35]	Ds[36]			Ds[36]			Ds[35]			Ds[35,36]		Ds[35]	Pf[37]
Microcystin	Jm[38]						Jm[38] Ts[39] Sp[40]	Jm[38] Ts[39] Sp[40]	Ts[39] Sp[40]	Ts[39] Sp[40]			Eg[41]	
Delta Water Samples (Laboratory)	Sb[33] Ts[39]	Ds[36]		Fm[42]	Ds[36,43]	Sb[33] Fm[42,44] Rt[45,46]	Fm[42]	DS[43]		Fm[42,44] Ds[43] Ha[47-49]	Ds[36] Fm[42,44] Ds[43]		Fm[44]	
Delta Water Samples (In-situ, field collected fish)	Fm[42] Sb[50]			Sb[50]		Is[12] Fm[42,44] Sb[50] Rt[17]	Fm[42] Ds[51] Sp[52] Is[12]	Sb[50]	Sb[50] Sp[52]	Ds[51] Sp[52]	Is[12]	Sb[50]		

Key: ***Fish species:*** Ch = Chinook Salmon; Sb = Striped Bass; Sp = Sacramento Splittail; Ds = Delta Smelt; Is = Inland Silversides; Rt = Rainbow Trout; Fm = Fathead Minnow; Jm = Japanese Medaka; Lmb = Largemouth Bass; Ts = Threadfin Shad; ***Invertebrate species:*** Ha = *Hyalella azteca*; Cd = *Chironomous dilutus*; Ce = *Ceriodaphia dubia*. Pf = *Pseudodiaptomus forbesi*; Eg = *Eudiaptomus gracilis*.

Sources: [1]Eder et al. 2008; [2]Eder et al. 2007; [3]Eder et al. 2009; [4]Geist et al. 2007; [5]Teh et al. 2005; [6]Jeffries et al. 2015b; [7]Connon et al. 2009; [8]Brander et al. 2016; [9]Riar et al. 2013; [10]Beggel et al. 2011; [11]Beggel et al. 2010; [12]Beggel et al. 2012; [13]Brander et al. 2013; [14]Brander et al. 2012a; [15]DeGroot and Brander 2014; [16]Forsgren et al. 2013, [17]Schlenk et al. 2012; [18]Hasenbein et al. 2015a; [19]Hasenbein et al. 2015b; [20]Callinan-Hoffmann et al. 2012; [21]Brander et al. 2012b; [22]Baldwin et al. 2009; [23]Maryoung et al. 2014; [24]Maryoung et al. 2015; [25]Beggel et al. 2012; [26]Jeffries et al. 2015a; [27]Fritsch et al. 2013; [28]Gehringer et al. 2012; [29]Connon et al. 2011a; [30]Deng et al. 2007; [31]Rigby et al. 2010; [32]Durieux et al. 2012; [33]Spearow et al. 2011; [34]Ostrach et al. 2008; [35]Connon et al. 2011b; [36]Hasenbein et al. 2014; [37]Teh et al. 2011 [38]Deng et al. 2010; [39]Acuña et al. 2012a; [40]Acuña et al. 2012b; [41]Ger et al. 2011; [42]Deanovic et al. 2014, unreferenced, see "Notes"; [43]Connon et al. 2011, unreferenced, see "Notes"; [44]Biales et al. 2015; [45]de Vlaming et al. 2006; [46]Lavado et al. 2009; [47]Werner et al. 2010a; [48]Werner et al. 2008; [49]Werner et al. 2010b; [50]Ostrach and Groff 2009; [51]Hammock et al. 2015; [52]Greenfield et al. 2008. Citations in red indicate evaluations conducted at concentrations detected in the Bay-Delta, or on Bay-Delta water samples.

See reference information for sources listed beginning on page 30.

of evidence, which, when taken together, provide a weight of evidence that contaminants, in combination with other stressors, have negatively affected Delta Smelt. There is also evidence of contaminant effects on salmon. Less is known about the precise role of contaminants on other Bay–Delta fish declines, but a synthesis of recent studies suggests the potential for contaminant effects, and identifies critical gaps in our knowledge (Table 1).

Evidence of Declining Species Abundance Not Fully Explained by Other Stressors

A step-decline in abundance of Delta Smelt, Longfin Smelt, Threadfin Shad, and Striped Bass (young-of-year) was observed in the early 2000s (Thomson et al. 2010). Declining numbers of estuary-dependent fish species such as Chinook Salmon (*Oncorhynchus tshawytscha*), Steelhead Trout (*O. mykiss*), and Green Sturgeon (*Apicenser medirostris*), as well as invertebrates—in particular calanoid copepods and mysids—and desirable primary producers have also been documented (Winder and Jassby 2011). Contaminants have been concomitantly detected at concentrations that can elicit acute and chronic effects (e.g., reduced growth, reduced reproduction) in related species. Studies of sublethal effects on Bay–Delta species began more recently. Although these investigations noted decreases in growth rates and fecundity, many did not fully assess the role of contaminants. The general conclusion of the recent investigations is that multiple stressors were involved (FLaSH; Brown et al. 2014).

Monitoring the abundance and distribution of aquatic species (e.g., algae, macroinvertebrates, fish) can identify changes in populations, but analyses of multiple stressors are required in order to understand why species abundance and composition fluctuates. Such analyses must include contaminants and their effects on organisms and the ecosystem if their role is to be defined.

Example of Correlations Between Declining Fish Abundance and Increasing Insecticide Use

Several investigations have conceptualized but not quantified the role of contaminants in Bay–Delta fish declines (Brooks et al. 2012; Scholz et al. 2012).

A new analysis, presented here as a representative example of changing pesticide use, indicates that pyrethroid insecticide use in the Delta is strongly correlated with fish abundances (Figure 1).

Why Pyrethroids as an Example? Although pyrethroids are classified as neurotoxicants, they have a number of additional effects that can be detrimental to fish, including endocrine disruption and growth and development alteration (Table 1). Pyrethroids are the fourth most-used group of insecticides worldwide (Hénault–Ethier 2015; Brander et al. 2016a), and their use has increased steadily since 1979, while the use of organophosphate insecticides (OPs) (e.g., diazinon chlorpyrifos) has declined since their peak in the early 1990s (Figure 2). Concentrations of pyrethroids were predicted to increase markedly in waters tributary to the Bay–Delta starting in 2000 (Jorgenson et al. 2013). The California Department of Pesticide Regulation's (CDPR) Surface Water Protection Program has ranked pyrethroids as high priority for monitoring because they have high potentials to cause surface water toxicity from urban and agricultural uses (Luo et al. 2014). The Central Valley Regional Water Quality Control Board (CVRWQCB)[2] is currently establishing a control program for pyrethroid insecticides to protect Bay–Delta watershed aquatic life. The hydrophobic nature and strong binding affinity of pyrethroids to particulate matter were thought to reduce or prevent their runoff into surface waters; however, studies have shown that runoff from areas treated with pyrethroids was more toxic to fish than runoff from areas treated with OPs (Werner et al. 2002; Jiang et al. 2016).

Associations between pyrethroid use (agricultural and professional urban application) in the six counties of the Delta (*http://www.cdpr.ca.gov/docs/pur/purmain.htm*) and fish abundance indices for the Pelagic Organism Decline (POD) species from Interagency Ecological Program (IEP) Fall Midwater Trawl (FMWT; 1978 to 2014) suggest that pyrethroids may be a contributor to fish population declines in the Delta (Table 2). The use of six pyrethroids in the Delta region (permethrin, esfenvalerate/fenvalerate, bifenthrin, cyfluthrin, cypermethrin, and lambda-

2 *http://www.waterboards.ca.gov/centralvalley/water_issues/tmdl/central_valley_projects/central_valley_pesticides/pyrethroid_tmdl_bpa/index.shtml*

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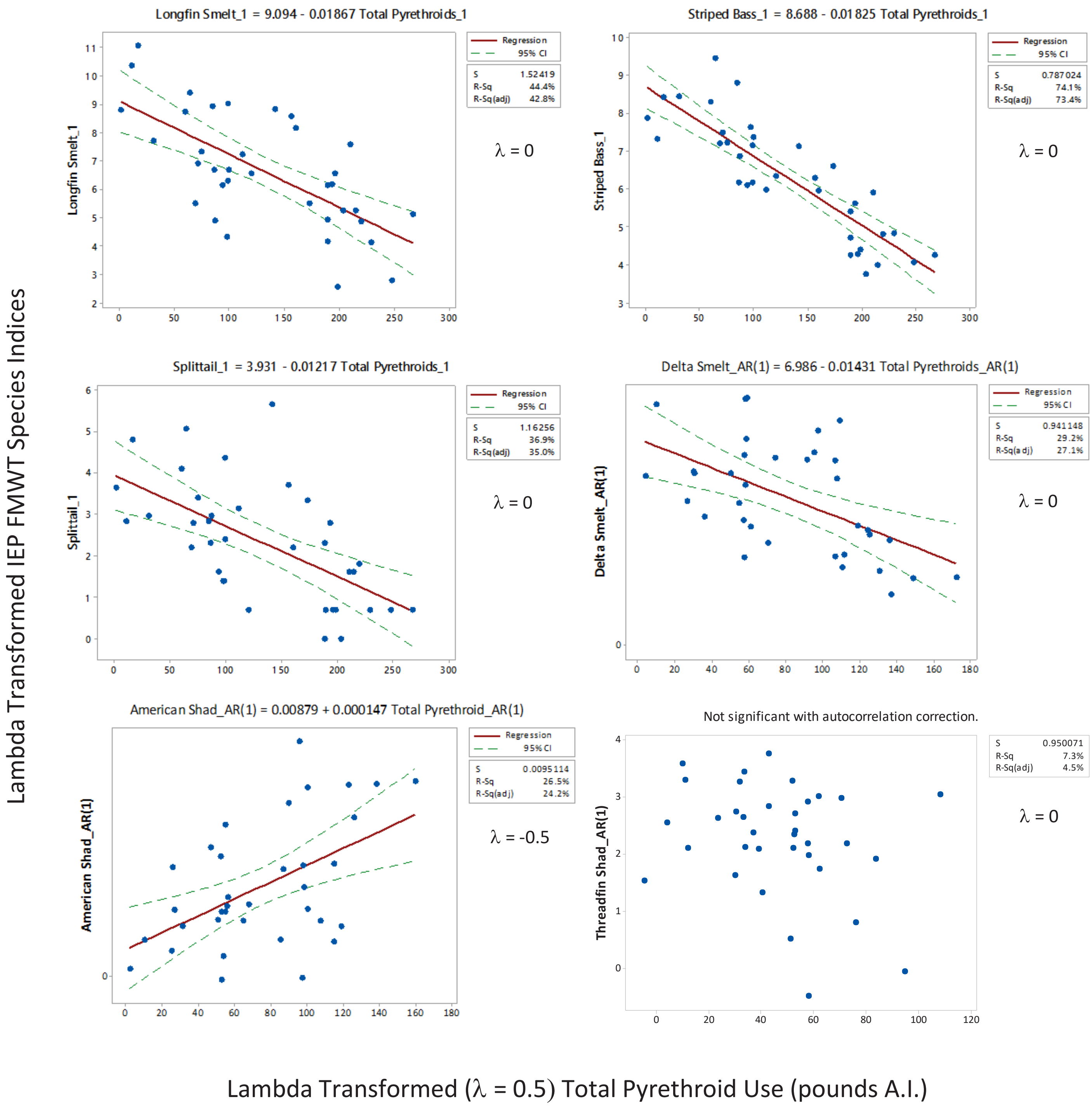

Figure 1 Ordinary least squares regression fitted line plots and 95% confidence intervals of IEP FMWT species abundance indices (autocorrelation corrected) as a function of annual pyrethroid pesticide use in the counties of the Delta from 1978–2014

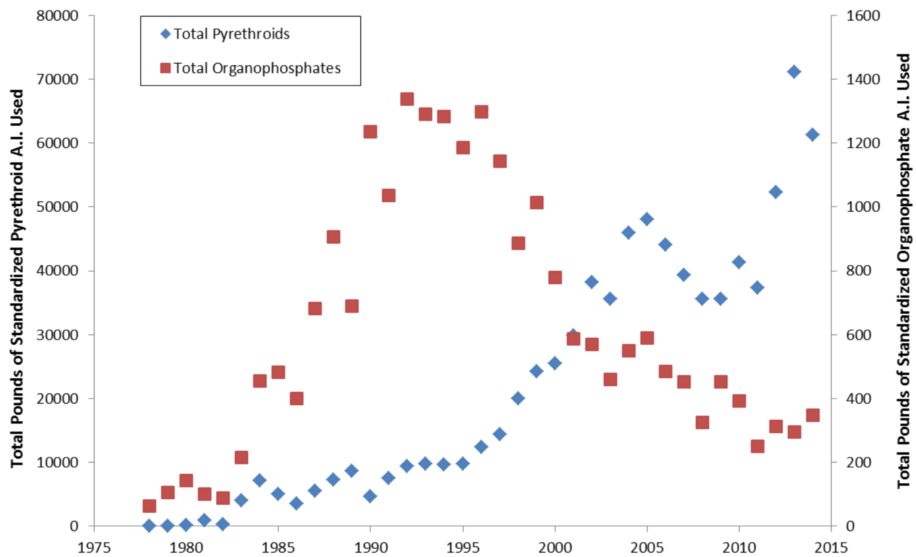

Figure 2 Plot displaying the total pounds of A.I. for pyrethroid use and organophosphate use in the counties of the Delta during 1978-2014 from the California DPR PUR database. The pounds of A.I. were standardized to the toxicity strength of the pesticides using conversion factors (see Appendix A, Table A–1).

cyhalothrin) explains 24% to 73% of the interannual variability in FMWT species abundance indices (Figure 1). See Appendix A for further details of the statistical analyses.

Understanding interactions between contaminant exposure and environmental factors, and their effect on populations, will likely require comprehensive analyses of disparate datasets. For example, Bailey et al. (1994) used flow-adjusted Striped Bass abundance indices and pesticide concentrations to correlate rice agricultural discharges to their decline. Conceptually, flow variability is also hypothesized to be the most important decadal-scale driver in reducing the ecological resilience of the Bay–Delta which contributed to the POD (Baxter et al. 2010). More recently a synthesis report established quantitative relationships between Delta Smelt abundance indices and habitat location (X2; location at salinity of 2 PSU) and recruitment variables (IEP MAST 2015). Herein, models were developed to compare the relative influence of flow and pyrethroid use on species abundance (Table 3). The model that explained the greatest amount of variability in an abundance index was for Longfin

Table 2 Pearson's *r*, Spearman's rho, and Kendall's tau correlation coefficients measuring associations between IEP FMWT abundance indices and pyrethroid use in the Delta.

		Transformed pounds of pyrethroid pesticide use (λ = 0.5)					
		Pearson's *r*		Spearman's rho		Kendall's tau-a	
Transformed IEP FMWT abundance indices	**Lambda transformation**	**Correlation coefficient**	***p*-value**	**Correlation coefficient**	***p*-value**	**Correlation coefficient**	***p*-value**
Longfin Smelt	0	−0.67	<0.0001	−0.65	<0.0001	−0.48	<0.0001
Delta Smelt	0	−0.67	<0.0001	−0.58	<0.001	−0.40	<0.001
Sacramento Splittail	0	−0.61	<0.0001	−0.64	<0.0001	−0.45	<0.001
American Shad	−0.5	0.62	<0.0001	0.51	<0.01	0.35	<0.01
Threadfin Shad	0	−0.48	<0.01	−0.39	<0.02	−0.23	<0.05
Striped Bass	0	−0.86	<0.0001	−0.89	<0.0001	−0.69	<0.0001

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Table 3 Predictor variables and summary statistics for multiple linear regression models explaining IEP FMWT species abundance variability from 1978–2014.

Species	R^2-adj.	Predictor variables	Partial coefficients	95% CI	*p*-value
Longfin Smelt	0.79	Pyrethroid use	−1.097	(−1.422, −0.771)	<0.001
		Delta Inflow	−1.228	(−1.533, −0.902)	
Striped Bass	0.77	Pyrethroid use	−1.235	(−1.494, −0.977)	<0.001
		Delta Inflow	−0.336	(−0.622, −0.050)	
		Delta Exports	−0.322	(−0.602, −0.042)	
Delta Smelt	0.37	Pyrethroid use	−1.01	(−1.567, −0.452)	<0.001
		Delta Exports	0.422	(0.107, 0.737)	
American Shad	0.41	Pyrethroid use	0.00973	(0.00472, 0.01473)	<0.001
		Delta Exports	−0.00464	(−0.00778, −0.00150)	
Sacramento Splittail	0.54	Pyrethroid use	−0.744	(−1.089, −0.400)	<0.001
		Delta Inflow	−0.651	(−0.995, −0.307)	

Smelt ($R^2 - \text{adj} = 0.79$, $p < 0.001$, F-test), with average Delta inflow explaining slightly more variability than pyrethroid use. This is consistent with Baxter et al. (2010), where Longfin Smelt abundance trends were best explained by seasonal Delta outflow. For the other species, pyrethroid use was a more important determinant of abundance variability than flow. Overall, this analysis suggests that pyrethroid use may have played a comparable role to other stressors in the POD. The strong correlation observed suggests an urgent need for further analyses to assess whether this is a causal relationship, especially because research has highlighted deleterious effects at multiple levels of biological organization, in multiple species (Table 1).

These analyses are only a cursory evaluation of multiple-factor effects on fish species abundances; mechanistic studies are needed to evaluate the biological significance of the correlation. Recovery efforts for Bay–Delta aquatic species need to include analyses of contaminant effects in conjunction with other pertinent factors. Additional data and analyses are needed to better understand the interactions between habitat and biology. For example, Baxter et al. (2010) hypothesized that salinity, landscape, temperature, turbidity, nutrients, and harvest, in addition to flow and contaminants, were long-term drivers of the POD. In addition, Thomson et al. (Thomson et al. 2010) (2010) indicated that water clarity and Delta flow characteristics were drivers of Bay–Delta fish species abundances; however, the researchers did not evaluate possible contaminant effects. The ability to explain changes in fish abundance by pyrethroid use in the Delta may be altered by the inclusion of other important factors. For example, Bailey et al. (1994) showed that the discharge of rice agriculture pesticides, primarily carbamates, likely contributed greatly to earlier Striped Bass declines. However, carbamate insecticides have been replaced primarily with pyrethroids, and young-of-year Striped Bass abundances have not recovered. Monitoring, special studies, and models are needed to link the processes that occur from contaminant sources to a resulting species decline (e.g., pesticide runoff, bioenergetic costs of exposure to contaminants, decreases in food availability, or reductions in fecundity or fish survival).

It must be noted however, that pyrethroids are only one class of a multitude of pesticides detected in Bay–Delta waters, and are presented here as an example. Even though regulation of some pesticides has decreased their effect, replacement products can be similarly problematic. Effective attenuation measures are needed in order to reduce the entry of contaminants into California waterways, which will increase the probability of species recovery.

Evidence of Contaminants Detected in Fish Habitats at Levels of Concern

Monitoring entities and research studies have detected multiple contaminants occurring simultaneously in Delta water samples (Ensminger et al. 2013; Orlando et al. 2013, 2014). Multiple pesticides are continuously detected in the two primary tributaries to the Delta. For example, 27 pesticides or degradation products were detected in Sacramento River samples, and the average number of pesticides per sample was six. In San Joaquin River samples, 26 pesticides or degradation products were detected, and the average number detected per sample was 9. Water quality objectives do not exist for most of these compounds. However, these were targeted chemical analyses, and hundreds of compounds have been detected in individual Delta water samples using other non-targeted techniques (2016 in-person conversation with T. Young, J. Orlando and R. Connon, unreferenced, see "Notes").

Organisms are exposed to a dynamic mixture of contaminants (e.g., introduction of new chemicals, varied use patterns). Although pesticides generally have a seasonal pattern, PPCPs are continuously introduced into the environment (Deanovic et al. 2014, unreferenced, see "Notes"; Biales et al. 2015). This raises concern because exposure to chemical mixtures has shown adverse effects on aquatic organisms at concentrations at which no observable adverse effects occur for single constituents (Carvalho et al. 2014; Cedergreen 2014), and little is known about potential synergistic, antagonistic, or additive effects of exposure to contaminant mixtures.

Pyrethroids have been found in sediments of agricultural and urban waters upstream of the Delta at concentrations that are acutely toxic to numerous benthic and epibenthic macroinvertebrates (Amweg et al. 2005; Holmes et al. 2008; Weston et al. 2008; Weston et al. 2015b).

Copper is present throughout the Delta at concentrations known to cause adverse effects. The copper threshold established for enclosed bays and estuaries is 4.8 $\mu g\ L^{-1}$. Dissolved copper concentrations up to 4.64 and 4.93 $\mu g\ L^{-1}$ were detected in freshwater water samples from Cache–Lindsey Slough and Rough and Ready Island, respectively, and elevated dissolved copper concentrations of 37.2 and 58.9 $\mu g\ L^{-1}$ have also been detected at Suisun Bay and Carquinez Strait, respectively (Werner et al. 2010a). A recent study (Sommers et al. 2016) indicated that although the effect of copper on salmon olfaction is reduced in brackish and saline waters, copper can still cause avoidance behavior at environmentally relevant concentrations.

In a study conducted to evaluate the effects of pesticides, trace metals, and PPCPs present in Sacramento River samples, the most frequently detected substances were pharmaceuticals. PPCPs comprised 51% of the detected analytes: trace metals and pesticides comprised 28% and 21% of the analytes, respectively (Deanovic et al. 2014, unreferenced, see "Notes"). Other studies also found a high incidence of pharmaceuticals in Sacramento River water (Biales et al. 2015). Guo et al. (2010) completed a source, fate, and transport study that included 11 sampling sites in the Delta associated with the State Water Project (SWP). Forty-nine chemicals were detected, many at concentrations above those that elicit adverse effects.

Evidence of Effects on Surrogate Species Detected in Delta Waters or Sediment

Multiple studies have found sublethal, lethal, chronic, and acute toxicity of Bay–Delta waters to model test species of phytoplankton, invertebrates, and vertebrates (Jassby et al. 2003; Johnson et al. 2010; Blaser et al. 2011; Brooks et al. 2012; Scholz et al. 2012). Multiple-species studies that evaluated Bay–Delta ambient water samples, or conducted *in situ* exposures (referenced in Table 1), have repeatedly identified a broad set of mechanistic, systemic (immune, neurological, endocrine), histopathological (tissue damage), and whole-organism effects (e.g., growth, development, deformities). Endocrine-disruptive effects have been measured in samples from Sacramento River tributaries and in the Bay–Delta (Schlenk et al. 2012; Brander et al. 2013; Cole et al. 2016).

Although identification of chemical classes responsible for these effects is limited, because of the complexities resulting from mixtures of multiple chemicals, several studies (see Table 1) have highlighted pyrethroid pesticides as responsible

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for toxicity, endocrine disruption, and neurological impairments in both fish and their prey (Brander et al. 2013, 2016b; Hasenbein et al. 2015c; Jeffries et al. 2015b; Weston et al. 2015a).

Evidence of Effects on Delta Species of Concern

Delta Smelt: Several recent studies on Delta Smelt support that contaminants are a significant stressor. Ambient water samples collected in the Delta contained sufficient bioavailable compounds that in laboratory exposures Delta Smelt exhibited decreases in growth and altered development compared to fish exposed to control water. Specific effects were detected in gene expression associated with their immune system and muscular system (Hasenbein et al. 2014). Apoptosis and necrosis were also observed (Connon et al. 2012). Delta Smelt collected from the estuary were observed to have tissue-level effects, demonstrated through histopathology, which was associated with decreased growth (Hammock et al. 2015). These lines of evidence support that contaminants are bioavailable in Bay–Delta waters at concentrations that are affecting Delta Smelt.

In addition to studies that rely on ambient water or field-collected fish, studies have examined the effect of specific contaminants on cultured smelt. Pyrethroids have been documented to cause general stress responses and effects on the immune, nervous, muscular and osmoregulatory systems (Jeffries et al. 2015b). Decreased growth, abnormal development, and altered behavior have been detected from exposure to pyrethroids at levels detected in the Delta (Connon et al. 2009; Jeffries et al. 2015b). However, pyrethroids are not the only contaminant thought to be negatively affecting Delta Smelt. Smelt exposed to copper in the lab at levels detected in the Delta exhibited effects on their immune, nervous, and muscular systems (Connon et al. 2011a). Growth and development, as well as behavior, were also negatively affected, the latter raising concern with about the effects on homing ability (Connon et al. 2011a). Ammonium induced effects similar to those observed after exposure to pyrethroids and metals (Connon et al. 2011b), affecting immune- and muscular-system functioning, as well as development and behavior (Connon et al. 2011b; Hasenbein et al. 2014). The weight of evidence supports the hypothesis that multiple contaminants are having a direct effect on Delta Smelt by affecting multiple levels of biological organization.

Contaminants can cause indirect effects by causing trophic cascades that affect population dynamics, food webs, community structure, and the Bay–Delta ecosystem as a whole (Fleeger et al. 2003; Johnston and Roberts 2009). Indirect effects of contaminants can also result in changes in nutrient and oxygen dynamics, altering phytoplankton and zooplankton communities (Brown et al. 2016; Moyle et al. 2016). Delta Smelt are known to be food limited (Hammock et al. 2015), and trend data shows reductions in prey availability over time (Hennessy 2011). Ambient water samples (Werner et al. 2008; Werner et al. 2010b), mesocosm studies (Hasenbein et al. 2015c), and laboratory studies (Hasenbein et al. 2015a; Hasenbein et al. 2015b) suggest that smelt prey organisms exhibit effects when exposed to ambient Delta waters or control waters amended with Delta-relevant concentrations of contaminants. Not only do pesticides reduce prey abundance, but pyrethroids have been shown to transfer to fish through prey (Muggelberg et al. 2016).

Taken together, these lines of evidence support the hypothesis that Delta Smelt are exposed to toxic levels of multiple contaminants found in the Delta. Delta Smelt populations are in decline, and the decline is significantly associated with multiple stressors. Delta water samples caused deleterious effects in Delta Smelt, and Delta Smelt collected from the Delta exhibit contaminant effects. Laboratory studies show that multiple levels of biological organization are affected by multiple chemicals, and negative organism-level responses (measured as growth, development, and behavior abnormalities) have been observed. In addition to these direct effects, food availability for Delta Smelt may be reduced by contaminants, and this may indirectly affect the population. A huge data gap is that limited studies examine the relationships between contaminants and specific responses by Delta Smelt, particularly during the early embryo-to-larval life stages.

Other POD Species. Much less is known about the role of contaminants in the decline of the other POD species. Although Longfin Smelt, and Threadfin Shad declines were significantly correlated with pyrethroid use, a large data gap exists since no contaminant exposure studies have been conducted on these species. The Striped Bass decline is also significantly correlated with pyrethroid use, but exposure studies with Striped Bass have focused on polycyclic aromatic hydrocarbons (PAHs) and polyhalogenated aromatic hydrocarbons (PHAHs), including PCBs and dioxins. Exposure and bioaccumulation of polybrominated diphenyl ethers (PBDEs), PCBs, and legacy pesticides can result in these contaminants being transferred maternally from females to eggs, which affects egg size, fecundity, brain and liver development, impaired growth, and survival (Ostrach et al. 2008). These compounds are widespread in the Bay–Delta, and studies have demonstrated their effect on fish health and development (Spearow et al. 2011; Durieux et al. 2012).

Salmon abundance is declining, and several important stressors have been identified. Both pesticides and copper exposure can affect fish migration and orientation. The most commonly observed links with these behavioral disruptions include cholinesterase (ChE) inhibition, altered brain neurotransmitter levels, and sensory deprivation (Scott and Sloman 2004). Scholz et al. (2000) also concluded that exposures to low concentrations of diazinon likely increased the straying of the adult hatchery Chinook salmon over the control group. Furthermore, juvenile salmonids exposed to pesticides during development may fail to imprint to their natal waters, which can lead to increased adult straying (NMFS 2009). Chlorpyrifos exposure directly affects the nervous system (Baldwin et al. 2009) and the olfactory system (Maryoung et al. 2015). There is evidence that behavioral effects of pesticides affect salmon populations in other ecosystems. For example, cypermethrin prevented male Atlantic salmon from detecting and responding to the reproduction-priming pheromone prostaglandin, which is released by ovulating females (Moore and Waring 2001). Copper concentrations of $2\,\mu g\ L^{-1}$ significantly affect the olfactory system in juvenile salmonids (see video[3], Sandahl et al. 2007; Grossman 2016), increasing predation risk and impairing osmotic homeostasis (Grosell et al. 2002). This is of concern because dissolved copper concentrations detected in water samples from Cache–Lindsey Slough and Rough and Ready Island were above threshold. Also, copper causes cholinesterase (ChE) inhibition, so its effects may be additive when present with OPs. In addition to behavioral effects, OPs have been shown to affect the immune system in Chinook Salmon, increasing their susceptibility to disease (Eder et al. 2008). Histopathological abnormalities and reduced growth have been reported for both invertebrate and fish species (Baldwin et al. 2009; Hasenbein et al. 2015b). Impaired gonadal or thyroid hormone levels in salmon have also been observed (Scott and Sloman 2004). Perhaps the most important point provided by existing studies is that the behavioral effects of contaminants on salmon should be investigated further. Contaminants could be the proximate cause of salmon mortality that is currently attributed to disease and predation (Grossman 2016).

In summary, this section illustrates how using a weight-of-evidence approach can facilitate a better understanding of the potential for contaminants to be influencing factors in the declining abundance of Bay–Delta fish species. Multiple studies support the potential importance of contaminants affecting Delta Smelt. Salmon studies are sufficient to prompt more study on behavioral effects. The paucity of research on the other POD species illustrates that this approach can identify critical data gaps.

Evidence that Contaminant Exposure Leads to Population Effects

Numerous contaminants detected throughout the Bay–Delta can affect the overall health of individuals, leading to behavior and reproductive impairment that translate to alterations in population dynamics. Global decreases in aquatic biodiversity have been associated with increases in pesticide contamination; for example, macroinvertebrate family richness is reduced by ~30% even when pesticide concentrations were within regulatory thresholds (Stehle and Schulz 2015). Models predict that a 6% reduction in length and 16% in mass would result in a >50% reduction in spawner abundance over 20 years in Chinook salmon (Baldwin et al. 2009). Population growth rates of Delta species are affected by exposure to contaminants (Brooks et al. 2012). Recent research

3 See page 2 at this link: *http://pubs.acs.org/doi/suppl/10.1021/es062287r* (accessed 2016 October 24).

http://dx.doi.org/10.15447/sfews.2016v14iss4art5

conducted in the Delta determined that contaminants sourced via water treatment plants disrupt endocrine system function in Inland Silversides (*Menidia beryllina*), resulting in alterations to gonado-somatic indices (GSI), testicular necrosis, and biased sex ratios (Brander et al. 2013). Adult Inland Silversides exposed to low, Delta-relevant concentrations ($0.5\,ng\,L^{-1}$) of the pyrethroid bifenthrin had a significant reduction in reproductive output and biased sex ratios (fertilized eggs per female; Brander et al. 2013, 2016b). Risks associated with exposure to endocrine-disrupting compounds (EDCs), have been extensively reviewed (Bortone and Davis 1994; Tyler et al. 1998; Brander et al. 2013, 2016a). Risk of extinction in isolated populations has recently been associated with biased sex ratios (Grayson et al. 2014). Studies have demonstrated that exposures to neurotoxic insecticides (Baldwin et al. 2009) affect populations of multiple species and their community structures (Hasenbein et al. 2015c; Orlinskiy et al. 2015). More globally, Feist et al. (2011) describe how urban runoff contaminants in the U.S. Pacific Northwest caused up to 90% mortality of pre-spawning Coho Salmon (*Oncorhynchus kisutch*), thus, severely affecting population numbers through reductions in recruitment.

A SYNTHESIS OF SPECIFIC BAY–DELTA CONTAMINANTS

Metals and Metalloids

Contaminants that biomagnify pose major risks to aquatic species at higher trophic levels in the Bay–Delta; including fish, birds, and mammals. Two bioaccumulative contaminants, selenium and mercury, were among the high-priority water quality issues described by Luoma et al. (2008).

Linares–Casenave et al. (2015) reported high selenium concentrations in tissues of older, reproductively mature female White Sturgeon in the Bay–Delta. This is concerning because selenium-enriched yolk in sturgeon eggs can cause developmental defects as well as mortality of embryos and yolk-sac larvae, affecting recruitment. Similarly, kidney lesions, reduced growth and deformities have been observed in Sacramento Splittail fed a selenium-based diet (Deng et al. 2007). White Sturgeon and Splittail populations are exposed to high levels of selenium through their diet, notably from *Corbula amurensis*, the invasive overbite clam (Feyrer et al. 2003; Stewart et al. 2013). In recent years, the average selenium concentrations in White Sturgeon from the bay have been below the threshold ($11.3\,\mu g\text{–}g^{-1}$ dry weight in muscle) established to prevent effects on Sturgeon reproduction as part of the North Bay Total Maximum Daily Load (TMDL; Baginska 2015). Extensive research has been conducted to support development of the TMDL and revised criteria for the Bay, including an ecosystem-scale selenium model, a model of transport, fate, and uptake into the food web, and additional monitoring and review (Chen et al. 2012; Presser and Luoma 2013). Long-term trend monitoring by the Regional Monitoring Program for Water Quality in San Francisco Bay (Bay RMP) and the USGS also continues (SFEI 2013; Stewart et al. 2013). The Bay RMP is performing pilot studies to evaluate non-lethal methods of monitoring selenium in sturgeon muscle that would increase the number of samples available to track long-term trends. A more precise understanding of the concentrations that elicit deleterious effects would be valuable.

Mercury, in the highly toxic form of methylmercury, can pose major risks to both aquatic and terrestrial species at higher trophic levels in the Bay–Delta, including fish, birds, and mammals. Methylmercury exposure is a significant concern for special-status bird species, including the federally endangered Ridgway's Rail (*Rallus obsoletus*) and California Least Tern (*Sternula antillarum browni*). Forster's Tern (*Sterna fosteri*) is the species at greatest risk: Ackerman et al. (2014) found that 79% of eggs from this species were above a high-risk threshold of $1\,\mu g\ g^{-1}$ fresh wet weight. The control plans for mercury in both the Bay and the Delta (SFBRWQCB 2006; Wood et al. 2010) include a concentration target for prey fish to protect piscivorous birds. Average concentrations of methylmercury in species of concern are also commonly in the range known to affect biochemical processes, damage cells and tissue, and reduce reproduction in fish; particularly in peripheral areas of the Delta (Sandheinrich and Wiener 2011). For example, Gehringer et al. (2012) presented histopathological evidence of immunosuppression in juvenile largemouth bass from methylmercury contaminated areas in the Delta.

Copper exposure was shown to elicit general stress responses, affect the immune, nervous and muscular systems, and impair growth, development, and behavior in Bay–Delta fishes (Geist et al. 2007; Connon et al. 2011a; Gehringer et al. 2012) and invertebrates (Callinan–Hoffmann et al. 2012). Copper toxicity and accumulation in fishes differs between species, between freshwater and saltwater environments, as well as among the specific organs that are affected (Blanchard and Grosell 2006). While increased salinity is generally considered as protective against loss of olfactory function from dissolved copper, the presence of sub-lethal levels of dissolved copper altered the behavior of juvenile Chinook Salmon by inducing an avoidance response in both freshwater and seawater (Sommers et al. 2016). Further, species-specific evaluations are needed at higher salinity sites in order to determine potential effects on species of concern.

Persistent Organic Pollutants

PAHs and PHAHs including PCBs and dioxins are widespread in the Bay–Delta. Numerous studies have demonstrated their effect on fish health and development (Spearow et al. 2011; Durieux et al. 2012). Two contaminants of concern have received significant attention in the last few years: polybrominated diphenyl ethers (PBDEs) and perfluorooctane sulfonate (PFOS), however, effect-based assessments are lacking for Bay–Delta species.

PBDE flame retardants have been detected in Bay fish and wildlife since the 1990s. High detections spurred voluntary reductions and a California ban that took effect in 2006, which resulted in reduced concentrations in bivalves, fish, and bird eggs (Sutton et al. 2015). On the other hand, concern has increased regarding PFOS. PFOS is widely used as a stain repellant for textiles, furniture, and carpets; as a surfactant in fire-fighting foams and metal finishing processes; as an ingredient in the production of fluoropolymers; and as an insecticide. PFOS has been detected globally, including in San Francisco Bay birds and seals (2016 in-person conversation between M. Sedlak and J. Davis, unreferenced, see "Notes"). Bird eggs collected in the southern portion of the bay in 2006 and 2009 contained levels of PFOS above a threshold (1 $\mu g\ g^{-1}$ wet weight) that affects offspring survival in birds. Fortunately, more recent results (2012) are 70% lower than prior levels and well below the threshold. However, PFOS concentrations in seals do not show similar declines. PBDEs and PFOS have not been monitored in the Delta.

Ammonia and Ammonium

Toxicity to aquatic organisms is primarily attributable to the un-ionized form, ammonia. Ammonium is increasingly converted into ammonia as pH rises. Ammonium can enhance cell membrane permeability increasing its toxicity to species, and their susceptibility to the synergistic effects of multi-contaminant exposures (Connon et al. 2011b; Hasenbein et al. 2014). Freshwater mussels, for example, are highly sensitive to increased ammonia concentrations (USEPA 2013) and total ammonia nitrogen concentrations detected in the Sacramento River, downstream of Hood, are at levels potentially toxic to *Pseudodiaptomus forbesi* (Teh et al. 2011).

Pesticides

Multiple insecticides, fungicides, herbicides, and antibacterials are commonly detected throughout the Bay–Delta. The CDPR reports that 13,084 pesticide formulations are registered in the state, including 1,040 registered active ingredients, and >60% of those pesticide products are applied in the Central Valley (Pesticide Use Report; *http://www.cdpr.ca.gov*). OPs, pyrethroids and phenylpyrazoles (e.g., fipronil) are of greatest concern with regard to fish and zooplankton health. However, there is also concern over the use of herbicides, and their potential effect on the food web. In 2014, over 12,000 L of herbicide (formulation Fluridone) were applied to over 2,600 acres to control water hyacinth in the Delta, but this does not include the herbicides applied for other aquatic weeds such as *Egeria densa*, spongeplant (*Limnobium laevigatum*), and curly leaf pondweed (*Potamogeton crispus*).

Organophosphate insecticide registrants agreed to phase out urban sales in 2001. Many researchers have called attention to the decreased use of OPs (Oros and Werner 2005; Kuivila and Hladik 2008; Johnson et al. 2010) with a move toward increased use of pyrethroids, phenypyrazoles, and neonicotinoids (e.g.,

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imidacloprid), yet studies continue to detect OPs in Bay–Delta waters (Ensminger et al. 2013; Weston et al. 2015a).

Pyrethroid insecticide exposure has negative effects on hormonal and neurological development or reproductive output. At low concentrations (ng L^{-1}) they act as EDCs through blocking, mimicking, or synergizing endogenous hormones (Brander et al. 2016a). Pyrethroid metabolites are reported to have even greater estrogenic activity than parent compounds (DeGroot and Brander 2014) as well as a significant occurrence (>20%) of deformities in offspring of exposed adults (2016 in-person conversation with B. Decourten, see "Notes"). Pyrethroids such as bifenthrin and permethrin are present in the Bay–Delta at concentrations that alter numerous metabolic processes, which result in protein degradation (Werner and Moran 2008; Vandenberg et al., 2012). They also alter osmoregulation capacity (Riar et al. 2013; Jeffries et al. 2015b), nervous- and muscular-system functions (Connon et al. 2009), and behavior (Beggel et al. 2010), as well as result in reduced growth and development (Geist et al. 2007; Forsgren et al. 2013; Riar et al. 2013). Larval deformities and histopathological abnormalities have also been reported for Sacramento Splittail exposed to pyrethroids (Teh et al. 2005).

Fipronil and its degradation products have been detected in urban creeks and tributaries to the Bay–Delta. It is a broad-spectrum insecticide used on pets and for structural pest control. Its occurrence in the Bay–Delta poses new challenges because degradation products have been shown to be more toxic than their parent compounds (Weston and Lydy 2014). Delta-relevant studies on Fipronil are limited to acute toxicity evaluations on invertebrates. However, effects to nervous and muscular systems, decreased swimming performance, and potential endocrine disrupting properties have been demonstrated with Fathead Minnow that require further investigation (Beggel et al. 2010, 2012). Fipronil concentrations in bay sediment have raised concern for potential effects on benthic invertebrates (SFEI 2013).

Pharmaceuticals and Personal Care Products

Pharmaceuticals and personal care products (PPCPs), such as pain and blood pressure medications, antidepressants, antibiotics, antibacterials, and micro-plastics are used in large quantities and can enter waterways from indoor drains (e.g., excretion, improper disposal, bathing) through wastewater treatment plants. Over the past 2 decades, the U.S. Food and Drug Administration (FDA) center for Drug Evaluation and Research listed 2,817 drugs (medications containing an active substance; excluding personal care products), with 45 new drugs approved in 2015 alone.[4] A large number of PPCPs have been detected in the Bay–Delta (SFEI 2013; Deanovic et al. 2014, unreferenced, see "Notes"; Biales et al. 2015), but their relative contributions to the contaminant load in the Bay–Delta have not been comprehensively assessed. PPCPs are not regulated in surface and drinking water, and the risks to aquatic life are largely unknown.

Ibuprofen is one of the most commonly detected pharmaceuticals in wastewater effluent worldwide (Fent et al. 2006). Exposure to ibuprofen was shown to affect the expression of genes involved in oxidative stress, aerobic respiration, immune function, and osmoregulation, as well as skeletal development in Inland Silversides (Jeffries et al. 2015a). Although concentrations of pharmaceuticals detected in water samples are relatively low compared to those that elicit responses in fish, the concentration detected in water samples may be misleading because un-metabolized ibuprofen levels in wild fish plasma and bile for example, can be 100 to 1000 times higher, respectively, than those found in surrounding water samples (Brozinski et al. 2013).

Triclosan is an antibacterial widely used in consumer products (e.g., toothpaste, hand soaps), and is also found in wastewater effluent. Triclosan has been shown to negatively affect swimming behavior in fish by disrupting the excitation–contraction processes of skeletal muscle (Fritsch et al. 2013). Triclosan can readily accumulate in fish muscle and brain, thus posing a risk to Bay–Delta fishes.

Cyanotoxins

Naturally occurring cyanobacteria (blue–green algae) are common in ecosystems worldwide, and can produce toxins that negatively affect the ecosystem

4 *http://www.fda.gov/Drugs/DevelopmentApprovalProcess/DrugInnovation/ucm474696.htm*

much like chemical contaminants. At least 46 species of cyanobacteria have been shown to produce toxins that pose health risks to humans and wildlife (Carey et al. 2012; Lehman et al. 2013). Common cyanobacteria genera can produce a suite of toxins, such as hepatotoxins (microcystins), cytotoxins (cylindrospermopsin), neurotoxins (anatoxin-*a*, antillatoxin, saxitoxins), and dermatoxins (lyngbyatoxins). Research in the Bay–Delta has primarily focused on *Microcystis* spp. blooms, which were first recorded in 1999, and occur annually (Kurobe et al. 2013; Lehman et al. 2013). *Microcystis* can thrive in highly altered and nutrient-rich habitats. They can produce microcystin, which may promote liver cancer in humans and wildlife (Ibelings and Havens 2008). Studies conducted on Threadfin Shad and Sacramento Splittail demonstrated that consumption of *Microcystis* adversely affected their nutritional status, and resulted in severe liver and gonadal lesions (Acuña et al. 2012a, 2012b). Cyanobacterial blooms can further affect wildlife by lowering dissolved oxygen concentrations, and can also cause taste and odor problems in drinking water (Paerl et al. 2001). In a synthesis of Delta data from 2004 to 2008, Lehman et al. (2013) found that dry years resulted in higher microcystin concentrations in the water and mesoplankton tissues. Miller et al. (2010) concluded that microcystin-contaminated freshwater that entered Monterey Bay was bioaccumulated by bivalves, resulting in the death of 21 southern sea otters. This raises concern for risks to sturgeon and other species that consume bivalves, including humans.

UPDATE ON HUMAN HEALTH CONCERNS

Contaminant Exposure through Fish Consumption

Contamination of sport fish by two legacy contaminants, mercury and PCBs, is a high priority management issue in the Bay–Delta. Concentrations of mercury (in its highly toxic form, methylmercury) and PCBs are high enough that the California Office of Environmental Health Hazard Assessment has issued advisories that cover the entire estuary. These advisories have been updated and expanded in recent years (Gassel et al. 2007, 2011). Methylmercury is a major driver of advisories in the Bay–Delta, and though PCBs are also a major driver for Bay advisories, they are lesser studied in the Delta. Risks to human health and the resulting consumption advisories are an important part of the bay mercury (SFBRWQCB 2006) and Delta methylmercury (Wood et al. 2010) control plans as well as the bay PCBs TMDL (SFBRWQCB, 2008).

Spatial patterns in sport fish methylmercury in the Delta have been fairly well-characterized, but very few data are available on inter-annual variation and long-term trends. Existing time-series at specific Delta locations are far from ideal, because of inconsistencies in sampling location, sample sizes, size ranges, and species, but the data do suggest consistent spatial patterns over time, with relatively high concentrations at the sites around the periphery of the Delta, and lower concentrations in the Central Delta (Davis et al. 2000, 2008, 2013; Melwani et al. 2009). Time-series based on repeated, directly comparable measurements are needed to rigorously characterize long-term trends that would serve as a performance measure to evaluate the effectiveness of the methylmercury TMDL.

Striped Bass is an important indicator species for methylmercury contamination throughout the Bay–Delta because of their high trophic position, consequentially high bioaccumulation, and popularity for consumption. Striped Bass from the Bay–Delta have the highest average mercury concentration in US estuaries (Davis et al. 2012). A historical dataset exists for Striped Bass in the bay, allowing trends over 39 years from 1971 to 2009 (Figure 3) to be evaluated. Concentrations measured in recent years are not significantly different from those measured in the early 1970s.

Cyanobacteria

The magnitude, frequency, and distribution of cyanobacterial blooms are expected to increase in the Bay–Delta as a result of climate change (Carey et al. 2012) and excessive discharge of nutrients. Humans can be exposed to cyanotoxins from recreational contact as well as consumption of fish and shellfish, and drinking water; effects range from skin irritation to death. In the Bay–Delta, incidents of human health effects are poorly captured, but the World Health Organization has documented effects from all over

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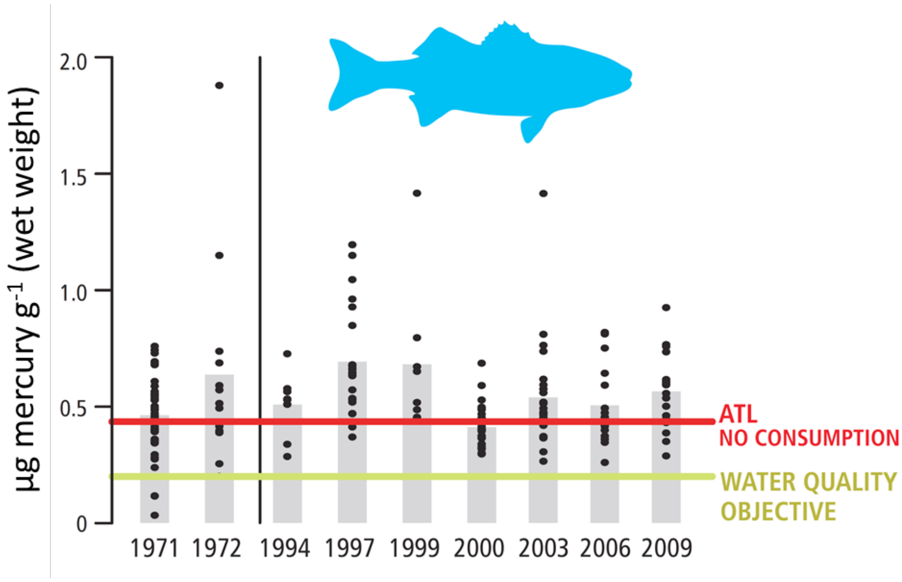

Figure 3 Mercury concentrations (µg g^{-1} wet weight) in striped bass from the Bay-Delta, 1971-2009. Bars indicate average concentrations. Points represent individual fish. Source: RMP (1994-2009) and California State Department of Public Health (1971-1972). "Advisory Tissue Level (ATL) No Consumption" is the Office of Environmental Health Hazard Assessment advisory tissue level of 0.44 µg g^{-1} calculated to protect women aged 18-45 years and children aged 1-17 years. Water quality objective for striped bass in the bay is 0.2 µg g^{-1}. To correct for variation in fish length, all plotted data have been calculated for a 60-cm fish using the residuals of a length vs. log(Hg) relationship.

the world (*http://www.who.int/water_sanitation_health/bathing/srwe1-chap8.pdf?ua=1*).

Contaminants in Drinking Water

Contaminant effects on drinking water are very different from contaminant effects on the ecosystem because treated water complies with drinking water standards before its distribution. However, contaminants can affect the ability to meet standards, treatment requirements, aesthetic qualities of drinking water, water management programs, and drinking water provision costs. The Delta is an important source of drinking water for 25 million people in the San Francisco Bay area, Central Valley, and southern California. Priority drinking water quality issues described by Luoma et al. (2008) included salinity, bromide and natural organic matter, and remain important issues for Delta drinking water supplies. New drinking water regulations adopted or proposed by the USEPA and the SWRCB's Division of Drinking Water are driving additional monitoring and science needs for the Delta. Additional contaminants receiving attention include pathogens, cyanotoxins, PPCPs, and emerging disinfection by-products and their precursors.

Organic carbon reacts with drinking water treatment disinfectants to form carcinogenic byproducts, which are regulated at low levels to protect public health. Salinity affects the aesthetic qualities of drinking water and creates water-management challenges for blending, groundwater recharge, and water reuse. Bromide, a component of salinity, also contributes to the formation of carcinogenic disinfection byproducts during the water treatment process. Levels of these constituents in Delta water vary significantly because of hydrology and water project operations. Organic carbon concentrations increase during wet weather because of higher loading from stormwater, agricultural, forested land, or other runoff sources. An analysis of Delta water quality at Banks Pumping Plant in wet and dry years indicated that salinity and bromide concentrations were significantly higher in dry years, especially in the summer months (Archibald Consulting 2012) when seawater intrusion into the Delta is more pronounced (CDWR 2010). The recent severe drought (2012 to 2015) resulted in Delta water quality conditions that posed water management and water-treatment challenges for drinking water agencies. Wei–Hsiang et al. (2010) evaluated the potential long-term changes in Delta water quality from sea level rise and levee failures of subsided western Delta islands, and found that under these long-term scenarios increases in salinity and bromide concentrations would significantly increase treatment costs for Delta water supplies.

Pathogens, such as *Cryptosporidium* spp. and *Giardia* spp., enter surface waters from animal and human sources, and can cause illness if consumed. Controlling the formation of disinfection by-products, from high concentrations of organic carbon and bromide in the source water, while implementing disinfection to inactivate pathogens, is an ongoing operational challenge for drinking water agencies that treat Delta water supplies. In recent years, the USEPA and SWRCB's Division of Drinking Water adopted more stringent drinking water regulations for disinfection by-products and pathogens, and the regulatory requirements are tied to concentrations of organic carbon and pathogens in the source water. Under these regulations, drinking water agencies are required to monitor their source water for *Cryptosporidium* to determine if more advanced treatment is needed to reduce pathogen levels in drinking water supplies.

In July 2013, the CVRWQCB adopted a new Drinking Water Policy for Surface Waters of the Sacramento–San Joaquin Delta and Upstream Tributaries (CVRWQCB 2013). The policy includes a narrative (i.e., non-numeric) water quality objective and monitoring requirements for *Cryptosporidium* and *Giardia*. The Delta Regional Monitoring Program (Delta RMP)[5] initiated a 2-year pathogen monitoring study in April 2015 to characterize ambient concentrations in the Delta concurrently with *Cryptosporidium* monitoring performed by drinking water agencies at their treatment plant intakes. The coordinated pathogen monitoring study is expected to characterize ambient background conditions and potential sources of pathogens in the Delta to fill an important data gap.

Cyanotoxin levels in the Delta are also a concern for drinking water, and cyanotoxins such as microcystin and cylindrospermapsin in drinking water may require regulation. The USEPA has proposed to include cyanotoxins on the draft fourth Drinking Water Contaminant Candidate List (CCL 4) and as part of the Unregulated Contaminant Monitoring Rule. The purpose of these programs is to identify priority contaminants that need further study and regulation, and to require public water systems to monitor for suspected drinking water contaminants. In June 2015, to protect public health, the USEPA published non-regulatory Drinking Water Health Advisories for young children and adults that provide technical guidance on microcystin and cylindrospermopsin.

The California Department of Water Resources (CDWR) initiated microcystin monitoring in the SWP facilities in 2006. Between 2006 and 2012, dissolved microcystin was detected in 1% of samples, but in 2013, the CDWR changed laboratories and methods. The new method measures total microcystin, including the microcystin contained in cyanobacteria cells, resulting in more frequent detections at more locations and at higher concentrations. Consequently, microcystin has been frequently detected throughout the SWP at levels that exceed the health advisories. From July 2013 to August 2015, most samples from Clifton Court Forebay, in the south Delta, exceeded the microcystin health advisory that protects young children. Some drinking water treatment facilities can remove microcystin, but cyanotoxins are still a concern for drinking water supplies from the Delta.

Emerging water quality concerns for Delta drinking water supplies include PPCPs and additional disinfection byproducts of public health concern, such as nitrosamines, which may be human carcinogens. Guo et al. (2010) conducted a source, fate, and transport study of EDCs and PPCPs that included several sampling locations in the Delta. The six most frequently detected contaminants were carbamazepine, diuron, sulfamethoxazole, caffeine, primidone, and tris (2-chloroethyl) phosphate (TCEP), with the highest concentrations occurring at sites downstream of wastewater treatment plant discharges. The investigators concluded there is no evidence of human health risk from low levels of PPCPs detected; however, more toxicological studies are needed. Lee et al. (2015) conducted a monitoring study in the Delta to evaluate the presence and

5 *http://www.waterboards.ca.gov/centralvalley/water_issues/delta_water_quality/comprehensive_monitoring_program/index.shtml*

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source of N-nitrosodimethylamine (NDMA), other nitroamines, and their precursors. They found that wastewater treatment plants are an important source of NDMA precursors in the Delta, because they found higher levels of NDMA precursors downstream from the Sacramento Regional Wastewater Treatment Plant and the Stockton Regional Wastewater Control Facility. NDMA was not detected in river samples, likely because of dilution and photolysis.

In summary, contaminants continue to be detected in the Bay–Delta at concentrations that exceed regulatory standards, potentially causing detrimental effects. For example, mercury still occurs at levels that pose a risk to human health through consumption of contaminated fish, and Delta drinking water supplies are threatened by contaminant issues such as cyanotoxins, pharmaceuticals and personal care products, and new carcinogenic disinfection byproducts.

SCIENCE CHALLENGES, GAPS, AND RECOMMENDATIONS

Lacking the Right Monitoring Endpoints

Contaminant monitoring in the Bay–Delta, particularly in the Delta, falls short of answering priority questions to adequately inform water quality management. We cannot assume that reduced acute toxicity from one chemical or chemical class protects beneficial uses. Today's management questions are deeper and more far-reaching. Are contaminants delaying salmon from moving upstream when they need to? Are contaminants limiting productivity of nutritious fish food? And if so, is this constraining them to areas of greater risk for entrainment, predation, or other hazard? Are our control methods for aquatic vegetation and other invasive species affecting our primary productivity of the beneficial species? Managers need to consider multiple needs for multiple resources, and the cascading effects of contaminants. With more advanced monitoring, more integrative synthesis, and better input from multidisciplinary teams, resource managers will be better equipped with the information they need to make decisions.

Extensive water quality monitoring in the bay, has made it one of the most thoroughly-monitored estuaries in the world. The Bay RMP began monitoring in 1993, and has succeeded in its aims so well that funding has grown and been sustained. High quality monitoring data and special studies from the Bay RMP have guided dozens of important decisions about water quality management in the bay (Trowbridge et al. 2016). Monitoring has also provided an essential performance measure to evaluate the success of management decisions in meeting water quality goals. Collaborative governance by diverse interests allows the Bay RMP to optimize the use of funds, and to adapt to stay relevant as the ecosystem changes, new issues emerge, and knowledge advances.

A Delta RMP has been established and monitoring began in 2015. This program should be supported in becoming a long-term, robust, and comprehensive monitoring program that informs regulatory measures and management decisions.

More Spatial and Temporal Coverage

Better spatio-temporal coverage is critical to understand how water management changes can affect contaminant transport, fate, and effects. Monitoring for the Bay–Delta should include sites that are upstream and in back sloughs where more toxicity has been exhibited, rather than in larger channels (Werner et al. 2008; Werner et al. 2010b; Markiewicz et al. 2012). This will facilitate identification of toxicity and sources. Models like the Co-Occurrence Pesticide Species Tool (Hoogeweg et al. 2012) should be used to select monitoring stations where the greatest risk is posed by the likely co-occurrence of pesticides and sensitive species.

Fixed stations, like the CDWR monitoring station on the Sacramento River at Hood, should be installed in key areas to facilitate a combination of real-time physicochemical and flow-through biological monitoring. Such stations offer a more controllable test environment, thereby enhancing linkages between laboratory- and field-based study results. To better understand how instream chemical concentrations and abiotic stressors affect multiple species, methods from multiple disciplines spanning levels of biological hierarchy could be employed simultaneously (Biales et al. 2015).

Monitoring and assessment for Delta drinking water supplies should be expanded to include PPCPs and implemented at sufficient spatio-temporal scales to inform water management and drinking water treatment operations.

Time-series for mercury in Delta sport fish, based on repeated, directly comparable measurements, are needed for the rigorous characterization of long-term trends that would serve as a performance measure to evaluate the effectiveness of the Delta methylmercury TMDL.

Diversified Testing

Integrative toxicological studies using multiple species of diverse sensitivities, in conjunction with non-target chemical analyses, can be used to evaluate the ecological effects of contaminants, including unknown compounds. Simply monitoring for chemicals and comparing them to benchmarks of individual chemicals has proven inadequate to assess the ecological effects of contaminants (Bispo et al. 1999). Targeted chemical analyses have been shown to under-estimate mixture toxicity by a factor of two to ten compared to non-targeted analyses (Moschet et al. 2014). Employing non-targeted analyses could greatly advance the understanding of contaminant effects in the ecosystem by proactively assessing waters for new chemicals without limiting them to known compounds. Monitoring of contaminant presence should be paired with monitoring of effects on relevant species using sublethal effect endpoints. For example, the use of *Ceriodaphnia dubia* was appropriate in the past because they are sensitive to OPs and carbamates. However, *C. dubia* are relatively insensitive to several replacement insecticides; therefore, more appropriate species should be included to evaluate ecological effects. In a summary of toxicity tests from the Central Valley, researchers found that larval fish tests showed a higher frequency of toxicity than either invertebrates or algae, even though insecticides were determined to be the main cause of toxicity (Markiewicz et al. 2012). Had monitoring only included invertebrates, these sublethal effects on fish would have gone undetected.

To monitor surface waters, a comprehensive set of effect-based tools should be further developed that include important species, endpoints, and mechanisms of toxicity, and which consists of a combination of whole organism and *in vitro* tests. These effect-based assays are essential to address effects of low-level mixtures and unknown contaminants. In addition, biological assays can be tailored to comprehensively assess water quality by simultaneously evaluating contaminant effects on multiple modes of action (Escher et al. 2008, 2014). Environmental assessments should include techniques that are able to link physiological, biochemical, and molecular endpoints to organismal health condition. Although the association of sublethal effects and reproductive output has been demonstrated in non-native and surrogate species, analogous responses for threatened Bay–Delta species need to be confirmed. Sublethal effect concentration studies, particularly on early life stages of Bay–Delta species with contaminants of concern, should be performed.

More Synthesis, Analysis, and Use of Adaptive Management

Increased synthesis and analysis of monitoring data would allow for better trend analysis as well as improved assessment of ecosystem health. Past syntheses and analyses have been infrequent or incomplete because most Delta contaminant evaluations were special studies rather than systematic or comprehensive monitoring programs. Periodic events can go undetected by rigidly scheduled environmental monitoring (Brooks et al. 2012), thus monitoring needs to adapt to changing use patterns and be focused to identify risk to aquatic organisms. Regular analysis and synthesis are required to adaptively manage monitoring so management needs, and spatial and temporal variability, can be addressed.

Adaptive management has been successfully applied to contaminants. The successful reduction of PBDEs in the bay food web discussed above is an excellent example of adaptive management. In another example, a program was initiated in 1983 to address fish toxicity and drinking water taste and odor concerns associated with rice pesticides. By 2003, the Department of Food and Agriculture, Central Valley Regional Water Quality Control Board (CVRWQCB), the CDPR, County Agricultural Commissioners, and rice growers successfully worked together to identify management practices, water quality standards,

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monitoring requirements and risk evaluations (e.g., use changes), and a communication and coordination mechanism to ensure that management practices would meet the performance goals and would not result in adverse effects on water quality.

Contaminants risks from past and present land use should be considered during planning and execution of habitat restoration efforts. With tens of thousands of acres of habitat restoration planned for the Delta and Suisun Marsh, those efforts could easily be confounded by contaminants. Many contaminants are sediment-bound, so sediment disturbance could cause resuspension and increased bioavailability. Additionally, repeated wetting and drying could increase risk over continual wetting (e.g., mercury methylation). Because wetlands are zones of deposition, sediment-bound contaminants will accumulate and may reduce the productivity and effectiveness of restoration efforts.

Robust planning, monitoring, analysis, reporting, and adjustments with cooperative participation and communication among regulators, industry, and other stakeholders can lead to reduced risk and improved water quality. Use of performance-based goals focused on contaminant effects alongside detection would better represent ecosystem health and function.

Integrate Efforts

Monitoring efforts of the Bay and Delta RMPs, the IEP's Environmental Monitoring Program (EMP), the CDWR's Municipal Water Quality Investigations (MWQIs), the SWRCB's Surface Water Ambient Monitoring Program (SWAMP), and the USGS's National Water Quality Assessment Program should be better integrated with each other and special studies. Their integration would not only make monitoring in the Delta more efficient, but it would facilitate multi-disciplinary evaluation of data across programs to allow for a better understanding of how water quality affects multiple levels of biological organization. Use of real-time monitoring data could provide in-depth information to interpret *in situ* testing results for multiple species at key sites, which would significantly enhance Bay–Delta monitoring efforts.

CHALLENGES

Managing Multiple Contaminants

A challenge is that the Water Quality Control Plan for the Sacramento and San Joaquin River Basins[6] calls for protection of water quality whether the toxicity is caused by a single substance or the interactive effect of multiple substances, yet control programs and regulatory tools have typically addressed single chemicals or classes of chemicals. The CVRWQCB Basin Plan addresses the need to consider cumulative effects, and the policy assumes potential additive toxicity when pollutants are known carcinogens, or manifest their toxic effects on the same organ systems or through similar mechanisms of action. However, the ability to evaluate such effects is limited by lack of sufficient data on mechanisms of action for many contaminants; therefore, chemical-specific criteria are often used, which are under-protective of aquatic populations. Chemical mixtures of compounds with unknown interactions, or those having no specific criteria, are not adequately addressed (Johnson et al. 2010; Brooks et al. 2012).

Consistent Resources

Resource managers need consistent financial support from state and federal entities to better address contaminants and water quality in the Bay–Delta. With all the gaps identified above, even with additional integration of existing programs, current contaminant monitoring programs and research are desperately underfunded.

CONCLUSION

Contaminant issues that were of concern in 2008 persist, and contaminants continue to be detected in ambient water samples at concentrations that cause detrimental effects. Enhanced monitoring in the Delta is a critical need. The limited, existing Delta contaminant monitoring is reactive—measuring what we know is of concern rather than proactively addressing new potential threats—while the use of pesticides, pharmaceuticals, and personal care products changes frequently, creating an ever-evolving cocktail of contaminants. Contaminants

6 *http://www.waterboards.ca.gov/centralvalley/water_issues/basin_plans/*

thus do not occur as single compounds, but rather as mixtures that can interact additively, synergistically, and antagonistically with each other as well as with water quality parameters and food web processes, creating variable exposures and effects in time and space. The intertwined multiple-stressor effects of contaminants and their effects on Bay–Delta species requires a dedicated research program.

Contaminants likely played a significant role in the POD, but the specific role of contaminants in the health of the ecosystem will not be adequately understood until relationships are identified and tested through comprehensive studies that also relate the presence of contaminants to biological responses. Important Bay–Delta species are in decline, and their reduced abundance cannot be fully explained by other stressors. Direct effects on surrogate and important species range from decreased disease resistance and altered swimming behavior to lethality; and indirect effects are likely occurring through the food web. Multiple contaminants are detected in Bay–Delta waters, particularly in areas known to once support important species. Quantification of correlative relationships points to the need to include contaminant effects in ecosystem evaluations. The weight of evidence therefore suggests that numerous contaminants detected throughout the Bay–Delta have detrimentally affected the Bay–Delta ecosystem.

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EXHIBIT
3

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DEPARTMENT OF INTEGRATIVE BIOLOGY   BERKELEY, CALIFORNIA 94720-3140

24 March 2017

Mr. Daniel McClure
Central Valley Regional Water Quality Control Board
11020 Sun Center Dr., Suite 200
Rancho Cordova, CA 95670-6114

Dear Mr. McClure:

I would like to provide some comments on "Proposed Amendments to the Water Quality Control Plan for the Sacramento River and San Joaquin River Basins for the Control of Pyrethroid Pesticides Discharges". As a faculty member at UC Berkeley, I have worked almost exclusively on pyrethroid toxicology since 2003, and on other compounds with similar chemical properties for 20 years before that. My pyrethroid research has focused largely on documenting their presence and toxicity in many Region 5 waterbodies, development of techniques to determine if pyrethroids are responsible for observed toxicity, determining their bioavailability, and documenting genetic mutations that are appearing in wild populations of invertebrates chronically exposed to them.

I will note at the outset that I am sympathetic to the difficulties that confront Region 5 staff in controlling pyrethroid discharges. Among those challenges, pyrethroids cause sublethal toxic effects below concentrations we can even measure in the environment. Pyrethroid contamination, and its associated toxicity, is so pervasive that it exists in nearly all urban runoff and a substantial fraction of agricultural and POTW discharges. There are jurisdictional considerations, with potential Region 5 options constrained by the regulatory responsibilities of DPR and EPA's Office of Pesticide Programs. Given all this, I acknowledge that Region 5 staff face considerable challenges.

As a scientist, however, I feel it is my obligation to try and insure regulatory actions fully and appropriately utilize available scientific knowledge, and can withstand challenges to the science that underlies them. The approach staff has used to address the bioavailability of pyrethroids, and to regulate only what they view as the bioavailable fraction, fails on both these counts.

Very briefly, staff propose: 1) quantifying the total pyrethroids in a water sample; 2) using literature-derived values for K_{oc} and K_{doc} to mathematically discount the pyrethroid that may be bound to particles or dissolved organic matter; 3) placing regulatory limits only on the remaining "freely dissolved" fraction of the pyrethroid, usually likely to be <10% of the total; and 4) placing no limits on the remaining ~90% of pyrethroid in water samples, presuming it to be not bioavailable to organisms. There are numerous serious problems with such an approach:

Novelty – The proposed approach is not common or well validated, in fact, this is actually the first time it has ever been used in a regulatory context. Certainly there are many papers in the scientific literature that discuss partitioning of pyrethroids among the various pools (dissolved, particulate, etc.), but I am not aware of any prior regulatory application of the theory, or attempts to only place limits on only the "bioavailable" freely dissolved fraction. I have checked with European collaborators, and they are aware of none there either. While the first use of a regulatory approach does not inherently make it wrong, it does call for a particularly strong and convincing justification to toss aside decades of regulation of the total contaminant concentration, and an explanation for why it has to be done now for pyrethroids when it has never been done for other compounds with very similar chemical properties (e.g., DDT, PCBs). The staff report fails to make the case for applying a unique and untested regulatory approach to pyrethroids, and simply glosses over inherent assumptions that are most certainly wrong.

I cannot help but note that over the past year, as the staff report was under development, dischargers and the pyrethroid manufacturers forcefully and repeatedly argued against use of Hyalella toxicity testing because the methodology has not been standardized (i.e., protocols not yet promulgated by EPA or a similar standard-setting entity). However, these very same stakeholders have no problem accepting the chemical approach of using K_{oc} and K_{doc} values to regulate only the freely dissolved fraction. Not only is the measurement of these parameters not standardized, but their application in a regulatory context has never even been done before! Yet dischargers and pyrethroid manufacturers are quite happy to accept this unstandardized approach without reservation because it removes ~90% of the pyrethroid in the effluent from regulatory limits. This double standard makes their concerns about standardization in toxicity testing appear specious and hypocritical.

Bioavailability of particle-bound contaminant – The association of pyrethroids with suspended particles will reduce bioavailability of the compounds to organisms living in the water column if they do not feed upon those particles. But as contaminants become increasingly particle associated (e.g., pyrethroids, DDT, PCBs, combustion-derived aromatic hydrocarbons), *contaminant uptake via ingestion becomes the dominant uptake route* for organisms that feed on these particles by filter feeding or deposit feeding. There are dozens of publications, my own included, that show assimilation of such substances via ingestion. A few examples using compounds with hydrophobicity comparable to pyrethroids include:

1) Mussels feeding on suspended algal cells assimilated 98% of the PCB on that material (Chemosphere 36:3181-3197 (1998)).
2) An amphipod feeding on sediments containing benzo(a)pyrene assimilated 46-60% of the ingested contaminant (Chemosphere 26:209-224 (1993)).
3) Hexachlorobenzene assimilation efficiency from ingested particles ranged from 39-57% in a clam, 15-36% in an oligochaete worm, and 53% in a mysid (see previous reference under #2).

Yet despite overwhelming scientific evidence to the contrary, the staff report assumes biological uptake from particle-bound pyrethroids to be zero, or at least negligible, and therefore in no need of regulatory control. Characterization of the particle-bound fraction as non-bioavailable, as done in the staff report, is indefensible. While it may apply to organisms that do not interact with the particles to which the pyrethroid is adsorbed, and is sometimes used in the scientific literature in this limited context, it is not an accurate characterization for countless filter-feeding and deposit-feeding aquatic species.

I should also note that the exclusion of particle-bound pyrethroids from regulatory limits is likely to be of greatest significance with respect to agricultural discharges, since they often have the highest suspended sediment loads. The proposed approach provides a disincentive for growers to control release of suspended sediments. There is no reason for a grower to reduce suspended sediment discharge, especially if those sediments are coming from untreated areas, since doing so will only increase the likelihood that the grower's pyrethroid releases from treated land will cause a regulatory exceedance. The potential to manipulate suspended sediment so as to avoid a pyrethroid exceedance is akin to simply diluting to meet a treatment standard; neither should be acceptable practice to avoid regulatory limits.

Limited K_{oc} and K_{doc} data – The numerical values assigned to K_{oc} and K_{doc} are critical when employing the staff's recommended approach, but these values are likely to be highly site specific. Since it is not realistic to expect K_{oc} and K_{doc} to be measured by dischargers in every sample, staff expects default literature values to be necessary. Based on staff's quality assurance criteria, they found only a single study, using laboratory water and a sediment from a pond in Massachusetts, to provide acceptable K_{oc} and K_{doc} values for non-POTW waters. Staff recommended that everyone use these default values (e.g., bifenthrin K_{oc} = 4,228,000, K_{doc} = 1,737,127). Simply on the face of it, it is blatantly absurd to expect that a single measurement, derived from one Massachusetts pond, is applicable to every water sample taken anywhere in Region 5, but that is precisely what the staff report advocates.

There are great quantitative and qualitative differences in the amount and type of particulate and organic matter from place to place, and from one time to the next, and thus their potential adsorption of pyrethroids varies tremendously. The staff report fails to provide any sense of how much variation might be expected in the single K_{oc} or K_{doc} it proposes to apply everywhere, and there is good reason to suspect it is likely to be enormous. An earlier version of the staff report used K_{oc} and K_{doc} from other studies that tested multiple sediments, and reported a two order-of-magnitude variation in each of these parameters among the sediments evaluated. The site-to-site variability in K_{oc} and K_{doc} is so great, that a recent literature review on the topic simply concluded such parameters are essentially useless to predict toxicological risk, stating, "the bioavailability and toxicity of pesticides to aquatic organisms in the presence of particles cannot simply be predicted by the partitioning of pesticides between water and particles using the K_{oc}" (Knauer et al., Integ. Environ. Assess. Manage.; Manuscript in press but not yet assigned to a specific issue but available on journal's website.)

In addition, literature K_{oc} and K_{doc} values for pyrethroids are based on clean laboratory waters to which uniform, homogenized, well-characterized particulates or dissolved organics are added. To the best of my knowledge, they have never been measured in any field samples, with all the "messy" particulate and dissolved organic carbon they may contain, yet the proposed approach advocates applying them to field samples throughout Region 5 without validation.

For POTW effluents, the limited data makes the approach even more dubious. The same quality assurance procedures that were used to find almost all existing K_{oc} and K_{doc}

estimates for non-POTWs unsuitable for use in the staff report, were not applied to POTW-related data simply because there was only one study that had generated these values for POTWs. Ironically, that one study is one on which I was the lead investigator, though the pyrethroid partitioning work was done by a subcontractor. Nevertheless, if most of the non-POTW data are unacceptable for use because they did not meet quality assurance standards, why does POTW data with these very same omissions become acceptable? Wouldn't the better answer be acceptable POTW values don't exist, rather than the implied rationale of the staff report as, 'It could be wrong, but it's all we've got, so we'll use it anyway'?

Yet despite the absolute lack of any information on potential site-to-site variability in K_{oc} and K_{doc}, the extraordinarily limited single-site data on which the default values are based, or any demonstration that these values are useful predictors in field situations at all, the proposed approach proposes applying these default values throughout Region 5. On what basis does staff presume that the K_{oc} and K_{doc} values derived from a single pond in Massachusetts apply to every stormwater runoff sample and every agricultural discharge in Region 5? How can a given discharge that attains a final pyrethroid criteria value of 1 be declared compliant, while one that scores a 2 is in exceedance, with all the associated regulatory consequences, when both of two variables used to calculate that score could be off by a factor of 100 or more? The application proposed is not remotely supportable by the current state of knowledge.

RECOMMENDATIONS

I have voiced these concerns repeatedly in the several Board meetings held over the past year, but to no avail. After all, if the proposed TMDL trigger levels are based on an approach: 1) never before used anywhere in the world, 2) that disregards 90% of the pollutant, 3) that incorporates numerical values that have never been shown to be generally applicable or field-verified, and 4) that is not scheduled to be re-assessed by the Board for 15 years, what could possibly go wrong?

As I mentioned initially, the challenges in regulating pyrethroids are immense, and I can accept that some compromises may be necessary because of concerns such as enforceability, feasibility of attainment, or cost. But regulatory approaches based upon these kinds of considerations should be identified as such, not defended as scientifically based. My concern is that once Region 5 adopts the approach, other jurisdictions may be quick to do so as well, with the assumption that Region 5's adoption implies a scientific rigor that is not actually there. Nevertheless, if Region 5 elects to pursue the approach currently in the staff report, despite consideration of my comments and others that may be received, I recommend the following:

1) The use of default K_{oc} and K_{doc} values in a wide variety of water types should receive immediate validation. I do NOT mean compilation and review of the data that dischargers will be gathering as part of their obligations under the TMDL, but a special study to be done in the first couple years after adoption of the TMDL. This study should attempt direct measurement of K_{oc} and K_{doc} in a wide variety of field samples so as to determine whether the proposed laboratory-derived default values have any real world validity, establish the variability of these parameters among samples, determine if perhaps use of a few default

values could be more defensible (e.g., each applied to only a specified range of suspended sediment or dissolved organic carbon concentrations), and assess their value in predicting toxicity. This study should also evaluate the suitability of using Tenax extractions as an alternative to SPME-based default values. It may be possible for commercial laboratories to actually do Tenax-based analyses on many or most samples, avoiding the need for default values all together, and there is evidence that Tenax provides an estimate of toxicological risk that is at least as good if not better than SPMEs (see for examples: Environ. Toxicol. Chem. 20:706-711 (2001); Environ. Sci. Technol. 41:5672-5678 (2007); Environ. Toxicol. Chem. 27:2124-2130 (2008); J. Environ. Monit. 13:792-800 (2011); Environ. Poll. 173:47-51 (2013). Disclosure: I am a co-author on two of these studies.)

2) I would suggest that sampling done both during the initial baseline data collection period under the TMDL, and then to determine compliance for at least the following few years, ALWAYS includes toxicity testing with Hyalella azteca. Given the enormous uncertainties behind the "freely dissolved only" approach being recommended, and the fact that the trigger levels being proposed are nearly the same as the species' LC50s, it is unlikely that compliance with numerical triggers will actually be protective of this species. It is toxicity to this species that led to the current 303(d) listings for pyrethroids, and if the proposed approach does not protect this species, then how can the TMDL ever be expected to eventually lead to de-listing? In addition, Hyalella azteca is a species commonly used to measure toxicity in most toxicity laboratories in Region 5, it is a resident species found throughout Region 5 and all of California, and it is often found in such high abundance as to be the dominant macroinvertebrate. Toxicity to it cannot be lightly dismissed, so it is essential to establish if the proposed triggers are protective.

I should also add that many commercial laboratories only report mortality, yet by their very nature, pyrethroids are neurotoxins that cause paralysis prior to death. When an actively swimming animal is unable to do anything more than lay on the bottom twitching, most reasonable people would consider that an adverse effect that bears noting. Yet because paralysis is not a standardized endpoint, nor is it in the interest of dischargers to document it, many testing laboratories have turned a blind eye to immobility, not reporting it and treating it as if there is no effect at all. Paralysis may be a more subjective endpoint to quantify than death because there can be a gradation in severity, but it is no less environmentally relevant, so I would encourage an effort to standardize and report a paralysis endpoint among laboratories.

3) During Board hearings, staff presented graphs using 108 samples from my prior studies, showing those toxic samples that would have been flagged as exceedances based on their proposed criteria, and those samples that would have been in compliance but were toxic nonetheless. Staff repeatedly insisted that they could not use this kind of analysis to set the criteria, arguing that a toxic sample that was in compliance for pyrethroids, may simply have been toxic due to some other unknown substance. While I personally doubt whether other substances were playing a significant role in toxicity within this data set, I cannot prove that. However, if staff considers data of this type to be unsuitable to set the criteria, as they asserted repeatedly, then it would seem comparable data collected in the coming years would be equally unsuitable to evaluate the criteria. The uncertainly of toxicity due to unknown substances would still remain. Staff have proposed a phased approach, in which

the early years of the TMDL will be used to review the data that are collected to see how well the exceedance threshold identifies the samples found to be toxic. But their past arguments seem to already discount this type of data, since if they argue such data cannot be used to set criteria, then they cannot be used to evaluate them either. Greater consideration to how the appropriateness of the proposed trigger values will be evaluated is needed, since staff seem to have already dismissed the only approach possible with the data being gathered.

4) Greater clarity is needed in the staff report on when an acute criterion (1-hr average concentration), versus a chronic criterion (4-day average concentration), is to be used. In nearly all instances, it is likely that the discharger will have taken only a single grab sample, so an "averaging period" becomes a moot point. The staff report is silent on whether a single grab sample should be viewed as an acute exposure or if it can be assumed to be representative of exposure that lasted many days. Assumption of chronic exposure, that perhaps may be appropriate with a POTW effluent, becomes less clear in, for example, agricultural irrigation runoff. Of particular concern is the last sentence of Appendix B, which explicitly places stormwater runoff within the acute category. My work both in the American River and in Cache Slough has shown elevated pyrethroid concentrations and/or toxicity persisting in these waterbodies for 5 days after a storm, and would certainly best be considered as chronic exposure. In winters such as we have just had, back-to-back rainy periods, and the associated pyrethroid inputs via runoff, can extend over many weeks. I suggest modifying the Appendix B sentence noted, and also providing explicit guidance elsewhere in the staff report.

Thank you for your consideration of these comments and recommendations.

Sincerely,

Donald P Weston

Donald P. Weston, Ph.D.
Emeritus Adjunct Professor