Executive Summary

The main objective of this project was to determine the relative ranking of potential areas of concern with respect to pesticide exposure to sensitive and endangered aquatic species in the Sacramento River watershed, San Joaquin River watershed and Bay-Delta estuary in California. An area of concern is defined as an area where and when one or more species of concern are likely to be present when environmental concentrations may exceed toxicological benchmarks.

To determine potential areas of concern, a co-occurrence assessment was conducted that included 12 Federal and/or State listed threatened and endangered pelagic species (henceforth referred to as species of concern) and 40 different pesticides. Estimating temporal and spatial co-occurrence is a time consuming and intricate undertaking in a complex and dynamic landscape.

The investigation involved the use of simulation modeling, historical water quality monitoring data, and Geographic Information System (GIS) analysis in a weight-of-evidence context. The pesticides selected for analysis (Table E1) include herbicides, fungicides, and insecticides, and were based on a list of pesticides published by the Central Valley Regional Water Quality Control Board in 2009 estimated to pose the highest overall risk to aquatic life.

Table E1. Pesticides selected for analysis

Chemical Name	CAS NUMBER	Type	Chemical Name	CAS NUMBER	Type
(S)-Metolachlor	87392-12-9	Herbicide	Imidacloprid	105827-78-9	Insecticide
Abamectin	71751-41-2	Insecticide	Indoxacarb	173584-44-6	Insecticide
Bifenthrin	82657-04-3	Insecticide	Lambda-cyhalothrin	1465-08-6	Insecticide
Bromacil	314-40-9	Herbicide	Malathion	121-75-5	Insecticide
Captan	133-06-2	Fungicide	Mancozeb	8018-01-7	Fungicide
Carbaryl	63-25-2	Insecticide	Maneb	12427-38-2	Fungicide
Chlorothalonil	1897-45-6	Fungicide	Methomyl	16752-77-5	Insecticide
Chlorpyrifos	2921-88-2	Insecticide	Naled	300-76-5	Insecticide
Cyhalofop-Butyl	122008-85-9	Herbicide	Oxyfluorfen	42874-03-3	Herbicide
Clomazone	81777-89-1	Herbicide	Paraquat Dichloride	1910-42-5	Herbicide
Copper Hydroxide	20427-59-2	Fungicide	Pendimethalin	40487-42-1	Herbicide
Copper Sulfate	7758-98-7	Fungicide	Permethrin	52645-53-1	Insecticide
Cyfluthrin	68359-37-5	Insecticide	Propanil	709-98-8	Herbicide
Cypermethrin	52315-07-8	Insecticide	Propargite	2312-35-8	Insecticide
Deltamethrin	52918-63-5	Insecticide	Pyraclostrobin	175013-18-0	Fungicide
Diazinon	333-41-5	Insecticide	Simazine	122-34-9	Herbicide
Dimethoate	60-51-5	Insecticide	Thiobencarb	28249-77-6	Herbicide
Diuron	330-54-1	Herbicide	Tralomethrin	66841-25-6	Insecticide
Esfenvalerate	66230-04-4	Insecticide	Trifluralin	1582-09-8	Herbicide
Hexazinone	51235-04-2	Herbicide	Ziram	137-30-4	Fungicide

Species of concern for this study include nine threatened and endangered fish, amphibians, and invertebrates. Seasonal runs of Chinook salmon were treated as distinct species for this analysis, thereby accounting for essentially 12 unique species.

1. Chinook Salmon (*Oncorhynchus tshawytscha*)
    - Sacramento River winter-run
    - Central Valley spring-run
    - Central Valley fall run
    - Central Valley late fall run
2. Central Valley steelhead (*Oncorhynchus mykiss*)
3. Southern North American Green Sturgeon (*Acipenser medirostris*)
4. Delta Smelt (*Hypomesus transpacificus*)
5. Striped Bass (*Morone saxatilis*)
6. San Francisco Longfin Smelt (*Spirinchus thaleichthys*)
7. Threadfin Shad (*Dorosoma petenense*)
8. California Red-legged Frog (*Rana draytonii*)
9. California Freshwater Shrimp (*Syncaris pacifica*)

Daily pesticide concentrations were predicted at the Public Land Survey Section (PLSS) section from runoff, erosion and drift sources. Pesticides loads were estimated using 10-years of historical pesticide use data obtained from the California Department of Pesticide Regulation's Pesticide Use Reporting (PUR) database. Application sites represented in the simulations included fruit, vegetable, grain, nuts, rice, and urban/residential landscape maintenance, and structural pest control. Loadings from agricultural uses were predicted using the Pesticide Root Zone Model (PRZM) and the Rice Water Quality Model (RICEWQ). PRZM was also used to estimate runoff from urban/residential applications. Drift was only assumed to occur in agricultural settings and was estimated using a linear equation accounting for application method, application area, and surface water area in the PLSS.

Approximately 9,115,000 pesticide applications were represented in the simulations, accounting for a total applied mass of 98,279,000 lbs of active ingredient (a.i.) for the 40 chemicals. Approximately 14.2% of the applied amount was predicted to reach surface waters via runoff, erosion, drift, and discharge. This is likely an over-prediction because conservative methods and assumptions were used for the assessment. Runoff from agriculture accounted for over 86% of the mass losses loadings. Erosion and drift from agricultural applications accounted for approximately 5.0% and 4.4% of mass loadings. Another 4.3% was predicted to discharge and runoff from rice paddies. Urban runoff accounted for less than 1%. The urban analysis was limited to an evaluation of only four of the 40 pesticides included in the study. Additionally, evaluators need to consider even those contributions of low percentage are not indicative of a lesser emphasis importance to the system.

A toxicological threshold was produced for each pesticide. Where available, the threshold was based on the acute benchmark developed by the U.S. Environmental Protection Agency's Office of Pesticide Programs (OPP) for the most sensitive aquatic non-plant species. An additional

safety factor was applied to achieve OPP's level of concern for threatened and endangered species.

Indicator days (days during which at least one pesticide was estimated to exceeded the toxicity threshold) showed distinct spatial-temporal patterns. Indicator days for urban regions were predicted to occur primarily during the late fall through early spring period. Indicator days for agricultural areas occur predominately during the spring/summer crop growing season. Indicator days for rice growing areas were prevalent in the latter part of the crop season.

Co-occurrence was estimated at the PLSS level by overlaying monthly distributions of indicator days with monthly distributions of species richness. Monthly distributions of species abundance were developed for each species for rivers and streams in the study area. Co-occurrence was also estimated using historical water quality monitoring data collected from 250+ monitoring stations in the study area.

Species richness was determined to be nearly constant from January to July. From August to December, the species richness varied by month and location. November was lowest in terms of species richness. The maximum (100th percentile) of species richness was 0.917 (11 out of the 12 species were present in at least one PLSS section) and the 90th percentile was 0.5 (six species).

Areas with very high co-occurrence (exceeding the 90th percentile values for species richness and indicator days) are concentrated in the southern Delta Estuary in San Joaquin County and smaller regions in the Northern Delta Estuary in Sacramento County and western Yolo County. Areas with high co-occurrence (exceeding the 80th percentile values for species richness and indicator days) are present in clusters scattered on the outskirts of the main agricultural areas in the Sacramento River and San Joaquin River Watershed and in the northern section of the Bay-Delta Watershed. Many of these areas have limited or no monitoring data for the forty pesticides evaluated during this study.

Using the co-occurrence approach, risk managers can determine which criteria (percentile levels) should be used to determined potential areas of concern. Results can be used to identify and rank areas of highest risk, aid in placement of BMPs, and support current and future monitoring programs by strategic placement of sampling locations and frequency. Ultimately, it is hoped that this project will improve decision making and optimize resource spending of groups which seek to improve long-term sustainability of aquatic habitats in the study area.