CHAPTER 11

EFFECTS OF THE ACTION – INTRODUCTION

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11 EFFECTS OF THE ACTION

Our analysis of the effects of the action to threatened and endangered species includes three primary components which are integrated into the risk analysis: exposure analysis, response analysis, and species life-history considerations.

Section 7 regulations define "effects of the action" as all consequences to listed species or critical habitat that are caused by the proposed action, including the consequences of other activities that are caused by the proposed action.

A consequence is caused by the proposed action if it would not occur but for the proposed action and it is reasonably certain to occur. Effects of the action may occur later in time and may include consequences occurring outside the immediate area involved in the action (Sec § 402.02). This effects analyses section is organized following the stressor, exposure, response, risk assessment framework.

11.1 Stressors Associated with the Proposed Action

For this consultation, the Environmental Protection Agency's (EPA's) proposed action encompasses all currently approved product labels containing the active ingredients bromoxynil and prometryn. This opinion evaluates these separately to avoid the misinterpretation that the analysis is comparing the two herbicides. The potential stressors we expect to result from the proposed action include bromoxynil and prometryn; other ingredients of these product formulations (including "inert" ingredients and other active ingredients); label recommended tank mixtures (including other pesticide formulations and adjuvants); and toxic metabolites and degradates of product formulation ingredients. We also consider abiotic stressors (e.g. temperature) and aquatic parameters (e.g., water hardness) that influence the response of the species to stressors associated with the proposed action.

Here, we describe our approach to assessing the toxicity of pesticide mixtures containing bromoxynil or prometryn. Consideration of the toxicity resulting from exposure to pesticide mixtures is an important part of the Effects Analysis of this Opinion. This is due in part to the identified need to consider all effects of the action when making jeopardy determinations and establishing RPAs and RPMs. Pesticide mixtures are explicitly permitted on EPA-authorized product labels, and are therefore part of the action under consultation here. Additionally, monitoring data showing that pesticide mixtures are common in aquatic habitats throughout the United States (Gilliom et al 2007; Bradley et al 2017; Lisa et al. 2018) supports the expectation that ESA-listed species will be exposed to complex pesticide mixtures. Methods of predicting mixture toxicity are widely available and utilize readily available exposure and toxicity data. Finally, failing to consider mixtures may underestimate pesticide risk to such an extent as to lead to erroneous conclusions and ineffective protections for listed species.

11.1.1 Formulated Products

Pesticide mixtures can be divided into three categories; formulated products, tank mixes, and environmental mixtures. Formulated products are produced and sold as one product containing multiple active ingredients. Since the exact types and amounts of the active ingredients are shown on the product labels, it is possible to predict the resulting aquatic concentrations following their use. Several formulated products containing bromoxynil (n=26) and a single formulated product for prometryn have been identified as part of this action and are shown in Table 1.

Table 1. Currently registered formulated products containing bromoxynil or prometryn and at least one other active ingredient.

Registration number	Product Name	A.I. %	Active Ingredient
264-1023	HUSKIE™ HERBICIDE	13.40% 12.90% 3.30%	bromoxynil octanoic acid ester heptanoic acid ester pyrasolfotole
264-1035	HUSKIE™ COMPLETE Herbicide	22.56% 2.82% 0.45%	bromoxynil pyrasulfotole thiencarbazone-methyl
264-1168	Wolverine® Advanced Herbicide	6.13% 5.93% 4.56% 1.50%	bromoxynil octanoic acid ester heptanoic acid ester fenoxaprop-p-ethyl pyrasolfotole
264-690	BRONATE Advanced™ HERBICIDE	18.70% 18.10% 40%	bromoxynil octanoic acid ester heptanoic acid ester MCPA
34704-1052	BROMAC® ADVANCED	18.70% 18.10% 40%	bromoxynil octanoic acid ester Heptonoic acid ester of bromoxynil 2-ethylhexyl ester of MCPA
34704-886	BROMAC®	21.80% 21.80%	bromoxynil equivalent MCPA equivalent
34704-892	BROZINE®	10.81% 21.62%	bromoxynil equivalent atrazine
34704-996	AGSCO B-4 HERBICIDE®	14.21% 44.92%	bromoxynil equivalent 2,4-D
42750-103	BROX-M™ ADVANCED	36.80% 40%	bromoxynil equivalent MCPA
42750-50	BROXTM-At Herbicide	10.81% 21.62%	bromoxynil equivalent Atrazine
42750-52	BROX-M Herbicide	31.70% 21.80%	bromoxynil equivalent MCPA

Registration number	Product Name	A.I. %	Active Ingredient
62719-536	Starane® NXTcp	33.40% 26.20%	bromoxynil octanoic acid ester fluroxypyr, applied separately or as tank mix
62719-557	Starane® NXT	37.29% 9.23%	bromoxynil fluroxypyr
62719-557/ ID-080005	Starane® NXT	37.29% 9.23%	bromoxynil fluroxypyr
66330-434	X2682aa Herbicide	35.17% 13% 2.59%	bromoxynil octanoic acid ester fluroxypyr 1-methylheptyl ester flucarbazone-sodium
71368-28	Mextrol ® EC Herbicide	31.70% 34%	bromoxynil octanoic acid ester MCPA
71368-39	Maestro® D Herbicide	30.10% 31.20%	bromoxynil octanoic acid ester 2,4-D
71368-77	Maestro® Advanced Selective Herbicide	18.70% 18.10% 40%	bromoxynil octanoic acid ester bromoxynil heptonoic acid ester MCPA
71368-89	CLEANSWEEP™ M HERBICIDE	28% 27.30%	bromoxynil octanoic acid ester MCPA
71368-90	CLEANSWEEP® D HERBICIDE	24.10% 31.22%	bromoxynil octanoic acid ester 2,4-D
71368-93	NUP-08131 Selective Herbicide	17.88% 17.30% 46.37%	bromoxynil octanoic acid ester heptanoic acid ester 2,4-D
71368-98	Vandetta F Herbicide	24.81% 26.59% 4.60%	bromoxynil octanoic acid ester MCPA fluroxypyr 1-methylheptyl ester
100-1163	Syngenta Crop Protection. LLC Suprend® Herbicide	79.30% 79.30% 0.70%	prometryn trifloxysulfuron-sodium Suprend® Herbicide Y

79.30%

Tank mixes refer to a situation where the pesticide user applies multiple pesticides simultaneously at the use site. Tank mixes are explicitly allowed on product labels and their use is often encouraged to increase pesticide efficacy. Environmental mixtures result from unrelated pesticide use over the landscape and are typically detected in ambient water quality monitoring efforts. Estimates of risk from these three types of mixtures were generated here using current product labels, routine toxicity data, and Estimated Environmental Concentrations (EEC). These estimates of risk contribute to the overall qualitative mixtures analysis.

Current methodologies for calculating mixture toxicity indicate that additivity is the appropriate initial assumption (Cedergreen 2014). Therefore, additive toxicity is the default assumption in this Opinion unless available data suggest antagonism (less than additive toxicity) or synergism (greater than additive toxicity) is more appropriate. Additive toxicity can be calculated by using either dose-additive or response-additive equations, depending on the nature of the pesticides under consideration. For chemicals with similar modes of action (i.e., organophosphate pesticide that inhibit Acetylcholinesterase (AChE)), dose-addition is appropriate. Conversely, response-addition is appropriate for chemicals with dissimilar modes of action. The preponderance of evidence supports this approach and is consistent with the best available scientific information and peer-reviewed publications.

Estimates of additive toxicity utilize two main pieces of information - exposure concentrations and taxa-specific toxicity values. Exposure concentrations were generated using EPA's Pesticide Water Calculator (PWC), which incorporates chemical-specific parameters (e.g., breakdown rates in water and soil) and application-specific parameters (e.g., application method and rate) to calculate anticipated water concentrations over several different averaging durations (e.g. 1-day and 4-day average peak concentrations). Likewise, standard measures of toxicity (typically the LC50, or the concentration that is lethal to 50% of the test organisms) were gathered from various EPA sources for the relevant taxa groups to which National Marine Fisheries Service (NMFS) listed species belong. Calculating toxicity at the taxa level is important, since taxa groups can have vastly different sensitivities to a given pesticide. For example, aquatic invertebrates are more sensitive to organophosphates than are mammals (i.e., much lower LC50 values), and therefore will have different estimates of expected risk following exposure to mixtures. Calculations of taxa-level toxicity are also useful for representing species for which no species-specific toxicity data are available.

Calculations of dose-addition follow the reasoning that cumulative toxicity reflects the sum of the individual LC50s normalized to their respective exposure concentrations. An assumption is that the compounds share the same mechanism of action (e.g. are both acetylcholinesterase inhibitors). An example calculating dose-addition is a sigmoidal equation of the following form:

E(Cmix) =100/(1+(cumulative LC50)^slope)

Where slope is an appropriate logistic slope (e.g. around 1 for enzyme inhibition) and the cumulative LC50 is the sum of each of the LC50 values normalized by their respective exposure concentrations.

Calculations of response-addition of chemicals A and B, or the sum of the toxic response, can be done using the following equation:

E(Cmix)= 100*((mortality A)+(mortality B)-(mortality A*mortality B))

Where mortality is a function of taxa-specific LC50 or median effective concentration (EC50) values, chemical-specific EECs, and an appropriate probit slope (e.g. the standard 4.5 for mortality). Response-addition does not assume a common mechanism of action for the compounds.

Example of mixture toxicity of a formulated product

One of the bromoxynil formulated products contains 2 lb atrazine plus 1 lb bromoxynil octanoate per gallon (*Brox-At Herbicide* EPA Reg No. 42750-50). The product is used on corn and sorghum, with application rates of up to 3 pints/Acre for a single application and 4 pints/Acre/season. NMFS simulated a single application at the 3 pint/Acre rate (0.75 lbs atrazine and 0.375 lbs bromoxynil octanoate/A) to generate EECs with the AgDrift. Note, this is slightly less than the maximal rate allowed with bromoxynil alone (0.5 lbs per acre). Therefore, NMFS also generated values for comparison to a single a.i. products (e.g. *Broclean* 34704-891) that allow the 0.5 a.i. rate. The AgDrift runs used Tier 1 Aerial, ASAE Fine to Medium (default), and assumed a Bin 6 (water body 1 meter deep and 10 meters wide). These estimates provide values for drift only. They represent maximum exposure from drift before any dissipation of the active ingredient(s) occurs.

Table 2. Aquatic EECs (drift only)

Active Ingredient	Product(s)	Rate	EECs (ppb) in with differing buffers to Bin 6 Habitat		
		(lb/A)	0 ft	66 ft	200 ft
Atrazine	*Brox-At Herbicide*, B*rozine*	0.75	24.9	9.75	3.60
Bromoxynil octanoate	*Brox-At Herbicide*, B*rozine*	0.375	12.5	4.87	1.80
Bromoxynil octanoate	*Broclean*	0.5	16.6	6.50	2.40

To assess the cumulative toxicity following exposure to the products, NMFS used response-addition. Toxicity information for bromoxynil octanoate is presented below (11.4.5). Toxicity information for atrazine is from EPA's 2016 atrazine assessment.

Table 3. Predicted toxicity of Brozine® to fish using the response addition model

Fish				
Chemical	**EEC (µg/L)**	**LC50 (µg/L)**	**Slope**	**Mortality**
atrazine	24.9	5300	4.5	*0.00%*
bromoxynil octanoate	12.5	100	4.5	*0.00%*
			Mixture	*0.00%*

Table 4. Predicted toxicity of Brozine® to aquatic invertebrates using the response addition model

Invertebrate				
Chemical	**EEC (µg/L)**	**EC50 (µg/L)**	**Slope**	**Mortality**
atrazine	24.9	48	4.5	*9.98%*
bromoxynil octanoate	12.5	11	4.5	*59.86%*
			Mixture	*63.87%*

Table 5. Predicted toxicity of Brozine® to aquatic plants using the response addition model

Aquatic Plant				
Chemical	**EEC (µg/L)**	**EC50 (µg/L)**	**Slope**	**Mortality**
atrazine	24.9	4.6	4.5	*99.95%*
bromoxynil octanoate	12.5	51	4.5	*0.30%*
			Mixture	*99.95%*

The results above demonstrate how the cumulative toxicity of a formulated product mixture depends on the taxa being considered. For fish, exposures to the mixture is not toxic (Table 3). For aquatic invertebrates, exposure would produce 64% mortality predominately due to bromoxynil octanoate toxicity (Table 4). For aquatic plants, exposure would result in almost 100% morality due not to the bromoxynil octanoate, but to the atrazine (Table 5). Using just the bromoxynil octanoate exposure would assess the effect to be 0.3% mortality.

11.1.2 Tank mixtures and environmental mixtures

While pesticide labels explicitly allow, and sometimes even recommend, mixing the product with additional ingredients, including other pesticides, they typically do not define which ingredients to add at the time of application. So while tank mixtures need to be considered as a part of the action, unlike formulated products it is not feasible to develop a list of all tank mixtures. Sources of historical use data are available to provide some information about likely tank mixtures, with the California Department of Pesticide Regulation (CalDPR) database (http://calpip.cdpr.ca.gov/main.cfm) being the most extensive. Recent data from pesticide use in California for the years 2016 and 2017 did not indicate that adjuvants were included in recent applications but does provide evidence that tank mixtures can be common practice associated with pesticide applications. Suggested tank mixtures from available product labels for bromoxynil and prometryn were not summarized in this Opinion. Rather, all tank mixtures are assumed to produce additive toxicity and are described qualitatively. Sources of historical use data are available to provide some information about likely tank mixtures, with the CalDPR database (http://calpip.cdpr.ca.gov/main.cfm) being the most extensive. Environmental mixtures are also assumed to produce additive toxicity and are described qualitatively in this Opinion. Consequently, the effects that these other ingredients may have on listed salmonids and designated critical habitat remain an uncertainty and are a recognized data gap in EPA's action under this consultation. Remaining areas of uncertainty, and recognized data gaps in EPA's action under this consultation, include the toxic effects of degradates and metabolites, as well as the effects of abiotic stressors such as elevated temperature.

11.2 Important Habitat Use and Life History Considerations for Anadromous Fish

Anadromous fish are born in freshwater and spend a portion of their life cycle in marine habitats. Generalized life history characteristics for listed anadromous fish are described in Table 6.

Table 6. General life histories of anadromous fish

Species	General Life History Descriptions		
(number of listed ESUs or DPSs[1])	Spawning Migration	Spawning Habitat	Juvenile Rearing and Migration
Chum (2)	Mature adults (usually three to four years old) enter rivers as early as July, with arrival on the spawning grounds occurring from September to January. Chum salmon are semelparous[3]	Generally spawn from just above tidewater in the lower reaches of mainstem rivers, tributary stream, or side channels to 100 km upstream.	The alevin life stage primarily resides just below the gravel surface until they approach or reach the fry stage. Immediately after leaving the gravel, swim-up fry migrate downstream to estuarine areas. They reside in estuaries near the shoreline for one or more weeks before migrating for extended distances, usually in a narrow band along the Pacific Ocean's coast. Preferred prey: fish, invertebrates
Chinook (9)	Mature adults (usually three to five years old) enter rivers (spring through fall, depending on run). Adults migrate and spawn in river reaches extending from above the tidewater inland hundreds of miles from the Pacific. Migrating adults typically follow the thalweg. Chinook salmon migrate and spawn in four distinct runs (spring, fall, summer, and winter). Chinook salmon are semelparous.	Generally spawn in the middle and upper reaches of main stem rivers and larger tributary streams.	The alevin life stage primarily resides just below the gravel surface until they approach or reach the fry stage. Immediately after leaving the gravel, fry distribute to floodplain habitats that provide refuge from fast currents and predators. Juveniles exhibit two general life history types: Ocean-type fish migrate to sea in their first year, usually within six months of hatching. Ocean-type juveniles may rear in the estuary for extended periods. Stream-type fish migrate to the sea in the spring of their second year. Preferred prey: fish, invertebrates

Species (number of listed ESUs or DPSs[1])	**General Life History Descriptions**		
	Spawning Migration	**Spawning Habitat**	**Juvenile Rearing and Migration**
Coho (4)	Mature adults (usually two to four years old) enter the rivers in the fall. The timing varies depending on location and other variables. Coho salmon are semelparous.	Spawn throughout smaller coastal tributaries, usually penetrating to the upper reaches to spawn. Spawning takes place from October to March.	Following emergence, fry move to shallow areas near stream banks. As fry grow they distribute up and downstream and establish territories in small streams, lakes, and off-channel ponds and other floodplain habitats. Here they rear for 12-18 months. In the spring of their second year juveniles rapidly migrate to sea. Initially, they remain in nearshore waters of the estuary close to the natal stream following downstream migration. Preferred prey: fish, invertebrates
Sockeye (2)	Mature adults (usually four to five years old) begin entering rivers from May to October. Sockeye are semelparous.	Spawn along lakeshores where springs occur and in outlet or inlet streams to lakes.	The alevin life stage primarily resides just below the gravel surface until they approach or reach the fry stage. Immediately after leaving the gravel, swim-up fry migrate to nursery lakes or intermediate feeding areas such as floodplain habitats along the banks of rivers. Populations that migrate directly to nursery lakes typically occupy shallow beach areas of the lake's littoral zone; a few cm in depth. As they grow larger they disperse into deeper habitats. Juveniles usually reside in the lakes for one to three years before migrating to off shore habitats in the ocean. Some are residual, and complete their entire lifecycle in freshwater. Preferred prey: fish, invertebrates
Steelhead (11)	Mature adults (typically three to five years old) may enter rivers any month of the year, and spawn in late winter or spring. Migrating adults typically follow the thalweg. Steelhead are iteroparous.	Usually spawn in fine gravel in a riffle above a pool.	The alevin life stage primarily resides just below the gravel surface until they approach or reach the fry stage. Immediately after leaving the gravel, swim-up fry usually inhabit shallow water along banks of stream or floodplain habitats on streams margins. Steelhead rear in a wide variety of freshwater habitats, generally for two to three years, but up to six or seven years is possible. They smolt and migrate to sea in the spring. Preferred prey: fish, invertebrates

1 Evolutionarily Significant Unit (ESU), Distinct Population Segment (DPS)
2 spawn only once
3 may spawn more than once

11.3 Analyzing Exposure

In this section we describe the methods used to characterize pesticide exposure to listed species. The procedures rely on models that identify potential interactions of pesticides with listed species and quantify the magnitude of exposure based on how the pesticides and the listed species behave in the environment. We begin with a description of the development of aquatic habitat bins, linking physical characteristics that define aquatic habitats used by listed species with modeling parameters used to predict exposure. Finally we describe incident reporting for pesticide uses that resulted in effects on non-target species.

11.3.1 Estimating Aquatic Exposure Concentrations Associated with Pesticide Uses

The National Research Council Committee of the National Academy of Sciences recommended that fate and transport models be used to estimate time-varying and space-varying pesticide concentrations in generic habitats relevant to listed species (NAS 2013). Physical characteristics of aquatic habitats, including depth, width, and flow rate affect the environmental concentrations and dissipation patterns of pesticides. A generic habitat defines these physical parameters and uses them to derive EECs. The 2-meter deep, static "Farm Pond" that is routinely used by EPA in screening level assessments is an example of a generic habitat. Defining generic habitats to represent all listed species is a challenge given the diversity in the habitats they occupy. Ultimately, the Services identified 10 habitat "bins," a number EPA felt could feasibly be evaluated given the scope of the analysis (Table 7)[1]. The generic habitats included one aquatic-associated terrestrial habitat, three static freshwater habitats of varying volume, three flowing water habitats of variable volume and flow rates, and three marine/estuarine habitats representative of nearshore tidal, nearshore subtidal, and offshore habitats.

Table 7. Generic aquatic habitats parameters for exposure modeling

Generic Habitat Bins	Depth (meters)	Width (meters)	Length (meters)	Flow (m^3/second)
1 – Aquatic-associated terrestrial habitats	NA	NA	NA	NA
2- Low-flow	0.1	2	length of field[1]	0.001
3- Moderate-flow	1	8	length of field	1
4- High-flow	2	40	length of field	100
5 – Low-volume	0.1	1	1	0
6- Moderate-volume	1	10	10	0
7- High-volume	2	100	100	0
8- Intertidal nearshore	0.5	50	Length of field	NA
9- Subtidal nearshore	5	200	Length of field	NA

[1] Interim Approaches for National-Level Pesticide Endangered Species Act Assessments Based on the Recommendations of the National Academy of Sciences April 2013 Report. Available at https://www.epa.gov/sites/production/files/2015-07/documents/interagency.pdf

[1]length of field – The habitat being evaluated is the reach or segment that abuts or is immediately adjacent to the treated field. The habitat is assumed to run the entire length of the treated area.

The Services identified the bin(s) representative of habitats utilized by each listed species. A single species may occur in a range of habitats represented by multiple bins. The EPA Preliminary Ecological Risk Assessments identify each of the species bin assignments (EPA 2017 a, b, c). Bin 1 represents habitats in the terrestrial-aquatic transition zone, such as riparian habitats and rocky shorelines. These habitats are important to water quality and habitat structure and function. In particular, riparian vegetation acts as a buffer trapping pollutants in stormwater runoff and provides shade and allocthonous materials[2] to aquatic food webs.

Flowing water habitats represented by bins 2, 3, and 4 vary considerably in depth, width, and velocity, which influence both initial concentration and rates of dissipation. These bins are defined by differing flow rates that are products of velocity (influenced by the gradient and other factors) and habitat volume (width and depth). Flow rates vary temporally and spatially in these habitats and are influenced by several factors. For example, bends in the shoreline, shoreline roughness, and organic debris can create back currents or eddies that can concentrate allocthonous inputs. Dams and other water control structures would also significantly influence flow. Some small streams and channels are intermittent and can become static and temporally cut off from connections with surface water flows during dry seasons. Low flow habitats may also occur on the margins of higher flow systems (e.g. floodplain habitats associated with higher flowing rivers).

Bin 2 is intended to represent habitats with flow rates occurring of 0.001-1 m^3/second including springs, seeps, brooks, small streams, and a variety of floodplain habitats (oxbows, side channels, alcoves, etc.) used by salmonids. Pacific salmonids inhabit lower flow habitats in some phase of their lifecycle for activities such as spawning, rearing, or migration. Bin 3 flow rates are representative of small to large streams (1-100 m^3/second) and bin 4 definitions (larger volumes and flow rates exceeding 100 m^3/second) correspond with larger riverine habitats. These habitats are used by listed salmonids during spawning migrations.

Bins 5, 6, and 7 represent freshwater habitats that are relatively static, where flow is less likely to substantially influence the rate of pesticide dissipation. Examples of bin 5 habitats (volumes <100 m^3) include vernal pools, small ponds, floodplain habitats that are cut off from main channel flows, and seasonal wetlands. Salmonid juveniles use a variety of small volume floodplain habitats to forage, over-winter, and shelter from larger predators such as backwater areas and off-channel ponds that are relatively static and may temporarily loose connection to the

[2] In ecology, allochthonous material is something from outside an ecosystem that contributes organic matter and nutrients to that ecosystem. For example, leaves and branches from riparian vegetation fuel the invertebrate community which, in turn, feed larger invertebrates and fish.

main stream channel. Bin 6 volumes (100 – 20,000 m^3) correspond with many ponds, vernal pools, wetlands, and small shallow lakes and Bin 7 represents larger volume habitats (>20,000 m^3) such as lakes, impoundments, and reservoirs. Impoundments are frequently encountered by anadromous fish during spawning migrations of adults and out-migrations of juveniles. Ponds and lakes are also utilized by salmonids for rearing, particularly juvenile sockeye salmon which rear in lakes for one to three years.

Bins 8, 9, and 10 were designed to characterize marine habitats. Marine habitats are generally defined by water depth and distance from shoreline. The nearshore, or neritic zone is the relatively shallow area that extends from the coastlines to the edge of the continental shelf at depths of approximately 200 meters. Nearshore habitats are subdivided into the intertidal zone (Bin 8, the area between shoreline and mean low tide mark), and the subtidal zone (Bin 9, nearshore habitats that extend from the mean low tide mark to the continental shelf and are generally submerged). Bin 10 is intended to represent the deep offshore habitats (>200 meters in depth) that extend beyond the continental shelf. Depths within the intertidal zone are variable between locations but generally range from 0 to <10 meters. Depth within the intertidal habitat depends on the tidal cycle and tidal range. Surface waters can persist during low tides and are used by listed salmonids. Offshore habitats are also used by listed salmonids.

In addition to the above aquatic habitat Bins 2-10, NMFS also estimated pesticide concentrations present in direct runoff from a site following a pesticide application (Bin “0”). This aquatic bin does not represent a ‘habitat’ where salmon may reside, but does provide useful information regarding the concentration of pesticide entering aquatic habitats. Note that the runoff concentration (Bin 0) does not capture dilution upon entering an aquatic habitat Bin (which would decrease the exposure concentration) or the contribution of drift to an aquatic habitat Bin (which would increase the exposure concentration).

EPA’s PWC (PWC version 1.52, available from https://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/models-pesticide-risk-assessment) was used to generate aquatic exposure estimates for the different habitat bins for each of the labeled uses. Detailed information on the PWC is available at the above URL. The PWC is an edge-of-field exposure model that estimates the concentration of pesticide in a water body adjacent to a single use site (e.g. a field of crops) resulting from drift and runoff following applications. The PWC incorporates factors that influence exposure concentrations including the pesticide’s physical properties, application rates and methods, precipitation, and soil type. NMFS uses PWC EECs to calculate exposure concentrations that individuals could experience when located immediately adjacent to a use site following an authorized use of a pesticide. PWC EECs do not reflect the contribution to exposure risk due to any additional use to other sites within the range of the species.

The PWC scenarios were chosen from ESA Scenarios developed by EPA for previous assessments (EPA, 2017a) and that were developed for specific regions (Hydrologic Units at the HUC-2 scale). Generic habitat bins (rather than the standard Farm Pond or Reservoir) were used based on the dimensions of the aquatic habitats used by salmon and discussed above. The field length varied with the HUC2 region associated with the PWC Scenario.

Application efficiencies of 0.95 and 0.99 were used for aerial and ground applications (respectively). Application drift values for aerial and ground applications were calculated for each habitat bin using AgDRIFT (2.1.1). Like the PWC, AgDRIFT is a field-scale model in that it estimates the amount of pesticide transported off-site following application to a single use site. NMFS uses AgDRIFT as an additional exposure model to estimate the contribution of spray drift only to water bodies that are not immediately adjacent to a single use site. The model inputs and the estimated deposition rates of bromoxynil and prometryn are presented in Table 8.

Table 8. Average estimated deposition as a fraction of the application rate (AgDRIFT 2.1.1)

AgDRIFT Simulation (bin range*)	Bin 2 (0-2 m)	Bin 5 (0-1 m)	Bin 6 (0-10 m)	Bin 7 (0-100 m)
Ground Tier 1[1]	0.2448	0.3833	0.0704	0.0101
Aerial Tier 1[2]	0.4372	0.4686	0.2968	0.0925

**Bin range = distance to near-side and far-side of habitat from treatment area (see Table 7)*
[1] High Boom, ASAE fine-medium coarse, 50th percentile distribution
[2] Fine-Medium Droplet Distribution (EPA default)

Note that these values differ from the standard Farm Pond used by EPA in their Ecological Risk Assessments (EPA 2004). For some PWC inputs, NMFS choose to rely on values described in this Chapter as more representative of the habitats specific to the listed-species considered in this Opinion. These included the drift fractions (Table 8 above) and applications rates (summary of pesticide labels in Tables 1&2 in Chapter 5). For other PWC inputs, NMFS relied on information provided in the EPA assessments (e.g. application timing and pesticide properties). The PWC inputs specific to bromoxynil and prometryn are described below.

Estimates for runoff (Bin 0) are not directly available from the output of the PWC. Calculating the runoff concentrations (Bin 0) used the *.zts files generated as part of the PWC runs (i.e. by the PRZM component). The runoff concentration leaving the field can be calculated based on the runoff estimate (RUNF0 column) and the pesticide mass estimate (RFLX1 column).

NMFS did not calculate EECs for the larger flowing water bodies (Bins 3 & 4) or the marine water bodies (Bins 8-10). Adequate exposure models for these water bodies are not currently available. For example, NMFS considers the PWC to be a field-scale model and not appropriate for estimating pesticide concentrations at a watershed scale where multiple application sites will combine to produce an aggregate exposure. NMFS relied on estimates for Bins 0 & 2 as qualitatively representing upper estimates for EECs in Bins 3 & 4. Contributions from other sites within the watershed that did not see applications will serve to reduce these EECs via dilution.

In relying on field scale modeling NMFS did not assume that use will occur to every authorized use site, nor did NMFS assume that all uses are applied at the same day and time. The EECs NMFS derived with exposure modeling do not assume application to more than one site at a time and do not factor in potential increased risk from applications to multiple use sites. Rather than relying on watershed models which require making highly uncertain assumptions regarding the presence/absence and timing of multiple pesticide applications, we relied on field scale models which are intended to generate realistic exposure estimates for treatment to a single use site. The EECs generated represent concentrations that are expected to occur in an aquatic habitat at the edge of the treated field when the pesticide is applied according to product labeling. While they are quantitative in nature, we apply them qualitatively recognizing that they represent only the modeled situation. As discussed in the uncertainty section, use sites receiving lower application rates, or aquatic habitats that are not immediately adjacent to the treated sites are expected to have lower EECs. Ultimately, we look at several lines of evidence (such as the density of use sites within a species range, the proximity of use sites to species habitat, chemical persistence, etc.) to weigh the information for our qualitative determinations.

11.3.2 Estimating Terrestrial Exposure Concentrations Associated with Pesticide Uses

AgDRIFT (Version 2.1.1) was used to generate estimates for pesticide drift deposition in riparian habitats for characterizing potential impacts to riparian plants and invertebrates. Application rates and methods were based on information from the pesticide labels summarized in the Master Use Summary Tables in Chapter 5 (e.g. a label will specify the maximum application rate and approved methods for authorized use). These estimates predict exposure from drift that would be expected in the 10 meters downwind of the target site. Labels do not currently require any buffer to aquatic habitats or riparian zones. The estimates were based on a single application.

11.3.3 Estimating Co-Occurrence Associated with Pesticide Uses

NMFS evaluated co-occurrence of listed salmonids with the stressors of the actions by comparing the spatial distribution of salmonids with the labeled uses of the two a.i.s. We relied on previous analyses performed by EPA and provided as part of three recent Biological Evaluations (EPA 2017a; EPA 2017b; EPA 2017c). Details of the procedure and rationale are available in sections of the EPA BEs. In brief, use sites described on the pesticide labels (e.g. carrots) were assigned to land use categories. Some use sites were grouped into an aggregate category (e.g. carrots as part of Vegetables and Ground Fruit), while some crops (e.g. corn) were kept as an individual land use category. Geo-spatial information associated with the use sites and the land use categories were primarily based on 2010-2015 data from the National Land Cover

Database and the NASS Cropland Data Layer. The use of aggregate land use categories for some use sites accounted for uncertainties associated with the spatial location of pesticide use. Over the 15-year period of the action, cropping patterns for many crops may change due to market demand or crop rotations. Additionally, there is the potential for mis-classification of crops. Relying on broader aggregate land use categories for specific use sites was considered conservative and less likely to undergo significant changes during the 15-year interim.

11.3.4 Mitigation to Minimize or Avoid Exposure

Mitigation has not been proposed beyond the restrictions described in product labeling that would minimize or avoid exposure of ESA-listed species to the potential stressors of the action.

11.3.5 Analyzing Exposure to Bromoxynil

Table 9 shows the extent of overlap for different authorized uses with each species' range. The GIS layers are based on information provided by EPA and used in previous assessments (EPA 2017a; EPA 2017b; EPA 2017c). Since the GIS location information is not specific to a.i., but to land use, it is applicable to bromoxynil applications. Each authorized use was assigned to a GIS layer (Table 11). The overlap data represent upper estimates of the area within a species range where authorized use of bromoxynil could occur. NMFS does not know the actual extent of use that will occur over the 15-years of the action. The uncertainty in the actual extent of use is discussed below and handled qualitatively in the assessment Also, NMFS recognizes that authorized use sites may only represent a subset of a GIS layer. Bromoxynil is authorized for use on industrial sites that will be only a subset of developed land GIS layer. Likewise, fallow land and Conservation Reserve Programs will represent only a portion of the cultivated land GIS layer. NMFS does not have a method to refine the location of these authorized uses within these GIS layers. Finally, use on alfalfa will also occur on only a portion of Pasture land. For this use site, additional information from the NASS was used to inform the overlap. These uncertainties in estimating the overlap between use and species ranges will be addressed in the Risk Characterization section.

Table 9. Percent of an ESU range that overlaps with a GIS Layer associated with bromoxynil uses (mean over 2010-2015).

Species	Vegetables	Corn	Wheat	Other Grains	Other Crops	Pasture	Developed	Right of Way	Cultivated
Chum salmon, Columbia River ESU	0.16	0.10	0.41	0.03	0.52	9.82	8.34	13.46	2.47
Chum salmon, Hood Canal summer-run ESU	0.00	0.01	0.00	0.01	0.00	4.17	3.15	7.86	0.28
Chinook salmon, California coastal ESU	0.00	0.00	0.00	0.01	0.00	9.52	1.18	5.09	1.28
Chinook salmon, Central Valley spring-run ESU	2.65	2.90	2.41	1.22	5.42	33.52	5.74	9.54	41.22
Chinook salmon, Lower Columbia River ESU	0.11	0.06	0.05	0.02	0.12	6.04	5.47	9.86	1.09
Chinook salmon, Puget Sound ESU	0.60	0.44	0.05	0.05	0.10	5.76	9.64	13.05	1.80
Chinook salmon, Sacramento River winter-run ESU	2.06	2.72	1.82	1.43	7.65	24.65	10.38	13.87	39.69
Chinook salmon, Snake River fall-run ESU	2.66	0.76	6.38	0.44	3.55	19.31	4.00	7.79	17.50
Chinook salmon, Snake River spring/summer run ESU	0.99	0.20	3.51	0.39	1.52	14.26	1.18	3.49	8.51
Chinook salmon, Upper Columbia River spring-run ESU	1.69	0.78	2.46	0.14	2.21	8.99	4.46	8.34	12.37
Chinook salmon, Upper Willamette River ESU	1.06	0.29	1.02	0.11	6.43	14.16	6.47	11.27	6.68
Coho salmon, Central California coast ESU	0.02	0.00	0.02	0.27	0.08	12.75	10.65	13.86	2.96
Coho salmon, Lower Columbia River ESU	0.11	0.06	0.05	0.02	0.12	6.13	5.55	9.95	1.10
Coho salmon, Oregon coast ESU	0.00	0.02	0.01	0.00	0.03	8.51	0.89	5.89	0.08
Coho salmon, S. Oregon and N. Calif coasts ESU	0.00	0.00	0.03	0.02	0.11	7.04	0.76	5.50	0.85
Sockeye, Ozette Lake ESU	0.00	0.00	0.00	0.00	0.00	2.71	0.21	3.27	0.00
Sockeye, Snake River ESU	1.74	0.66	3.70	0.19	2.77	14.58	3.47	6.52	12.26
Steelhead, California Central Valley ESU	2.42	2.45	2.29	1.22	5.13	33.56	6.38	9.90	36.29
Steelhead, Central California coast ESU	0.03	0.00	0.12	0.39	0.22	17.25	14.66	17.84	4.30

Species	Vegetables	Corn	Wheat	Other Grains	Other Crops	Pasture	Developed	Right of Way	Cultivated
Steelhead, Lower Columbia River ESU	0.11	0.06	0.05	0.02	0.12	6.03	5.75	9.95	1.14
Steelhead, Middle Columbia River ESU	1.10	0.48	5.44	0.19	4.35	6.49	1.88	5.93	15.31
Steelhead, Northern California ESU	0.00	0.00	0.00	0.00	0.00	8.14	0.50	4.40	0.03
Steelhead, Puget Sound ESU	0.64	0.45	0.05	0.05	0.10	5.94	10.28	13.80	1.87
Steelhead, Snake River Basin ESU	0.99	0.20	3.51	0.39	1.52	14.26	1.18	3.49	8.51
Steelhead, South-Central California coast ESU	0.73	0.06	0.17	0.66	1.30	34.32	2.68	4.95	8.11
Steelhead, Southern California ESU	0.37	0.00	0.12	0.05	0.10	12.16	21.76	24.61	1.54
Steelhead, Upper Columbia River ESU	1.78	0.88	2.55	0.14	2.23	9.08	4.30	8.14	13.07
Steelhead, Upper Willamette River ESU	1.34	0.40	1.60	0.24	8.35	17.45	9.19	13.89	10.18

Estimates of Aquatic EECs following Uses of Bromoxynil

NMFS generated aquatic EECs for each authorized use of bromoxynil using the PWC. Exposure modeling focused on bromoxynil octanoate as the applied chemical. Formulated products consist of either bromoxynil octanoate or bromoxynil heptanoate. EECs were not generated for bromoxynil heptanoate since the chemical properties are similar to bromoxynil octanoate (EPA 2018). Any differences in EECs were considered likely to be minor. The chemical inputs for the PWC runs for bromoxynil octanoate are shown in Table 10.

Once applied, bromoxynil octanoate will convert to bromoxynil (the phenol form). To assess potential EECs associated with the formation of bromoxynil (phenol) a representative subset of uses were modeled with the PWC using manual parent/daughter runs with bromoxynil octanoate as the parent and bromoxynil (phenol) as the daughter. The only change to the PWC inputs was the addition of the daughter chemical (parameters in Table 10).

The EECs generated by NMFS for both bromoxynil octanoate and bromoxynil are displayed in the Risk Characterization and are in Appendix C.

Table 10. Chemical Inputs Parameters for PWC runs.

Physical / Chemical Property	Bromoxynil octanoate	Bromoxynil
Sorption Coefficient(mL/g)	20964	192.2
Koc flag	TRUE	TRUE
Water Column Metabolism Halflife (days)	1.2	15.5
Water Reference Temperature (°C)	25	25
Benthic Metabolism Halflife (days)	12.6	9.6
Benthic Reference Temperature (°C)	25	25
Aqueous Photolysis Halflife (days)	4.6	0.7
Photolysis Reference Latitude (°)	40	54
Hydrolysis Halflife (days)	43.5	0
Soil Halflife (days)	1.5	2.9
Soil Reference Temperature (°C)	20	20
Foliar Halflife (days)	0	0
Molecular Weight (g/mol)	403.11	276.91
Vapor Pressure (torr)	1.39E-06	2.50E-06
Solubility (mg/L)	3	211
Henry's Constant	1.00E-05	1.76E-07

Application information for the PWC runs are summarized in Table 11. Application rates are based on maximum rates allowed by the labels. Application timing information is from EPA (2018). The label restrictions summarized here do not incorporate the changes proposed in EPA's Bromoxynil and Bromoxynil Esters Interim Registration Review Decision (Docket Number EPA-HQ-OPP-2012-0896). See chapter 18 for information on how the interim registration review decision was incorporated into the Opinion. Efficiency and drift inputs were summarized earlier (Table 8). PWC runs for bromoxynil octanoate were performed using external batch files (Appendix C).

Table 11. Inputs used in estimating exposures to uses of Bromoxynil octanoate[1].

Use Site	PWC Scenarios	GIS Overlap Layer	Application Rate(s) (kgs a.i./ha)	Application Date(s) (Relative)	Application Efficiency/Drift
Alfalfa seedlings	GrasslandESA17a.scn GrasslandESA17b.scn GrasslandESA18a.scn GrasslandESA18b.scn	Pasture	0.616	10	Ground (0.99) Air (0.95)
Barley	OtherGrainESA17a.scn OtherGrainESA17b.scn OtherGrainESA18a.scn OtherGrainESA18b.scn	Other Grains	0.8176 0.4088	10 30	Ground (0.99) Air (0.95)
Corn	CornESA17a.scn CornESA17b.scn CornESA18a.scn CornESA18b.scn	Corn	0.8176	-20	Ground (0.99) Air (0.95)
Conservation Reserve Program	ROWESA17a.scn ROWESA17b.scn ROWESA18a.scn ROWESA18b.scn	Cultivated	0.817	10	Ground (0.99) Air (0.95)
Fallow Land	OtherCropESA17a.scn OtherCropESA17b.scn OtherCropESA18a.scn OtherCropESA18b.scn	Cultivated	1.6532	10	Ground (0.99) Air (0.95)
Flax	OtherGrainESA17a.scn OtherGrainESA17b.scn OtherGrainESA18a.scn OtherGrainESA18b.scn	Other Grains	0.4	-20	Ground (0.99) Air (0.95)
Garlic	VegetableESA17a.scn VegetableESA17b.scn VegetableESA18a.scn VegetableESA18b.scn	Vegetables and Ground Fruit	0.8176	10	Ground (0.99) Air (0.95)
Grasses grown for seed and sod	OtherCropESA17a.scn OtherCropESA17b.scn OtherCropESA18a.scn OtherCropESA18b.scn	Other Crops	0.8176	10	Ground (0.99) Air (0.95)
Industrial sites	DevelopedESA17a.scn DevelopedESA17b.scn DevelopedESA18a.scn DevelopedESA18b.scn	Developed	0.8176	10	Ground (0.99) Air (0.95)

Use Site	PWC Scenarios	GIS Overlap Layer	Application Rate(s) (kgs a.i./ha)	Application Date(s) (Relative)	Application Efficiency/Drift
Mint	VegetableESA17a.scn VegetableESA17b.scn VegetableESA18a.scn VegetableESA18b.scn	Vegetables and Ground Fruit	0.6132 0.6132 0.6132 0.6132	-10 45 90 135	Ground (0.99) Air (0.95)
Non-residential turfgrass	OtherCropESA17a.scn OtherCropESA17b.scn OtherCropESA18a.scn OtherCropESA18b.scn	Other Crops	0.8176	10	Ground (0.99) Air (0.95)
Oat	OtherGrainESA17a.scn OtherGrainESA17b.scn OtherGrainESA18a.scn OtherGrainESA18b.scn	Other Grains	0.8176 0.4088	10 30	Ground (0.99) Air (0.95)
Onion – dry bulb	VegetableESA17a.scn VegetableESA17b.scn VegetableESA18a.scn VegetableESA18b.scn	Vegetables and Ground Fruit	0.8176	10	Ground (0.99) Air (0.95)
Rights-of-way	ROWESA17a.scn ROWESA17b.scn ROWESA18a.scn ROWESA18b.scn	Right of Way	0.8176	10	Ground (0.99) Air (0.95)
Rye	OtherGrainESA17a.scn OtherGrainESA17b.scn OtherGrainESA18a.scn OtherGrainESA18b.scn	Other Grains	0.8176 0.4088	10 30	Ground (0.99) Air (0.95)
Sorghum	OtherGrainESA17a.scn OtherGrainESA17b.scn OtherGrainESA18a.scn OtherGrainESA18b.scn	Other Grains	0.8176	10	Ground (0.99) Air (0.95)
Sudan grass	OtherGrainESA17a.scn OtherGrainESA17b.scn OtherGrainESA18a.scn OtherGrainESA18b.scn	Other Grains	0.8176	10	Ground (0.99) Air (0.95)
Triticale	OtherGrainESA17a.scn OtherGrainESA17b.scn OtherGrainESA18a.scn OtherGrainESA18b.scn	Other Grains	0.8176	10	Ground (0.99) Air (0.95)
Wheat	WheatESA17a.scn WheatESA17b.scn WheatESA18a.scn WheatESA18b.scn	Wheat	0.8176 0.4088	10 30	Ground (0.99) Air (0.95)

1 Application rate of bromoxynil adjusted for molecular weight

Terrestrial EECs

AgDRIFT (Version 2.1.1) was used to generate estimates for pesticide drift deposition in riparian habitats for characterizing potential impacts to riparian plants and invertebrates. These estimates predict exposure from drift that would be expected in the 10 meters downwind of the target site.

Labels do not currently require any buffer to aquatic habitats or riparian zones. These estimates assume a single application. Table 12 presents the resulting terrestrial EECs.

Table 12. Average estimated drift deposition onto 10 meter riparian habitat adjacent to field following bromoxynil application.

Labeled Application Rate in lbs active ingredient (a.i.)/acre (use site)[3]	Average drift deposition on riparian habitat (lbs a.i./A)	
	Ground Application[1]	Aerial Applications[2]
Bromoxynil		
0.25 (flax)	0.0176	0.0742
0.375 (alfalfa seedling, mint, dry bulb onion)	0.0264	0.1113
0.5 (barley, corn, CRP, garlic, grasses grown for seed/sod, industrial sites, nonresidential turfgrass, oats, rights-of-way, rye, sorghum, Sudan grass, triticale, wheat)	0.0352	0.1484
1 (fallow)	0.0704	0.2967

[1] *AgDrift Tier 1 ground application: High Boom, ASAE fine-medium coarse, 50th percentile distribution*
[2] *AgDrift Tier 1 aerial application: Fine-Medium Droplet Distribution (EPA default)*
[3] *Rate depends on soil type (lower rate for sandy loam soil, higher rate for medium and fine soils)*

11.3.6 Analyzing Exposure to Prometryn

Table 13 shows the extent of overlap for different authorized uses of prometryn with each species' range. The GIS layers are based on information provided by EPA and used in previous assessments (EPA 2017a; EPA 2017b; EPA 2017c). Since the GIS location information is not specific to a.i., but to land use, it is applicable to prometryn applications. Each authorized use was assigned to a GIS layer (Table 15). The overlap data represent upper estimates of the area within a species range where authorized use of prometryn could occur. NMFS does not know the actual extent of use that will occur over the 15-years of the action. The uncertainty in the actual extent of use is discussed below and handled qualitatively in the assessment. Also, NMFS recognizes that authorized use sites may only represent a subset of a GIS layer. While prometryn is authorized for use on a number of Vegetables, they still represent a subset of all possible Vegetables within the GIS layer. This uncertainty in estimating the overlap between use and species ranges will be considered in the Risk Characterization section of this Opinion.

Table 13. Percent of an ESU range that overlaps with GIS Layers associated with prometryn uses (mean percent over 2010-2016).

Pesticide:	Prometryn	
Crop:	Cotton	Vegetables
Chum salmon, Columbia River ESU	0.00	0.16
Chum salmon, Hood Canal summer-run ESU	0.00	0.00
Chinook salmon, California coastal ESU	0.00	0.00

Chinook salmon, Central Valley spring-run ESU	1.08	2.65
Chinook salmon, Lower Columbia River ESU	0.00	0.11
Chinook salmon, Puget Sound ESU	0.00	0.60
Chinook salmon, Sacramento River winter-run ESU	0.03	2.06
Chinook salmon, Snake River fall-run ESU	0.00	2.66
Chinook salmon, Snake River spring/summer run ESU	0.00	0.99
Chinook salmon, Upper Columbia River spring-run ESU	0.00	1.69
Chinook salmon, Upper Willamette River ESU	0.00	1.06
Coho salmon, Central California coast ESU	0.00	0.02
Coho salmon, Lower Columbia River ESU	0.00	0.11
Coho salmon, Oregon coast ESU	0.00	0.00
Coho salmon, S. Oregon and N. California coasts ESU	0.00	0.00
Sockeye, Ozette Lake ESU	0.00	0.00
Sockeye, Snake River ESU	0.00	1.74
Steelhead, California Central Valley ESU	1.20	2.42
Steelhead, Central California coast ESU	0.00	0.03
Steelhead, Lower Columbia River ESU	0.00	0.11
Steelhead, Middle Columbia River ESU	0.00	1.10
Steelhead, Northern California ESU	0.00	0.00
Steelhead, Puget Sound ESU	0.00	0.64
Steelhead, Snake River Basin ESU	0.00	0.99
Steelhead, South-Central California coast ESU	0.02	0.73
Steelhead, Southern California ESU	0.00	0.37
Steelhead, Upper Columbia River ESU	0.00	1.78
Steelhead, Upper Willamette River ESU	0.00	1.34

Estimates of Aquatic EECs following Uses of Prometryn

NMFS generated aquatic EECs for each authorized use of prometryn using the PWC. The chemical inputs for the PWC runs for prometryn are shown in Table 14. Application information for the PWC runs are summarized in Table 15. Application rates are based on maximum rates allowed by the labels. Application timing information is from EPA (2017). Efficiency and drift inputs were summarized earlier (Table 8). The PWC runs for prometryn were performed using external batch files (Appendix C). The EECs generated by NMFS for prometryn are displayed in the Risk Characterization and are in Appendix C.

Table 14. Chemical Inputs Parameters for PWC runs.

Physical / Chemical Property	Prometryn
Sorption Coefficient(mL/g)	538
Koc flag	TRUE
Water Column Metabolism Halflife (days)	807
Water Reference Temperature (°C)	25
Benthic Metabolism Halflife (days)	0
Benthic Reference Temperature (°C)	20
Aqueous Photolysis Halflife (days)	0
Photolysis Reference Latitude (°)	40
Hydrolysis Halflife (days)	0
Soil Halflife (days)	309
Soil Reference Temperature (°C)	25
Foliar Halflife (days)	0
Molecular Weight (g/mol)	241.4
Vapor Pressure (torr)	1.24E-06
Solubility (mg/L)	33

Prometryn Label review. The label restrictions summarized here do not incorporate the changes proposed in EPA's Prometryn Interim Registration Review Decision (Docket Number EPA-HQ-OPP-2013-0032). See chapter 18 for information on how the interim registration review decision was incorporated into the Opinion.

Important characteristics to consider to evaluate potential drift from prometryn treated sites to salmonid habitats include:

1. Application methods: Aerial and ground spray, chemigation.
2. Buffers: No buffers (i.e. setbacks) to designated critical habitats or any habitats occupied by listed Pacific salmonids are required by labeling. Therefore, we will not assume a buffer (0 feet distance to water body) in AgDRIFT simulations.
3. Release height: Labels indicate ground applications of less than 4 feet (48 inches) above canopy of crop to reduce drift. Limits all applications to <10 feet above crop canopy

with exceptions for higher spray altitudes for aircraft safety. Therefore, we will assume a high boom (50 inches) rather than the low boom (20 inches) for ground spray simulations in AgDRIFT, and a release height of 10 feet for aerial applications.

4. Droplet size: Two labels specify a medium – coarse droplet size distribution for aerial and ground applications (EPA Reg. No. 100-620, 100-1163). Other labels do not specify a droplet size (i.e. EPA Reg. No. 9779-297, 34704-692). While the product may legally be applied at finer distributions prone to greater drift, we will assume a medium droplet size distribution to ensure the simulations are consistent with agricultural practices. AgDRIFT simulations will use the ASAE Fine to Medium/Coarse option for ground applications and the ASAE Fine to Medium (default) for aerial applications.

5. Wind Speed: Labels recommended or prohibited applying the product when wind speeds exceed 10 mph. This wind speed is consistent with AgDRIFT Tier 1 assumptions. Therefore, a wind speed of 10 mph will be assumed in AgDRIFT simulations.

Table 15. Inputs used in estimating exposures to uses of Prometryn.

Use Site	PWC Scenarios	GIS Overlap Layer	Application Rate(s) (kgs a.i./ha)	Application Date(s) (Relative)	Application Efficiency/Drift
Carrot	VegetableESA17a.scn VegetableESA17b.scn VegetableESA18a.scn VegetableESA18b.scn	Vegetables and Ground Fruit	2.24 2.24 2.24	-5 14 21	Ground
Celeriac	VegetableESA17a.scn VegetableESA17b.scn VegetableESA18a.scn VegetableESA18b.scn	Vegetables and Ground Fruit	2.24	-1	Ground
Celery	VegetableESA17a.scn VegetableESA17b.scn VegetableESA18a.scn VegetableESA18b.scn	Vegetables and Ground Fruit	2.24 2.24	-14 14	Ground
Chinese celery	VegetableESA17a.scn VegetableESA17b.scn VegetableESA18a.scn VegetableESA18b.scn	Vegetables and Ground Fruit	2.24 2.24	-14 14	Ground
Cilantro	VegetableESA17a.scn VegetableESA17b.scn VegetableESA18a.scn VegetableESA18b.scn	Vegetables and Ground Fruit	1.79 1.79	-5 14	Ground
Cotton	CottonESA18a.scn CottonESA18b.scn	Cotton	2.24 2.24 0.73 0.73 0.73	-35 -7 7 14 21	Air Air Ground Ground Ground
Dill - CA only	VegetableESA18a.scn VegetableESA18b.scn	Vegetables and Ground Fruit	1.79	14	Ground

Use Site	PWC Scenarios	GIS Overlap Layer	Application Rate(s) (kgs a.i./ha)	Application Date(s) (Relative)	Application Efficiency/Drift
Florence fennel	VegetableESA17a.scn VegetableESA17b.scn VegetableESA18a.scn VegetableESA18b.scn	Vegetables and Ground Fruit	2.24 2.24	-14 14	Ground
Okra (1 application)	VegetableESA17a.scn VegetableESA17b.scn VegetableESA18a.scn VegetableESA18b.scn	Vegetables and Ground Fruit	1.68	-5	Ground
Okra (2 applications)	VegetableESA17a.scn VegetableESA17b.scn VegetableESA18a.scn VegetableESA18b.scn	Vegetables and Ground Fruit	0.84 0.84	-5 21	Ground
Parsley – CA only	VegetableESA18a.scn VegetableESA18b.scn	Vegetables and Ground Fruit	2.24	-10	Ground
Parsley – states other than CA	VegetableESA17a.scn VegetableESA17b.scn VegetableESA18a.scn VegetableESA18b.scn	Vegetables and Ground Fruit	0.56 0.56 0.56	-10 25 50	Ground
Rhubarb	VegetableESA17a.scn VegetableESA17b.scn VegetableESA18a.scn VegetableESA18b.scn	Vegetables and Ground Fruit	2.24	3	Ground
Sesame	VegetableESA17a.scn VegetableESA17b.scn VegetableESA18a.scn VegetableESA18b.scn	Vegetables and Ground Fruit	1.12	35	Ground
Seed Crops – WA State only	VegetableESA17a.scn VegetableESA17b.scn	Vegetables and Ground Fruit	1.12 1.12	-5 14	Ground

Estimates of Terrestrial EECs following Uses of Prometryn

AgDRIFT (Version 2.1.1) was used to generate estimates for pesticide drift deposition in riparian habitats for characterizing potential impacts to riparian plants and invertebrates. These estimates predict exposure from drift that would be expected in the 10 meters downwind of the target site. Labels do not currently require any buffer to aquatic habitats or riparian zones. These estimates assume a single application. Table 16 presents the resulting terrestrial EECs.

Table 16. Average estimated drift deposition onto 10 meter riparian habitat adjacent to field following application of prometryn.

Labeled Application Rate in lbs active ingredient (a.i.)/acre (use site)	Average drift deposition on riparian habitat (lbs a.i./A)	
	Ground Application	Aerial Applications
Prometryn		
0.5 (parsley)	0.0352	X
1 (sesame, WA seed crops)	0.0704	X

1.5 (okra)	0.1056	X
1.6 (cilantro, CA dill)	0.1127	X
2 (carrot, celeriac, celery, Chinese celery, Florence fennel, CA parsley, rhubarb)	0.1408	X
1.6 - 2.4 (cotton)	0.1127-0.169	0.4748-0.7122

[1] AgDrift Tier 1 ground application: High Boom, ASAE fine-medium coarse, 50th percentile distribution
[2] AgDrift Tier 1 aerial application: Fine-Medium Droplet Distribution (EPA default)
[3] Rate depends on soil type (lower rate for sandy loam soil, higher rate for medium and fine soils)
X aerial applications not approved

11.4 Analyzing Responses

The response analysis of this opinion evaluates toxicity information from the stressors of the action and organize them into assessment endpoints which target potential effects to individual salmonids and their supporting habitats. The assessment endpoints represent biological and habitat attributes that, when adversely affected, lead to reduced fitness of individual salmonids or degrade the Physical and Biological Features (PBFs) essential to the conservation of the species. For the reasons described in the following sections, we determine that in total the toxicity information included in this summary provides the best available scientific information for quantitative concentrations that would trigger a response. We place higher weight on those studies that are well-designed, more relevant to our species and habitat, and conducted with stressors of the action. Uncertainties in the available toxicity information are discussed as they are encountered and identified at the end of this section. Following the response analysis, the risk analysis compares anticipated environmental concentrations described in the exposure analysis with assessment endpoints to evaluate whether individual fitness or habitat endpoints might be compromised. Salmonid and designated critical habitat risk hypotheses are evaluated separately in the *Effects of the Proposed Action on Designated Critical Habitat Section*.

The EPA provided draft and preliminary Ecological Risk Assessments for bromoxynil and prometryn as substitutes for Biological Evaluations for the purposes of this ESA section 7 consultation (EPA 2017d; EPA 2018). We relied on the available response information for bromoxynil and prometryn in these assessments and supplemented with data from the ECOTOX and EPA OPP's Pesticide Ecotoxicity Database.[3] The OPP database includes the MRID submissions reviewed by EPA in conjunction with pesticide registrations or reregistrations that have been evaluated by EPA biologists and judged acceptable for use as core or supplemental data to support an ecological assessment. Here we describe the types of data that reflect effects

[3] NMFS accessed the most recent version of Pesticide Ecotoxicity Database. The database is a preliminary copy presently under development. The data continues to receive additional quality assurance checks. NMFS reports these data with this consideration in mind. Overall EPA asserts that the majority of data accurately reflects the Agency data evaluation reports for these studies. EPA OPP is expected to review and make any additional corrections to the data reported in this opinion from this database prior to finalization of the opinion.

that can influence the persistence of populations exposed to environmental toxicants and factors that affect the toxicity and vulnerability of salmonids to pesticides.

11.4.1 Data Quality Requirements

The ESA mandates the use of the best available scientific and commercial data when determining the effects of pesticides on threatened and endangered species. The following paragraphs describe NMFS' data quality acquisition and review process for the information used in in this assessment. Sources of information include ecological effects data for pesticides provided by the registrants as part of the 40 CFR Part 158 guideline requirements, compiled in EPA databases, and found through searches of the open literature. For most pesticides, a substantial amount of ecological effects data are identified through using the ECOTOX as its search engine to access relevant data compiled from scientific journals, books, government reports, and theses and dissertations.

Data acceptable for inclusion into the ECOTOX must be from an English-language primary data source reporting measurable adverse responses occurring concurrently with exposures of ecologically relevant and taxonomically verifiable species to ambient concentrations, doses, or application rates over a discrete exposure duration. The ECOTOX reports these exposures in standardized environmentally relevant units of exposure intensity (i.e., mg active ingredient per liter for aquatic organisms) and exposure duration in days. NMFS also applies the additional data acceptability requirements required by EPA's Office of Pesticide Programs (OPP): the entire article must be a publically available document published in English, the information must be presented as a full article, treatments must be compared to an acceptable control, and the paper must clearly indicate whether the exposure occurred in the laboratory or field. Failure of data acceptability criteria means the data cannot be used in a quantitative assessment, it does not mean the data cannot inform the assessment in some other way. For example, exposures that are not expressed in environmentally relevant exposure units can still be used to inform the Effects Characterization.

A second tier of review may be applied to ECOTOX data, depending on how a study will be used in the assessment:

- Studies establishing an effects threshold concentration above which mortality or sublethal effects occur.
- Studies providing data used to assemble a species sensitivity distribution (SSD), with particular emphasis on studies providing influential data for the distribution (i.e., values near the 5^{th} and 95^{th} percentiles and the median).

- Studies that represent the most sensitive response thresholds for assessment endpoints (e.g., reproduction, behavior, or sensory effects).
- Other studies in the arrays that contain data influential in describing how a species may be affected by the registration of the pesticide.

Searches of the open literature are necessary to supplement data acquired through the ECOTOX for a number of reasons. The ECOTOX attempts to be comprehensive, but searches for content to populate the database do not locate all relevant literature and, once content is identified, it can take up to six months or more for it to be acquired and encoded into ECOTOX. Data included in ECOTOX are limited to single chemical exposures of substances with verifiable chemical abstract numbers. This means information on mixtures like pesticide products and tank mixes need to be identified through the open literature. The ECOTOX content identifies primarily adverse biological effects in live, whole organisms, so information describing mechanisms of effect at sub-organism levels or from in-vitro tests also need to be identified through open literature searches.

11.4.2 Direct Effects

Direct effects on survival resulting from exposure to pesticides that are deposited in surface waters through runoff and drift transport pathways are described by dose-response data from laboratory toxicity studies with results reported as median lethal concentrations (LC50s), median lethal doses (LD50s), slopes of dose response curves, and SSDs showing variability in lethal responses among tested species. Effects on other responses affecting population persistence are described as statistically significant thresholds obtained from dose-response data with results reported as the Lowest Observed Effect Concentration (LOEC) and No Observed Effect Concentration (NOEC) tested in the study along with and the magnitude of effects observed at these thresholds. These responses include, but are not limited to:

- reproduction (e.g., percent hatch, egg viability),
- impaired growth that could increase individual mortality (e.g., predation risk and gape limitation on prey selection) or decrease reproduction (e.g., delayed sexual maturation, gonad size),
- behaviors and impaired motor function (i.e., swimming, ability to migrate) that could increase individual mortality (e.g., predator avoidance), or decrease growth or reproduction (e.g. feeding, reproductive behavior), impaired sensory function that could increase individual mortality, or decrease growth or reproduction (e.g. predator or prey detection, homing ability)

Survival

Individual survival is typically measured by incidences of death at the end of 96-hour (h) exposures (acute test[4]) and incidences of death at the end of 21 d, 30 d, 32 d, and “full life cycle” exposures (chronic tests[5]) to a subset of freshwater and marine fish species reared and exposed in laboratories under controlled conditions (temperature, pH, light, salinity, etc.; EPA 2004). The LC50 is the statistically derived concentration sufficient to kill 50% of the test population. It is derived from the number of surviving individuals at each concentration tested at the end of a 96 h exposure and is usually estimated by probit or logit analysis and more recently by non-linear curve fitting techniques. Ideally, to maximize the utility of a given LC50 study, a slope, variability around the LC50, and a description of the experimental design, such as experimental concentrations tested, number of treatments and replicates used, solvent controls, etc., are needed. The slope of the observed dose response relationship is particularly useful in interpolating incidences of death at concentrations below or above an estimated LC50. The variability of an LC50 is usually depicted by a confidence interval (95% CI) or error (standard deviation or standard error) and is illustrative of the degree of confidence associated with a given LC50 estimate (i.e., the smaller the range of uncertainty, the higher the confidence in the estimate). Without an estimate of the variability, it is difficult to infer the precision of the estimate. Furthermore, survival experiments are of most utility when conducted with the most sensitive life stage of a listed species or a representative surrogate. In the case of ESA-listed Pacific salmonids, there are several surrogates including hatchery reared coho salmon, Chinook salmon, steelhead, and chum salmon, as well as rainbow trout.[6] We consider the range in response of these surrogates to specified exposures to characterize the likely response of listed salmonids.

In addition to laboratory tests of survival, a summary of reported lethality incidents are provided from in EPA’s incident database (Sections 11.4.5.7 and 11.4.6.9). Section 6(a)(2) of the Federal Insecticide, Fungicide and Rodenticide Act requires pesticide product registrants to report adverse effects information, such as incident data involving fish and wildlife. Criteria require reporting of large-scale incidents. For example, pesticide registrants are required to report the following (40 CFR part 159):

[4] Organisms are exposed for 96 hours in static or flowing water (flow-through) to varying concentrations of the chemical. At 96 hours, dead organisms are counted in each treatment. Concentrations may be renewed at various intervals (24, or 48 hr) or maintained through continuous introduction of the chemical.

[5] Organisms are exposed for longer than 96 hours, typically more than 14 days.

[6] Rainbow trout and steelhead are the same genus species (Oncorhynchus mykiss), with the key differentiation that steelhead migrate to the ocean while rainbow trout remain in freshwaters. Rainbow trout are therefore good toxicological surrogates for freshwater life stages of steelhead, but are less useful as surrogates for the life stages that use estuarine and ocean environments.

- Fish – Affecting 1,000 or more individuals of a schooling species or 50 or more individuals of a non-schooling species.

- Birds – Affecting 200 or more individuals of a flocking species, or 50 or more individuals of a songbird species, or 5 or more individuals of a predatory species.

- Mammals, reptiles, amphibians – Affecting 50 or more individuals of a relatively common or herding species or 5 or more individuals of a rare or solitary species.

The number of documented incidents is believed to be a very small fraction of total incidents caused by pesticides for a variety of reasons. Incident reports for non-target organisms typically provide information only on mortality events and plant damage. Sub-lethal effects in organisms such as abnormal behavior, reduced growth and/or impaired reproduction are rarely reported, except for phytotoxic effects in terrestrial plants. An absence of reports does not necessarily equate to an absence of incidents given the nature of the incident reporting.

Information on unintended pesticide effects on non-target plants and animals is compiled in the Ecological Incident Information System (EIIS). The EIIS is a database containing adverse effect reports, typically mortalityof non-target organisms where such effects have been associated with the use of pesticides. Other Ecological Incident databases used are the Incident Data System (IDS), Aggregated Incident Database, and Avian Information Monitoring System (AIMS).

Each incident record indicates whether the incident occurred due to a misuse, registered use, or whether it is undetermined. Each incident is additionally classified with a certainty of the association with the identified a.i. and are classified as: "highly probable," "probable," "possible," and "unlikely."

Growth and Reproduction

The FIFRA guideline tests that EPA requires pesticide registrants to conduct evaluate select growth and reproduction endpoints (chronic tests). In these tests, fish are exposed to the a.i. for variable durations depending on the species tested and may have static renewal or flow through exposures, both techniques to maintain an exposure concentration. Fish are fed twice daily, ad libitum (i.e., an overabundance of food is available at time of feeding). The lowest concentration eliciting a statistically significant difference from controls (no treatment) to growth or reproductive endpoints is recorded (i.e., the LOEC), as well as the lowest exposure concentration tested that is not different than the control (i.e., the NOEC). Many researchers have commented on the poor application of environmental statistics and laboratory testing regarding NOECs and LOECs (Laskowski 1995, Chapman et al. 1996, Suter 1996, Baas 2009, Landis and Chapman 2011). Prominent limitations include: (1) NOECs and LOECs are statistically derived, a function of the concentrations selected by the experimenters, and often are highly variable among studies; (2) ignore the fundamental model of toxicology i.e., does not use the dose-response relationship;

(3) ignore critical data at other treatment concentrations i.e., effects at higher treatment concentrations are not reported; (4) use a lack of evidence as a no-effect; and (5) are limited to the concentrations tested. NOECs typically correspond to an EC10 to EC30 on an exposure response curve (Moore and Caux 1997). A 30% effect rate within a population can be striking, particularly if the effect is on a critical biological endpoint such as reproduction, growth, migration, or olfactory-mediated behaviors. Previous salmonid population modeling suggests that when 14% mortality occurs to juveniles population growth rate is substantially affected (NMFS 2009). We therefore exercise caution in interpreting a NOEC as a true "no response" to an exposure.

Growth of individual organisms is an assessment endpoint derived from the chronic fish and invertebrate toxicity tests described above. Reproduction, at the scale of an individual, can be measured by the number of eggs produced per female (fecundity), and at the population scale by measuring the number of offspring per female in a population over multiple generations. The EPA Preliminary Ecological Risk Assessments summarized reproductive endpoints at the individual scale from chronic, freshwater fish experiments described above. Other assessment measures of reproduction include egg size, spawning success, sperm and egg viability, gonadal development, and hormone levels-most of which are rarely measured in standardized toxicity tests conducted pursuant to pesticide registration.

Other Effects

Responses that are not typically evaluated in laboratory toxicity studies have significant implications for survival in the wild. Swimming is a critical function for anadromous salmonids to complete their life cycle. Impairment of swimming may affect feeding, migrating, predator avoidance, and spawning. It has been used to assess behavioral responses of fish to various toxicants, including pesticides (Little and Finger 1990). Swimming capacity is a measure of orientation to flow as well as the physical capacity to swim against it (Howard 1975; Dodson and Mayfield 1979). Swimming activity includes measurements of frequency and duration of movements, speed and distance traveled, frequency and angle of turns, position in the water column, and form and pattern of swimming. Little and Finger (1990) concluded that swimming-mediated behaviors are frequently adversely affected at 0.3 – 5.0 % of reported fish LC50s, and that 75% of reported adverse effects to swimming occurred at concentrations lower than reported LC50s.

Olfaction conveys critical environmental information that fishes use to mate, locate food, discriminate kin, avoid predators, and home (i.e., navigate). Any or all of these essential olfactory-mediated behaviors may be affected by exposure to contaminants such as pesticides (reviewed by Tierney et al. 2010). For example, copper impairs and destroys salmonid olfactory sensory neurons in a matter of minutes at low µg/L levels and effects persist for hours to weeks depending on exposure concentration and duration (Baldwin 2003). Measured behavioral effects in salmonids from impaired olfaction include compromised alarm response, loss of ability to avoid copper, interrupted spawning migrations, loss of homing ability, and delayed and reduced downstream migration of juveniles (Hansen 1999, Baldwin 2003, Sandahl et al. 2004, McIntyre et al. 2008, Mebane and Arthaud 2010, Baldwin 2011). Disruption of these essential behaviors reduces the likelihood of an individual salmonid completing its life cycle.

Certain critical biochemical responses can indicate organism-level responses affecting survival and fitness in the wild. For example estrogen mimics like nonylphenol, used as a surfactant in tank mixes and fracking, has been linked to endocrine disrupting effects in aquatic systems (Arsenault et al. 2004, Brown et al. 1999, Brown et al. 2003, Brown et al. 2005, Madsen et al. 2004, Schoenfuss et al. 2008a). Another example is impaired neurotransmitter function through changes in acetylcholinesterase levels. Acetylcholinesterase is a crucial enzyme in the proper functioning of cholinergic synapses in the central and peripheral nervous systems of vertebrates and invertebrates. Of consequence to salmon, anticholinesterase insecticides have been shown to interfere with salmon swimming behavior (Beauvais et al. 2000, Brewer et al. 2001, Sandahl et al. 2005), feeding behavior (Sandahl et al. 2005), foraging behavior (Morgan and Kiceniuk 1990), homing behavior (Scholz et al. 2000), antipredator behaviors (Scholz et al. 2000) and reproductive physiology (Moore and Waring 1996, Waring and Moore 1997, Scholz et al. 2000).

We located no study results that evaluated swimming effects or olfactory responses in fish following exposure to the pesticides evaluated in this opinion. The one study reporting effects of prometryn on acetylcholinesterase is discussed in the response section for the herbicide.

11.4.3 Indirect Effects

Indirect effects to fish and habitats exposed to the pesticides evaluated in this opinion are evaluated using toxicity tests of species representing the prey and habitat salmonids depend on.

Invertebrate Prey

Fish can consume a very high proportion of the invertebrate community in aquatic habitats (Huryn 1996, 1998). Juvenile salmonids consume a wide range of invertebrates, including those from all functional feeding groups. Changes in abundance of any of these groups could change prey availability for these fish. Pesticides may kill or injure aquatic insects and other macroinvertebrates that serve as food for rearing juvenile salmonids of all five species and adult steelhead. Lack of food may affect a salmonid’s growth and development, ultimately affecting their ability to complete their life cycle. Juvenile salmonids are generally opportunistic drift-feeders, and are therefore sensitive to factors that influence the general quantity and quality of invertebrate prey items. If, for instance, there were reductions in the production of invertebrate grazers or the inputs of invertebrate prey from riparian vegetation, salmonids may be forced to alter their foraging behavior (e.g., take more risks, select less energy-rich prey). Alternatively, changes in abundance and composition may have minimal impacts to salmonids if they do not alter the overall quality or quantity of prey, or impact foraging behaviors. Whether or not production of prey decreases or shifts (or increases) after exposure to pesticides will depend in part on the composition of the community (structure and function) and the relative sensitivities of those taxa. Multiple experiments conducted in mesocosms have demonstrated that the particular composition of the community at the time of pesticide exposure influences the magnitude of the impact as well as the trajectory of the recovery (Hessan et al. 1994, Lytle and Lytle 2002, Schulz et al. 2003a, Schulz et al. 2003b, Heckmann and Friberg 2005, Rohr and Crumrine 2005, Van den Brink et al. 2006, Van den Brink et al. 2007, Colville et al. 2008, Downing et al. 2008, Maund et al. 2009) and this would likely be the case in salmonid habitats.

Mixtures of pesticides present a particular challenge in assessing impacts on salmon habitat. Most of the experiments described above were conducted in mesocosms with a single exposure of a single pesticide, something that rarely occurs in salmonid habitat. In streams and rivers of the United States pesticides frequently co-occur with other pesticides (Gilliom 2007). A final consideration in assessing how pesticides may impact salmonids and their habitats is the question of resiliency of these aquatic ecosystems. The recovery of secondary production, to rates observed prior to exposure, depends on the communities themselves and the exposure. For example, univoltine species of macroinvertebrates (i.e. that produce one generation per year) will require a long time to recover. Additionally, if pesticides persist in the landscape, exposures may occur repeatedly (or continuously) depending on application rate, precipitation, and conditions in the watershed. In habitats that receive pesticidal inputs repeatedly throughout the year, salmonid prey may be chronically suppressed.

Riparian Vegetation and Aquatic Primary Producers

We evaluate the available information to assess whether riparian vegetation and aquatic primary producers may be affected by the a.i.s. Riparian vegetation is important for providing shade to the stream, stabilizing the stream banks, reducing sedimentation, and providing organic material inputs, both in terms of plant material and terrestrial insects. Riparian vegetation is a major focus of restoration efforts of salmonid habitat throughout their range to help reduce pesticide loading into aquatic resources. Riparian vegetation is an important assessment endpoint for herbicidal impacts on salmon habitats. Generally there are sparse data regarding the effects of herbicides (and much less with insecticides, aracnicides, or miticides) on wild plants within riparian systems, other than weed species. The EPA requires submission of crop effects data as part of the registration process for herbicides (USEPA 1996). This information currently provides the only basis for evaluating effects on herbaceous plants unless data are available from other sources. The overall assumption is that the sensitivity of plant species tested (typically plants used in agriculture) in the registrant-provided guideline studies will be representative of riparian species. There is no way to know this is the case, therefore a high degree of uncertainty regarding the toxicity of the a.i.s to riparian vegetation exists. We also evaluate if and to what extent aquatic primary producers are affected by the stressors of the action. Primary producers including periphyton, diatoms, macrophytes, and plankton are integral components of aquatic food chains, serving as food for salmonid prey. Reductions in primary productivity may lead to impacts to salmonid prey. Although typically not tested for effects to freshwater and marine primary producers, we search for and evaluate any information on pesticide effects to primary producers.

11.4.4 Environmental Factors That Modify Pesticide Toxicity

The physical and chemical properties of water, its temperature, hardness, pH, oxidation/reduction potential, and content of naturally occurring substances like carbon, organic acids, can influence pesticide toxicity. The information submitted by the EPA only discussed these factors in context of pesticide transformation, fate, and transport because these factors influence pesticide degradation half-life and biological availability. For example pesticide half-lives are longest at the optimum pH, with increasing hydrolysis at lower and higher pH values. Substances like minerals, silt, and organic acids can bind to pesticides, reducing their bioavailability to target and non-target organisms.

Searches of the open literature for bromoxynil and the benzonitrile pesticide class did not produce any information on environmental factors that may modify the toxicity of these herbicides. Searches of the open literature for prometryn and the pesticide class “triazines” identified one paper suggesting that the toxicity and bioaccumulation of triazines may be enhanced by increased temperature and one paper suggesting that toxicity may be enhanced by increased temperature and reduced dissolved oxygen. A study of the effects of temperature on the bioaccumulation and liver enzyme activity of rainbow trout exposed to terbutryn and terbuthylazine indicated that temperature only affected the bioaccumulation factor of terbutryn. The bioaccumulation factor for fish exposed at 17 degrees Celsius was 80% higher than the bioaccumulation factor for fish exposed at 4 degrees Celsius. For both herbicides, the activity of the liver enzymes EROD and UDPGT declined over increasing temperature, but data were confounded by the effects of netting stress (Tarja 2003). The study on the effects of temperature and low dissolved oxygen on the toxicity of atrazine to catfish indicated that both factors increased toxicity to catfish (Gaunt 2000).

Increased toxicity for fish at elevated temperatures is a generally accepted principle. As ectotherms, the metabolism of aquatic organisms increases at higher temperatures. This includes metabolism for life functions (e.g. oxygen consumption, excretion, homeostasis) and biotransformation of toxicants. A toxicant that effects energy metabolism or respiratory gas exchange may make it difficult for organisms to meet increased metabolic needs under higher temperatures. Increased metabolism requires higher rates of active uptake and diffusion of water and solute moving over the gills, increasing uptake and excretion of aquatic toxicants (Cairns 1975).

We expect elevated temperatures across the freshwater habitats of listed cold-water fish to co-occur with the two a.i.s. As shown in the Environmental Baseline, many listed cold-water fish reside in watersheds listed on State 303(d) lists as impaired due to temperature exceedances. We expect that cold-water fish and their prey exposed to both elevated temperature and the two herbicides and their degradates in the environment will be adversely affected at relatively lower concentrations compared to exposures to the two herbicides and their degradates at non-elevated temperatures in laboratory and field assays. While we cannot quantify the degree to which elevated temperature may increase toxicity, we will treat temperature qualitatively as a factor expected to increase the risk of reregistration of bromoxynil, the bromoxynil esters, and prometryn, to cold-water fish.

11.4.5 Analyzing Response to Bromoxynil

Bromoxynil is a postemergence benzonitrile herbicide, which inhibits photosynthetic electron transport in chloroplasts and impairs plant respiration by uncoupling mitochondrial oxidative phosphorylation (Worthing 1991, cited in Zottini 1994). Research suggests that, by binding at the quinone Q(B) binding site, bromoxynil reduces the redox potential of Quinone Q(A) in photosystem II, triggering release of free radical oxygen which leads to oxidative damage (Rutherford 2001, Idedan 2011, Ishikita 2011). Information on the mechanism by which bromoxynil exerts toxic effects on aquatic animals was not found in EPA assessments or a search of the open literature. While bromoxynil is a registered a.i., it is not used in any registered end-use products. End-use products are formulated with the bromoxynil esters bromoxynil octanoate and bromoxynil heptanoate (Figure 1). These registered a.i.s break down to bromoxynil after application. The EPA Preliminary Risk Assessments evaluated bromoxynil octanoate, bromoxynil heptanoate, bromoxynil, and the aqueous photolysis degradate 4-cyano-2-bromophenyl octanoate (EPA 2018a).

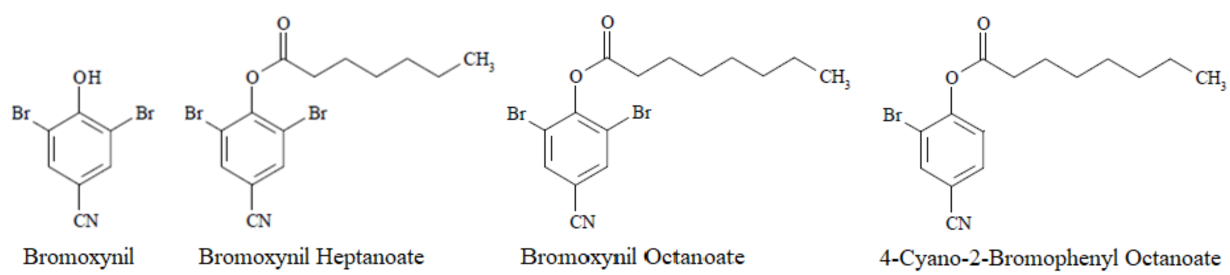

Figure 1. Structure of bromoxynil, bromoxynil esters, and degradate of concern, 4-cyano-2-bromophenyl octanoate.

Data for the toxicity of bromoxynil and its esters are reported in both ECOTOX and the EPA's Pesticide Ecotoxicity Database. Although measured data are not available for the degradate 4-cyano-2-bromophenyl octanoate, estimates based on the Ecological Structure Activity Relationships (ECOSAR) Predictive Model indicate that it would likely have toxicity to aquatic organisms within at least one order of magnitude of the bromoxynil esters (Table 17). ECOSAR estimates can help inform the relative toxicity of the various bromoxynil degradates; however empirical data are given greater consideration, when available.

Table 17. Comparison of observed toxicity with ECOSAR estimates for bromoxynil, bromoxynil heptanoate, bromoxynil octanoate, and 4-cyano-2-bromophenyl octanoate.

	Bromoxynil		Bromoxynil heptanoate		Bromoxynil octanoate		4-cyano-2-bromophenyl octanoate
	measured mg/L	ECOSAR estimate mg/L	measured mg/L	ECOSAR estimate mg/L	measured mg/L	ECOSAR estimate mg/L	ECOSAR estimate mg/L
FRESHWATER							
Fish							
Acute	2.1	258*	0.03	0.56	0.023	0.88	0.268*
Chronic	2[a]	23	--	0.02	0.009	0.04	0.009
Green algae							
Acute	2.18[b]	256*	0.08	0.2	0.21	0.35	0.087
Chronic	--	122	--	0.16	--	0.24	0.076
Invertebrate							
Acute	16	51	0.03	0.81	0.011	1.32	0.371*
Chronic	3.1[c]	9.7	--	0.21	0.003	0.37	0.085
Lemna	0.0931[d]	234*	0.22	--	--	--	--
SALTWATER							
Fish							
Acute	--	139	--	0.69	0.17	1.11	0.323*
Chronic	--	--	--	0.18	--	0.28	0.092
Mysid							
acute	--	--	--	0.13	0.065	0.24	0.049
chronic	--	--	--	0.01	0.015[e]	0.04	0.002

**Likely exceeds limits of solubility*
a Memmert and Knoch, 1991; MRID 50946002
b Banmore and Moore, 2014; MRID 49541402
c Memmert and Knoch, 1991; MRID 50946001
d Hoberg, 1993; MRID 48540504
e Based on acute to chronic ratio (EPA, 2018)

Bromoxynil octanoate and heptanoate are classified as very highly toxic, and bromoxynil is moderately toxic to freshwater fish. Bromoxynil octanoate readily hydrolyzes to bromoxynil (t½ = 11.5 - 28 d at pH 7). Bromoxynil octanoate is hardly mobile (Koc = 20,964 mL/g) and non-persistent. It dissipates in the environment by abiotic hydrolysis, photolytic degradation, and microbially mediated metabolism in both the aerobic and anaerobic environments. Bromoxynil octanoate rapidly degrades to bromoxynil in aerobic terrestrial and aquatic environments (t½ = 2 and 0.6 d, respectively). Bromoxynil does not degrade by abiotic hydrolysis at any measured pH (USEPA 2018).

11.4.5.1 Salmonid Lethality

Bromoxynil lethality data reported in both the ECOTOX and EPA's Pesticide Ecotoxicity Database differ slightly from toxicity values from the preliminary ecological risk assessment (Table 18). Some values in the risk assessment were corrected for purity by multiplying the endpoint value by the purity percentage and data used in the risk assessment were reassessed for additional corrections and updates. For example, the LC50 for Bluegill exposure to 21.5% Bromoxynil was multiplied by 0.215 to arrive at an LC50 of 4,945 ppb to reflect the expected LC50 for pure bromoxynil and a number of LC50s from the OPP database were reclassified from "supplemental" to "fulfilling guideline requirements." References are identified in the OPP Pesticide Ecotoxicity Database as eight digit MRID numbers while the Draft Ecological Risk Assessment identifies the references as six digit accession numbers. NMFS found a few anomalies between the two databases. In some cases the data reported in ECOTOX as coming from the Pesticide Ecotoxicity Database (i.e., ECOTOX 344) were not found in the current version of this database. In a few cases, the values reported differed slightly between the databases.

The data in Table 18 show that among the acceptable data, rainbow trout are the most sensitive species tested in freshwater, with LC50s reported at 3,870 and 2,100 ppb for bromoxynil (moderately toxic) and 50 and 100 ppb for bromoxynil octanoate (highly toxic to very highly toxic). The dataset for bromoxynil is generally very limited. The only data available for acute toxicity of bromoxynil heptanoate to freshwater fish is for bluegill, with an LC50 of 29 ppb (very highly toxic). The only data available for acute exposures of saltwater fish is for sheepshead minnow, with an LC50 reported at 170 ppb (highly toxic).

Table 18. Fish toxicity data for acute exposures to bromoxynil and bromoxynil esters reported in the OPP Pesticide Ecotoxicity Database, ECOTOX, and the Draft Ecological Risk Assessment for the Registration Review of Bromoxynil and Bromoxynil Esters.

Species	Purity (%)	Exposure Duration	Database Toxicity Value and slope, where reported (ppb)	Database Source(s)[a]	OPP Pesticide Ecotoxicity Database Study Classification	Draft Risk Assessment; LC50 (ppb)	Draft Risk Assessment; Accession or MRID No. Author, Year	Draft Risk Assessment; Fulfills Guideline Requirement
Bromoxynil								
Bluegill	21.5	96 hours	LC50=23,000 NOEC=18,000	MRID 00159171	supplemental	4,945	072336 Sousa, 1983	Yes
	95		LC50=4,000 (slope=4,500) NOEC=1,200	MRID 00155071	supplemental	4,000	260441 Nicholson, 1985	Yes
Brook Stickleback	AI	2.1 days; 25 hours	No survival=86-110	Muir et al., 1991; ECOTOX 8791	not coded	NA	NA	NA
Fathead Minnow	95	96 hours	LC50=13,800	Broderius et al., 1995; ECOTOX 15031	not coded	NA	NA	NA
	98		LC50=13,800	Geiger et al., 1988; ECOTOX 12859	not coded	NA	NA	NA
			LC50=11,500	Brooke et al., 1984; ECOTOX 12448	not coded	NA	NA	NA
		34 days	LOEC=3,010 NOEC=1,710	Call and Geiger, 1992; ECOTOX 150898	not coded	NA	NA	NA
Rainbow trout	21.5	96 hours	LC50=18,000 NOEC=11,000	MRID 00138086	supplemental	3,870	072254 Hoberg, 1983	Yes
	95		LC50=2,090 (slope=5,890) NOEC=800	MRID 00155072	core	2,100	260441 Nicholson, 1985	Yes
	97.9	21 days	LOEC=3.9 NOEC=2000	M-184895-01-1	not coded	NA	NA	NA
Bromoxynil heptanoate								
Bluegill	94.8	96 hours	LC50=29 (slope=10.1) NOEC=15	MRID 43059601	core	29	43059601 Bettencourt, 1993	Yes
Bromoxynil octanoate								
Bluegill	87.3	96 hours	LC50=59 (61[b], slope=8.1) NOEC=32	MRID 00114107	core	53	248229 Sousa, 1981	Yes

Species	Purity (%)	Exposure Duration	Database Toxicity Value and slope, where reported (ppb)	Database Source(s)[a]	OPP Pesticide Ecotoxicity Database Study Classification	Draft Risk Assessment; LC50 (ppb)	Draft Risk Assessment; Accession or MRID No. Author, Year	Draft Risk Assessment; Fulfills Guideline Requirement
Brown bullhead	36.6	96 hours	LC50=42 NOEC<16	MRID 00061188	supplemental	23	247924 Harper and Ball, 1965	No, supplemental
Fathead Minnow	97.2	35 days	LOEC=39	USEPA, 1992, ECOTOX 344[c]	not coded	NA	NA	NA
Goldfish	36.6	96 hours	LC50=460 NOEC=63	MRID 00109418	supplemental	170	247924 Harper and Ball, 1965	No, supplemental
Rainbow trout	36.6	96 hours	LC50=150 NOEC=80	MRID 00061186	core	50	247924 Harper and Ball, 1965	Yes
	87.3		LC50=100 (slope=7.4) NOEC=32	MRID 00114108	core	100[d]	264229 Sousa, 1981	Yes
Sheepshead minnow	98	96 hours	LC50=174 (170[b], slope=17.6) NOEC<160	MRID 42250601	core	170	42250601 Machado, 1992	Yes

[a] Unless otherwise indicated, data from the OPP Pesticide Ecotoxicity Database was also reported in ECOTOX as USEPA, 1992, ECOTOX 344.
[b] LC50 reported in the ECOTOX database differed from the LC50 reported in the current OPP Pesticides Ecotoxicity Database.
[c] ECOTOX reported data from the 1992 Pesticides Ecotoxicity Database that was not found in the current database.
[d] Value appears in species Risk-plots within Chapter 12.
Not coded = EPA has not classified this study (e.g. "core", "supplemental", etc.)
NA = not applicable

11.4.5.2 Salmonid Growth And Fitness

Thresholds for statistically significant impacts to growth at different concentrations (i.e. the LOECs and NOECs), and the magnitude of effects were reported in the Draft Ecological Risk Assessment as early-life stage tests on the effects of bromoxynil octanoate on fathead minnow (Table 19). The ECOTOX reported data for bromoxynil effects on brook stickelback, zebra danio, and fathead minnow, but these data are not in the OPP Pesticide Ecotoxicity Database and NMFS expects that these data did not fulfill guideline requirements.

While the chronic fish study for fathead minnow exposure to bromoxynil octanoate is supplemental, the Draft Ecological Risk Assessment stated that this data, taken in conjunction with the previous early life-stage fish study conducted in 1987 (MRID 4111003) satisfies the guideline requirement (72-4(a)). The results indicate that reproductive effects of bromoxynil octanoate to freshwater fish may occur at levels greater than 9 ppb. (MRID 41928301 and 40111003).

Table 19. Fish toxicity data for growth and fitness responses to bromoxynil and bromoxynil ester exposures reported in the OPP Pesticide Ecotoxicity Database, ECOTOX, and the Draft Ecological Risk Assessment for the Registration Review of Bromoxynil and Bromoxynil Esters.

Species	Purity (%)	Exposure Duration	Database Toxicity Value and slope, where reported (ppb)	Database Source(s)	OPP Pesticide Ecotoxicity Database Study Classification	Draft Risk Assessment; Response (ppb)	Draft Risk Assessment; Endpoint Affected	Draft Risk Assessment; MRID No. Author, Year Fulfills guideline?
Bromoxynil								
Brook Stickleback	Active Ingredient	62 days	change in abundance =285.8-651	Robinson 1989 ECOTOX# 53661	not coded	NA	NA	NA
Fathead Minnow	98	Until hatch	development LOEC=634 MATC=504 NOEC=400	Call and Geiger, 1992 ECOTOX# 150898	not coded	NA	NA	NA
		34 days	decreasing growth NOEC=3010		not coded	NA	NA	NA
Zebra Danio	Formulation	5 days	larval survival, hatch and deformity EC10=2,656 EC50=3,207	Padilla et al. 2012 ECOTOX# 161191	not coded	NA	NA	NA
Bromoxynil Octanoate								
Fathead Minnow	97.2	35 days	early life stage chronic LOEC=5.7[d] NOEC=3.4[d] HATCH LOEC = 39 SURVIVE LOEC = 39	MRID 41928301 ECOTOX 344	Supplemental*	LOAEL=39[a] MATC=26 NOAEL=18[a]	decreased larval growth, survival and embryo hatching success	41928301 Sousa, 1991 Supplemental
	63		early life stage chronic	MRID 40111003	Not Acceptable	LOAEL=18[a] MATC=12 NOAEL=9[a]	decreased larval survival	40111003 Suprenant, 1987 Does not fulfil guideline

[a] Value appears in species Risk-plots within Chapter 12.
Not coded = EPA has not classified this study (e.g. "core", "supplemental", etc.)
NA = not applicable
** NOAEC of 18 µg ai/L and a LOAEC of 39 µg ai/L based on decreased larval growth (37% wet weight; 16% length), survival (49%) and embryo hatching success (38%) at the LOAEC. This chronic fish study is supplemental, but taken in conjunction with the previous early life-stage fish study conducted in 1987 (MRID 4111003) they satisfy the guideline requirement (72-4(a)).*

11.4.5.3 Invertebrate Prey

For the indirect effects analysis the Draft Ecological Risk Assessment reported acute toxicity data for *Daphnia magna* and *D. pulex* (Table 20). Based on toxicity tests using Daphnia magna, assessment data classify bromoxynil as only slightly toxic to freshwater aquatic invertebrates (EC50 = 15,910 and 19,220 ppb) while bromoxynil octanoate as classified as very highly toxic (EC50s of 11 and 96 ppb and as highly to very highly toxic to estuarine and marine invertebrates (EC50 = 65 and 155 ppb). One study reported in ECOTOX demonstrated rapid decrease in toxicity when bromoxynil was aged in hard water. This study also indicated that neonates and 7-day old adults were more sensitive to bromoxynil than 14 or 15 day old organisms (Buhl et al. 1993b).

Daphnia magna freshwater chronic NOECs for bromoxynil octanoate reported in the Draft Risk Assessment were within about an order of magnitude lower than acute the EC50s, at 2.5 ppb for reproduction and growth and 2.6 ppb for survival. Information indicating effects of chronic exposure to bromoxynil at concentrations lower than used in the EPA assessment were not found in ECOTOX or the open literature. Both aquatic invertebrate studies are supplemental individually, but taken together they satisfy the guideline requirement for a life-cycle aquatic invertebrate study. The results indicate that aquatic invertebrate reproductive impairment may occur at bromoxynil octanoate levels greater than 2.5 ppb. (MRID 41928302 and 40111001).

Information on the effects of chronic exposure to bromoxynil for estuarine and marine invertebrates found in ECOTOX indicate an EC10 for growth effects at 800 ppb. Data were not available for estuarine and marine invertebrates exposures to bromoxynil heptanoate or octanoate.

Table 20 Acute toxicity data for aquatic invertebrates exposed to bromoxynil and bromoxynil esters.

Species	Purity (%)	Exposure Duration	Database Toxicity Value and slope, where reported (ppb)	Database Source(s)[a]	OPP Pesticide Ecotoxicity Database Study Classification	Draft Risk Assessment; EC50 (ppb)	Draft Risk Assessment; Accession or MRID No. Author, Year	Draft Risk Assessment; Fulfills Guideline Requirement
Bromoxynil								
Midge	39.4	48 hours	EC50=1,900	Buhl and Faerber, 1989	not coded	NA	NA	NA
		25 hours	EC50=2,350	ECOTOX# 3914	not coded	NA	NA	NA
Pacific Oyster	Active Ingredient	9 days	LC50=7,000	His and Seaman, 1993 ECOTOX# 19372	not coded	NA	NA	NA
Scud	Active Ingredient	up to 48 hours	2.1-650	Muir, et al., 1991 ECOTOX# 8791	not coded	NA	NA	NA
Daphnia magna	21.5	48 hours	EC50=74,000	MRID 00138087	supplemental	15,910	00138087 Hoberg, 1983	Yes
	95		EC50=19,220 NOEC=13,000	MRID 00155070	core	19,220	260441 Nicholson, 1985	Yes
Bromoxynil heptanoate								
Daphnia magna	94.8	48 hours	EC50=31 (slope=2.8) NOEC<8.7	MRID 43059602	core	31	43059602 Putt, 1993	Yes
Bromoxynil octanoate								
Daphnia pulex	36.6	48 hours	EC50=32 NOEC=18	MRID 00109417	core	11	247924 Harper, 1964	Yes
Daphnia magna	87.3		EC50=114 (110[b], slope=3.4) NOEC=22	MRID 00114109	core	96[c]	248229 Suprenant, 1981	Yes
	95.1		EC50=41-161	Buhl et al., 1993 ECOTOX# 8846	not coded	NA	NA	NA
Eastern oyster	98	96 hours	EC50=155 (slope=1.2) NOEC=55	MRID 42244501	core	NA	NA	NA
Mysid	94.9	96 hours	LC50=65 (slope=5.6) NOEC=31	MRID 43487601	supplemental	NA	NA	NA

[a] Unless otherwise indicated, data from the OPP Pesticide Ecotoxicity Database was also reported in ECOTOX as USEPA, 1992, ECOTOX 344.
[b] EC50 reported in the ECOTOX database differed from the EC50 reported in the current OPP Pesticides Ecotoxicity Database.
[c] Value appears in species Risk-plots within Chapter 12.
Not coded = EPA has not classified this study (e.g. "core", "supplemental", etc.)
NA = not applicable

Table 21 Chronic toxicity data for aquatic invertebrates exposed to bromoxynil and bromoxynil octanoate.

Species	Purity (%)	Exposure Duration	Database Toxicity Value and slope, where reported (ppb)	Database Source(s)	OPP Pesticide Ecotoxicity Database Study Classification	Draft Risk Assessment; Response (ppb)	Draft Risk Assessment; Endpoint Affected	Draft Risk Assessment; MRID No. Author, Year; Fulfills guideline?
Bromoxynil								
Daphnia magna	97.9	21 days	reproduction rate LOEC=9.8,NOEC=3100	M-160922-01-2	not coded	NA	NA	NA
Naturally occurring aquatic invertebrates in a prairie wetland	Active Ingredient	62 days	emergence, abundance, biomass NOEC=285.8-651	Robinson 1989 ECOTOX# 53661	not coded	NA	NA	NA
Pacific Oyster	Active Ingredient	9 days	growth EC10=800	His and Seaman, 1993 ECOTOX# 19372	not coded	NA	NA	NA
Bromoxynil octanoate								
Daphnia Magna	33.4	28 days	growth LOEC=20-40; NOEC=10-20	Buhl et al., 1993 ECOTOX# 8023	not coded	NA	NA	NA
		21,28 days	Population growth rate LOEC=20-40;NOEC=10-20		not coded	NA	NA	NA
		21,28 days	Progeny counts/numbers LOEC=10-20		not coded	NA	NA	NA
		21 days	Progeny counts/numbers NOEC=5-10		not coded	NA	NA	NA
	63	21 days	hatch, survival LOEC=5.3 NOEC=2.6	MRID 40111001	supplemental	NA	NA	NA
	97.2			MRID 41928302	Acceptable	NOAEL=2.5 LOAEL=5.9 MATC=3.8	reproduction and growth	41928302 Putt, 1991, yes
	60					NOAEL=2.6 LOAEL=5.3 MATC=3.7	survival	40111001 Suprenant, 1986, yes

Not coded = EPA has not classified this study (e.g. "core", "supplemental", etc.)
NA = not applicable

11.4.5.4 Phytoplankton And Aquatic Vascular Plants

The Draft Risk Assessment included guideline tests for exposures to bromoxynil and bromoxynil octanoate for the five required species groups and for exposures to bromoxynil heptanoate for two of the five required species groups. Lemna gibba was the most sensitive to bromoxynil, but *Pseudokirchneriella subcapitata* was twice as sensitive to bromoxynil heptanoate than bromoxynil. The freshwater diatom *Navicula pelliculosa* was the most sensitive species to bromoxynil octanoate, followed by the marine diatom *Skeletonema costatum* and the green algae *Selenastrum capricornutum*. The bluegreen algae *Anabaena flos-aquae* was least sensitive, with an LC50 greater than the maximum tested concentration of 650 ppb (Table 22).

Table 22. Toxicity data for aquatic plants exposed to bromoxynil and bromoxynil esters.

Species	Purity (%)	Exposure Duration	Database Toxicity Value and slope, where reported (ppb)	Database Source(s)[a]	OPP Pesticide Ecotoxicity Database Study Classification	Draft Risk Assessment; IC50/EC50 (ppb)	Draft Risk Assessment; Accession or MRID No. Author, Year, Fulfills Guideline?
Bromoxynil							
Algae		21 days	population growth rate 25-10000	His and Seaman, 1993 ECOTOX# 19372	not coded	NA	NA
		5-30 days	population growth rate EC50=500-2000	Cullimore 1975 ECOTOX# 4871	not coded	NA	NA
		62 days	biomass NOEC=286-651	Robinson 1989 ECOTOX# 53661	not coded	NA	NA
Anabaena flos-aquae	97.2	96 hours	growth EC50=1,370 NOEC=300	MRID 49541401	not coded	1,370	49541401 Yes
Blue-Green Algae	98	24 hours	photosynthesis 5,538-27,691	Das and Bagchi, 2010 ECOTOX# 167045	not coded	NA	NA
Chlamydomonas eugametos		48 hours	abundance LOEC=276,915 NOEC=27,691	Hess 1980 ECOTOX# 6513	not coded	NA	NA
Chlamydomonas moewusii	95	72 hours	germination,abundance NOEC=22,153	Cain, and Cain, 1983 ECOTOX# 61203	not coded	NA	NA
Chlorella fusca var. vacuolata	97	24 hours	population growth rate EC50=35,999 NOEC=20,962	Junghans, et al., 2006 ECOTOX# 163051	not coded	NA	NA
Chlorella pyrenoidosa	95	96 hours	population growth rate EC50=4,406-4,414	Ma and Liang, 2001 ECOTOX# 61984	not coded	NA	NA
		0.75-1.5 days	chlorophyll IC50=10,000	Kratky and Warren, 1971 ECOTOX# 40616	not coded	NA	NA
Chlorella sp.	Formulation	96 hours	population change number/time EC50=10,000	Walsh et al., 1987 ECOTOX# 9933	not coded	NA	NA
		96 hours	population change number/time EC50=2,600-9,700		not coded	NA	NA
Chlorella vulgaris	95	96 hours	population growth rate EC50=89,126	Ma et al., 2002 ECOTOX# 65938	not coded	NA	NA
Chlorella vulgaris Pseudokirchneriella subcapitata	98	96 hours	population growth rate LOEC=100,000 NOEC=10,000	Garten Jr. and Frank, 1984 ECOTOX# 62406	not coded	NA	NA
Isochrysis galbana		1-6 days	population growth rate EC20=7,500	His and Seaman, 1993 ECOTOX# 19372	not coded	NA	NA
Lemna gibba	97	14 days	growth EC50=93 NOEC=68	MRID 48540504	not coded	93.1	48540504 Supplemental

Species	Purity (%)	Exposure Duration	Database Toxicity Value and slope, where reported (ppb)	Database Source(s)[a]	OPP Pesticide Ecotoxicity Database Study Classification	Draft Risk Assessment; IC50/EC50 (ppb)	Draft Risk Assessment; Accession or MRID No. Author, Year, Fulfills Guideline?
Lemna minor		2-96 hours	population EC50=8,065 biomass LOEC=3,125 NOEC<3,125	Fairchild et al., 1997 ECOTOX# 18093	not coded	NA	NA
Navicula pelliculosa	94.5	72 hours	growth EC50=176, NOEC=23	MRID 48540503	not coded	176.4	48540503 Yes
Oscillatoria chalybea	99	5 days	abundance EC100=27691 LOEC=2769	Schrader et al., 1998 ECOTOX# 69879	not coded	NA	NA
Pseudokirchneriella subcapitata	95	96 hours	abundance EC50=4,229	Ma et al., 2006 ECOTOX# 83543	not coded		
	97.2	96 hours	growth EC50=2,180 NOEC=804	MRID 49541402	not coded	2180	49541402 Yes
	99	5 days	abundance EC100>276915 LOEC=276915	Schrader et al., 1998 ECOTOX# 69879	not coded		
	Formulation	72 hours	population growth rate EC50=5407	Katsumata et al., 2009 ECOTOX# 150061	not coded		
		1-96 hours	biomass LOEC=6250 NOEC=3125	Fairchild et al., 1997 ECOTOX# 18093	not coded		
		96 hours	abundance EC50=2400-3400	St.Laurent et al., 1992 ECOTOX# 45196	not coded		
		96 hours	population EC50=7762	Fairchild et al., 1997 ECOTOX# 18093	not coded		
Scenedesmus acutus var. acutus	95	96 hours	population growth rate EC50=53436	Ma and Liang, 2001 ECOTOX# 61984	not coded	NA	NA
Scenedesmus quadricauda	95	96 hours	population growth rate EC50=3700	Ma et al., 2003 ECOTOX# 71458	not coded	NA	NA
Skeletonema costatum	97.2	96 hours	growth EC50>4790 NOEC=4790	MRID 49571201	not coded	>4790 No effects	49571201 Yes
	Formulation	72 hours	population change number/time EC50=720-3200	Walsh et al., 1987 ECOTOX# 9933	not coded		
Synechococcus elongatus	98	96 hours	population growth rate LOEC=8307-41537 NOEC=5538-27691	Bagchi et al., 2012 ECOTOX# 159044	not coded	NA	NA
Thalassiosira pseudonana	Formulation	72 hours	population change number/time EC50=1000-5300	Walsh et al., 1987 ECOTOX# 9933	not coded	NA	NA
Bromoxynil *heptanoate*							
Lemna gibba	94.8	14 days	growth EC50=219 (slope=3.3) NOEC=77	MRID 43059604	core	219	43059604 Hoberg, 1993 Yes

Species	Purity (%)	Exposure Duration	Database Toxicity Value and slope, where reported (ppb)	Database Source(s)[a]	OPP Pesticide Ecotoxicity Database Study Classification	Draft Risk Assessment; IC50/EC50 (ppb)	Draft Risk Assessment; Accession or MRID No. Author, Year, Fulfills Guideline?
Pseudokirchneriella subcapitata	94.8	5 days	growth EC50=80 (slope=1.4) NOEC=8	MRID 43059605	core	80	43059605 Hoberg, 1993 Yes
Bromoxynil octanoate							
Anabaena flos-aquae	Tech	5 days	growth EC50>630 NOEC=630	MRID 41606005	supplemental	> 63	41606005 Giddings, 1990 Supplemental
Chlorella pyrenoidosa	96	96 hours	biomass EC50=324,550 LOEC=100,000 NOEC=50,000	Ma et al., 2007 ECOTOX# 107918	not coded	NA	NA
Chlorella vulgaris	96	96 hours	biomass EC50=5720 LOEC=1000, NOEC=500	Ma et al., 2007 ECOTOX# 107918	not coded	NA	NA
Lemna gibba	97.2	14 days	growth EC50>91, NOEC=18	MRID 42574601	invalid	NA	NA
Microcystis aeruginosa	Formulation	3-7 days	population growth rate 20000	Yu et al., 2014 ECOTOX# 172743	not coded	NA	NA
Navicula pelliculosa	97.2	5 days	growth EC50=51 (slope=1.65) NOEC=9.3	MRID 41606001	core	51[a]	41606001 Giddings, 1990 Yes
Pseudokirchneriella subcapitata	96	96 hours	biomass EC50=4430 LOEC=1000, NOEC=500	Ma et al., 2007 ECOTOX# 107918	not coded	NA	NA
	97.2	5 days	abundance EC50=207 (220, slope=0.44) NOEC=18 (16)	MRID 41606004	Supplemental	NA	NA
	Active ingredient	5 days	abundance EC50=210 NOEL=160	USEPA, 1992 ECOTOX# 344	not coded	NA	NA
Scenedesmus acutus var. acutus	96	96 hours	biomass EC50=7540 LOEC=2000, NOEC=1000	Ma et al., 2007 ECOTOX# 107918	not coded	NA	NA
Scenedesmus quadricauda	96	96 hours	biomass EC50=5820 LOEC=500	Ma et al., 2007 ECOTOX# 107918	not coded		
	97.2					210[a]	41606004 Giddings, 1990 Yes
Skeletonema costatum	97.2	5 days	abundance EC50=130 (140,144) NOEL=33	MRID 41606002	supplemental	140	41606002 Giddings, 1990 Yes

[a] Value appears in species Risk-plots within Chapter 12.
Not coded = EPA has not classified this study (e.g. "core", "supplemental", etc.)
NA = not applicable

11.4.5.5 Terrestrial (Riparian) Vegetation

Riparian vegetation is important for providing shade to the stream, stabilizing the stream banks, reducing sedimentation, and providing organic material inputs, both in terms of plant material and terrestrial insects. Riparian vegetation is a major focus of restoration efforts within California, and when present can reduce pesticide loading into aquatic resources. Riparian vegetation is an important assessment endpoint for herbicidal impacts on salmon habitats. Generally there are sparse data regarding the effects of herbicides (and much less with insecticides, aracnicides, or miticides) on wild plants within riparian systems, other than weed species. The EPA requires submission of crop effects data as part of the registration process for herbicides (USEPA 2012). This information currently provides the only basis for evaluating effects on herbaceous plants unless data are available from other sources. The overall assumption is that the sensitivity of plant species tested (typically plants used in agriculture) in the registrant-provided guideline studies will be representative of riparian species. There is no way to know this is the case, therefore a high degree of uncertainty regarding the toxicity of the a.i.s to riparian vegetation exists.

Bromoxynil octanoate is more toxic to dicot plant species than monocot plant species with respect to seedling emergence and vegetative vigor, but not germination (Table 23). Dicot EC25 values for seedling emergence and vegetative vigor for bromoxynil octanoate and heptanoate ranged over an order of magnitude from 0.011 to 0.12 lb/acre while EC25 values for monocots ranged from 0.19 to greater than 0.60 lb/acre. The only data found for bromoxynil toxicity was for an EC25 of 0.008 lb/acre common fiddleneck

Table 23. Bromoxynil effects on terrestrial plants.

Study Type	% AI	Species	EC_{25} (lb ai/A)	Most Sensitive Endpoint	MRID # Author, Year	Fulfills Guideline Requirements
Bromoxynil heptanoate						
Seedling Emergence	94.8	dicot -- lettuce all monocots tested	0.014 >0.45	shoot length shoot length	43059603 Hoberg, 1993	Yes
Vegetative Vigor		cabbage ryegrass	0.011 0.19	shoot weight root weight	43059603 Hoberg, 1993	Yes
Bromoxynil octanoate*						
Germination	97.6	dicot -- tomato all monocots tested	>0.45 >0.45	germination, radicle length germination, radicle length	43273801 Hoberg, 1994	Yes
Seedling Emergence	33.58	dicot –tomato all monocots tested	0.12 > 0.60	shoot length emergence, shoot length	43633701 Hoberg, 1995	Yes
Vegetative Vigor	33.58	dicot--tomato, cabbage monocot--onion	0.017 0.37	plant dry weight plant dry weight	43633701 Hoberg, 1995	Yes

** Values appears in habitat Risk-plots within Chapter 15.*

11.4.5.6 Field Studies

The ECOTOX included one dataset from an experimental prairie wetland reporting no effects on 19 resident taxa at concentrations of bromoxynil as high as 651 ppb over 62 days (Robinson 1989). A seconds study from the same research group applied a single spray application of a 1:1 mixture of bromoxynil octanoate and bromoxynil butyrate at nominal concentrations of 2.5 and 50 ppb reported complete mortality of brook sticklebacks held in cages in subsurface waters, occurred within 24 hours at pond nominal concentrations of 100 and 500 pg/L. Mortality of caged *Hyalella azteca* at the highest dose levels ranged from 85 to 95% at 50 hours.

11.4.5.7 Field Incidents

A search of the OPP Incident Data System (IDS) on May 1, 2018 returned multiple incidents associated with possible bromoxynil impacts on non-target terrestrial plants (PC Codes 035301, 035302 and 128920). There were 127 major incidents reported, which are listed below in Table 24. Most of the reported incidents were to crops treated directly with bromoxynil. There is one honey bee incident in the table, however that incident involves multiple pesticides and appears unlikely to be directly related to bromoxynil exposure (there is no certainty index indicated in IDS). Registrants also reported 56 aggregate minor plant incidents between 2000 and 2017. No additional details are available for these incidents. An update to this search for entries from May 2, 2018 – April 17, 2019 added 12 additional incidents, all related to treated crops. While these incidents represent evidence of environmental exposures to bromoxynil, NMFS does not consider them contributing appreciably to the effects of the action.

Table 24. Incidents Reported for Bromoxynil and Bromoxynil Esters

Incident Number	Start Date	State	Certainty Index	Legality	Use Site	Species Impacted	Distance	Magnitude
I014404- 025	5/20/1991	WA	Possible	Misuse	Onion	Potato		N/R
I001664- 001	4/11/1994	OR	Possible	Misuse (accidental)	WHEAT	Pea	1/8 TO 1/2 MILE	UNKNOWN
I012366- 026	5/19/1998	MI	Possible	Undetermined	Tree farm/plantation	Blue Spruce		82 acres
I013563- 003	5/3/1999	CA	Possible	Misuse (accidental)	Onion	Onion		64.5 acres
I008805- 003	5/11/1999	IL	Possible	Misuse (accidental)	Agricultural Area	Onion	Treated directly	50% of the crop
I010390- 002	5/17/2000	IL	Probable	Registered Use	Corn	Corn	Treated directly	11.3 acres
I010563- 052	7/1/2000	MO	Possible	Registered Use	Corn	Corn	Treated directly	N/R
I011723- 083	5/21/2001	IL	Probable	Misuse (accidental)	CORN	Corn	Treated directly	All 180 acres
I011723- 084	6/2/2001	IN	Possible	Registered Use	CORN	Corn	Treated directly	All 132 acres
I011723- 085	6/13/2001	KS	Possible	Registered Use	CORN	Corn	Treated directly	All 30 acres
I011723- 086	6/14/2001	IN	Possible	Registered Use	CORN	Corn	Treated directly	All 200 acres
I011723- 087	6/21/2001	IN	Possible	Registered Use	CORN	Corn	Treated directly	All 70 acres
I012089- 004	8/7/2001	CA	Possible	Registered Use	Agricultural Area	Onion	Treated directly	33 acres
I012366- 049	9/26/2001	CA	Probable	Misuse (accidental)	N/R	Onion		33 acres
I012994- 001	5/22/2002	VA	Possible	Misuse (accidental)	Corn, field	Corn	Treated directly	45 acres out of 85
I013103- 029	6/14/2002	ND	Possible	Registered Use	Wheat, spring	Wheat	Treated directly	320 acres
I013103- 031	6/21/2002	NE	Possible	Registered Use	Alfalfa	Alfalfa	Treated directly	70 acres
I013430- 025	6/21/2002	ND	Possible	Misuse (accidental)	Corn, field	Corn, Field	Treated directly	90 acres out of 130
I013103- 030	6/24/2002	IN	Possible	Registered Use	Corn, field	Corn	Treated directly	36 acres
I013430- 022	7/8/2002	ND	Possible	Registered Use	Wheat, spring	Wheat, Spring	Treated directly	165 acres
I013430- 024	7/24/2002	ND	Probable	Registered Use	Wheat, spring	Barley	Treated directly	360 of 670 acres

Incident Number	Start Date	State	Certainty Index	Legality	Use Site	Species Impacted	Distance	Magnitude
I013430- 023	7/30/2002	ND	Probable	Registered Use	Wheat, spring	Wheat, Spring	Treated directly	200 acres
I014123- 016	5/29/2003	ND	Possible	Registered Use	Barley	Barley	Treated directly	300 acres
I014123- 017	5/29/2003	NE	Possible	Registered Use	Barley	Barley	Treated directly	90 acres
I014123- 022	5/29/2003	NE	Possible	Registered Use	Barley	Barley	Treated directly	80 acres
I014216- 010	6/2/2003	ND	Possible	Registered Use	Barley	Barley	Treated directly	90 acres
I014216- 011	6/2/2003	ND	Possible	Registered Use	Oat	Oats	Treated directly	90 acres
I014216- 024	6/2/2003	ND	Possible	Registered Use	Barley	Barley	Treated directly	90 acres
I014216- 028	6/2/2003	ND	Possible	Registered Use	Barley	Barley	Treated directly	1300 acres
I014216- 031	6/2/2003	ND	Possible	Registered Use	Barley	Barley	Treated directly	510 acres
I014216- 032	6/2/2003	ND	Possible	Registered Use	Oat	Barley	Treated directly	90 acres
I014216- 033	6/2/2003	ND	Possible	Registered Use	Barley	Barley		180 acres
I014216- 034	6/5/2003	ND	Possible	Registered Use	Barley	Barley		70% of 230 acres
I014216- 042	6/6/2003	MT	Possible	Registered Use	Wheat, winter	Wheat		400 acres
I014216- 043	6/6/2003	MT	Possible	Registered Use	N/R	Wheat		500 acres
I014216- 053	6/9/2003	AR	Possible	Registered Use	Cotton	Cotton		400 acres
I014216- 019	6/11/2003	ND	Possible	Registered Use	Wheat, spring	Wheat, Spring	Treated directly	300 acres
I014216- 015	6/12/2003	MN	Possible	Misuse (accidental)	Corn, field	Corn, Field	Treated directly	25 acres
I014216- 026	6/12/2003	ND	Possible	Registered Use	Corn, field	Corn, Field	Treated directly	160 acres
I014216- 030	6/12/2003	ND	Possible	Registered Use	Barley	Barley		130 acres
I014216- 029	6/13/2003	ND	Possible	Registered Use	Barley	Barley	Treated directly	420 acres
I014216- 025	6/18/2003	ND	Possible	Registered Use	Barley	Barley	Treated directly	360 acres
I014216- 027	6/18/2003	ND	Possible	Registered Use	Barley	Barley	Treated directly	240 acres
I015291- 021	6/3/2004	ND	Possible	Registered Use	Wheat, spring	Wheat, Spring	Treated directly	120 acres
I015291- 022	6/3/2004	ND	Possible	Registered Use	Wheat, spring	Wheat, Spring		120 acres
I015291- 004	6/4/2004	ND	Possible	Registered Use	Barley	Barley	Treated directly	400 acres
I015291- 006	6/11/2004	ND	Possible	Registered Use	Barley	Barley	Treated directly	240 acres

Incident Number	Start Date	State	Certainty Index	Legality	Use Site	Species Impacted	Distance	Magnitude
I016328- 032	5/21/2005	ID	Possible	Registered Use	Barley	Barley		149 acres
I016407- 040	6/4/2005	SD	Possible	Registered Use	Wheat, spring	Wheat, Spring		69 acres
I016407- 056	6/16/2005	ND	Possible	Misuse	Barley	Barley		32 acres
I016595- 038	7/14/2005	IA	Possible	Registered Use	Corn, field	Corn, Field	Treated directly	20 acres
I016662- 027	8/26/2005	IA	Possible	Registered Use	Corn, field	Corn, Field	Treated directly	160 acres
I017691- 055	6/14/2006	ND	Possible	Registered Use	Wheat, spring	Wheat	Treated directly	60 acres
I017865- 032	7/15/2006	IL	Possible	Registered Use	Corn, field	Corn	Treated directly	62 acres
I017865- 033	7/15/2006	IL	Possible	Registered Use	Corn, field	Corn	Treated directly	50 acres
I018502- 020	3/21/2007	CA	Possible	Undetermined	Agricultural Area	Alfalfa	Treated directly	703 acres
I018502- 019	4/23/2007	CA	Possible	Undetermined	Agricultural Area	Oats	Treated directly	456acres
I021411- 017	2009	MT	Possible	Registered Use	Pea, dry	Pea	Vicinity	100% of 220 acres
I021411- 018	2009	ND	Possible	Registered Use		Pea	On site	100% of 52.5 A
I021485- 016	2009	ID	Possible	Registered Use	Agricultural Area	Winter Wheat	On site	193.0 acres
I021485- 022	2009	ND		Registered Use	Agricultural Area	Lentil	On site	475.0 acres
I021485- 024	2009	ND	Possible	Undetermined	Lentil	Lentil	On site	500 acres
I021283- 024	7/1/2009	ND	Probable	Registered Use	Agricultural Area	Lentil	Vicinity	587.8 acres
I021283- 021	7/2/2009	ND	Probable	Registered Use	Agricultural Area	Lentil	Vicinity	769.4 acres
I021283- 025	7/2/2009	MT	Probable	Registered Use	Agricultural Area	Pea	Vicinity	120 acres
I021283- 027	7/2/2009	MT	Probable	Registered Use	Agricultural Area	Pea	Vicinity	112 acres
I021283- 020	7/3/2009	ND	Probable	Registered Use	Agricultural Area	Lentil	Vicinity	509 acres
I021283- 015	7/6/2009	MT	Probable	Registered Use	Agricultural Area	Lentil	Vicinity	345 acres
I021283- 016	7/6/2009	MT	Probable	Registered Use	Agricultural Area	Lentil	Vicinity	345 acres
I021283- 018	7/6/2009	ND	Probable	Registered Use	Agricultural Area	Lentil	Vicinity	552 acres
I021283- 023	7/6/2009	ND	Probable	Registered Use	Agricultural Area	Lentil	Vicinity	983 acres
I021283- 028	7/6/2009	MT	Probable	Registered Use	Agricultural Area	Pea	Vicinity	120 acres
I021283- 029	7/6/2009	ND	Probable	Registered Use	Agricultural Area	Lentil	Vicinity	500 acres

Incident Number	Start Date	State	Certainty Index	Legality	Use Site	Species Impacted	Distance	Magnitude
I021283- 022	7/7/2009	ND	Probable	Registered Use	Agricultural Area	Lentil	Vicinity	475 acres
I021283- 035	7/7/2009	ND	Probable	Undetermined	Agricultural Area	Lentil	Vicinity	475 acres
I021485- 015	7/7/2009	ND	Possible	Registered Use	Agricultural Area	Pea	On site	100% of 100 A
I021283- 014	7/8/2009	ND	Probable	Registered Use	Agricultural Area	Lentil	On site	350 acres
I021283- 019	7/8/2009	ND	Probable	Undetermined	Agricultural Area	Lentil	Vicinity	702 acres
I021283- 7017	7/9/2009	ND	Probable	Registered Use	Agricultural Area	Lentil	Vicinity	100 acres
I021411- 016	7/14/2009	MT	Possible	Registered Use	Pea	Pea	Treated directly	500 acres
I021283- 033	9/10/2009	ND	Probable	Registered Use	Agricultural Area	Lentil	Vicinity	349 acres
I021283- 034	9/10/2009	ND	Probable	Registered Use	Agricultural Area	Lentil	Vicinity	785 acres
I021751- 001	3/4/2010	CA	Possible	Undetermined	Tree farm/plantation	Wheat	On site	250 acres
I021813- 022	3/22/2010	CA	Possible	Undetermined	Wheat	Alfalfa	Vicinity	100% of 20 acres
I023574- 004	5/5/2010	ID	Possible	Undetermined		Bean	N/R	476 acres
I022475- 017	7/1/2010	MT	Possible	Undetermined	Lentils	Lentil	On site	100% of 845 acres
I022475- 016	7/5/2010	MT	Possible	Undetermined	Lentils	Lentil	Vicinity	100% of 182.5 acres
I022217- 037	7/13/2010	MT	Possible	Undetermined	Agricultural Area	Wheat	Treated directly	200 acres
I022217- 031	7/17/2010	NM	Possible	Misuse (intentional)	Sorghum	Sorghum	Treated directly	100 % 155 acres
I022286- 037	7/17/2010	NM	Possible	Misuse	Agricultural Area	Sorghum	Treated directly	100 of 155 acres
I022392- 030	9/1/2010	ND	Possible	Undetermined	Wheat, spring	Wheat, Spring	Treated directly	100% of 37 acres
I023213- 032	6/8/2011	ND	Possible	Undetermined	Wheat, spring	Spring Wheat	Treated directly	100% of 333 acres
I023213- 033	6/8/2011	ND	Possible	Undetermined	Wheat, spring	Spring Wheat	On site	100% of 310 acres
I023213- 051	7/15/2011	MT	Possible	Undetermined	Wheat, spring	Spring Wheat	On site	100% of 618 acres
I023302- 036	7/18/2011	MT	Unlikely	Registered Use	Lentils	Lentil	N/R	100 percent

Incident Number	Start Date	State	Certainty Index	Legality	Use Site	Species Impacted	Distance	Magnitude
I023302- 022	8/2/2011	MT	Possible	Registered Use	Lentils	Lentil	N/R	100 percent
I023302- 026	8/18/2011	ND	Possible	Registered Use	Wheat, spring	Wheat, Spring	Treated directly	0.513
I023302- 027	8/22/2011	MN	Possible	Misuse (intentional)	Wheat, spring	Wheat, Spring	Treated directly	100% of 60 acres
I024443- 018	3/26/2012	CA	Unrelated	Undetermined	Oat	Grape	Vicinity	60 acres
I024051- 026	4/17/2012	TX	Possible	Undetermined	Sorghum	Sorghum	On site	100% of 300 acres
I024202- 022	5/8/2012	ID	Possible	Undetermined	Wheat, winter	Wheat, Winter	On site	100% of 120 acres
I026819- 00001	5/20/2012					Honey Bee	N/R	
I024295- 035	5/31/2012	MN	Possible	Registered Use	Wheat, spring	Wheat, Spring	Treated directly	100% of 180 acres
I024431- 043	6/6/2012	ND	Possible	Registered Use	Sorghum	Cereal	Treated directly	100% of 420 acres
I024295- 030	6/11/2012	MI	Possible	Misuse (accidental)	Barley	Barley	Treated directly	100% of 92 acres
I024431- 044	6/20/2012	ND	Possible	Undetermined	Sorghum	Cereal	Treated directly	100% of 160 acres
I024431- 041	7/23/2012	TX	Possible	Registered Use	Sorghum	Sorghum	Treated directly	100% of 45 acres
I025344- 024	5/6/2013	TX	Possible	Undetermined	Agricultural Area	Sorghum	Treated directly	100% of 600 acres
I028066- 007	5/14/2015	MT	Possible	Undetermined		Cereal	Treated directly	1925 acres
I028118- 004	5/22/2015	ND	Possible	Undetermined	Wheat	Wheat	Treated directly	1150 acres
I028247- 00011	6/2/2015	MT	Probable	Registered Use	Wheat	Wheat, Spring	On Site	735 acres
I028066- 015	6/10/2015	ND	Possible	Undetermined	Wheat	Wheat	Treated directly	2000 acres
I028118- 005	6/10/2015	ND	Possible	Undetermined	Wheat	Wheat	Treated directly	598 acres
I028066- 017	6/11/2015	MT	Possible	Undetermined	Wheat	Wheat	Treated directly	440.17
I028066- 008	6/13/2015	MT	Possible	Undetermined	Agricultural Area	Cereal	Treated directly	650

Incident Number	Start Date	State	Certainty Index	Legality	Use Site	Species Impacted	Distance	Magnitude
I028344- 00007	6/14/2015		Possible	Undetermined	Wheat	Wheat	On Site	385 acres
I028118- 014	6/17/2015	MT	Unlikely	Undetermined	Wheat	Wheat	Treated directly	2500 acres
I028344- 00010	6/17/2015		Possible	Registered Use	Wheat	Wheat	On Site	
I028118- 015	6/19/2015	MT	Unlikely	Undetermined	Wheat	Wheat	Treated directly	1870
I028066- 009	6/20/2015	MT	Possible	Undetermined	Agricultural Area	Cereal	Treated directly	1000 acres
I029611- 00002	6/25/2015	KS	Possible	Registered Use	Sorghum	Sorghum	On Site	102 acres
I029071- 00009	6/1/2016	MT				Wheat, Spring	N/R	2500 acres
I029269- 00005	6/18/2016	MT				Wheat	On Site	1412 acres
I029351- 00006	6/23/2016		Possible	Undetermined	Wheat	Wheat	On Site	3119 acres
I029351- 00007	6/23/2016	ND				Wheat	On Site	320 acres
I029992- 00001	3/1/2017	CA	Probable	Registered Use	Wheat	Wheat	On Site	226 acres
I030199- 00013	5/26/2017		Probable	Registered Use	Wheat, spring	Spring Wheat	On Site	144 acres
031236 – 00076	6/1/2018	SD	Possible	Registered Use	Agricultural Cropland	Spring Wheat	Treated Directly	300 acres
031236 – 00053	6/6/2018	MT	Probable	Misuse	Agricultural Cropland	Spring Wheat	Treated Directly	300 acres
031585 – 00064	6/19/2018	ND	Probable	Registered Use	Agricultural Cropland	Spring Wheat	Treated Directly	100% of 320 acres
031236 – 00081	6/21/2018	MN	Possible	Registered Use	Agricultural Cropland	Spring Wheat	Treated Directly	29 acres
031377 – 00026	7/1/2018	ND	Possible	Registered Use	Agricultural Cropland	Beets	Treated Directly	620 acres
031377 – 00009	7/3/2018	IL	Possible	Registered Use	Agricultural Cropland	Soybean	Treated Directly	180 acres
031585 – 00065	8/1/2018	ND	Possible	Registered Use	Agricultural Cropland	Spring Wheat	Treated Directly	62% of 420 acres
031585 – 00066	8/3/2018	KS	Probable	Registered Use	Agricultural Cropland	Winter Wheat	Treated Directly	83% of 866 acres
031585 – 00067	8/7/2018	MT	Highly Probable	Registered Use	Agricultural Cropland	Wheat	Treated Directly	100% 0f 250 acres
031585 – 00068	8/10/2018	ID	Probable	Registered Use	Agricultural Cropland	Spring Wheat	Treated Directly	100% of 90 acres
031585 – 00069	9/19/2018	SD	Highly Probable	Registered Use	Agricultural Cropland	Winter Wheat	Treated Directly	100% of 320 acres
031585 – 00070	10/10/2018	WA	Highly probable	Registered Use	Agricultural Cropland	Spring Wheat	Treated Directly	99.8 % of 168 acres

11.4.5.8 Bioconcentration And Bioaccumulation

While bioconcentration and bioaccumulation data were not found in the open literature or the ECOTOX database, the Draft Risk Assessment reports that the KOW indicates that bromoxynil will not appreciably bioconcentrate in aquatic animals. A steady-state bioconcentration factor for whole fish was reported at 230 with 85-97% depuration in 14 days; 79% as degradate bromoxynil in fish tissue (MRID 42277301a/ 42277301b).

11.4.5.9 Degradate Toxicity

Toxicity data for the photolysis degradate 4-cyano-2-bromophenyl octanoate were not found in the open literature, in ECOTOX or reported in the draft risk assessment. The EPA's assessment concluded that, because the ECOSAR Predictive Model indicated that it would likely have toxicity to aquatic organisms within at least one order of magnitude of the bromoxynil esters (Table 17).

11.4.5.10 The Effects Of Water Physical And Chemical Properties On Bromoxynil Toxicity

One study did indicate that elevated temperature increased bromoxynil toxicity to two species of nuisance plants, which may be extrapolated to riparian vegetation. Exposure to a temperature of 30oC resulted in greater injury to wild mustard and redroot pigweed compared with plants exposed at 10oC (Nalewaja and Skrzypczak 1986).

11.4.5.11 Water Hardness Effects On Bromoxynil Toxicity

Increased water hardness was reported to reduce toxicity of technical grade bromoxynil and two formulations[7] to daphnia by approximately 1.5 to 2 fold (Buhl et al. 1993a). Feeding similarly reduced toxicity. However, the response in soft-water treated organisms was confounded by stress caused by adjusting study organisms from hard water culture media (275 +/- 5 mg $CaCO_3$/L) to spiked soft water test media (40.2 +/- 0.3 mg $CaCO_3$/L). Water hardness was not reported in any of the MRID DERs examined for this analysis so we cannot place this study in context of the studies used in the EPA assessments. However, standard exposure conditions in laboratory tests require a water hardness between 40 and 200 mg $CaCO_3$/L. It is important to note that the hardness of waters in much of the range of listed anadromous species is below 60 mg $CaCO_3$/L; this suggests that responses within the freshwater habitats of listed salmonids will be comparable or potentially more sensitive than responses observed under laboratory conditions (Figure 2).

[7] Buctril(r) (33.4% a.i.) and Bronate(r) (31.7% bromoxynil plus 34% MCPA)

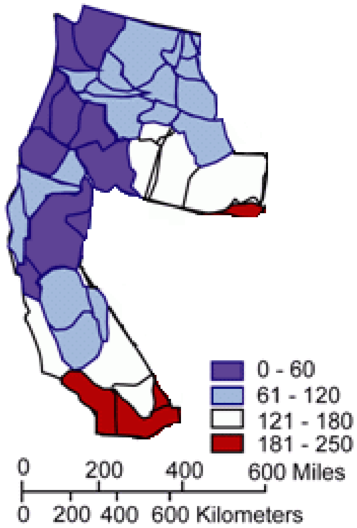

Figure 2. Water hardness among watershed accounting units (6 digit hucs) as calcium carbonate in milligrams per liter.

11.4.6 Analyzing Response to Prometryn

Prometryn is a substituted thiomethyl triazine that, as a registered end product, is applied as a pre-emergence herbicide or as a targeted post emergence herbicide. Prometryn blocks photosynthetic electron transport by binding to the D-1 quinone-binding protein (Q8) (Khan 1996, EPA 2009). Prometryn was reported to be stable at pH 5, 7, and 9 at 22°C (MRID 405737-04, Acceptable). Although we found no information that toxicity is affected by pH, the longer it persists in the aquatic environment the greater the probability that salmonids and their habitats may be exposed and negatively affected. Aquatic habitats throughout salmonids' distribution experience acidic, neutral, and alkaline pHs, typically pH may range from 6 to 9.

The EPAs assessment also evaluated the prometryn degradate, hydroxypropazine (Figure 3. Structure of prometryn and degradate of concern, hydroxypropazine). This degradate is expected to form and persist in acidic soils and aquatic systems while it degrades more rapidly in neutral to slightly alkaline soils. Among the other degradates, prometryn sulfoxide degrades rapidly and triazine sulfonic acid derivative would only be of concern in some neutral and alkaline soils.

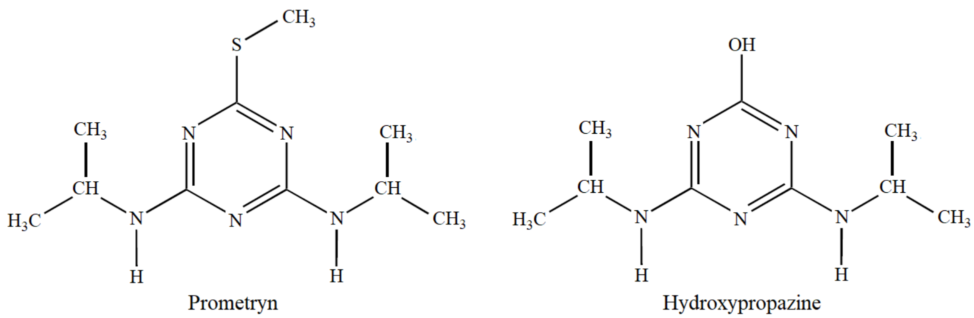

Figure 3. Structure of prometryn and degradate of concern, hydroxypropazine

11.4.6.1 Responses To Prometryn Exposures

The mode of action for toxic effects of prometryn in fish was identified in EPA's assessment as neurological effects (Popova 1976). The EPA Preliminary Risk Assessments evaluated prometryn and its persistent degradate hydroxypropazine, but information on the toxicity of this degradate is not available. The Draft Risk Assessment indicated that the EPA communication with the registrant through waiver requests concluded that ECOSAR was not a viable resource to predict the toxicity of hydroxypropazine, and in the absence of data for aquatic species, the degradate will be considered as toxic as the parent.

11.4.6.2 Salmonid Lethality

The ECOTOX and Pesticide Ecotoxicity database included data on prometryn lethality for 12 species. The Draft Risk Assessment reported only those data applied to their analysis: 96 hour LC_{50}s for prometryn are reported at 2900 ppb for the coldwater fish, rainbow trout (MRID 00070686), 10,000 ppb for the warmwater species, bluegill sunfish (MRID 00070686) and 5140 ppm for the marine/estuarine species, sheepshead minnow (MRID 405737-17). The LC_{50} values in these assessments qualitatively classify prometryn as moderately toxic to freshwater and estuarine/marine fish species. The rainbow trout LC_{50} is based on six nominal concentration levels ranging from 560 to 8730 ppb, a solvent (acetone) control, and negative control. The water temperature for this test varied from 12.8 to 17.2ºC, the study did not verify that the solvent control was the same concentration used in the test levels, and the outcome of the positive control (DDT) gave an LC_{50} estimate that was 10x higher than a previous study estimate. Assuming that the difference in DDT LC_{50} values may come as a result of differing methodologies, EPA acknowledged that the endpoint used may be underestimating toxicity of prometryn to freshwater fish. Despite these issues, EPA still considered the study to provide an acceptable LC_{50} for 99% a.i. prometryn. Literature searches conducted January 10, 2012 did not identify additional data on the effects of prometryn on fish survival.

The 96 hour LC_{50}s for exposures to an apparent wettable powder (W) pesticide formulation containing 80% a.i. were 7200 ppb for rainbow trout and 10,000 ppb for bluegill, but the source MRIDs for these data were not identified. Pesticide formulations include Caparol 80W, which contains 80% prometryn reflect percent a.i. LC_{50} values of 5800 ppb for rainbow trout (MRID 00121154) and 8000 ppb for bluegill (MRID 00121155). These LC_{50} values qualitatively classify Caparol 80W as moderately toxic to freshwater species. Primaze 80W, which contains 40% prometryn and 38% atrazine LC_{50}s were 9600 ppb for rainbow trout (MRID 00024738) and 21000 ppb for bluegill (MRID 00040692). These data qualitatively classify Primaze 80W as moderately toxic to rainbow trout and slightly toxic to bluegill.

Table 25 Acute toxicity of prometryn and prometryn formulations to fish.

Species	Purity	Exposure Duration	Database Toxicity Value and slope, where reported (ppb)	Database Source(s)[a]	OPP Pesticide Ecotoxicity Database Study Classification
Bluegill	99	96 hours	LC50=10000; NOEC=5600	MRID 00070686	core
	Caparol 80W	96 hours	LC50=10000; NOEC=10000	MRID TN 0387, 00121155	core
	Primaze 40/38	96 hours	LC50<21000; NOEC=21000	MRID TN 0229, 00040692	supplemental
Common Carp	Formulation	96 hours	LC50=8000 to 9000[b]	Popova 1976 ECOTOX# 7890	not coded
	99.3	35 days	LC50=2314; LOEC=1100 to 1200; NOEC=50-80	Velisek et al., 2015 ECOTOX# 174033	not coded
Fathead Minnow	99	32 days	LOEC=1390; NOEC=802	USEPA 1992 ECOTOX# 344	not coded
Goldfish	99	96 hours	LC50=4000; NOEC=560	MRID 00070686	supplemental
	Formulation	48 hours	LC50=8700	Nishiuchi and Hashimoto 1967 ECOTOX# 15192	not coded
	99	96 hours	LC50=4000; NOEL<560	USEPA 1992 ECOTOX# 344[c]	not coded
Guppy	Formulation	48 hours	LC50=8500	Tscheu-Schluter 1976	not coded
		72 hours	LC50=7000	ECOTOX# 6167	
Japanese Medaka	Formulation	48 hours	LC50=4300	Nishiuchiand Hashimoto, 1967 ECOTOX# 15192	not coded
Minnow	Formulation	96 hours	LC50=4500	Popova 1976 ECOTOX# 7890	not coded
Rainbow Trout	97	96 hours	LC50=5720; NOEC=2550	MRID 49076601	not coded
	99	96 hours	LC50=2900* (slope=3410); NOEC=560	MRID 00070686	core, used in EPA assessment
	Caparol 80W	96 hours	LC50=7200	MRID TN 0256, 00121154	core
	Primaze 40/38	96 hours	LC50=9620 (slope=11800); NOEC=6500	MRID TN 0244, 00024738	core
Sheepshead Minnow	98.1	96 hours	LC50=5100 (slope=5290); NOEC=880	MRID 40573717	
Spot	99	48 hours	LC50>1000 hatch LOEC=1200 hatch NOEC=80	MRID 40228401	supplemental
	Formulation	24 hours	NOEC=1000	Butler 1965 ECOTOX# 807	not coded
		48 hours	NOEC=1000	and ECOTOX# 14134	not coded
Western Mosquitofish	Formulation	24 hours	10000	Fabacher and Chambers 1974 ECOTOX# 946	not coded
		2-96 hours	1000 to 5000	Darwazehand Mulla 1974 ECOTOX# 6210	not coded
Zebra Danio	Formulation	5 days	LC50=900	Popova 1976	not coded
		96 hours	LC50=2300 to 3000	ECOTOX# 7890	

** Value appears in species Risk-plots within Chapter 12.*

11.4.6.3 Salmonid Growth And Fitness

Freshwater fish chronic toxicity data used in EPA Draft Risk Assessment includes only NOEC of 600 ppb and LOEC of 1200 ppb for fathead minnow (MRID 43801702). Response magnitude at the LOEC threshold was 16.7% and 17% reduced growth at dry weight and wet weight, respectively.

Table 26. Chronic toxicity data for fish exposed to prometryn.

Species	Purity	Exposure Duration	Database Toxicity Value and slope, where reported (ppb)	Database Source(s)[a]	OPP Pesticide Ecotoxicity Database Study Classification
Carassius sp.	99.3	14 to 30 days	growth NOEC=80	Velisek,J. et al., 2013	not coded
		30-60 days	histological changes, general 80	ECOTOX# 174034	not coded
		60 days	growth LOEC=8 NOEC=0.51		not coded
Common Carp	99.3	14 to 21 days	growth LOEC=4000 NOEC=1200	Velisek,J. et al., 2015 ECOTOX# 174033	not coded
		28 days	growth, specific growth rate NOEC=4000		not coded
		35 days	developmental changes, general 0.51-4000		not coded
		7 to 35 days	growth LOEC=4000 NOEC=1200 to 4000		not coded
Fathead Minnow	98.4	32 days	Early life stage LOEC=1200* NOEC=620*	MRID 43081702	core, used in EPA assessment
Goldfish	Active ingredient	96 hours	acetylcholinesterase LOEC=2500 NOEC=500 to 2500	Mosiichuk,N.M. et al., 2015 ECOTOX# 174030	not coded
Zebra Danio	Formulation	5 days	multiple effects reported as one result at 19308.35	Padilla,S. et al., 2012 ECOTOX# 161191	not coded

**Value appears in species Risk-plots within Chapter 12.*
Not coded = EPA has not classified this study (e.g. "core", "supplemental", etc.)

11.4.6.4 Salmonid Swimming, Olfaction, And Critical Biochemical Responses

Additional sublethal effects information specific to prometryn were not identified. Atrazine, a related triazine herbicide, has been reported to impact certain sublethal endpoints connected to fitness, for example endocrine, physiological, and ion-osmotic responses related to the smoltification process (Nieves-Puigdoller et al. 2007; Moore et al. 2007). However, we did not have any prometryn-specific data to support the hypothesis that similar effects would result from exposures to prometryn.

11.4.6.5 Invertebrate Prey

Prometryn is classified as slightly toxic to freshwater invertebrates, with a Daphnia magna EC50 of 18590 ppb (Table 27). It is moderately toxic to estuarine and marine invertebrates with an EC50 of 1700 ppb for mysid shrimp and >1 mg/L for eastern oyster. ECOTOX data also include a 48 hour LC50 of 9700 ppb for Daphnia magna, which is nearly half the value used in EPA assessment RQ analyses, but does not alter the risk presumption (Marchini et al. 1988).

At 1000 ppb, the *Daphnia magna* chronic lifecycle NOAEC for prometryn was substantially lower than the acute EC50 (Table 28). Chronic data for marine and estuarine species are not presented in any of the EPA assessments. ECOTOX includes NOECs for *Penaus duorarum* 1000 ppb for exposures up to 2 days and data for decreased shell deposition in Crassostrea virginica over 1000 ppb over 4 days exposure (Butler 1965). The Information indicating effects of chronic exposure to prometryn at concentrations lower than used in the EPA assessments were not found in ECOTOX for traditional laboratory test species. However, a NOAEC for population growth rate and abundance of the protozoan *Urotricha furcata* was reported at 15.2 ppb.

Table 27 Acute toxicity data for aquatic invertebrates.

Species	Purity	Exposure Duration	Database Toxicity Value and slope, where reported (ppb)	Database Source(s)[a]	OPP Pesticide Ecotoxicity Database Study Classification
Americamysis bahia	98.1	4 days	LC50=2,320 (1,700b slope=9,230); NOEC=650	MRID 40573718	core
Artemia salina	Formulation	24 hours	EC50=21,000	Gaggi et al. 1995 ECOTOX# 15077	not coded
Cloeon dipterum	Formulation	3 to 48 hours	LD50>40,000	Nishiuchi and Asano 1979 ECOTOX# 6954	not coded
Crassostrea virginica	99	96 hours	EC50>1000	MRID 40228401	supplemental
Daphnia magna	97	48 hours	EC50=14200 (slope=7460); NOEC=6940	MRID 49139003	not coded
	98.9	48 hours	EC50=18,590; NOEL<10,000	MRID 70146	core
	Active ingredient	24 hours	EC50=23,500	Marchini et al. 1988	not coded
		48 hours	EC50=9,700*	ECOTOX# 13154	Used in EPA assessment
Daphnia pulex	Formulation	3 hours	LC50>40,000	Nishiuchi and Hashimoto 1967 ECOTOX# 15192	not coded
Mercenaria mercenaria	98.1	48 hours	EC50=21,000; NOEC=16,000	MRID 40573719	core
Moina macrocopa	Formulation	3 hours	LC50>40,000	Nishiuchi and Hashimoto 1967 ECOTOX# 15192	not coded
Pacifastacus leniusculus	99.3	24 hours	LC0=9600; LC100=612500; LC50=76800	Velisek et al. 2013 ECOTOX# 167249	not coded
	99.3	48 hours	LC0=1600; LC100=184300; LC50=17000		not coded
	99.3	72 hours	LC0=1500; LC100=136200; LC50=14700		not coded
	99.3	96 hours	LC0=1400; LC100=104500; LC50=12100		not coded
Paramecium aurelia	Formulation	0.31 hours	1000000	Komala,Z., 1975	not coded
	Formulation	24 hours	10000	ECOTOX# 7969	not coded
Penaeus duorarum	99	48 hours	LC50>1000	MRID 40228401	supplemental

	Formulation	48 hours	NOEC=1000	Butler,P.A., 1965 ECOTOX# 14134	not coded
Procambarus fallax f. virginalis	99.3	53 days	LC50=40; LOEC=140; NOEC=0.51	Velisek,J. et al., 2014 ECOTOX# 174018	not coded

** Value appears in species Risk-plots within Chapter 12.*
Not coded = EPA has not classified this study (e.g. "core", "supplemental", etc.)

At 1000 ppb, the *Daphnia magna* chronic lifecycle NOAEC for prometryn was substantially lower than the acute EC50 (Table 28). Chronic data for marine and estuarine species are not presented in any of the EPA assessments. ECOTOX includes NOECs for *Penaus duorarum* 1000 ppb for exposures up to 2 days and data for decreased shell deposition in Crassostrea virginica over 1000 ppb over 4 days exposure (Butler 1965). The Information indicating effects of chronic exposure to prometryn at concentrations lower than used in the EPA assessments were not found in ECOTOX for traditional laboratory test species. However, a NOAEC for population growth rate and abundance of the protozoan *Urotricha furcata* was reported at 15.2 ppb.

Table 28 Chronic toxicity data for aquatic invertebrates.

Species	Purity	Exposure Duration	Database Toxicity Value and slope, where reported (ppb)	Database Source(s)[a]	OPP Pesticide Ecotoxicity Database Study Classification
Americamysis bahia	97.8	28 days	Life cycle LOEC=220; NOEC=110; EGGHATCH LOEC = 220000; SURVIVE LOEC = 220000	MRID 49074501	not coded
Crassostrea virginica	Formulation	96 hours	shell deposition 1000	Butler,P.A., 1965 ECOTOX# 14134, ECOTOX# 807	not coded
Daphnia magna	98.1	21 days	Life cycle LOEC=2000; NOEC=1000 (reduced length)	MRID 40573720	core used in EPA assessment
Penaeus duorarum	Formulation	24 to 48 hours	multiple effects reported as one result NOEC=1000	Butler,P.A., 1965 ECOTOX# 807	not coded
Procambarus clarkii	99.3	25 days	histological changes, general 0.51-1.44	Stara,A. et al., 2014 ECOTOX# 174021	not coded
Procambarus fallax f. virginalis	99.3	53 days	developmental changes, general 0.51-4320 dilation 0.51-4320; growth LOEC=140; NOEC=0.51	Velisek,J. et al., 2014 ECOTOX# 174018	not coded
Urotricha sp.	99.2	8 days 24 hours	abundance EC50=26.9; LOEC=30.3; NOEC=15.2; change in abundance over time EC50=26.1; LOEC=30.3; NOEC=15.2; population growth rate EC50=38.3; LOEC=30.3; NOEC=15.2; abundance EC50=26.9; LOEC=30.3; NOEC=15.2; abundance EC10=2400; EC50=4300; LOEC=4500; NOEC=2200	Liebig,M. et al., 2008 ECOTOX# 105114	not coded

Not coded = EPA has not classified this study (e.g. "core", "supplemental", etc.)

11.4.6.6 Aquatic Phytoplankton And Vascular Plants

Aquatic plant EC50s span several orders of magnitude (Table 29). Data for the effects of prometryn on all five standard aquatic plant test species indicate that prometryn is highly toxic to this species group.

Table 29 Toxicity data for aquatic plants.

Species	**Purity**	**Exposure Duration**	**Database Toxicity Value and slope, where reported (ppb)**	**Database Source(s)[a]**	**OPP Pesticide Ecotoxicity Database Study Classification**
Algae	99.2	96 hours	photosynthesis EC50=320; EC50=80	Schmitt-Jansen,M. and R. Altenburger, 2005 ECOTOX# 80430	not coded
	Active ingredient	1 hours	biomass 0.3-30000	Rotter,S. et al., 2013 ECOTOX# 174068	not coded
			diversity, evenness 0.3-30000		not coded
			photosynthesis EC50=760 to 5940		not coded
	Formulation	1 hours	photosynthesis EC50=13.03; EC50=23.17		not coded
Anabaena flos-aquae	98.4	5 days	growth EC50=40.1 (slope=3.38); NOEC=20.2	MRID 42520902	core
Anabaena variabilis	Active ingredient	48 hours	chlorophyll a concentration EC50=724.06	Hawxby,K. et al., 1977 ECOTOX# 7485	not coded
Ankistrodesmus falcatus	Formulation		change number over time) EC50=20	Tscheu-Schluter,M., 1976 ECOTOX# 6167	not coded
Chara canescens	99		1 hour chlorophyll EC50=40.06; 5 hour chlorophyll EC50=17.86; 24 hour chlorophyll EC50=17.14	Kuster,A. and R. Altenburger, 2007 ECOTOX# 103269	not coded
Chlamydomonas reinhardtii	97.3	1-6 days	chlorophyll 7500	Jin,Z.P. et al., 2012 ECOTOX# 174027	not coded
		96 hours	abundance EC50=12; LOEC=7.5; NOEC=5; chlorophyll 2.5-12.5		not coded

Chlamydomonas segnis	98.5	14 hours	population changes, general 0.75	Yee,D. et al., 1985 ECOTOX# 10626	not coded
Chlorella fusca var. vacuolata	99	24 hours	population growth rate EC01=0.41; EC50=12.5; NOEC=0.82	Faust,M. et al., 2001 ECOTOX# 62304	not coded
	99.7	24 hours	population growth rate EC50=16.65	Altenburger,R. et al., 2004 ECOTOX# 94907	not coded
	Formulation	24 hours	index to size; count, number, abundance EC50=12.26	Grote,M. et al., 2005 ECOTOX# 120653	not coded
		24 hours	population abundance EC50=15.83		not coded
Chlorella pyrenoidosa	77	96 hours	population growth rate EC50=12	Ma,J. et al., 2001 ECOTOX# 61983	not coded
	98	0.67 to 1.67 hours	photosynthesis LOEC=120.68; NOEC=12.07	Davis,D.E. et al., 1976 ECOTOX# 19633	not coded
		12 to 18 days	population growth rate LOEC=24.14; NOEC=2.41		not coded
		2 hours	photosynthesis LOEC=120.68; NOEC=12.07		not coded
		3 to 21 days	population growth rate LOEC=24.14; NOEC=2.41		not coded
	Active ingredient	24 hours	population doubling time EC50=241.35	Hawxby,K. et al., 1977 ECOTOX# 7485	not coded
	Formulation	72 hours	population changes, general 24.14-2413.54	Tubea,B. et al., 1981 ECOTOX# 14352	not coded
Chlorella vulgaris	77.13	96 hours	population growth rate EC50=53.6	Ma,J. et al., 2002 ECOTOX# 65938	not coded
	97	72 hours	population growth rate EC50=57	Shi,Y. et al., 2014 ECOTOX# 174031	not coded
Chlorococcum sp.	Active ingredient	24 hours	population doubling time EC50=724.06	Hawxby,K. et al., 1977 ECOTOX# 7485	not coded
Cryptomonas sp.	99.2	14 days	abundance EC10=37.9; EC50=100; LOEC>34.8; NOEC=34.8	Liebig,M. et al., 2008 ECOTOX# 105114	not coded
			change number over time) EC10=16.6; EC50=36.3; LOEC=23.2; NOEC=15.5		
			population growth rate EC10=56.9; EC50=194.8; LOEC>34.8; NOEC>34.8		
		6 days	abundance EC50=28.4; LOEC=30.3; NOEC=15.2		
			change number over time) LOEC=30.3; NOEC=15.2		
			population growth rate EC50=17.7; LOEC=30.3; NOEC=15.2		
		7 days	abundance EC10=18.2; EC50=31.5; LOEC=34.8; NOEC=23.2		
			change number over time) EC10=7.9; EC50=22.9; LOEC=10.3; NOEC=6.9		

			population growth rate EC10=21.6; EC50=39.3; LOEC=34.8; NOEC=23.2		
Dunaliella tertiolecta	Formulation	96 hours	population changes, general EC50=53	Gaggi,C. et al., 1995 ECOTOX# 15077	not coded
Halophila ovalis	95	24 hours	photosynthesis EC10=3.7; EC50=11	Wilkinson,A.D. et al., 2015 ECOTOX# 173418	not coded
		48 hours	photosynthesis EC10=1.6; EC50=6.7	Wilkinson,A.D. et al., 2015 ECOTOX# 173418	not coded
Lemna aequinoctialis	Formulation	8 days	abundance IC50=41.03	Grossmann,K. et al., 1992 ECOTOX# 78497	not coded
Lemna gibba	98.4	14 days	growth EC50=11.8* (slope=2.79); NOEC=3.99	MRID 42520901	core, used in EPA assessment
Lemna minor	99		chlorophyll 1 hour EC50=92.44; 5 hour EC50=22.93;24 hour EC50=20.03	Kuster,A. and R. Altenburger, 2007 ECOTOX# 103269	not coded
		24 hours	abundance EC50=37.65		not coded
	Active ingredient	6 days	population growth rate EC20=28.48; EC50=53.82; EC80=118.99	Drost,W. et al., 2003 ECOTOX# 81431	not coded
		72 hours	population growth rate EC20=35.72; EC50=69.99; EC80=98.96		not coded
Lemna perpusilla	Formulation	7 days	mortality 3000	Nishiuchi,Y., 1974 ECOTOX# 15281	not coded
		7 days	population changes, general EC50=13.03	Liu,L.C. and A. Cendeno-Maldonado, 1974 ECOTOX# 8628	not coded
Lyngbya birgei	Formulation	48 hours	population changes, general 24.14-2413.54	Tubea,B. et al., 1981 ECOTOX# 14352	not coded
Lyngbya sp.	Active ingredient	24 hours	population doubling time EC50=313.76	Hawxby,K. et al., 1977 ECOTOX# 7485	not coded
Navicula pelliculosa	98.4	5 days	abundance EC50=1*; NOEL=0.3	U.S. Environmental Protection Agency, 1992 ECOTOX# 344 [MRID 42620201 in EPA assessment]	not coded, acceptable for EPA assessment
Oscillatoria perornata	Active ingredient	5 days	abundance 2413.54	Schrader,K.K. and M.D. Harries, 2001 ECOTOX# 62248	not coded
Pseudokirchneriella subcapitata	77	96 hours	abundance EC50=11.7	Ma,J. et al., 2006 ECOTOX# 83543	not coded
	98.1	96 hours	growth EC50=12; NOEC=8	MRID 42520903	core
	Active ingredient	5 days	abundance 241.35	Schrader,K.K. and M.D. Harries, 2001 ECOTOX# 62248	not coded
	Formulation	96 hours	population changes, general EC50=21	Gaggi,C. et al., 1995 ECOTOX# 15077	not coded
Scenedesmus acutus	Formulation	24 hours	abundance IC50=45.86	Grossmann,K. et al., 1992 ECOTOX# 78497	not coded
Scenedesmus acutus var. acutus	77	96 hours	population growth rate EC50=1.65	Ma,J., 2002 ECOTOX# 65945	not coded

Scenedesmus quadricauda	77.13	96 hours	population growth rate EC50=9.7	Ma,J. et al., 2003 ECOTOX# 71458	not coded
Skeletonema costatum	98.4	5 days	abundance EC50=7.6; NOEL=2.22	U.S. Environmental Protection Agency, 1992 ECOTOX# 344	not coded
			growth EC50=7.6; NOEC=2.22	MRID 42620202	core
Spirodela polyrrhiza	Formulation	7 days	population changes, general EC50=84.47	Liu,L.C. and A. Cendeno-Maldonado, 1974 ECOTOX# 8628	not coded

** Value appears in species Risk-plots within Chapter 12.*
Not coded = EPA has not classified this study (e.g. “core”, “supplemental”, etc.)

11.4.6.7 Terrestrial (Riparian) Vegetation

Data for prometryn toxicity to terrestrial plants generally do not suggest that monocots and dicots differ in sensitivity or that the sensitivity of seedling emergence differs substantially from vegetative vigor. EC25 values ranged from 0.01 to 1.41 lb/acre.

Table 30. Non-target Terrestrial Plant Seedling Emergence and Vegetative Vigor Toxicity

Crop	Species	NOAEC (lb ai/A)	EC_{25} (lb ai/A)*	Most sensitive parameter
Seedling Emergence (MRID 41035904)				
Monocots	Oat	0.075	0.070	Dry weight
	Ryegrass	0.20	0.24	Height Percent seedlings emerged
	Corn	0.20	0.384	Dry weight
	Onion	0.038	0.098	Height
Dicot	Soybean	0.20	0.31	Dry weight
	Lettuce	0.038	0.040	Dry weight
	Carrot	1.6	0.34	Percent of seedlings emerged
	Tomato	0.20	0.16	Dry weight
	Cucumber	0.038	0.067	All
	Cabbage	0.038	0.014	Height
Vegetative Vigor (MRID 41035903)				
Monocots	Oat	0.80	1.41	Dry weight
	Ryegrass	1.6	ND	Dry weight, height, survival
	Corn	0.80	0.510	Dry weight
	Onion	0.10	0.161	Dry weight
Dicot	Soybean	0.10	0.175	Dry weight
	Lettuce	<0.013	0.010	Dry weight
	Carrot	0.80	ND	Dry weight, height, survival
	Tomato	0.10	0.058	Dry weight
	Cucumber	0.019	0.006	Height
	Cabbage	0.05	0.10	Dry weight
** Values appear in habitat Risk-plots in Chapter 15*				

11.4.6.8 Field Studies

A single aquatic field study exposing mosquitofish to prometryn applied at a rate of one to five pounds per acre reported mortality over two to four days (Darwazeh and Mulla 1974).

11.4.6.9 Field Incidents

As of our request for prometryn incident data in April of 2019, there have been no more ecological incidents since the last time the OPP Incident Data System was searched in May 1, 2017. As of April 2017, there were ten reported incidents with the use of prometryn. Among these incidents, seven were considered a registered use and three of them were undetermined. There was only one incident that did not involve terrestrial plants; there was one additional incident involving a fish kill. Prometryn was unlikely to be the cause of the kill since the other pesticides detected in the tissue of the dead fish were considered more likely to have caused the fish kill. While these incidents represent evidence of environmental exposures to prometryn, NMFS does not consider them contributing appreciably to the effects of the action.

Table 31. Incidents Reported for Prometryn

Incident ID	Year	State	Certainty	Legality	Use Site	Appl. Method	Magnitude
I004021-005 I004021-004 I004668-011	1996	LA	Unlikely	Registered Use	Cotton	Not reported	Thousands of fish
I024834-001	2012	AZ	Possible	Registered Use	Swiss Chard	Not reported	3 acres Swiss chard
I019130-056	2007	MO	Probable	Undetermined	Corn	Broadcast	86 acres corn
I007796-006 I007796-005	1998	TX	Possible	Undetermined	Cotton	Not reported	1424 acres
I009573-014	1999	TX	Probable	Registered Use	Cotton	Broadcast	70% of 68 acres corn
I016903-008	2005	TX	Possible	Registered Use	Cotton	Band	60 acres cotton
I016903-009	2005	GA	Possible	Registered Use	Cotton	Band	26 acres cotton

11.4.6.10 Bioconcentration, Bioaccumulation, And Biomagnification Of Prometryn

Prometryn residues did not accumulate to a significant degree in bluegill sunfish continuously exposed to prometryn at 0.05 ppm for 28 days in a flow through system. The maximum mean bioconcentration factors were 54x for edible tissues, 130x for non-edible tissues, and 85x for the whole fish. These values are lower than might be expected considering the high octanol/water coefficient of prometryn (log Kow = 3.46). While the study did not fully characterize unknowns, the low degree of bioconcentration of this chemical is sufficient to suggest that prometryn does not bioaccumulate in fish (MRIDs 41027701 and 40573715).

11.4.6.11 Degradate Toxicity

The Draft Risk Assessment indicated that EPA communication with the registrant through waiver requests concluded that ECOSAR was not a viable resource to predict the toxicity of hydroxypropazine, and in the absence of data for aquatic species, the degradate will be considered as toxic as the parent.

11.4.6.12 Data Gaps And Uncertainties Identified From Review Of Available Toxicity Information

No data is currently available for estuarine/marine fish and estuarine/marine invertebrates to estimate chronic toxicity. However, in the absence of data measuring chronic effects to estuarine/marine invertebrates, an acute to chronic ratio estimates toxicity. In this case, the acute-to-chronic ratio (ACR) estimate uses the acute and chronic toxicity of the freshwater invertebrates, and the acute value of estuarine/marine invertebrates to calculate a chronic value for estuarine/marine invertebrates. This gives an idea of risk, assuming the toxicity pattern for acute and chronic values is consistent between freshwater organisms and estuarine/marine organisms.

11.5 Assessing Risk

Population Models

Sufficient data were available to construct population models for four Pacific salmon life history strategies. We ran life-history matrix models for ocean-type and stream-type Chinook salmon (*O. tshawytscha*), coho salmon (*O. kisutch*), and sockeye salmon (*O. nerka*). The basic salmonid life history we modeled consisted of hatching and rearing in freshwater, smoltification in estuaries, migration to the ocean, maturation at sea, and returning to the natal freshwater stream for spawning followed shortly by death. An acute toxicity model was constructed that estimated the population-level impacts of sub-yearling juvenile mortality resulting from exposure. For specific information on the construction and parameterization of the models see Appendix A. Potential population-level impacts resulting from mortality following freshwater exposure to pesticides were integrated into the models as alterations in the first year survival rate. We also evaluated population level responses resulting from varying the proportion of the population exposed. Population level impacts were assessed as changes in the intrinsic population growth rate and quantified as the percent change in population growth rate. The results of the models are presented in Appendix A. Changes that exceeded the variability in the baseline (*i.e.*, a standard deviation) were considered to be different. Importantly, the acute toxicity models excluded sublethal and indirect effects of the pesticide exposures. For example, the potential population-level impacts of reduced prey abundance are not captured by these models.

In analyzing risk, we integrate the exposure and response information to evaluate the likelihood of adverse effects from stressors of the action at the population and species level. We use two tools to integrating exposure and response, Risk-plots and where applicable, population models. A weight-of-evidence approach which considers the limitations and uncertainties inherent in the available information is then applied to characterize risk. Whenever possible, most sensitive toxicological endpoints used in the Risk-plots are from those studies that were conducted on species with best fit as surrogates to Pacific Salmonids (e.g. rainbow trout).

The following risk hypotheses for the effects of bromoxynil and prometryn on Pacific salmonids (chum, chinook, coho, sockeye, steelhead) are based on the life history, exposure, and response considerations described in the previous sections of this chapter.

11.5.1.1 Risk Hypotheses

Salmonid:

- Exposure to the pesticide is sufficient to reduce abundance via acute lethality.
- Exposure to the pesticide is sufficient to reduce abundance via reduction in prey availability.
- Exposure to the pesticide is sufficient to reduce abundance via impacts to growth (direct toxicity).
- Exposure to the pesticide is sufficient to reduce productivity via impairments to reproduction.
- Exposure to the pesticide is sufficient to reduce abundance and productivity via impairments to ecologically significant behaviors.

Critical Habitat:

- Exposure to the stressors of the action is sufficient to reduce the conservation value via reductions in prey in migration, and rearing sites.
- Exposure to the stressors of the action is sufficient to reduce the conservation value via degradation of water quality in migration, spawning, and rearing sites.
- Exposure to the stressors of the action is sufficient to reduce the conservation value via impacts to vegetative cover in migration, spawning, and rearing sites.

Mixtures:

- Mixtures: Formulated products and tank mixtures containing the active ingredient are anticipated to increase the risk of effects to fish in freshwater habitats.

11.6 Weighing the uncertainties in the best commercial and scientific information

All estimates of exposure and response must rely on assumptions with associated uncertainties that may contribute to the possibility of overestimating or underestimating risk, or in some circumstances may do either. Uncertainties may be due to natural variability, lack of knowledge, measurement error, or model error. Accounting for uncertainty is critical when weighing model outputs and when applying outputs in risk conclusions. This section describes how we utilized a variety of tools with different assumptions to increase our confidence in risk estimates, and how we weighed key assumptions and associated uncertainties of our risk assessment to reach conclusions consistent with the purpose of Section 7(a)(2)[8]. In Table 32, we identify key assumptions associated with estimates utilized in our assessment of the effects of the action. X's indicate if the assumption contributes to the possibility that risk will be underestimated or overestimated. In some cases, the assumption may contribute to the possibility of either underestimating or overestimating risk, depending on the specific circumstances being evaluated. In succeeding paragraphs below the table we discuss how these assumptions and associated uncertainties are factored into our weight-of-evidence approach presented in the risk characterization section below.

Table 32. Assessment assumptions and influence on risk estimates

Assumption (estimate)	Underestimate Risk	Overestimate Risk
1. Pesticide application rates- Pesticides will be applied at the highest labeled rate for the use site or crop grouping (EECs)		**X**
2. Treatment of authorized use sites- Pesticides may be applied on authorized use sites (Risk-plot)		**X**
3. Annual maximal exposures– the risk calculation only considers the likelihood of exposure to maximum annual values (e.g. 24-hr EEC). It does not account for effects over the full effective range of predicted exposures (Risk-plot)	**X**	
4. GIS data layers accurately represent the presence and absence of use sites (pesticide/species overlap analysis)	**X**	**X**
5. Exposure to multiple stressors do not increase risk – The risk estimates or information do not account for other real world stressors known to exacerbate response (e.g. temperature, other pesticides, etc.) (Risk-plot)	**X**	
6. Species surrogacy – The sensitivity of endangered species and their prey to pesticide exposure is comparable to that of available surrogate species (Risk-plot)	**X**	**X**

[8] Section 7(a)(2) of the ESA requires consultation with the Services by a Federal agency to insure a Federal action authorized, funded, or carried out is not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of habitat of such a species.

Assumption (estimate)	Underestimate Risk	Overestimate Risk
7. Exposure estimates accurately predict pesticide concentrations in habitats relevant to listed species (EECs, Risk-plot)	**X**	**X**
8. Responses to pesticides that degrade over time in the environment can be accurately predicted using toxicity data generated under test conditions that maintain concentrations at relatively constant concentrations (EECs, Risk-plot, Population models).	**X**	**X**
9. Effects to essential behaviors are assumed to have fitness consequences regardless of the presence/absence of a quantitative link to an apical endpoint (mortality, reproduction, or growth).	**X**	**X**

1. Pesticide application rate assumptions tend to **overestimate** risk: Exposure estimates assumed the pesticides are applied at the highest labeled rate for a particular crop, crop grouping, or other use site. This assumption contributes to the possibility that exposure and risk will be overestimated because applications may occur at lower than maximum rates. However, EPA's proposed action encompasses all uses authorized by approved product labels, so this assumption is needed to determine whether label requirements are likely to avoid jeopardy to listed species and adverse modification to designated critical habitat and to "ensure that no potentially unsafe pesticide applications are ignored" (NRC NAS 2013).

1) Treatment of authorized use sites assumptions tend to **overestimate** risk: Treatment of authorized use sites assumptions tend to overestimate risk: Risk-plots display exposure estimates for aquatic habitats adjacent to treated uses sites. In order to evaluate the full extent of EPA's authorization of pesticide use, we assume that pesticide treatment may occur to any use site authorized by product labeling. This assumption contributes to the possibility that exposure and risk may be overestimated. However, we do not assume that usage will occur everywhere that an authorized use site exists, nor do we assume that all usage occurs at the same day and time. Instead, we consider that pesticides may be applied to any authorized use site/location during the 15-year action. This distinction, between "will be applied to every" and "may be applied to any", is important in understanding the assumptions of our analysis. When we consider the extent of authorized use sites within a species range (e.g. acres of corn), we do not make the assumption that pesticides will be applied to every acre of corn. Instead, we assume that: 1) the pesticide may be applied to any acre of corn 2) the greater the extent of corn acres in the species range equates to a greater chance that application may occur in close proximity to species habitat. Our risk characterization incorporates a number of factors to

characterize the likelihood of exposure to the concentrations predicted by modeling (e.g. spatial overlap of use sites with range of species, seasonal overlap in use and presence of species, persistence of the compound, number of applications, and the duration of the species residency in areas where treatment may occur). Uncertainties associated with each of these factors are incorporated into the confidence rankings that qualify each risk estimate. For example, we consider usage data compiled by EPA to help characterize the uncertainty associated with the spatial overlap analysis. In this way, evidence that pesticide usage within a species range are probable represent one factor considered in the confidence rankings to evaluate each risk hypothesis (see Chapter 4 for details regarding the likelihood of exposure assessment).

2. Annual maximum exposures assumptions tend to **underestimate** risk: Risk-plots display annual time-weighted average concentrations for different durations (peak 1-day, 4-day, and 21-day EECs). However, exposure to lesser concentrations (submaximal) can also contribute to risk (Figure 4). While the maximum daily peak occurs one day a year, toxic residues may persist for days, weeks, or months, depending on the frequency of repeated applications and the persistence of the pesticide. The focus on annual maximum exposures de-emphasizes the range of submaximal exposures which may also be expected to cause mortality and other adverse effects, and thus contributes to the likelihood that risk will be underestimated. Therefore, to mitigate the impact of this assumption, chemical persistence and the number of applications allowed were adopted as factors in our analysis to weigh the likelihood of exposure.

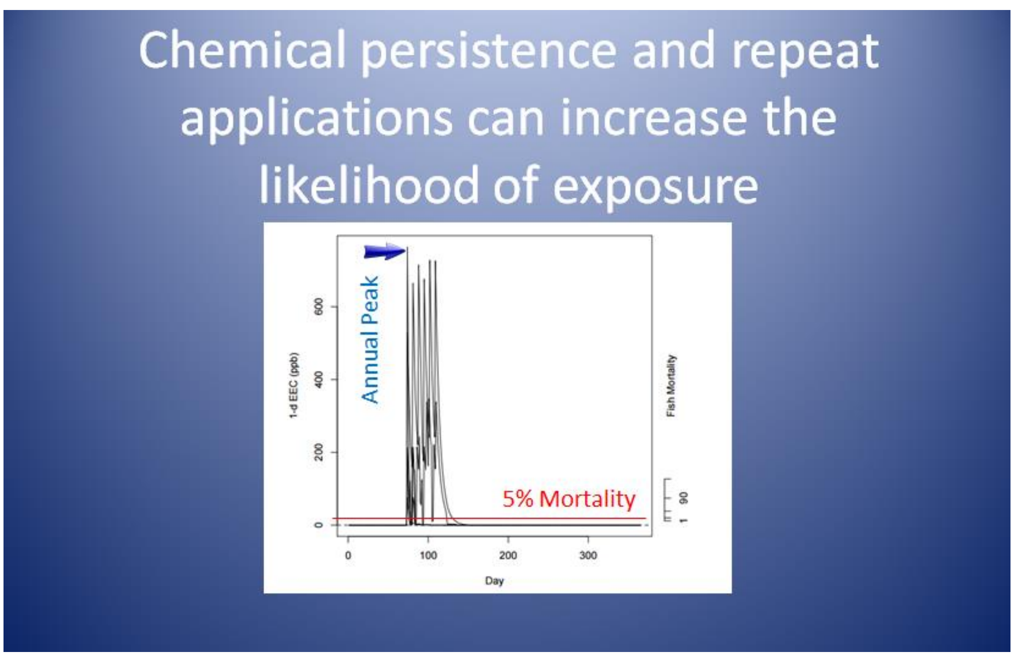

Figure 4. Conditions conducive to mortality and other adverse effects may persist for months due to the combinations of a chemical's persistence and repeat applications. The

time series plot presented here is for illustrative purposes only and does not represent bromoxynil or prometryn.

4. GIS data layer assumptions may **overestimate or underestimate** risk: Our analysis relies on GIS data layers representing land use classifications which we use as surrogates for locations where pesticides can be applied (pesticide use sites). Three issues arise that may contribute to an over- or under-estimate of risk.

    a. Accuracy of data layers. The GIS data layers contain inaccuracies, for example, local knowledge suggests that land use type is sometimes misclassified. The extent of the inaccuracies is uncertain as information quantifying the level of inaccuracy is available for only a subset of the layers relied upon. The Cropland Data Layer (CDL) has over 100 different cultivated classes which were grouped by USEPA in order to reduce the likelihood of errors of omission and commission between similar crop categories. CDL groupings were designed to minimize uncertainties, however they also introduce the possibility that overlap percentages include uses for which prometryn and/or bromoxynil have not been registered. Although we have confidence that registered use sites occur within the GIS layers, the extent and specific location of those use sites are somewhat less certain. We considered these uncertainties when evaluating the GIS layers as part of our "likelihood of exposure" analysis.

    b. The estimates of acreage of use sites within a species range presented in Risk-plots rely on an assumption that recent land use (sampling from a 6-year data set) will represent future land use over the next 15 years. This assumption is uncertain as changes in cropping patterns and other land uses may contribute to assessment inaccuracies.

    c. Data layer availability. In some cases, use sites are not well represented by existing data layers. For example, reliable data layers are not available for three bromoxynil use sites: Conservation Reserve Program (CRP) areas, fallow-land, and alfalfa. In estimating the percent overlap of these three uses with species ranges, additional information was considered (see Chapter 4, Likelihood of Exposure). However, the specific locations of these use sites were not mapped and remain highly uncertain.Overall, these different kinds of inaccuracy in GIS data would not tend to systematically over- or under-estimate risk, and we assumed these sources of uncertainty could contribute equally to the likelihood of underestimating or overestimating exposure. When data layers where not available to evaluate the presence/absence of use sites we expressed low confidence in risk estimates.

5. Assumption that exposure to multiple stressors will not increase risk may **underestimate** that risk: The risk summarized in the Risk-plots do not account for other real world stressors that may exacerbate responses to bromoxynil and prometryn (i.e. temperature, exposure to other pesticides, etc.). This assumption contributes to the likelihood that risk will be underestimated. To account for potential increases in risk associated with multiple stressors, we evaluated the available information supporting the risk hypothesis that pesticide mixtures applied as multi-a.i. formulations or tank mixtures could increase risk from direct and indirect effects for the listed species. The mixtures' risk hypotheses were evaluated qualitatively by generating exposure and response estimates for examples of multi-a.i. pesticide formulations and tank mixtures as described in the Effects of the Action below. Exposure to other stressors, including temperature stress, was evaluated in the Environmental Baseline based on the occurrence of impaired water quality due to exceedance of temperature thresholds (Clean Water Act section 303(d) listings) in the habitat of the listed species.

6. Species surrogacy assumptions may **underestimate or overestimate** risk: In most instances, the sensitivity of endangered species and their prey to the stressors of the action have not been tested; their sensitivities are assumed to be comparable to surrogate species that have been tested. These assumptions may underestimate or overestimate risk, depending on the relative sensitivity among the species. Species surrogacy represents a large source of uncertainty because sensitivities among even closely related species can span several orders of magnitude. Endpoints lacked sufficient data to construct Species Sensitivity Distributions. When more than one study was available for a particular endpoint (e.g. growth) consideration was given to both the sensitivity of response as well as the surrogacy of the test species. Relevant studies with sensitive endpoints were emphasized in order to weight the analysis in a way that errors were more likely to be protective of the listed species yet consider all of the available data.

7. Exposure estimate assumptions may **underestimate or overestimate** risk: Exposure estimates were developed for the aquatic habitat bins with the PWC model (an integration of PRZM5 and the VVWM), as described above (11.3). The accuracy of the exposure estimates depends on how well model inputs represent site-specific conditions. We generated geographically-specific EECs for a variety of aquatic habitats (bins) for all HUC2 regions within the distribution of listed Pacific salmonids. A substantial amount of variability in environmental conditions occurs at the HUC2 scale that influences exposure. Input variables were selected to represent sites vulnerable to runoff within the region as described in EPAs organophosphate BEs (EPA 2017 a, b, c). The models are designed to predict pesticide concentrations in aquatic habitats on the edge of a treated field. We expect the models to provide reasonable estimates of exposure in habitats located in close proximity to treated areas, particularly when the size of the assumed

drainage area is comparable with the size of single spray applications (e.g. smaller drainages areas such as those represented by the flowing aquatic bin 2, and the static freshwater bins 5, 6, and 7). While inputs are weighted to generate estimates at the higher end of the exposure range within the region, it's possible that exposure is underestimated for some sites (e.g. those that receive greater rainfall than assumed, or site with soil characteristics more conducive to runoff). However, overall we expect the EEC to provide reasonably accurate estimates with a tendency to overestimate exposure under most conditions. There is much greater uncertainty with regard to estimates generated for aquatic habitats represented by bin 3 and 4 with the PWC; unlike the other freshwater bin estimates which assume pesticide treatment of drainage areas consist with the size of single outdoor applications (<0.0001-600 acres), bins 3 and 4 assume drainage from much larger watersheds that would include multiple land uses, use sites, and areas where use may not be permitted (9,000-several million acres). The assumption that all of the use sites within these large watersheds are treated with pesticides tends to overestimate risk, while averaging concentrations over such large areas does not account for potential variation within the watershed and may underestimate risk when individuals are distributed in close proximity to use sites. We did not rely on EECs for bin 3 and 4 given the lack of confidence in these estimates. Even greater uncertainty exists for marine habitats where model estimates that account for complex currents and tidal exchange are not available. Consequently, we took a qualitative approach and assumed exposure in larger flowing freshwater habitats (streams and river) and marine habitats (bins 8, 9, and 10) would be something less than the concentrations predicted in runoff and in smaller streams (bin 2). Similarly, we did not rely on the prometryn EECs generated for static bins (5, 6, and 7) given a lack in confidence in these estimates. Prometryn is a persistent compound and may accumulate in the environment over time. The PWC model assumed applications occurred each year to the same location for 30 years in order to account for meteorolocial variablilty. This assumption, along with the assumption of a closed system (no inflow or outflow) tends to overestimate risk of persistent compounds due to the projected buildup which is amplified over the 30-year period. Conversely, modeling concentrations with applications over a single year would tend to underestimate risk because it would ignore accumulation that could occur. Consequently, we took a qualitative approach and assumed prometryn concentrations in static habitats (bins 5, 6, and 7) would be something less than the concentrations predicted in runoff and in smaller streams (bin 2). We consider exposures both qualitatively and quantitatively in our conclusions.

8. The assumption that field and laboratory exposure result in comparable responses may **underestimate or overestimate** risk: Standardized laboratory toxicity tests typically require that pesticide concentrations be maintained at a relatively stable concentration for the duration of the exposure period. In the natural environment, pesticides continue to

degrade and dissipate at varying rates depending on site-specific conditions and the pesticide's physical-chemical properties. The conventional approach for handling the uncertainty associated with the differing exposure patterns was assumed; exposure estimates using time-weighted average (TWA) concentrations that factor in degradation and dissipation were assumed to produce similar responses to toxicity test conducted under relatively constant exposure concentrations conducted with comparable exposure durations. TWA exposure estimated for acute durations (1d and 4d) were used to estimate responses based on acute toxicity studies and TWA estimates for chronic durations (21-d) were used to estimate responses using chronic studies. Utilizing average concentrations estimated under natural conditions can either underestimate or overestimate risk because response is a function of both exposure duration and concentration. Actual response may vary depending on site-specific dissipation pattern and toxicokinetic factors.

9. Assumptions on lack of information empirically linking effect endpoints with fitness level consequences may **underestimate or overestimate** risk: Sublethal effects to essential behaviors, such as impacts to a fish's ability to swim or a bird's ability to fly, can clearly translate to fitness level consequences by impairing an individual's ability to feed, escape predation, migrate, etc. If information is lacking to establish the degree to which impacts to a fish's ability to swim impact its ability to survive and reproduce, we can either assume the apical endpoints will not be impacted and likely underestimate the risk, or we can assume they will impact individual fitness which may overestimate risk. To ensure protection of the species, we logically infer observed impacts to a species essential behaviors (e.g. effects on the ability of salmon to feed, escape predation, migrate, home, osmoregulate, etc.) and impacts to the availability of food are capable of producing fitness level consequences regardless of the presence of empirical studies quantitatively linking these assessment measure to an apical endpoint. However, studies evaluating the potential impacts of bromoxynil and prometryn to essential behaviors were lacking. The paucity of studies evaluating ecologically relevant endpoints contributes to the uncertainty and may increase the likelihood of underestimating risk.

References for the bromoxynil ecological effects studies cited in this chapter can be found in EPA's EFED Registration Review Problem Formulation for Bromoxynil and Bromoxynil Esters as well as the Bromoxynil and Bromoxynil Esters Draft Ecological Risk Assessment for Registration Review. These documents can be found at https://www.regulations.gov/docket?D=EPA-HQ-OPP-2012-0896.

References for the prometryn ecological effects studies cited in this chapter can be found in EPA's EFED Registration Review Preliminary Problem Formulation for Prometryn as well as the Preliminary Ecological Risk Assessment in Support of the Registration Review of Prometryn. These documents can be found at https://www.regulations.gov/docket?D=EPA-HQ-OPP-2013-0032.

Other references cited can be found in Chapter 19.