UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
West Coast Region
1201 NE Lloyd Boulevard, Suite 1100
Portland, Oregon 97232-1274

https://doi.org/10.25923/he3h-6a48

Refer to NMFS No: [WCRO-2023-03583]

March 31, 2025

Becky Garnett
Manager, Standards and Assessment
U.S. Environmental Protection Agency, Region 10
1200 Sixth Avenue, Suite 155
Seattle, WA 98101

Re: Endangered Species Act Section 7(a)(2) Biological Opinion and Magnuson–Stevens Fishery Conservation and Management Act Essential Fish Habitat Response for the EPA Proposed Approval of Acrolein, Carbaryl, and Diazinon Idaho Water Quality Standards, Idaho

Dear Ms. Garnett:

Thank you for your letter dated August 15, 2024, requesting initiation of consultation with NOAA's National Marine Fisheries Service (NMFS) pursuant to section 7 of the Endangered Species Act of 1973 (ESA) (16 U.S.C. 1531 et seq.) for U.S. Environmental Protection Agency's (EPA) proposed approval of Idaho's water quality standards for acrolein, carbaryl, and diazinon. Thank you, also, for your request for consultation pursuant to the essential fish habitat (EFH) provisions in Section 305(b) of the Magnuson–Stevens Fishery Conservation and Management Act (16 U.S.C. 1855(b)) for this action.

In this biological opinion (opinion), NMFS concludes that the action, as proposed, would adversely affect but is not likely to jeopardize the continued existence of Snake River spring/summer and fall Chinook salmon (*Oncorhynchus tshawytscha*), Snake River sockeye salmon (*O. nerka*), Snake River Basin steelhead (*O. mykiss*), and Southern Resident killer whale (*Orcinus orca*). NMFS also determined the action will not destroy or adversely modify designated critical habitat for these five species. The rationale for our conclusions is provided in the attached opinion.

As required by section 7 of the ESA, NMFS provides an incidental take statement (ITS) with the opinion. The ITS describes reasonable and prudent measures (RPM) NMFS considers necessary or appropriate to minimize the impact of incidental take associated with this action. The take statement sets forth terms and conditions, including reporting requirements, that the EPA and Idaho Department of Environmental Quality (IDEQ), must comply with in order to be exempt from the ESA take prohibition.

NMFS reviewed the proposed action for potential effects on EFH pursuant to section 305(b) of the Magnuson-Stevens Fishery Conservation and Management Act (MSA), implementing regulations at 50 CFR 600.920, and agency guidance for use of the ESA consultation process to complete EFH consultation. We have concluded that the action would adversely affect EFH designated under the Pacific Salmon Fisheries Management Plan. One EFH conservation recommendation is provided, which is identical to one of the terms and conditions in the ITS.

As required by section 305(b)(4)(B) of the MSA, the EPA must provide a detailed response in writing to NMFS within 30 days after receiving an EFH conservation recommendation. Such a response must be provided at least 10 days prior to final approval of the action if the response is inconsistent with any of NMFS' EFH conservation recommendations unless NMFS and the federal agency have agreed to use alternative time frames for the federal agency response. The response must include a description of the measures proposed by the agency for avoiding, minimizing, mitigating, or otherwise offsetting the impact of the activity on EFH. In the case of a response that is inconsistent with the conservation recommendations, the federal agency must explain its reasons for not following the recommendations, including the scientific justification for any disagreements with NMFS over the anticipated effects of the action and the measures needed to avoid, minimize, mitigate, or offset such effects (50 CFR 600.920(k)(1)).

Please contact Taylor Dodrill, Contract Biologist supporting the Interior Columbia Basin Office at 301-427-7800 or at taylor.dodrill@noaa.gov, or Johnna Sandow at johnna.sandow@noaa.gov, if you have any questions concerning this consultation, or if you require additional information.

Sincerely,

Nancy L Munn

Nancy L. Munn, Ph.D.
Assistant Regional Administrator
Interior Columbia Basin Office

Enclosure

cc: A. Ramirez-Puentes
C. Cusack – USFWS
M. Lopez – NPT
C. Colter - SBT

Endangered Species Act (ESA) Section 7(a)(2) Biological Opinion and Magnuson–Stevens Fishery Conservation and Management Act Essential Fish Habitat Response

EPA Approval of Idaho Water Quality Standards for Acrolein, Carbaryl, and Diazinon

NMFS Consultation Number: WCRO-2023-03583

Action Agency: U.S. Environmental Protection Agency

Affected Species and NMFS' Determinations:

ESA-Listed Species	Status	Is Action Likely to Adversely Affect Species?	If Likely to Adversely Affect, is Action Likely to Jeopardize the Species?	Is Action Likely to Adversely Affect Critical Habitat?	If Likely to Adversely Affect, is Action Likely to Destroy or Adversely Modify Critical Habitat?
Snake River spring/summer Chinook salmon (*Oncorhynchus tshawytscha)*	Threatened	Yes	No	Yes	No
Snake River fall Chinook salmon *(O. tshawytscha)*	Threatened	Yes	No	Yes	No
Snake River Basin steelhead (*O. mykiss*)	Threatened	Yes	No	Yes	No
Snake River sockeye salmon (*O. nerka*)	Endangered	Yes	No	Yes	No
Southern Resident killer whale (*Orcinus orca*)	Endangered	Yes	No	Yes	No

Fishery Management Plan That Identifies EFH in the Project Area	Does Action Have an Adverse Effect on EFH?	Are EFH Conservation Recommendations Provided?
Pacific Coast Salmon	Yes	Yes

Consultation Conducted By: National Marine Fisheries Service, West Coast Region

Issued By: Nancy L Munn

Nancy L. Munn, Ph.D.
Assistant Regional Administrator
Interior Columbia Basin Office

Date: March 31, 2025

TABLE OF CONTENTS

TABLE OF CONTENTS .... **i**

TABLE OF TABLES .... **iv**

TABLE OF FIGURES .... **vi**

ACRONYMS .... **viii**

1. Introduction **1**

1.1. Background 1

1.2. Consultation History 1

1.3. Proposed Federal Action 3

1.3.1. Approval of Aquatic Life Criteria for Acrolein, Carbaryl, and Diazinon 3

1.3.2. Conservation Measures 5

1.4. Key Consultation Considerations 10

1.4.1. Water Quality Standard Implementation 10

1.4.2. Downstream Water Quality Standards 11

2. Endangered Species Act: Biological Opinion And Incidental Take Statement **12**

2.1. Analytical Approach 12

2.2. Rangewide Status of the Species and Critical Habitat 13

2.2.1. Rangewide Status of the Species 14

2.2.1.1. Snake River Spring/Summer Chinook Salmon 15

2.2.1.2. Snake River Fall-run Chinook Salmon 17

2.2.1.3. Snake River Sockeye Salmon 18

2.2.1.4. Snake River Basin Steelhead 19

2.2.1.5. Southern Resident killer whale 20

2.2.2. Rangewide Status of Designated Critical Habitat 23

2.2.2.1. Snake River Spring/Summer and Fall Chinook Salmon, Snake River Sockeye Salmon, and Snake River Basin Steelhead Critical Habitat 23

2.2.2.2. SRKW Critical Habitat 26

2.2.3. Climate Change Implications for ESA-listed Species and their Critical Habitat 27

2.3. Action Area 29

2.4. Environmental Baseline 31

2.4.1. Presence of ESA-listed Species and Designated Critical Habitat in the Action Area 31

2.4.1.1. Snake River Spring/Summer Chinook Salmon 32

2.4.1.2. Snake River Fall Chinook Salmon 33

2.4.1.3. Snake River Sockeye Salmon 34

2.4.1.4. Snake River Basin Steelhead 35

2.4.1.5. Southern Resident killer whale 36

2.4.2. Condition of Designated Critical Habitat in the Action Area 37
2.4.2.1. Land Cover and Human Activities 37
2.4.2.2. Water Quality 44
2.4.2.3. SRKW Critical Habitat 53
2.5. Effects of the Action 55
2.5.1. Effects of the Action on Salmonids 56
2.5.1.1. Approval of Acrolein Criteria 61
2.5.1.2. Approval of Carbaryl Criteria 69
2.5.1.3. Approval of Diazinon Criteria 83
2.5.1.4. Environmental Mixtures 100
2.5.2. Effects to Designated Critical Habitat of Anadromous Salmonids 103
2.5.2.1. Approval of Acrolein Criteria 104
2.5.2.2. Approval of Carbaryl Criteria 105
2.5.2.3. Approval of Diazinon Criteria 105
2.5.2.4. Environmental Mixtures 106
2.5.3. Effects to SRKW and Designated Critical Habitat 107
2.6. Cumulative Effects 110
2.7. Integration and Synthesis 112
2.7.1. Species 113
2.7.1.1. Snake River spring/summer Chinook salmon ESU 114
2.7.1.2. Snake River fall Chinook salmon ESU 115
2.7.1.3. Snake River sockeye salmon ESU 116
2.7.1.4. Snake River Basin steelhead DPS 118
2.7.1.5. Southern Resident killer whale DPS 119
2.7.2. Designated Critical Habitat 119
2.8. Conclusion 120
2.9. Incidental Take Statement 120
2.9.1. Amount or Extent of Take 121
2.9.2. Effect of the Take 123
2.9.3. Reasonable and Prudent Measures 123
2.9.4. Terms and Conditions 123
2.10. Conservation Recommendations 124
2.11. Reinitiation of Consultation 126
3. Magnuson–Stevens Fishery Conservation and Management Act Essential Fish Habitat Response 126
3.1. Essential Fish Habitat Affected by the Project 127
3.2. Adverse Effects on Essential Fish Habitat 127

3.3. Essential Fish Habitat Conservation Recommendations 128
3.4. Statutory Response Requirement 128
3.5. Supplemental Consultation 129
4. Data Quality Act Documentation and Pre-Dissemination Review 129
4.1. Utility 129
4.2. Integrity 129
4.3. Objectivity 129
5. References 131

TABLE OF TABLES

Table 1. Consultation History. 2

Table 2. Criteria for Protection of Aquatic Life for acrolein, carbaryl and diazinon. Excerpt from Idaho Administrative Code at IDAPA 58.01.02.210.01.a. 4

Table 3. Listing status, status of critical habitat designations and protective regulations, and relevant Federal Register decision notices for ESA-listed species considered in this opinion. 13

Table 4. Viable Salmonid Population (VSP) Risk and Viability Ratings for Snake River Spring/summer Chinook Salmon by Major Population Group and Population. 15

Table 5. Viable Salmonid Population (VSP) Risk and Viability Ratings for Snake River Basin Steelhead by Major Population Group and Population. 19

Table 6. Types of sites, essential physical and biological features (PBFs), and the species life stage each PBF supports. 23

Table 7. Geographical extent of designated critical habitat within the Snake River basin for ESA-listed salmon and steelhead. 24

Table 8. Land-use/cover composition in Idaho (USDA 2021). 38

Table 9. Proportion of land use types within habitat of salmonid species in Idaho. Where 0.0 is listed, values are much smaller than 1%, but not equal to 0%, whereas a (-) indicates no overlap with species habitat at all (USEPA 2024). 39

Table 10. NAWQA high annual estimates for carbaryl and diazinon usage (total kilograms) major crop groups in Idaho. See Wieben (2021) for estimation methods. 42

Table 11. Exposure scenarios used to estimate reductions in salmonid survival as part of the salmon translator model. Reproduced from EPA (2024). 61

Table 12. Toxicity of acrolein to salmonids. Information gathered from literature review and risk quotients calculated based on the proposed acute and chronic acrolein criteria of 3 µg/L. 65

Table 13. Summary of carbaryl chronic NOEC values calculated from the MAV and ACR for each ESA-listed fish (USEPA 2024). 76

Table 14. Summary of diazinon chronic NOEC values calculated from the MAV and ACR for each ESA-listed fish. 91

Table 15. Additive hazard indexes and interactions-adjusted hazard indexes for general acute toxicity, general chronic toxicity, and olfaction (most sensitive endpoint) for salmonids exposed to carbaryl and diazinon in environmental mixture. For comparison, OPP's thresholds of concern: acute = 0.5, chronic = 1, threatened and endangered species = 0.05. 102

TABLE OF FIGURES

Figure 1. Revised analysis of pesticide runoff vulnerability at the county level. Area of interest in red box (adapted from USEPA, 2024). Runoff vulnerability was derived using the Pesticide in Water Calculator, which considers agricultural crop scenarios with weather information to determine runoff and erosion potential. 8

Figure 2. Watershed improvement project locations in Idaho Basins (Provided by Idaho DEQ, 2023 via USEPA 2024)... 9

Figure 3. Overview of the action area for anadromous species in Idaho. 30

Figure 4. Designated critical habitat (blue lines) for: (A) Snake River spring/summer Chinook salmon; (B) Snake River fall Chinook salmon; (C) Snake River sockeye salmon; and (D) Snake River Basin Steelhead in Idaho. 32

Figure 5. Irrigation organizations in Idaho, shown in blue. 38

Figure 6. Land-use/cover classes across Idaho State (Dewitz 2021). 40

Figure 7. Cropland Data Layer across Idaho State based on USDA National Agricultural Statistics Service (USDA 2023). Land cover categories with an asterisk are most likely to be treated with carbaryl or diazinon (APHIS 2021; USEPA 2010; 2021d; Wieben 2021). These pesticides are approved to be applied to other fruits and vegetables, but were considered to contribute less to carbaryl/diazinon-treated acreage in Idaho. 41

Figure 8. E-pest high estimated carbaryl use in pounds per square mile for 2019 in the Pacific Northwest. 47

Figure 9. Idaho surface water pesticide monitoring locations for USGS-NAWQA (red points) and ISDA monitoring program (blue points). 48

Figure 10. Box and whisker summary statistics for sampled surface water concentrations (µg/L on log-scale) of carbaryl exceeding analytical detection limits (n= 53 samples). The box denotes the interquartile range, and whiskers indicate minimum and maximum values. Individual data points are overlaid. Red asterisks indicate where along the y-axis statistical outliers occur. 49

Figure 11. Surface water sampling with detectable concentrations overlaid on ESA species habitat (yellow circles = diazinon, orange circles = carbaryl, white + = pesticides below detection limits). Critical habitat (pink lines) for SR sockeye salmon, SR fall Chinook salmon, and SRB steelhead, and range (green polygons) for SR sockeye salmon, SR sp/su and fall Chinook salmon, SRB steelhead, and critical habitat for SRKW (orange polygons). Magnified panels show individual critical habitat (pink lines) and range (green polygons) for SR sockeye salmon, Chinook salmon, and SRB steelhead. 50

Figure 12. Spatial distribution of crops in Idaho that are most commonly treated with diazinon including apples, lettuce, onions, tomatoes, cherries, and potatoes. The inset shows the southern portion of Idaho, where most of these crops are grown. 52

Figure 13. E-pest high estimated diazinon use in pounds per square mile for 2017 in the Pacific Northwest. 52

Figure 14. Box and whisker summary statistics for sampled surface water concentrations (µg/L on log-scale) of diazinon exceeding analytical detection limits (n= 67 samples). The box denotes the interquartile range, and whiskers indicate minimum and maximum values. Individual data points (black) are overlaid. Red asterisks indicate where along the y-axis statistical outliers occur. 53

Figure 15. Salmonid and Sturgeon 96-hour LC_{50} values following acute exposure to carbaryl. Blue line represents the proposed acute carbaryl CMC (0.0021 mg/L). LC_{low}-based minimum effect levels are highlighted with yellow. Because of the high number of points, labels were left off for clarity and readability of the figure. Reproduced from EPA 2024. 72

Figure 16. Fish carbaryl chronic toxicity endpoints are displayed. The blue line represents the proposed carbaryl CCC (0.0021 mg/L or 2.1 µg/L). The salmonid minimum effect levels (i.e lowest NOECs) are highlighted with yellow. Points are labeled with the scientific name of the fish and the type of parameter that was measured for that endpoint. Reproduced from EPA 2024. 75

Figure 17. Salmonid and sturgeon 96-hour LC50 values following acute exposure to diazinon. Blue line represents the proposed acute diazinon CMC (0.00017 mg/L or 0.17 µg/L). LClow minimum effect levels are highlighted with yellow. 86

Figure 18. Fish diazinon chronic toxicity endpoints are displayed. The blue line represents the proposed diazinon CCC (0.00017 mg/L or 0.17 µg/L). The salmonid minimum effect levels (i.e lowest NOECs) are highlighted with yellow. Points are labeled with the scientific name of the fish and the type of parameter that was measured for that endpoint... 90

ACRONYMS

AChE	Acetylcholinesterase
ACR	Acute to Chronic Ratio
APHIS	Animal and Plant Health Inspection Service
ATP	Adenosine Triphosphate
BCF	Bioconcentration Factor
BE	Biological Evaluation
BMP	Best Management Practice
CAS	Chemical Abstract Service
CCC	Criterion Continuous Concentration
CFR	Code of Federal Regulations
CMC	Criterion Maximum Concentration
CWA	Clean Water Act
DART	Data Access in Real Time
DPS	Distinct Population Segment
DQA	Data Quality Act
EFH	Essential Fish Habitat
ESA	Endangered Species Act
ESU	Evolutionarily Significant Unit
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FR	Federal Register
GMAV	Genus Mean Acute Value
GMCV	Genus Mean Chronic Value
HAPC	Habitat Area of Particular Concern
HC5	Hazardous Concentration for 5% of Species
HI	Hazard Index
HUC	Hydrologic Unit Code
ICTRT	Interior Columbia Technical Recovery Team
IDEQ	Idaho Department of Environmental Quality
IPDES	Idaho Pollutant Dishcarge Elimination System
ISAB	Independent Scientific Advisory Board
ISDA	Idaho State Department of Agriculture
ITS	Incidental Take Statement
LCx	Lethal Concentration for x% of Test Organisms
LGD	Lower Granite Dam
LOEC	Lowest Observed Effect Concentration
MATC	Maximum Acceptable Toxicant Concentration
MEL	Minimum Effect Level
MPG	Major Population Group
MSA	Magnuson–Stevens Fishery Conservation and Management Act

NAWQA	National Water Quality Assessment
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Association
NOEC	No Observed Effect Concentration
NPDES	National Pollutant Discharge Elimination System
opinion	Biological Opinion
OP	Organophosphate
OPP	Office of Pesticide Programs
PBF	Physical or Biological Feature
PCE	Primary Constituent Element
PFMC	Pacific Fisheries Management Council
PGP	Pesticides General Permit
PIT	Passive Integrated Transponder
PLET	Pollutant Load Estimation Tool
RPA	Reasonable and Prudent Alternative
RPM	Reasonable and Prudent Measure
SMAV	Species Mean Acute Value
SMCV	Species Mean Chronic Value
Sp/su	Spring/summer
SRKW	Southern Resident Killer Whale
SR	Snake River
SRB	Snake River Basin
SSD	Species Sensitivity Distribution
TMDL	Total Maximum Daily Load
U.S.C.	U.S. Code
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
VSP	Viable Salmonid Population
WDFW	Washington Department of Fish and Wildlife
Web-ICE	Web-based Interspecies Correlation Estimation
WHO	World Health Organization
WOE	Weight of Evidence
WQS	Water Quality Standard

1. INTRODUCTION

This Introduction section provides information relevant to the other sections of this document and is incorporated by reference into Sections 2 and 3, below.

1.1. Background

National Marine Fisheries Service (NMFS) prepared the biological opinion (opinion) and incidental take statement (ITS) portions of this document in accordance with section 7(b) of the Endangered Species Act (ESA) of 1973 (16 U.S.C. 1531 et seq.), as amended, and implementing regulations at 50 CFR 402.

We also completed an essential fish habitat (EFH) consultation on the proposed action, in accordance with section 305(b)(2) of the Magnuson–Stevens Fishery Conservation and Management Act (MSA) (16 U.S.C. 1801 et seq.) and implementing regulations at 50 CFR 600.

We completed pre-dissemination review of this document using standards for utility, integrity, and objectivity in compliance with applicable guidelines issued under the Data Quality Act (DQA) (section 515 of the Treasury and General Government Appropriations Act for Fiscal Year 2001, Public Law 106-554). The document will be available within 2 weeks at the NOAA Library Institutional Repository (https://repository.library.noaa.gov/welcome). A complete record of this consultation is on file at the Interior Columbia Basin Office.

1.2. Consultation History

On May 2, 2018, the adoption of aquatic life criteria for acrolein, carbaryl, and diazinon was part of Idaho Department of Environmental Quality's (IDEQ) negotiated rulemaking (Idaho docket 58-0102-1802), which initiated after being identified as a high priority item in IDEQ's 2017 Triennial Review of Idaho Water Quality Standards (IDEQ 2017). The Idaho legislature approved the new criteria for acrolein, carbaryl and diazinon which became final and effective under state law on April 11, 2019, and is currently effective under state water quality standards (WQS) rules. The criteria are not in effect for Clean Water Act (CWA) purposes until approved by the U.S. Environmental Protection Agency (EPA).

The remaining consultation history is outlined in Table 1. As noted in this table, on August 15, 2024, the EPA requested initiation of formal consultation for Snake River (SR) spring/summer (sp/su) and fall Chinook salmon (*Oncorhynchus tshawytscha*), SR sockeye salmon (*O. nerka*), Snake River Basin (SRB) steelhead (*O. mykiss*), and designated critical habitats for SR sp/su Chinook salmon, SR fall Chinook salmon, SR sockeye salmon, SRB steelhead. In their request for initiation, the EPA made separate species and critical habitat determinations for each pesticide. For the four ESA-listed salmonids, they determined the approval of water quality standards for carbaryl and diazinon was likely to adversely affect these species and their critical habitat, and the approval of the acrolein standard was not likely to adversely affect these species and critical habitat. As explained in Section 2.5.1.1, NMFS does not concur with the not likely to adversely affect determination for acrolein. Furthermore, because NMFS considers the action as a whole (i.e., approval of all three pesticides), and approval of at least one of the three pesticides considered was found likely to adversely affect ESA-listed species or their critical habitat, formal consultation was warranted. The EPA came to a NLAA determination for Southern Resident killer whale (SRKW) (*Orcinus orca*) and its critical habitat. NMFS does not concur with the NLAA determination for SRKW and their designated critical habitat, and have included an analysis in this opinion. The EPA also requested concurrent EFH consultation for Pacific salmon [Chinook salmon and coho salmon (*O. kisutch*)]. The EPA determined that the proposed action is likely to adversely affect EFH for Idaho stocks of Chinook salmon and coho salmon.

Table 1. Consultation History.

Date	Summary of Key Events
January 21, 2022	Idaho Department of Environmental Quality (IDEQ) submitted water quality standards package to U.S. Environmental Protection Agency (EPA) for review and action under the Clean Water Act.
February 23, 2022	NMFS (National Marine Fisheries Service) confirmed list of Endangered Species Act (ESA)-listed threatened and endangered species.
March 9, 2022	IDEQ requested to be an applicant for the purposes this ESA consultation.
March 14, 2022	EPA recognized IDEQ as an applicant for this ESA consultation.
April 18, 2022	Kick-off meeting with U.S. Fish and Wildlife Service (USFWS), NMFS, and IDEQ staff. EPA provided overview of the Idaho pesticides water quality standards subject to ESA consultation, presented the ESA consultation project plan, discussed next steps, and confirmed points of contact.
July 31, 2023	Coordination meeting with USFWS, NMFS and IDEQ staff.
March 26, 2024	EPA shared a draft biological evaluation (BE) to NMFS and USFWS.
March 26 – June 4, 2024	Coordination meetings with USFWS, NMFS and EPA to discuss the draft BE, including information sufficiency requests and technical assistance.
May 24, 2024	NMFS and USFWS provided written comments on the draft BE.
June 4, 2024	EPA retrieved an updated list of USFWS ESA threatened and endangered species via the Information for Planning and Consultation (IPAC) report and confirmed that NMFS species list remains current. EPA submitted draft conservation measures to NMFS.
June 4 – July 16, 2024	Recurring meetings between EPA, USFWS and NMFS staff to discuss the proposed conservation measures. Discussions focused on updating conservation measures based on recent required label changes as part of the registration review for carbaryl under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), and bringing conservation measures into alignment with recommendations from previous ESA consultations.
July 18, 2024	EPA shared a revised BE with NMFS and USFWS.
August 6, 2024	NMFS requested that data used in the BE be included as supplemental information.
August 8, 2024	EPA provided supplemental spreadsheets to NMFS.
August 15, 2024	EPA submitted a request to initiate formal consultation with NMFS.
August 28, 2024	NMFS informed EPA by letter that their request and accompanying materials was sufficient to initiate formal consultation. NMFS indicated that August 15, 2024, serves as the consultation initiation date and provided an estimated consultation completion date of December 28, 2024.
November 25, 2024	NMFS notified EPA by email that consultation would not be completed by December 28, 2024.
January 30, 2025	NMFS provided a copy of the proposed action and terms and conditions section of the draft opinion to the EPA, the Nez Perce Tribe, and Shoshone-Bannock Tribes
February 5 – March 12, 2025	NMFS met with EPA on Februrary 5, 2025 to discuss the proposed action and terms and conditions excerpts. NMFS received comments from the Nez Perce Tribe on February 13, 2025, requesting minor additional information and clarifications. NMFS also received comments from IDEQ (applicant) on March 12, 2025, tailoring the terms and conditions to align with permit development and compliance processes.

In preparing this opinion, NMFS relied upon information from the BE (USEPA 2024) and its supporting documentation, published scientific literature, and other documents (e.g., government reports). This information provided the basis for our determinations as to whether the EPA can ensure that their proposed action is not likely to jeopardize the continued existence of ESA-listed species, and is not likely to result in the destruction or adverse modification of designated critical habitat.

Updates to the regulations governing interagency consultation (50 CFR part 402) were effective on May 6, 2024 (89 FR 24268). We are applying the updated regulations to this consultation. The 2024 regulatory changes, like those from 2019, were intended to improve and clarify the consultation process, and, with one exception from 2024 (offsetting reasonable and prudent measures), were not intended to result in changes to the Services' existing practice in implementing section 7(a)(2) of the ESA (89 FR 24268; 84 FR 45015). We have considered the prior rules and affirm that the substantive analysis and conclusions articulated in this biological opinion and incidental take statement would not have been any different under the 2019 regulations or pre-2019 regulations.

1.3. Proposed Federal Action

Under the ESA, "action" means all activities or programs of any kind authorized, funded, or carried out, in whole or in part, by federal agencies (see 50 CFR 402.02). Under the MSA, "federal action" means any action authorized, funded, or undertaken, or proposed to be authorized, funded, or undertaken by a federal agency (see 50 CFR 600.910).

1.3.1. Approval of Aquatic Life Criteria for Acrolein, Carbaryl, and Diazinon

Section 303(c) of the CWA requires states to submit new or revised WQS to EPA for review and approval or disapproval. EPA reviews these changes and approves the WQS if they meet the requirements of the CWA and EPA's implementing regulations. If the WQS do not meet the requirements of the CWA and EPA's implementing regulations, EPA disapproves the WQS. The objective of the CWA is to restore and maintain the chemical, physical, and biological integrity of the Nation's waters with an interim goal, where attainable, to achieve water quality that provides for the protection and propagation of fish, shellfish, and wildlife and recreation in and on the water by July 1, 1983 (CWA Section 101(a)(2)).

The action under consultation is the EPA's proposed approval of Idaho's new aquatic life criteria for acrolein, carbaryl and diazinon (IDAPA 58.01.02.210.01), pursuant to the EPA's authorities under the CWA §303(c) and implementing regulations at 40 CFR 131. The new criteria reflect EPA's current CWA §304(a) recommended criteria for these pollutants.[1] EPA proposes to approve the following acrolein, carbaryl and diazinon acute and chronic criteria at IDAPA 58.01.02.210.01.a. (Table 2).

[1]USEPA National Recommended Water Quality Criteria available at https://www.epa.gov/wqc/national-recommended-water-quality-criteria-aquatic-life-criteria-table

Table 2. Criteria for Protection of Aquatic Life for acrolein, carbaryl and diazinon. Excerpt from Idaho Administrative Code at IDAPA 58.01.02.210.01.a.

Criteria for Protection of Aquatic Life			
Compound	***[a]CAS Number***	***[b]CMC (µg/L)***	***[b]CCC (µg/L)***
Organic compounds			
Acrolein	107028	3	3
Carbaryl	63252	2.1	2.1
Diazinon	333415	0.17	0.17
a. Chemical Abstracts Service (CAS) registry numbers which provide a unique identification for each chemical.			
b. See definitions of Acute Criteria (CMC) and Chronic criteria (CCC), Section 010 of these rules. The unit µg/L denotes micrograms of compound per liter of water.			

In general, water quality criteria include the magnitude, duration, and frequency of a pollutant allowable (in this case, in surface waters of the state of Idaho) and are expressed in two ways. The criterion maximum concentration (CMC) is an estimate of the highest concentration of a material in ambient water to which an aquatic community can be exposed briefly (i.e., one hour) without resulting in an unacceptable adverse effect; this is the acute criterion. Acute criterion is defined in IDAPA 58.01.02.010 as:

> *…the maximum instantaneous or one (1) hour average concentration of a toxic substance or effluent which ensures adequate protection of sensitive species of aquatic organisms from acute toxicity due to exposure to the toxic substance or effluent. Acute criteria are expected to adequately protect the designated aquatic life use if not exceeded more than once every three (3) years.*

The criterion continuous concentration (CCC), or chronic criterion, is an estimate of the highest concentration of a material in ambient water to which an aquatic community can be exposed continuously without resulting in an unacceptable adverse effect. As specified in the Idaho rule the chronic criteria is defined in IDAPA 58.01.02.010 as:

> *…the four (4) day average concentration of a toxic substance or effluent which ensures adequate protection of sensitive species of aquatic organisms from chronic toxicity due to exposure to the toxic substance or effluent. Chronic criteria are expected to adequately protect the designated aquatic life use if not exceeded more than once every three (3) years.*

These criteria are in the current Idaho Administrative Code, but are not effective for CWA purposes until EPA approves them. Once approved, WQS provisions become effective for CWA purposes and are implemented in various CWA programs, including but not limited to, National Pollutant Discharge Elimination System (NPDES) permitting, monitoring and assessment, CWA Section 303(d) listing of impaired waters and issuance of total maximum daily loads (TMDL), Idaho's nonpoint source management program, and CWA Section 401 water quality certification issuance. Under the CWA, state WQS apply to surface waters within State boundaries. The action area for EPA's proposed approval of the new acrolein, carbaryl and diazinon criteria includes all waters of the United States within the state of Idaho's jurisdiction, and does not apply to waters that are within Indian Country as defined in 18 U.S.C. § 1151. Idaho was recently granted primacy to issue discharge permits and has assumed all aspects of the state-implemented program, the Idaho Pollutant Discharge Elimination System (IPDES). EPA retains authority to prepare discharge permits on Tribal reservations; for these actions, the IDEQ will issue CWA Section 401 certifications that confirm EPA-issued permits comply with the Idaho WQS.

1.3.2. Conservation Measures

The following conservation measures were identified by EPA as being an integral part of the proposed action. These measures will be taken by EPA and IDEQ and serve to minimize or compensate for potential effects, and promote the recovery of listed species.

Section 3 of the FIFRA authorizes EPA to register new pesticide products and new uses of existing pesticide products for use in the United States (USEPA 2004). Under FIFRA, EPA reviews each registered pesticide at least every 15 years to ensure that each pesticide can carry out its intended functions without creating unreasonable adverse effects to human health and the environment. When pesticides are reevaluated, EPA evaluates extensive environmental fate and toxicity data to determine the likelihood that exposure to one or more pesticides may cause adverse ecological effects, including harmful effects to aquatic life, wildlife, and vegetation. EPA’s ecological risk assessment and regulatory process for pesticides evaluates nontarget species, which include federally-listed species (USEPA 2004).

The EPA has certain ESA obligations for actions under FIFRA, which include evaluating pesticides’ potential effects on listed species (previous opinions for FIFRA registrations of carbaryl and diazinon are discussed further in Section 2.5.1). In January 2022, the Agency committed to fully complying with the ESA before registering any new conventional pesticides. In November 2022, the Agency released an updated workplan (USEPA 2022b) describing strategies to incorporate protections for ESA-listed species earlier in the FIFRA registration process.

As an initial step to accomplish these ESA-oriented goals, EPA has developed a series of FIFRA Interim Ecological Mitigation Measures for conventional and biological pesticides used on agricultural crops that include, but are not limited to (USEPA 2022b):

- Surface water protection statements users would follow when precipitation occurs or is forecasted to reduce ecological risk from movement of pesticides off the field through runoff or erosion;
- Conservation buffers and other conservation measures to reduce ecological risk from movement of pesticides off the field through runoff or erosion;
- Droplet size, windspeed, and release height limits to reduce ecological risks from spray drift;
- Spray drift buffers from aquatic habitats and conservation areas.

These measures are intended to provide early ecological mitigation options to reduce exposure to nontarget species, including listed species, based on the fate and transport characteristics of the chemical, as well as ensuring that pesticides with similar exposure pathway uses, and ecological risk profiles are treated comparably under FIFRA. EPA's expectation is to raise the baseline for ecological mitigation measures and ensure that the ecological risks and mitigation measures are managed consistently across pesticides. For each chemical undergoing registration review that presents ecological risks, the EPA will consider which mitigation measures to incorporate. These mitigation measures for acrolein, carbaryl, and diazinon are discussed below. In our subsequent analyses, these measures are assumed to be implemented as part of the proposed action.

As part of the acrolein proposed interim registration review (USEPA 2024a), the EPA has proposed label changes and incorporates other mitigation measures to reduce effects on nontarget species. Some of the proposed mitigation measures include reducing the number of applications per year from 8 to 6, reduction of maximum application rate from 15 ppm to 8 ppm, requiring updated signage to be posted around application equipment, and public notification for all applications through multiple channels (USEPA 2024a). As part of the public comment period for the proposed interim decision, EPA made a request to the general public for the submission of information on nontarget species and water management practices in irrigation canals. According to current label requirements, water treated with acrolein must be used for irrigation of fields where the treated water remains on the field or held for six days before being released into fish-bearing waters.

Carbaryl was selected as one of the chemicals for the early ESA mitigation pilots to incorporate early mitigation measures into registration review decisions. EPA released the draft risk assessment in 2021 (USEPA 2021e), this assessment identified potential concern to terrestrial species as well as fish and aquatic invertebrates on an acute and chronic basis. On February 27, 2024, EPA sent a letter to the carbaryl registrants outlining the necessary label changes, which include proposed mandatory spray drift language that prohibits application within 25 feet of aquatic habitats for ground liquid applications, 150 feet for aerial applications, obtainment of any applicable ESA bulletins six months prior to application, specific application changes for certain crops, water protection statements, restriction of application during rain or when the soil is saturated, among other changes (USEPA 2024b).

EPA is working to implement the NMFS biological opinion on malathion, chlorpyrifos and diazinon (NMFS 2022a), which was developed in response to a reinitiated formal consultation for these three pesticides requested by EPA (USEPA 2022b). Some of the reasonable and prudent measures (RPMs) included in the opinion mention amendments to the labeling of products containing diazinon and to not apply this product within 300 m of ESA-listed species habitat when soil is saturated or a storm is forecasted, and wind speeds exceed 10 or 15 mph when applying the product and tank mixing at certain application rates (NMFS 2022a). EPA released the required label changes (USEPA 2008a) in February 2024, which include prohibition of aerial applications, obtainment of any applicable ESA bulletins (USEPA 2024b) six months prior to application, language that prohibits application within 25 feet of aquatic habitats, and restriction of application of 65 feet away from aquatic habitat for applications with rates over 1.5 lbs/acre when wind is blowing toward the aquatic habitats, among others. EPA expects to issue the proposed interim decision for diazinon in fiscal year 2026 (USEPA 2023a).

As of June 5, 2018, IDEQ was approved by the EPA to administer the Idaho Pollutant Discharge Elimination System (IPDES) permitting program for dischargers to Idaho waters (IDEQ 2019).

EPA retains the authority to issue federal permits for point source discharges into Tribal waters or located on Tribal lands. Currently, IDEQ is working on reissuance of the draft Pesticides General Permit (PGP), a draft of which was issued on December 10, 2024. Until the IDEQ PGP is finalized, the 2016 PGP originally issued by EPA remains in effect (USEPA 2016a). The PGP applies to discharges to waters of the United States resulting from the application of biological or chemical pesticides that leave a residue, when the application is for mosquito and other flying insect, weed and algae, animal, and/or forest canopy pest control.

Conditions of the 2016 PGP may minimize adverse effects to threatened and endangered species. Operators must submit a Notice of Intent at least 30 days prior to application to obtain coverage to discharge to any waters of the United States containing NMFS listed Resources of Concern, except for those discharges in response to a Declared Pest Emergency Situation. Coverage under the 2016 PGP is available only for discharges and related activities that are not likely to adversely affect species that are federally-listed as endangered or threatened ("listed") under the ESA or habitat that is federally-designated as critical under the ESA ("critical habitat"). The PGP coverage does not include agricultural stormwater discharges and/or return flows from irrigated agriculture. The PGP only covers acrolein, not carbaryl or diazinon discharges.

The existing framework for EPA's oversight of the IPDES program and permits will also support minimizing adverse effects to threatened and endangered species. To ensure the integrity of state programs, EPA retains oversight authority over state-implemented NPDES programs under section 402(d) of the CWA, 33 U.S.C. section 1342(d) and retains authority to enforce permits. In this oversight role, EPA regularly reviews the IPDES program to ensure it is consistent with the CWA, federal regulations, applicable terms, and conditions established during water quality standards consultations with the Services, and the authority delegated to Idaho. The EPA's oversight activities (USEPA 2024c, d, e) include review and comment of certain draft permits, on an on-going basis, and in-depth assessments of the IPDES program through the Permit Quality Review and State Review Framework processes every five years. The permittee must take the necessary reasonable steps to minimize or prevent violation of the permit that has a reasonable likelihood of adversely affecting human health or the environment. As stated under 40 CFR 124.10(c)(1)(iv), a notice and draft copy of the IPDES permit being issued should be given to NMFS and USFWS, among other agencies. The public comment process allows the Services to raise concerns regarding potential adverse effects to listed species in the action area being permitted.

Since carbaryl and diazinon are not directly applied into the water, their applications are most likely to enter waterbodies through nonpoint sources such as runoff and erosion. The EPA *National Management Measures to Control Nonpoint Pollution from Agriculture* (USEPA 2023b) suggests that most pesticides enter surface waters through runoff from agricultural and urban areas. According to EPA's Draft Herbicide Strategy, all of the counties in Idaho are between medium and very low runoff vulnerability (Figure 1; USEPA 2024f). Common agricultural best management practices (BMP), such as grassed buffers at field edge, riparian buffer strips, and constructed wetlands as well as Idaho's low runoff vulnerability may help to reduce transport of pesticides from upland cropland to surface waters (Reichenberger 2007).

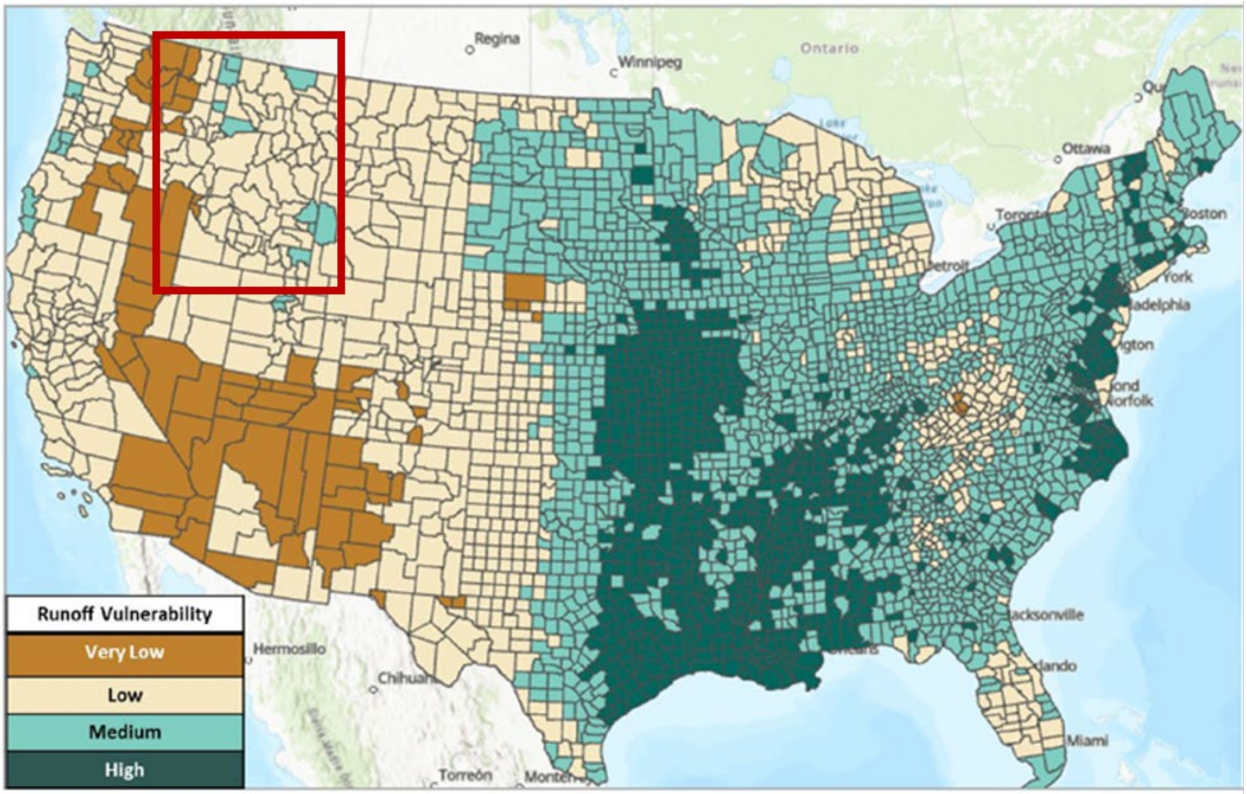

Figure 1. Revised analysis of pesticide runoff vulnerability at the county level. Area of interest in red box (adapted from USEPA, 2024). Runoff vulnerability was derived using the Pesticide in Water Calculator, which considers agricultural crop scenarios with weather information to determine runoff and erosion potential.

The state of Idaho currently has several watershed improvement projects in place to control agricultural runoff (Figure 2) and may address certain pollutants such as pesticides.

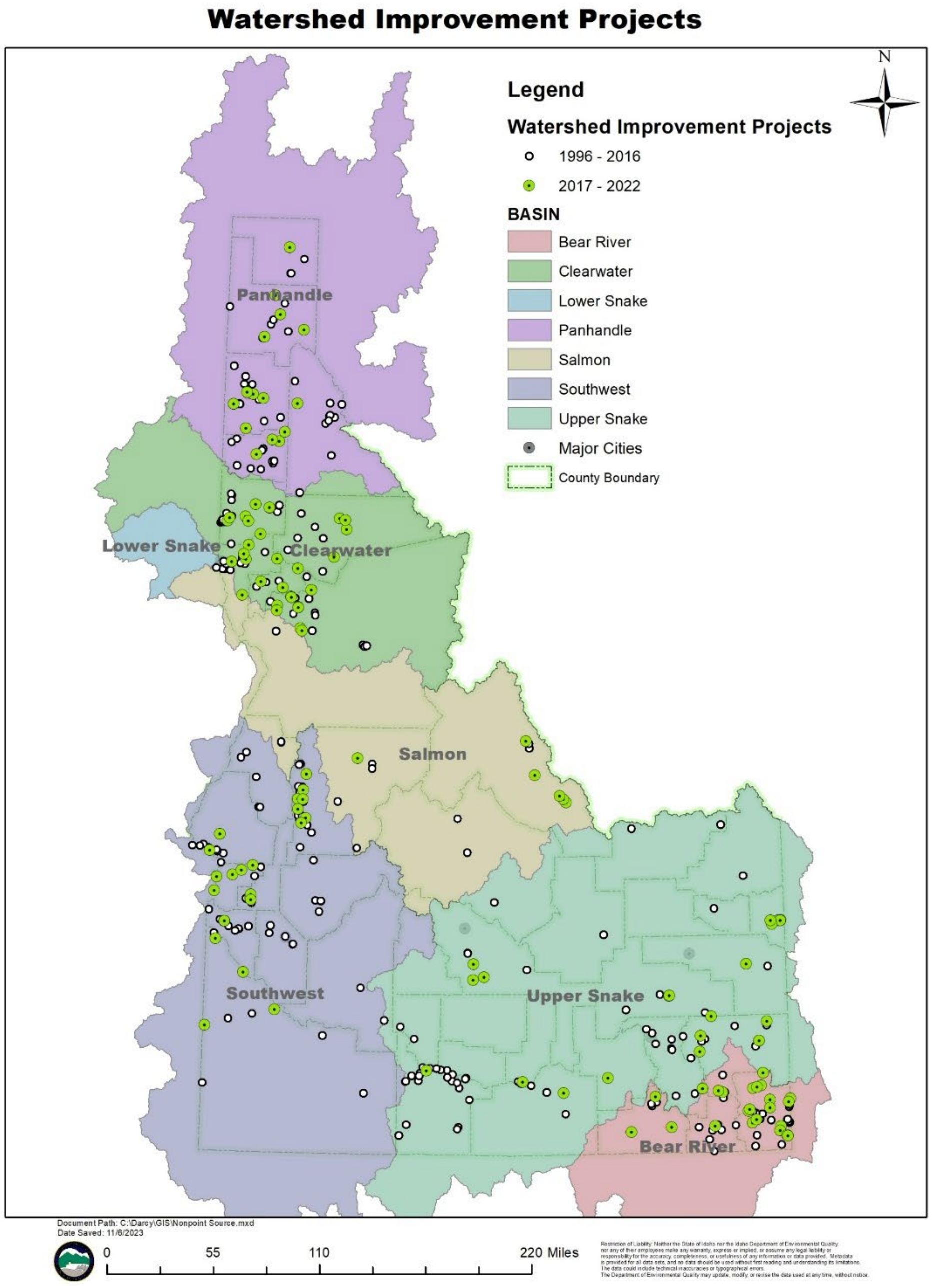

Figure 2. Watershed improvement project locations in Idaho Basins (Provided by Idaho DEQ, 2023 via USEPA 2024).

These projects are federally and state funded and aim to reduce sediment, phosphorus, nitrogen, and biological oxygen demand loads in the watersheds. Using the Pollutant Load Estimation Tool (PLET) and other calculation methods (USEPA 2024, Appendix F), IDEQ is able to calculate pollutant load reduction that would occur from implementing range of conservation practices, this tool provides an estimate on the measures' efficacy in preventing runoff. The PLET load reduction estimations are applied in Idaho most frequently to:

- Cropland
- Conservation tillage

- Cover crops
- Nutrient management
- Diversion and irrigation management
- Critical area planting
- Filter strips and vegetated buffers

The reissuance of the PGP by IDEQ will maintain the regulation of point applications of pesticides for weed and algae control, including acrolein, into the State's irrigation canals and/or waterbodies. The efforts currently in place to reduce pollutant loads entering surface waters, which include irrigation conversion and road resurfacing methods will support the reduction of other pollutant loads as a product of runoff and/or erosion. The measures being adopted by EPA under FIFRA to meet the Agency's mission of protecting human health and the environment while supporting responsible use of pesticides will also serve to reduce pesticide contamination in Idaho's surface waters (USEPA 2022b).

1.4. Key Consultation Considerations

1.4.1. Water Quality Standard Implementation

Since currently there are no CWA effective WQS for acrolein, carbaryl, and diazinon in Idaho, there are currently no impaired waterbodies, and consequently, no active TMDLs applicable under the CWA for these three pesticides in the state of Idaho. Following the EPA's approval of these criteria, surface water monitoring may be conducted. If the monitoring data indicates an exceedance of the CWA effective water quality standards, then data could be used to determine impairment decisions and, subsequently, development and implementation of TMDLs. On June 5, 2018, IDEQ was approved by EPA to administer its own NPDES permitting program for state-issued permits, however, the EPA retains the authority to issue permits for any facilities discharging into Tribal water or located on Tribal lands.

There is currently one IPDES permit for carbaryl. IDEQ issued an individual permit (Permit No. ID0027901) that became effective on October 1, 2021, for a fruit processing facility. The permit requires the permittee to monitor the effluent for the potential presence of carbaryl, along with other active ingredients from pesticides used by growers, to determine applicable criteria for the next permit reissuance. However, there are no effluent limits for carbaryl or other monitored pollutants. Based on the Enforcement and Compliance History Online Facility Report (queried 2/29/2024) and data report provided by IDEQ (2024), the facility has not reported any carbaryl detections since the permit's effectiveness date. Other IPDES permits might be issued in the future for other facilities that might encounter any of these three pesticides on the products being processed at the different facilities. Acrolein is managed under the 2016 PGP, which requires operators to submit a notice of intent 30 days prior to use of products containing acrolein.

There are currently no IPDES permits for diazinon or acrolein. It is likely that the vast majority of carbaryl and diazinon applications are for agricultural purposes, and are therefore not regulated as point sources. Therefore, nonpoint source management and environmental monitoring of these pesticides would be effective tools for ensuring the proposed pesticide criteria are met and water bodies are supporting designated uses (i.e., specific uses identified for each water body through state and tribal cooperation, such as support of salmonid fishes, drinking water supplies, maintenance of aquatic life, consumption of fish, recreational contact with water, and agriculture). However, pesticide monitoring in Idaho is limited, as described below.

The Idaho State Department of Agriculture (ISDA) is the regulatory agency for the registration, sale, distribution, use, storage, and disposal of pesticides under the authority of Idaho state laws and rules governing pesticides as part of a cooperative agreement between ISDA and EPA. As part of its fulfillment under the CWA and state requirements to monitor surface water for pesticides, ISDA operated an Agricultural Water Quality Program that included pesticide monitoring for surface water. Some of the program's overall objectives included: filling data gaps related to characterizing water quality associated with agriculture/rangelands, characterizing pesticide sources, and providing scientific data for efficient BMP implementation based on applicable BMPs discussed in Idaho's Agricultural Pollution Abatement Plan. Monitoring data collected as part of this program has historically been submitted to IDEQ. At this time and to the EPA's knowledge, ISDA's Water Quality Monitoring Program for pesticides has been discontinued. The data from this program collected between 2014 and 2019 is discussed in the BE. The United States Geological Survey (USGS) has also monitored for pesticides in the past through the National Water Quality Assessment (NAWQA), but has also discontinued this monitoring since 2019.

1.4.2. Downstream Water Quality Standards

The federal regulation at 40 CFR 131.10(b) requires that, when designating uses and developing water quality criteria to protect those uses, states shall consider "the water quality standards of downstream waters and shall ensure that its water quality standards provide for the attainment and maintenance of the water quality standards of downstream waters." In other words, states must consider and ensure the attainment and maintenance of downstream water quality standards during the establishment of designated uses and water quality criteria in upstream waters. The Idaho WQS include a narrative downstream protection provision (IDAPA 58.01.02.70.08):

> *Protection of Downstream Water Quality. All waters shall maintain a level of water quality at their pour point into downstream waters that provides for the attainment and maintenance of the water quality standards of those downstream waters, including waters of another state or tribe.*

Currently, there are no criteria in place for acrolein, carbaryl, or diazinon for the Nez Perce Reservation. Both Oregon and Washington recently adopted the same criteria for acrolein, carbaryl, and diazinon, as proposed in this action. As previously stated, these criteria are not yet applicable for CWA purposes until they are approved by EPA. Considering the downstream protection provision in the Idaho WQS, EPA and NMFS assume that the Idaho WQS will be implemented in a manner that ensures these identical downstream water quality criteria will be met. Given this provision, we expect any effects downstream of Idaho borders would be marginal and spatially limited in scope.

We considered, under the ESA, whether or not the proposed action would cause any other activities and determined that it would not.

2. Endangered Species Act: Biological Opinion And Incidental Take Statement

The ESA establishes a national program for conserving threatened and endangered species of fish, wildlife, plants, and the habitat upon which they depend. As required by section 7(a)(2) of the ESA, each Federal agency must ensure that its actions are not likely to jeopardize the continued existence of endangered or threatened species, or adversely modify or destroy their designated critical habitat. Per the requirements of the ESA, Federal action agencies consult with NMFS and section 7(b)(3) requires that, at the conclusion of consultation, NMFS provide an opinion stating how the agency's actions would affect listed species and their critical habitats. If incidental take is reasonably certain to occur, section 7(b)(4) requires NMFS to provide an ITS that specifies the impact of any incidental taking and includes reasonable and prudent measures (RPMs) and terms and conditions to minimize such impacts.

2.1. Analytical Approach

This opinion includes both a jeopardy analysis and an adverse modification analysis. The jeopardy analysis relies upon the regulatory definition of "jeopardize the continued existence of" a listed species, which is "to engage in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species" (50 CFR 402.02). Therefore, the jeopardy analysis considers both survival and recovery of the species.

This opinion also relies on the regulatory definition of "destruction or adverse modification," which "means a direct or indirect alteration that appreciably diminishes the value of critical habitat as a whole for the conservation of a listed species" (50 CFR 402.02).

The designations of critical habitat for ESA-listed salmonids use the term primary constituent element (PCE) or essential features. The 2016 final rule (81 FR 7414; February 11, 2016) that revised the critical habitat regulations (50 CFR 424.12) replaced these terms with physical or biological features (PBFs). The shift in terminology does not change the approach used in conducting a "destruction or adverse modification" analysis, which is the same regardless of whether the original designation identified PCEs, PBFs, or essential features. In this opinion, we use the term PBF to mean PCE or essential feature, as appropriate for the specific critical habitat.

The ESA Section 7 implementing regulations define effects of the action using the term "consequences" (50 CFR 402.02). As explained in the preamble to the final rule revising the definition and adding this term (84 FR 44976, 44977; August 27, 2019), that revision does not change the scope of our analysis, and in this opinion, we use the terms "effects" and "consequences" interchangeably.

We use the following approach to determine whether a proposed action is likely to jeopardize listed species or destroy or adversely modify critical habitat:

- Evaluate the rangewide status of the species and critical habitat expected to be adversely affected by the proposed action.
- Evaluate the environmental baseline of the species and critical habitat.
- Evaluate the effects of the proposed action on species and their critical habitat using an exposure–response approach. The degree to which a threatened or endangered species is affected will depend on a host of factors including the proportion of individuals exposed, the duration of exposure, when they are exposed during their life cycle, and if they are exposed more than once.
- Evaluate cumulative effects.
- In the integration and synthesis, add the effects of the action and cumulative effects to the environmental baseline, and, in light of the status of the species and critical habitat, analyze whether the proposed action is likely to: (1) directly or indirectly reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species; or (2) directly or indirectly result in an alteration that appreciably diminishes the value of critical habitat as a whole for the conservation of a listed species.
- If necessary, suggest a reasonable and prudent alternative (RPA) to the proposed action.

The analytical approach to analyzing effects of the action on the ESA-listed salmonids in Idaho and SRKW is covered in greater detail in section 2.5 below. There are limitations to the analysis presented in this opinion, as data regarding effects of pesticides on salmonids, particularly acrolein, are limited. Where this is the case, we describe the uncertainties associated with our analysis, and explain the basis for any assumptions made.

2.2. Rangewide Status of the Species and Critical Habitat

This opinion examines the status of each species that would be adversely affected by the proposed action. The status is determined by the level of extinction risk that the listed species face, based on parameters considered in documents such as recovery plans, status reviews, and listing decisions. This informs the description of the species' likelihood of both survival and recovery. The species status section also helps to inform the description of the species' "reproduction, numbers, or distribution" for the jeopardy analysis. The opinion also examines the condition of critical habitat throughout the designated area, evaluates the conservation value of the various watersheds and coastal and marine environments that make up the designated area, and discusses the function of the PBFs that are essential for the conservation of the species. The Federal Register notices and notice dates for the species and critical habitat listings considered in this opinion are included in Table 3.

Table 3. Listing status, status of critical habitat designations and protective regulations, and relevant Federal Register decision notices for ESA-listed species considered in this opinion.

Species	Listing Status	Critical Habitat	Protective Regulations
Chinook salmon (*Oncorhynchus tshawytscha*)			
Snake River spring/summer-run	T 4/22/92; 57 FR 14653[1]	12/28/93; 58 FR 68543[2]	6/28/05; 70 FR 37160
Snake River fall-run	T 4/22/92; 57 FR 14653	12/28/93; 58 FR 68543	6/28/05; 70 FR 37160

Species	Listing Status	Critical Habitat	Protective Regulations
Sockeye salmon *(O. nerka)*			
Snake River	E 11/20/91; 56 FR 58619	12/28/93; 58 FR 68543	ESA section 9 applies
Steelhead (*O. mykiss*)			
Snake River Basin	T 8/18/97; 62 FR 43937	9/02/05; 70 FR 52630	6/28/05; 70 FR 37160
Killer whale (*Orcinus orca*)			
Southern Resident	E 11/18/05; 70 FR 69903	8/02/21; 86 FR 41668	5/16/11; 76 FR 20870, ESA section 9, MMPA section 101 & 102 apply

Note: Listing status 'T' means listed as threatened under the ESA; 'E' means listed as endangered.
[1]The listing status for Snake River spring/summer Chinook salmon was corrected on 6/3/92 (57 FR 23458).
[2]Critical habitat for Snake River spring/summer Chinook salmon was revised on 10/25/99 (64 FR 57399).

2.2.1. Rangewide Status of the Species

This section describes the present condition of the SR sp/su Chinook salmon, SR fall Chinook salmon, and SR sockeye salmon evolutionarily significant units (ESUs), the SRB steelhead distinct population segment (DPS), and the SRKW DPS. NMFS expresses the status of a salmonid ESU or DPS in terms of likelihood of persistence over 100 years (or risk of extinction over 100 years). NMFS uses McElhany et al.'s (2000) description of a viable salmonid population (VSP) that defines "viable" as less than a 5% risk of extinction within 100 years and "highly viable" as less than a 1% risk of extinction within 100 years. A third category, "maintained," represents a less than 25% risk within 100 years (moderate risk of extinction). To be considered viable, an ESU or DPS should have multiple viable populations so that a single catastrophic event is less likely to cause the ESU/DPS to become extinct, and so that the ESU/DPS may function as a metapopulation that can sustain population-level extinction and recolonization processes (ICTRT 2007). The risk level of the ESU/DPS is built up from the aggregate risk levels of the individual populations and major population groups (MPGs) that make up the ESU/DPS. For non-salmonid species, such as the SRKW, we apply these same principles and approach to describe their viability, referring to these attributes as "viable population" criteria.

Attributes associated with a VSP are: (1) abundance (number of adult spawners in natural production areas); (2) productivity (adult progeny per parent); (3) spatial structure; and (4) diversity. A VSP needs sufficient levels of these four population attributes in order to: safeguard the genetic diversity of the listed ESU or DPS; enhance its capacity to adapt to various environmental conditions; and allow it to become self-sustaining in the natural environment (ICTRT 2007). These viability attributes are influenced by survival, behavior, and experiences throughout the entire salmonid life cycle, characteristics that are influenced in turn by habitat and other environmental and anthropogenic conditions. The present risk faced by the ESU/DPS informs NMFS' determination of whether additional risk will appreciably reduce the likelihood that the ESU/DPS will survive or recover in the wild.

The following sections summarize the status and available information on the species and designated critical habitats considered in this opinion based on the detailed information provided by the:

- ESA Recovery Plan for Snake River Spring/Summer Chinook Salmon & Snake River Basin Steelhead (NMFS 2017a);
- ESA Recovery Plan for Snake River Fall Chinook Salmon (NMFS 2017b);
- ESA Recovery Plan for Snake River Sockeye Salmon (NMFS 2015);
- Biological Viability Assessment Update for Pacific Salmon and Steelhead Listed Under the Endangered Species Act: Pacific Northwest (Ford 2022);
- 2022 5-Year Review: Summary & Evaluation of Snake River Spring/Summer Chinook Salmon (NMFS 2022b);
- 2022 5-Year Review: Summary & Evaluation of Snake River Fall Chinook Salmon (NMFS 2022c);
- 2022 5-Year Review: Summary & Evaluation of Snake River Sockeye Salmon (NMFS 2022d);
- 2022 5-Year Review: Summary & Evaluation of Snake River Basin Steelhead (NMFS 2022e);
- 2021 Southern Resident Killer Whales (*Orcinus orca*) 5-Year Review: Summary and Evaluation (NMFS 2021a); and
- Recovery Plan for Southern Resident Killer Whales (*Orcinus orca*) (NMFS 2008b).

These documents are incorporated by reference here. Additional information that has become available since these documents were published is also summarized in the following sections and contributes to the best scientific and commercial data available.

2.2.1.1. Snake River Spring/Summer Chinook Salmon

The SR sp/su Chinook salmon ESU, listed as threatened on April 22, 1992 (57 FR 14653), includes all naturally spawning populations of sp/su Chinook salmon in the Snake River (below Hells Canyon Dam) and in the Tucannon River, Grande Ronde River, Imnaha River, and Salmon River subbasins. The ESU also includes progeny of thirteen artificial propagation programs (85 FR 81822). Fish from all but one population (Tucannon River) in the ESU occupy waters within or forming the Idaho state border (i.e., Snake River) and may be affected by the proposed action. The current viability and proposed recovery goals for SR sp/su Chinook salmon populations are included in Table 4.

Table 4. Viable Salmonid Population (VSP) Risk and Viability Ratings for Snake River Spring/summer Chinook Salmon by Major Population Group and Population.

Major Population Group	**Population**	**VSP Risk Rating[1]**		**Viability Rating**	
		Abundance/ Productivity	**Spatial Structure/ Diversity**	**2022 Assessment**	**Proposed Recovery Goal[2]**
South Fork Salmon River	Little Salmon River (R.)	*Insuf. data*	Low	High Risk	Maintained
	South Fork Salmon River (SFSR) Mainstem	High	Moderate	High Risk	Viable
	Secesh R.	High	Low	High Risk	Highly Viable
	East Fork SFSR	High	Low	High Risk	Maintained
	Chamberlain Creek (Ck.)	High	Low	High Risk	Viable

Major Population Group	Population	VSP Risk Rating[1]		Viability Rating	
		Abundance/ Productivity	Spatial Structure/ Diversity	2022 Assessment	Proposed Recovery Goal[2]
Middle Fork Salmon River	Middle Fork Salmon River (MFSR) below Indian Ck.	High	Moderate	High Risk	Maintained
	Big Ck.	High	Moderate	High Risk	Maintained
	Camas Ck.	High	Moderate	High Risk	Maintained
	Loon Ck.	*Insuf. Data*	Moderate	High Risk	Viable
	MFSR above Indian Ck.	High	Moderate	High Risk	Maintained
	Sulphur Ck.	High	Moderate	High Risk	Maintained
	Bear Valley Ck.	Moderate	Low	Maintained	Viable
	Marsh Ck.	Moderate	Low	Maintained	Viable
Upper Salmon River	North Fork (Fk.) Salmon R.	*Insuf. Data*	Low	High Risk	Maintained
	Lemhi R.	High	High	High Risk	Viable
	Salmon R. Lower Mainstem	High	Low	High Risk	Maintained
	Pahsimeroi R.	High	High	High Risk	Viable
	East Fk. Salmon R.	High	High	High Risk	Viable
	Yankee Fk. Salmon R.	High	High	High Risk	Maintained
	Valley Ck.	High	Moderate	High Risk	Viable
	Salmon R. Upper Mainstem	High	Low	High Risk	Highly Viable
	Panther Ck.	*Insuf. Data*	-	-	Reintroduction
Lower Snake R.	Asotin Cr.			*Extirpated*	*Consider Reintroduction*
	Tucannon R.[3]	High	Moderate	High Risk	Highly Viable
Grande Ronde and Imnaha Rivers[3]	Wenaha R.	High	Moderate	High Risk	Viable[4]
	Lostine/Wallowa R.	High	Moderate	High Risk	Viable[4]
	Minam R.	Moderate	Moderate	Maintained	Viable[4]
	Catherine Ck.	High	Moderate	High Risk	Viable[4]
	Upper Grande Ronde R.	High	High	High Risk	Maintained
	Imnaha R.	High	Moderate	High Risk	Viable[4]
	Lookingglass Ck.			*Extirpated*	Consider Reintroduction
	Big Sheep Ck.			*Extirpated*	Consider Reintroduction

1Risk ratings are defined based on the risk of extinction within 100 years: High = greater than or equal to 25%; Moderate = less than 25%; Low = less than 5%; and Very Low = less than 1%.
2There are several scenarios that could meet the requirements for ESU recovery (as reflected in the proposed goals for populations in Oregon and Washington). What is reflected here for populations in Idaho are the proposed status goals selected by NMFS and the State of Idaho.
3The Tucannon River population is wholly within Washington and would not be exposed to Idaho criteria. The Lower Snake River MPG, which the Tucannon River is a part of, also includes the extirpated Asotin Creek population, which is within Idaho.
4At least one population must achieve high viability. No single population has been identified as being targeted for highly viable; results from ongoing monitoring will be used to identify which population can best achieve a highly viable status.

A summary of the current status of the SR sp/su Chinook salmon ESU can be found on NMFS' publicly available intranet site (www.fisheries.noaa.gov/s3/2024-08/status-species-snake-river-spring-summer-chinook-salmon-july-2024.pdf), and is incorporated by reference here.

Overall, the species is at a moderate-to-high risk of extinction. The SR sp/su Chinook salmon ESU continues to face threats from disease; predation; harvest; habitat loss, alteration, and degradation; and climate change (NMFS 2022b). Impaired water quality, which includes degradation due to pesticides, has been identified as a limiting factor for recovery of the SR sp/su Chinook salmon ESU. However, our understanding of the effects of many contaminants on aquatic life is incomplete, and more information is needed to determine if pesticides are limiting salmonid population viability (NMFS 2017a).

In addition, spatial structure and diversity are important for the viability of the species, as they provide resilience to anomalous events and localized population declines. This species was considered to have a high adaptive capacity to climate change, given its extensive life history diversity in both juvenile and adult life stages that affords greater potential for behavioral, physiological, or other adaptive response to ameliorate stressors (Crozier et al. 2019). Chinook salmon exhibit a variety of complex life history patterns that include variation in age at seaward migration (Healey 1991; Myers et al. 1998), which may influence the extent of potential exposure to contaminants as juveniles.

Monitoring and evaluation of contaminant sources and concentrations combined with the use of best management practices for proper pesticide application will be needed for successful recovery of this species (NMFS 2017a). Identification and reduction of point sources may be carried out through the implementation of the IPDES program, which can identify and reduce sources of pollutants. The use of buffers and filtration strips to manage nonpoint sources in agricultural areas or downstream thereof may also aid in recovery of the species by reducing pollutants and the potential for interactions of multiple toxic compounds.

2.2.1.2. Snake River Fall-run Chinook Salmon

The SR fall Chinook salmon ESU, listed as threatened on April 22, 1992 (57 FR 14653), includes one extant population of salmon that spawn in the mainstem of the Snake River and lower reaches of its major tributaries. This population occupies the Snake River from its confluence with the Columbia River to Hells Canyon Dam, and the lower reaches of the Clearwater, Imnaha, Grande Ronde, Salmon, and Tucannon Rivers. The majority of the fish spawn in the mainstem Snake River between the head of Lower Granite Reservoir (River Mile [RM] 146.8) and Hells Canyon Dam (RM 247.6), with the remaining fish distributed among lower sections of the major tributaries. The ESU also includes four artificial propagation programs.

A summary of the current status of the SR fall-run Chinook salmon ESU can be found on NMFS' publicly available intranet site (www.fisheries.noaa.gov/s3/2024-08/status-species-snake-river-fall-chinook-salmon-jul-2024.pdf), and is incorporated by reference here. Because there is only one extant population of Snake River fall Chinook salmon, ICTRT criteria indicate that this population should be "Highly Viable" to achieve recovery of this ESU (ICTRT 2007). The SR fall Chinook salmon ESU is considered to have a moderate risk rating for diversity, with a high adaptive capacity because of multiple juvenile outmigration strategies, which may influence risk of exposure to contaminants in this life stage. SR fall Chinook salmon either rapidly migrate downstream soon after emergence in the spring/summer (ocean type) or overwinter and migrate the next spring (yearling type). Spatial structure risk is also at only moderate risk for this species because fish currently spawn in all five historic major spawning areas.

While the ESU has improved since the time of listing and is currently considered viable (based on a low-risk rating for abundance and productivity, and a moderate risk rating for spatial structure and diversity), it is not meeting its recovery goals. The ESU continues to face threats from tributary and mainstem habitat loss, degradation, or modification; disease; predation; harvest (rate of up to 50% including ocean and Columbia River fisheries (NMFS 2020a)); hatcheries; and climate change (NMFS 2022c).

NMFS biological opinions on current use pesticides have identified SR fall Chinook salmon as at risk because of application of several of pesticide compounds to their critical habitat (NMFS 2008a, 2010, 2011). Recommended actions for recovery of the SR fall Chinook salmon ESU include information gathering to understand the sources, prevalence, exposure, and uptake of toxic pollutants, including pesticides (NMFS 2017b). The SR fall Chinook salmon recovery plan also recommends revising water quality criteria to ensure they are protective of salmonids, and implementing the NPDES program to address point source pollution. In addition, the recovery plan recommends implementing pesticide and fertilizer BMPs to reduce estuarine and upstream sources of toxic contaminants.

2.2.1.3. Snake River Sockeye Salmon

The SR sockeye salmon, listed as endangered on November 20, 1991 (56 FR 58619), includes all anadromous and residual sockeye salmon from the SR basin in Idaho (extant population occurs only in the Salmon River drainage), as well as artificially propagated sockeye salmon from the Redfish Lake captive propagation and SR sockeye salmon hatchery programs. The SR sockeye salmon ESU consists of a single MPG, with only one extant population (Redfish Lake) (ICTRT 2007). Currently, the SR sockeye salmon population is highly dependent on a captive brooding program at the Sawtooth Hatchery (Ford et al. 2011).

A summary of the current status of the SR sockeye salmon ESU can be found on NMFS' publicly available intranet site (www.fisheries.noaa.gov/s3/2024-08/status-species-snake-river-sockeye-salmon-july-2024.pdf), and is incorporated by reference here. The total number of returning adults documented in the Sawtooth Valley in 2020, 2021, 2022, and 2023 was 152, 55, 749, and 144, respectively (Johnson et al. 2021; Phillips 2022; IDFG 2022; Dan Baker, IDFG Hatchery Manager 2023). The ESU is classified as being at high risk for abundance, productivity, spatial structure, and diversity parameters, and is at a high risk of extinction within 100 years.

Because SR sockeye salmon spend a majority of time in freshwater in high altitude, remote streams and lakes, and juveniles migrate rapidly from these habitats to ocean, they are likely to have lower exposures to pesticides than other salmonid species considered in this opinion while in the action area. However, due to this species' high risk of extinction, they are unlikely to tolerate exposure to pesticides in combination with other stressors, such as climate change (Crozier et al. 2019). Therefore, monitoring and addressing pesticide runoff into migration corridors will be necessary for recovery (NMFS 2015). The Salmon and lower Snake rivers and their tributaries should be prioritized for pesticide monitoring, as SR sockeye salmon juveniles and adults migrate through these areas. The recovery plan (NMFS 2015) also recommends implementing pesticide and fertilizer BMPs to reduce estuarine and upstream sources of nutrients and toxic contaminants. In addition to the above actions to address contaminants, stream shading, managing water withdrawals, wetland and floodplain restoration, and continued hydropower dam operation to lower temperatures in migration corridors will be essential for recovery of the species (NMFS 2015).

2.2.1.4. Snake River Basin Steelhead

The SRB steelhead DPS was listed as a threatened ESU on August 18, 1997 (62 FR 43937), with a revised listing as a distinct population segment (DPS) on January 5, 2006 (71 FR 834). The DPS includes all naturally-spawning steelhead populations below natural and manmade impassable barriers in streams in the Snake River basin of southeast Washington, northeast Oregon, and Idaho. The DPS also includes the progeny of six artificial propagation programs. The DPS is comprised of five extant MPGs with 24 extant populations (Table 5). The SRB steelhead listing does not include resident forms of *O. mykiss* (rainbow trout) that co-occur with these steelhead. Fish from all but one population in the DPS occupy waters within or forming the Idaho state border (i.e., Snake River) and may be affected by the proposed action.

Table 5. Viable Salmonid Population (VSP) Risk and Viability Ratings for Snake River Basin Steelhead by Major Population Group and Population.

Major Population Group	Population	VSP Risk Rating[1]		Viability Rating	
		Abundance/ Productivity	Spatial Structure/ Diversity	2022 Assessment	Proposed Recovery Goal[2]
Lower Snake River (R.)	Tucannon R.[3]	High	Moderate	High Risk	Highly Viable or Viable
	Lower Snake R	Moderate	Moderate	Maintained	Highly Viable or Viable
Grande Ronde R.	Lower Grande Ronde	High	Moderate	High Risk	Viable or Maintained
	Joseph Cr.	Low	Low	Viable	Highly Viable, Viable, or Maintained
	Wallowa R.	High	Low	High Risk	Viable or Maintained
	Upper Grande Ronde	Very Low	Moderate	Viable	Highly Viable or Viable
Imnaha R.	Imnaha R.	Very low	Moderate	Viable	Highly Viable
Clearwater R.	Lower Mainstem Clearwater R.	Very Low	Low	Highly Viable	Viable
	South Fork (S. Fk.) Clearwater R.	Very Low	Moderate	Viable	Maintained
	Lolo Cr.	High	Moderate	Viable	Maintained
	Selway R.	Moderate	Low	Maintained	Viable
	Lochsa R.	Moderate	Low	Maintained	Highly Viable
	N. Fk. Clearwater R.	-	-	*Extirpated*	*N/A*
Salmon River	Little Salmon R.	Very Low	Moderate	Viable	Maintained
	S. Fk. Salmon R.	Moderate	Low	Maintained	Viable
	Secesh R.	Moderate	Low	Maintained	Maintained

Major Population Group	Population	VSP Risk Rating[1]		Viability Rating	
		Abundance/ Productivity	Spatial Structure/ Diversity	2022 Assessment	Proposed Recovery Goal[2]
	Chamberlain Ck.	Moderate	Low	Maintained	Viable
	Lower Middle Fork (M. Fk.) Salmon R.	Moderate	Low	Maintained	Highly Viable
	Upper M. Fk. Salmon R.	Moderate	Low	Maintained	Viable
	Panther Ck.	Moderate	High	High Risk	Viable
	N. Fk. Salmon R.	Moderate	Moderate	Maintained	Maintained
	Lemhi R.	Moderate	Moderate	Maintained	Viable
	Pahsimeroi R.	Moderate	Moderate	Maintained	Maintained
	East Fk. Salmon R.	Moderate	Moderate	Maintained	Maintained
	Upper Mainstem Salmon R.	Moderate	Moderate	Maintained	Maintained
Hells Canyon	Hells Canyon Tributaries	-	-	*Extirpated*	-

1Risk ratings are defined based on the risk of extinction within 100 years: High = greater than or equal to 25%; Moderate = less than 25%; Low = less than 5%; and Very Low = less than 1%.
2There are several scenarios that could meet the requirements for ESU recovery (as reflected in the proposed goals for populations in Oregon and Washington). What is reflected here for populations in Idaho are the proposed status goals selected by NMFS and the State of Idaho.
3The Tucannon River population is wholly within Washington and would not be exposed to Idaho criteria.

A summary of the current status of the SRB steelhead DPS can be found on NMFS' publicly available intranet site (www.fisheries.noaa.gov/s3/2024-08/status-species-snake-river-basin-steelhead-july-2024.pdf), and is incorporated by reference here. Overall, available information suggests that SRB steelhead continue to be at a moderate risk of extinction within the next 100 years. All populations that fall within the action area may be affected by the proposed action include, but those in more agricultural areas (e.g., Lower Snake, Lower Mainstem Clearwater) may be more at risk.

Pesticide management actions that will be necessary for the recovery of this species include monitoring and evaluation of contaminant sources and concentrations, and use of best management practices for proper pesticide application (NMFS 2017a). Identification and reduction of point sources may be carried out through the implementation of NPDES, which can identify and reduce sources of pollutants, and will aid in recovery efforts.

2.2.1.5. Southern Resident killer whale

The SRKW DPS, composed of J, K, and L pods, was listed as endangered under the ESA on November 18, 2005 (70 FR 69903). In 2021, as part of its 5-year review, NMFS concluded that SRKWs should remain listed as endangered. This section summarizes the status of SRKW throughout their range and information taken largely from the recovery plan (NMFS 2008b) and the most recent 5-year review (NMFS 2021a).

The SRKWs occur throughout the coastal waters off Washington, Oregon, and Vancouver Island, Canada, and are known to travel as far south as central California and as far north as southeast Alaska (NMFS 2008b; Hanson et al. 2013; Carretta et al. 2022). SRKWs are a long-lived species, and reach sexual maturity around age 10 (NMFS 2008b). Females typically produce fewer than 10 calves over their reproductive lifespan (Bain 1990; Olesiuk et al. 1990). Compared to Northern Resident killer whales, which are a resident killer whale population with a sympatric geographic distribution ranging from coastal waters of Washington State and British Columbia north to southeast Alaska, SRKW females appear to have reduced fecundity (Ward et al. 2013; Vélez-Espino et al. 2014), and all age classes of SRKWs have reduced survival compared to other fish-eating populations of killer whales in the Northeast Pacific (Ward et al. 2013).

Since the early 1970s, annual summer censuses have occurred in the Salish Sea using photo-identification techniques (Bigg et al. 1990; Center for Whale Research 2023). The population of SRKW was at its lowest known abundance (n = 67) in the early 1970s following live-captures for aquaria display and highest recorded abundance (98 animals) in 1995. Subsequently, the population declined from 1995-2001 (from 98 whales in 1995 to 81 whales in 2001). Although the population experienced growth between 2001 and 2006 and a brief increase from 78 to 81 whales as a result of multiple successful pregnancies (n = 9) in 2013 and 2014, the population has been declining since 2006. The 2024 summer census conducted by the Center for Whale Research reported 73 SRKWs in the population as of July 1, 2024, including the loss of two adult males since the 2023 Census (CWR 2024). The small size of the SRKW DPS makes it susceptible to demographic stochasticity, or randomness in the pattern of births and deaths among individuals in a population, which can amplify the probability of extinction (Gilpin and Michael 1986; Fagan and Holmes 2006; Melbourne and Hastings 2008).

The historical estimated abundance of SRKWs was 140 animals (NMFS 2008b), which included the number of whales killed or removed for public display in the 1960s and 1970s (summed across all years) added to the remaining population at the time the captures ended. Population estimates, including recent data from 2017-2021, project a downward trend over the next 25 years. The declining trend is, in part, due to the changing age and sex structure of the population and is related to the relatively low fecundity rate observed from 2017 to 2021. Because many reproductive-aged females have not produced a calf in the last decade, we would expect the SRKW population to decline even more rapidly if the number of females not reproducing continues to increase, or these females continue to fail to produce calves. In addition, recent genomic analyses indicate that the SRKW population has greater inbreeding and carries a higher load of deleterious mutations than do Alaska resident or transient killer whales, and that inbreeding depression is likely impacting the survival and growth of the population (Kardos et al. 2023). These factors likely contribute to the SRKW's poor status. As a long-lived species with a low reproductive rate, it will take time for SRKWs to respond to a reduction in threats.

The limiting factors described in the final recovery plan (NMFS 2008b) included reduced prey availability and quality, high levels of contaminants from pollution, and disturbances from vessels and sound. Oil spills, disease, and the small population size are also risk factors. It is likely that multiple threats are acting together to impact the whales (NMFS 2008b; Murray et al. 2021; NMFS 2021b). SRKW consume a variety of fish species (22 species) and one species of squid (Ford et al. 1998; Ford et al. 2000; Ford and Ellis 2006; Ford et al. 2016; Hanson et al. 2010), but salmon are identified as their primary prey. The best available information suggests an overall preference for Chinook salmon during the summer and fall. Chum salmon (*O. keta*), coho salmon (*O. kisutch*), and steelhead may also be important in the SRKW diet at particular times and in specific locations (Ford et al. 2016; Hanson et al. 2010). Chinook salmon is their primary prey despite the much lower abundance in comparison to other salmonids in some areas and during certain time periods. Factors of potential importance include the Chinook salmon's large size, high fat and energy content, and year-round occurrence in the SRKW geographic range. Chinook salmon have the highest value of total energy content compared to other salmonids because of their larger body size and higher energy density (kilocalorie per kilogram (kcal/kg)) (O'Neill et al. 2014). For example, in order for a killer whale to obtain the total energy value of one Chinook salmon, they would need to consume, on average, approximately 2.7 coho, 3.1 chum, 3.1 sockeye, or 6.4 pink salmon (O'Neill et al. 2014). Research suggests that killer whales are capable of detecting, localizing, and recognizing Chinook salmon through their ability to distinguish Chinook salmon echo structure as different from other salmon (Au et al. 2010). Though SRKW do not only consume Chinook salmon, the degree to which this species is able or willing to switch to non-preferred prey sources from their primary prey (i.e., Chinook salmon) in all times and locations is unknown and likely variable depending on time and location.

The occurrence of K and L pods off the Columbia River in March suggests the importance of Columbia River spring runs of Chinook salmon in their diet (Hanson et al. 2013). Chinook salmon genetic stock identification from SRKW fecal samples collected in winter and spring in coastal waters from California through Washington included 12 U.S. West Coast stocks, and showed that over half the Chinook salmon consumed originated in the Columbia River (Hanson et al. 2021). Chinook salmon is the dominant prey species for all pods for much of the year, particularly in summer, but diversity of prey species detected in fecal samples increases in early winter (Van Cise et al. 2024).

Overall, the SRKW DPS remains at a high risk of extinction (NMFS 2021a). The population has relatively high mortality and low reproduction and they are currently well below the population growth goals identified in their ESA Recovery Plan (NMFS 2008b). Unlike other North Pacific killer whale populations, which have generally been increasing since federal protection was initiated in the 1970s, the Southern Resident population remains small and vulnerable. Loss of any pod would hinder recovery of the DPS overall; the K pod is the most vulnerable because it is the smallest with a male bias and few females of reproductive age (NMFS 2021a). Management priorities for the species are outlined in the 2021-2025 Species in the Spotlight Action Plan. Key actions needed for 2021 through 2025 include protecting SRKW from harmful vessel impacts, targeting conservation of critical prey, obtaining a better understanding of whale health to advance recovery, and raising awareness about recovery needs of the species and inspire stewardship through education and outreach (NMFS 2021a).

In an effort to prioritize recovery efforts such as habitat restoration and help inform efforts to use fish hatcheries to increase the SRKW prey base, NMFS and WDFW developed a priority stock report identifying the important Chinook salmon stocks along the West Coast (NMFS and WDFW 2018). The list was created using information on (1) Chinook salmon stocks found in SRKW diet through fecal and prey scale/tissue samples, (2) SRKW body condition over time through aerial photographs, and (3) SRKW spatial and temporal overlap with Chinook salmon stocks ranging from S.E. Alaska to California. Extra weight was given to the salmon runs that support SRKWs during times of the year when the whales' body condition is more likely reduced and when Chinook salmon may be less available, i.e., winter months. This priority stock report will be updated over time as new data become available. The report was designed only to prioritize recovery actions for SRKW; currently, stock-specific abundance estimates have not been factored into the report, therefore it is not intended to assess fisheries actions or prey availability by area. The first 15 salmon stocks on the priority list include fall, spring, and summer Chinook salmon runs in rivers spanning from British Columbia to California, including the Fraser, Columbia, Snake, and Sacramento Rivers, as well as several rivers in Puget Sound watersheds NMFS and WDFW (2018).

2.2.2. Rangewide Status of Designated Critical Habitat

We review the status of critical habitat by examining the condition of PBFs throughout the designated area. These features are essential to the conservation of the ESA-listed species because they support one or more of life stages of the species (e.g., sites with conditions that support spawning, rearing, migration, and foraging).

2.2.2.1. Snake River Spring/Summer and Fall Chinook Salmon, Snake River Sockeye Salmon, and Snake River Basin Steelhead Critical Habitat

The PBFs essential to the conservation of SR sp/su Chinook salmon, SR fall Chinook salmon, SR sockeye salmon, and SRB steelhead are similar and the designated critical habitats of these four species overlap. Therefore, their status is evaluated together here. Proper function of these PBFs is necessary to support successful adult and juvenile migration, adult holding, spawning, incubation, rearing, and the growth and development of juvenile fish. Modification of PBFs may affect these life stages in the action area. Generally speaking, sites required to support one or more life stages of the ESA-listed species (i.e., sites for spawning, rearing, migration, foraging) contain PBFs essential to the conservation of the listed species (e.g., spawning gravels, water quality and quantity, side channels, or food) (Table 6).

Table 6. Types of sites, essential physical and biological features (PBFs), and the species life stage each PBF supports.

Site	Essential Physical and Biological Features	Species Life Stage
Snake River Basin steelhead[a]		
Freshwater spawning	Water quality, water quantity, and substrate	Spawning, incubation, and larval development
Freshwater rearing	Water quantity and floodplain connectivity to form and maintain physical habitat conditions	Juvenile growth and mobility
	Water quality and forage[b]	Juvenile development
	Natural cover[c]	Juvenile mobility and survival
Freshwater migration	Free of artificial obstructions, water quality and quantity, and natural cover[c]	Juvenile and adult mobility and survival
Snake River spring/summer Chinook salmon, fall Chinook salmon, and sockeye salmon		
Spawning and juvenile rearing	Spawning gravel, water quality and quantity, cover/shelter (Chinook only), food, riparian vegetation, space (Chinook only), water temperature, and access (sockeye only)	Juvenile and adult
Migration	Substrate, water quality and quantity, water temperature, water velocity, cover/shelter, food[d], riparian vegetation, space, safe passage	Juvenile and adult

[a] Additional PBFs pertaining to estuarine areas have also been described for Snake River steelhead. These PBFs will not be affected by the proposed action and have therefore not been described in this opinion.

[b] Forage includes aquatic invertebrate and fish species that support growth and maturation.
[c] Natural cover includes shade, large wood, log jams, beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks.
[d] Food applies to juvenile migration only.

Table 7 describes the geographical extent of critical habitat within the Snake River basin for each of the four ESA-listed salmon and steelhead species. Critical habitat includes the stream channel and water column with the lateral extent defined by the ordinary high-water line, or the bankfull elevation where the ordinary high-water line is not defined. In addition, critical habitat for the three salmon species includes the adjacent riparian zone, which is defined as the area within 300 feet of the line of high water of a stream channel or from the shoreline of standing body of water (58 FR 68543). The riparian zone is critical because it provides shade, streambank stability, organic matter input, and regulation of sediment, nutrients, and chemicals.

Table 7. Geographical extent of designated critical habitat within the Snake River basin for ESA-listed salmon and steelhead.

Evolutionarily Significant Unit (ESU)/ Distinct Population Segment (DPS)	Designation	Geographical Extent of Critical Habitat
Snake River sockeye salmon	58 FR 68543; December 28, 1993	Snake and Salmon Rivers; Alturas Lake Creek; Valley Creek, Stanley Lake, Redfish Lake, Yellowbelly Lake, Pettit Lake, Alturas Lake; all inlet/outlet creeks to those lakes.
Snake River spring/summer Chinook salmon	58 FR 68543; December 28, 1993 64 FR 57399; October 25, 1999	All Snake River reaches upstream to Hells Canyon Dam; all river reaches presently or historically accessible to Snake River spring/summer Chinook salmon within the Salmon River basin; and all river reaches presently or historically accessible to Snake River spring/summer Chinook salmon within the Hells Canyon, Imnaha, Lower Grande Ronde, Upper Grande Ronde, Lower Snake–Asotin, Lower Snake–Tucannon, and Wallowa subbasins.
Snake River fall Chinook salmon	58 FR 68543; December 28, 1993	Snake River to Hells Canyon Dam; Palouse River from its confluence with the Snake River upstream to Palouse Falls; Clearwater River from its confluence with the Snake River upstream to Lolo Creek; North Fork Clearwater River from its confluence with the Clearwater River upstream to Dworshak Dam; and all other river reaches presently or historically accessible within the Lower Clearwater, Hells Canyon, Imnaha, Lower Grande Ronde, Lower Salmon, Lower Snake, Lower Snake–Asotin, Lower North Fork Clearwater, Palouse, and Lower Snake–Tucannon subbasins.
Snake River Basin steelhead	70 FR 52630; September 2, 2005	Specific stream reaches are designated within the Lower Snake, Salmon, and Clearwater River basins. Table 21 in the Federal Register details habitat areas within the DPS's geographical range that are excluded from critical habitat designation.

Spawning and rearing habitat quality in tributary streams in the Snake River varies from excellent in wilderness and roadless areas to poor in areas subject to intensive human land uses (NMFS 2015; NMFS 2017a). Critical habitat throughout much of the Interior Columbia (which includes the Snake River and the Middle Columbia River) has been degraded by intensive agriculture, alteration of stream morphology (i.e., channel modifications and diking), riparian vegetation disturbance, wetland draining and conversion, livestock grazing, dredging, road construction and maintenance, logging, mining, and urbanization. Reduced summer streamflows, impaired water quality, and reduction of habitat complexity are common problems for critical habitat in non-wilderness areas. Human land use practices throughout the basin have caused streams to become straighter, wider, and shallower, thereby reducing rearing habitat and increasing water temperature fluctuations. While the action area only includes anadromous watersheds in Idaho, all populations have some risk of exposure to pesticides in the Columbia and Snake Rivers and estuary, as pesticides in current use have been detected in surface water.

In many stream reaches designated as critical habitat in the Snake River basin, streamflows are substantially reduced by water diversions (NMFS 2015; NMFS 2017a). Withdrawal of water, particularly during low-flow periods that commonly overlap with agricultural withdrawals, often increases summer stream temperatures, blocks fish migration, strands fish, and alters sediment transport (Spence et al. 1996). Reduced tributary streamflow has been identified as a major limiting factor for SR sp/su Chinook salmon and SRB steelhead in particular (NMFS 2017a).

Many stream reaches designated as critical habitat for these species are listed on the Clean Water Act 303(d) list for impaired water quality, such as elevated water temperature (IDEQ 2022). Many areas that were historically suitable rearing and spawning habitat are now unsuitable due to high summer stream temperatures, such as some stream reaches in the Upper Grande Ronde. Removal of riparian vegetation, alteration of natural stream morphology, and withdrawal of water for agricultural or municipal use all contribute to elevated stream temperatures. Water quality in spawning and rearing areas in the Snake River has also been impaired by high levels of sedimentation and by heavy metal contamination from mine waste (e.g., IDEQ 2001).

The construction and operation of water storage and hydropower projects in the Columbia River basin, including the eight run-of-river dams on the mainstem lower Snake and lower Columbia Rivers, have altered biological and physical attributes of the mainstem migration corridor. Hydrosystem development modified natural flow regimes, resulting in warmer late summer and fall water temperature. Changes in fish communities led to increased rates of piscivorous predation on juvenile salmon and steelhead. Reservoirs and project tailraces have created opportunities for avian predators to successfully forage for smolts, and the dams themselves have created migration delays for both adult and juvenile salmonids. Physical features of dams, such as turbines, also kill out-migrating fish. In-river survival is inversely related to the number of hydropower projects encountered by emigrating juveniles. However, some of these conditions have improved. The Bureau of Reclamation and U.S. Army Corps of Engineers have implemented measures in previous Columbia River System hydropower consultations to improve conditions in the juvenile and adult migration corridor including 24-hour volitional spill, surface passage routes, upgrades to juvenile bypass systems, and predator management measures. These measures are ongoing and their benefits with respect to improved functioning of the migration corridor PBFs will continue into the future.

In summary, critical habitat for SR sp/su and fall Chinook salmon, SR sockeye salmon, and SRB steelhead has been degraded in some areas due to agriculture, development, land- and water-use practices, and dams. Because of this, several PBFs, particularly habitat availability, water quality, and water quantity, may not fully support salmonids throughout their critical habitat.

2.2.2.2. SRKW Critical Habitat

Critical habitat for the SRKW DPS was first designated on November 29, 2006 (71 FR 69054) in inland waters of Washington State. NMFS published a final rule to revise SRKW critical habitat in 2021 (86 FR 41668; August 2, 2021). This rule, which became effective on September 1, 2021, maintains the previously designated critical habitat in inland waters of Washington (Puget Sound, see 71 FR 69054; November 29, 2006) and expands it to include six additional coastal critical habitat areas off the coast of Washington, Oregon, and California (about 15,910 square miles [mi^2]). Critical habitat includes approximately 2,560 mi^2 of inland waters of Washington in three specific areas: (1) the Summer Core Area in Haro Strait and waters around the San Juan Islands; (2) Puget Sound; and (3) the Strait of Juan de Fuca. It also includes 15,910 mi^2 (41,207 square kilometers [km^2]) of marine waters along the U.S. west coast between the 20-feet (ft) (6.1-m) depth contour and the 656.2-ft (200-m) depth contour from the U.S. international border with Canada south to Point Sur, California.

Based on the natural history of SRKWs and their habitat needs, NMFS identified the following PBFs essential to conservation for critical habitat: (1) water quality to support growth and development; (2) prey species of sufficient quantity, quality, and availability to support individual growth, reproduction, and development, as well as overall population growth; and (3) passage conditions to allow for migration, resting, and foraging. A brief summary of the prey PBFs is presented below. Detailed information on all the PBFs essential to conservation can be found in the 2006 critical habitat final rule (71 FR 69054, November 29, 2006) and the recent 2021 critical habitat expansion final rule (86 FR 41668, August 2, 2021), and the Final Biological Report that supports the 2021 critical habitat rule (NMFS 2021c), which are incorporated here by reference.

Prey species of sufficient quantity, quality and availability are essential to conservation as SRKWs need to maintain their energy balance all year long to support daily activities (foraging, traveling, resting, socializing), as well as gestation, lactation, and growth. Reduced prey availability has been strongly associated with killer whale mortality and to a lesser degree with low fecundity (Ford et al. 2010; Nelson et al. 2024; Ward et al. 2009; Wasser et al. 2017). Most wild salmon stocks throughout the whales' geographic range are at fractions of their historic levels and 28 ESUs and DPSs of salmon and steelhead are listed as threatened or endangered under the ESA, with the Chinook salmon ESUs being most important to the SRKW diet. Historically, overfishing, habitat losses, and hatchery practices were major causes of decline for salmonids. Poor ocean conditions over the past two decades have reduced salmonid populations already weakened by the degradation and loss of freshwater and estuary habitat, fishing, hydropower system management, and hatchery practices. In addition to sufficient quantity of prey, fish need to be accessible and of sufficient quality and size to support SRKW. Contaminants affect the quality of SRKW prey in Puget Sound and in coastal waters of Washington, Oregon, and California. The size of Chinook salmon is also an important aspect of prey quality (i.e., SRKWs primarily consume large Chinook salmon), so changes in Chinook salmon size (for instance as shown by Ohlberger et al. (2018)) may affect the quality of this feature of critical habitat. This shift may be largely due to direct effects from size-selective removal by marine mammals and fisheries, followed by evolutionary changes toward these smaller sizes and early maturation (Ohlberger et al. 2018). Smaller fish have a lower total energy value than larger ones (O'Neill et al. 2014). Therefore, SRKWs need to consume more fish in order to meet their caloric needs as a result of a decrease in average size of older Chinook salmon.

Human activities managed under a variety of legal mandates have the potential to affect SRKW critical habitat PBFs, including those that could increase water contamination and/or chemical exposure, decrease the quantity, quality, or availability of prey, or inhibit safe, unrestricted passage between important habitat areas to find prey and fulfill other life history requirements. Examples of these types of activities include (but are not limited to), in no particular order: (1) salmon fisheries and bycatch; (2) salmon hatcheries; (3) offshore aquaculture/mariculture; (4) alternative energy development; (5) oil spills and response; (6) military activities; (7) vessel traffic; (8) dredging and dredge material disposal; (9) oil and gas exploration and production; (10) mineral mining (including sand and gravel mining); (11) geologic surveys (including seismic surveys); and (12) activities occurring adjacent to or upstream of critical habitat that may affect essential features, labeled “upstream activities” (including activities contributing to point-source water pollution, power plant operations, liquefied natural gas terminals, desalinization plants) (NMFS 2021c).

2.2.3. Climate Change Implications for ESA-listed Species and their Critical Habitat

There is a large and growing body of literature on past, present, and future impacts of global climate change, exacerbated and accelerated by human activities. Some of the likely effects commonly mentioned are sea level rise, increased frequency of severe weather events, and change in air and water temperatures. NOAA’s climate information portal provides basic background information on these and other measured or anticipated effects (see http://www.climate.gov). As observed by Siegel and Crozier (2019), long-term trends in warming have continued at global, national, and regional scales. The 10 warmest years in the historical record (1890-2023) have all occurred in the past decade, with 2023 recorded as the warmest year on record by a wide margin (Lindsey and Dahlman 2024).

Climate change generally exacerbates threats and limiting factors, including those currently impairing salmon and steelhead survival and productivity. The growing frequency and magnitude of climate change related environmental downturns will increasingly imperil many ESA-listed stocks in the Columbia River basin and amplify their extinction risk (Crozier et al. 2019, 2020, 2021). This climate change context means that opportunities to rebuild these stocks will likely diminish over time. As such, management actions that increase resilience and adaptation to these changes should be prioritized and expedited. For example, the importance of improving the condition of and access and survival to and from the remaining functional, high-elevation spawning and nursery habitats is accentuated because these habitats are the most likely to retain remnant snowpacks under predicted climate change (Tonina et al. 2022).

Climate change is already evident and it will continue to affect air temperatures, precipitation, and wind patterns in the Pacific Northwest (ISAB 2007; Philip et al. 2021), resulting in increased droughts and wildfires and variation in river flow patterns. These conditions differ from those under which native anadromous and resident fishes evolved and will likely increase risks posed by invasive species and altered food webs. Increasing temperatures may also interact with pollutant loads to amplify toxic effects. For example, the toxicity of pesticides, including organophosphates, increases with temperature for rainbow trout and other cold-water fish (Patra et al. 2015; Laetz et al. 2014; Mayer and Ellersieck, 1986). The frequency, magnitude, and duration of elevated water temperature events have increased with climate change and are exacerbated by the Columbia River hydrosystem (USEPA 2021a, 2021b; Scott 2020). Thermal gradients (i.e., rapid change to elevated water temperatures) encountered while passing dams via fish ladders can slow, reduce, or altogether stop the upstream movements of migrating salmon and steelhead (e.g., Caudill et al. 2013). Additional thermal loading occurs when mainstem reservoirs act as a heat trap due to upstream inputs and solar irradiation over their increased water surface area (USEPA 2021a, 2021b, 2021c). Consider the example of adult sockeye salmon in 2015, when high summer water temperatures contributed to extremely high losses of Columbia River and Snake River stocks during passage through the mainstem Columbia and Snake River (Crozier et al. 2020), and through tributaries such as the Salmon and Okanogan rivers, below their spawning areas. Some stocks are already experiencing lethal thermal barriers during a portion of their adult migration. The effects of longer or more severe thermal barriers in the future could be catastrophic. For example, Bowerman et al. (2021) concluded that climate change will likely increase the factors contributing to prespawn mortality of Chinook salmon across the entire Columbia River basin.

Columbia River basin salmon and steelhead spend a large portion of their life-cycle in the ocean, and as such the ocean is a critically important habitat influencing their abundance and productivity. Climate change is also altering marine environments used by Columbia River basin salmon and steelhead. This includes increased frequency and magnitude of marine heatwaves, changes to the intensity and timing of coastal upwelling, increased frequency of hypoxia (low oxygen) events, and ocean acidification. These factors are already reducing, and are expected to continue reducing, ocean productivity for salmon and steelhead. This does not mean the ocean is getting worse every year, or that there will not be periods of good ocean conditions for salmon and steelhead. For example, near-shore conditions off the Oregon and Washington coasts were considered “good” in 2011-2012, “poor” in 2015-2017, “good” in 2021, and “fair” in 2022-2024 (NOAA 2024). Unfortunately, the magnitude, frequency, and duration of downturns in marine conditions are expected to increase over time due to climate change, and any long-term effects of the stressors that fish experience during freshwater stages that do not manifest until the marine environment will be amplified by the less-hospitable conditions there due to climate change. Together with increased variation in freshwater conditions, these downturns will further impair the abundance, productivity, spatial structure, and diversity of the region’s native salmon and steelhead stocks (ISAB 2007; Isaak et al. 2018). As such, these climate dynamics will reduce fish survival through direct and indirect impacts at all life stages.

All habitats used by Pacific salmon and steelhead will be affected by climate dynamics. However, the impacts and certainty of the changes will likely vary by habitat type. Some changes affect salmon at all life stages in all habitats (e.g., increasing temperature), while others are habitat-specific (e.g., stream-flow variation in freshwater, sea-level rise in estuaries, upwelling in the ocean). How climate change will affect each individual salmon or steelhead stock also varies widely, depending on the extent and rate of change and the unique life-history characteristics of different natural populations (Crozier et al. 2008). The continued persistence of salmon and steelhead in the Columbia basin relies on restoration actions that enhance climate resilience (Jorgensen et al. 2021) in freshwater spawning, rearing, and migratory habitats, including access to high elevation, high quality cold-water habitats, and the reconnection of floodplain habitats across the interior Columbia River basin.

As a warming climate is likely to cause additional stressors for Pacific salmonids, SRKWs, which primarily feed on Chinook salmon, may experience reduced prey availability (NMFS and WDFW 2018). In addition to long-term anthropogenic climate change, cyclic and year-to-year natural climate variability can also affect SRKWs by way of impacts on their prey, and this natural climate variability is likely heightened by climate change. For example, evidence suggests that marine survival among salmonids fluctuates in response to 20 to 30-year cycles of climatic conditions and ocean productivity. Naturally occurring climatic patterns, such as the Pacific Decadal Oscillation, El Niño and La Niña events, and the North Pacific Gyre Oscillation, can cause changes in ocean productivity that can affect productivity and survival, of salmon (Mantua et al. 1997; Francis and Hengeveld 1998; Beamish et al. 1999; Benson and Trites 2002; Dalton et al. 2013; Kilduff et al. 2015), affecting the prey available to SRKWs.

2.3. Action Area

"Action area" means all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action (50 CFR 402.02).

Under the CWA, state WQS apply to surface waters within state boundaries, excepting waters under Nez Perce Tribe jurisdiction. The WQS for acrolein, carbaryl, and diazinon that EPA proposes to approve could be applied in any of Idaho's surface waters. Within this large area, ESA-listed salmon and steelhead occupy waters and have designated critical habitat in the Clearwater River basin, Salmon River basin, and the Snake River basin from Hells Canyon Dam, downstream to the state border. For purposes of this consultation, we are defining the action area as including all waters of the U.S. in Idaho that are within watersheds supporting anadromous salmonid species and/or their designated critical habitats (Figure 3) and where the relevant proposed pesticide criteria may be implemented. In this opinion, we refer to these as "anadromous watersheds." The CWA (40 CFR 131.10(b) and the downstream protection provision in the Idaho WQS requires the action be implemented such that downstream states' water quality criteria (if any) are attained and maintained at the border. Given this provision, we expect any effects downstream of Idaho borders would be marginal and spatially limited in scope.

Because the action will impact prey species for SRKW, the action area also includes all areas of the Pacific Ocean where the marine ranges of salmonid prey species subject to this consultation (i.e., primarily SR sp/su Chinook salmon and SR fall Chinook salmon) overlap with SRKW. This area includes the whales' entire coastal range from the mouth of the Columbia River and its plume, south as far as central California (Weitkamp 2010, Shelton et al. 2019) and north as far as Southeast Alaska (NMFS 2008b, Hanson et al. 2013, Carretta et al. 2022).

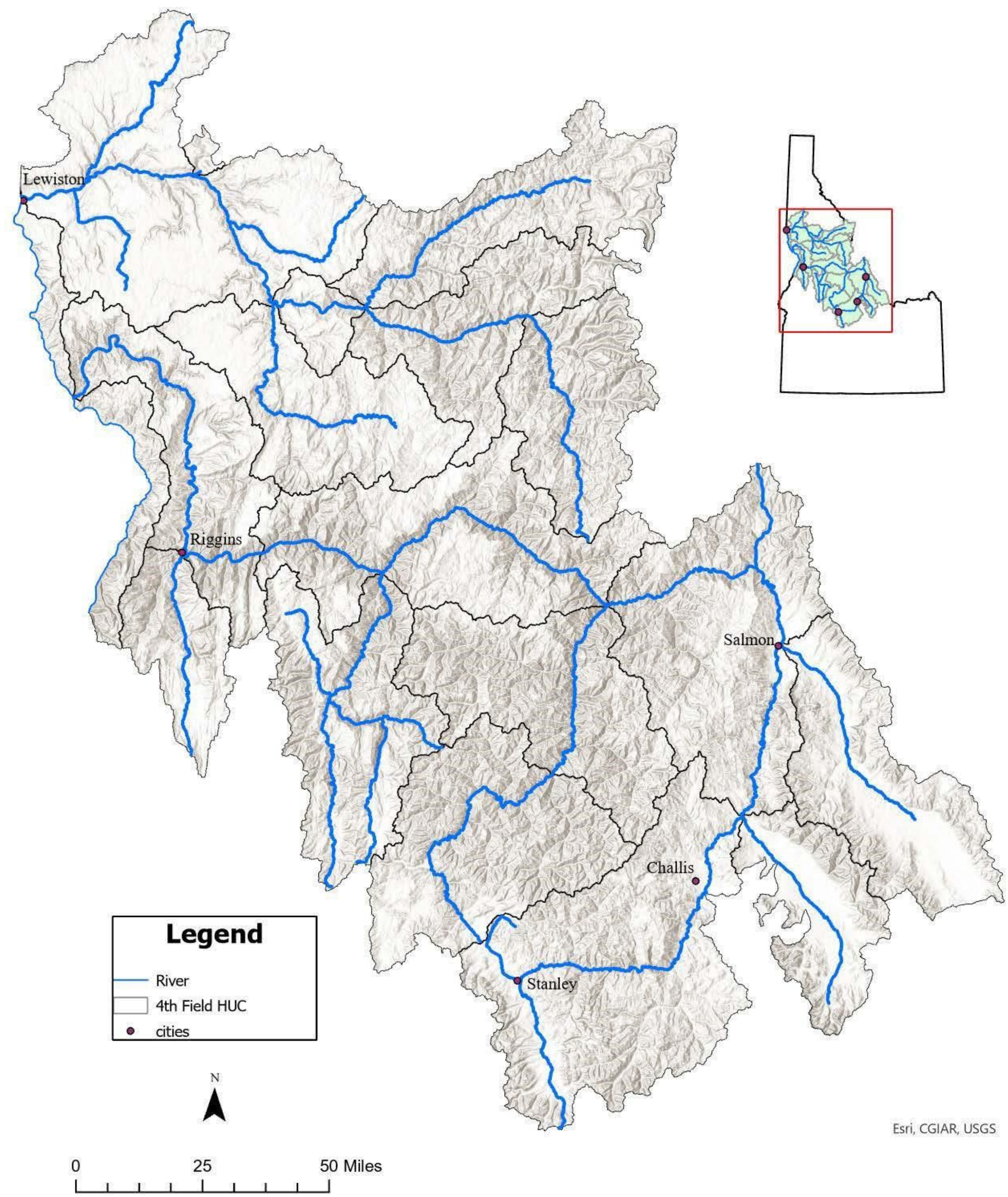

Figure 3. Overview of the action area for anadromous species in Idaho.

2.4. Environmental Baseline

The "environmental baseline" refers to the condition of the listed species or its designated critical habitat in the action area, without the consequences to the listed species or designated critical habitat caused by the proposed action. The environmental baseline includes the past and present impacts of all Federal, State, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultations, and the impact of State or private actions which are contemporaneous with the consultation in process. The consequences to listed species or designated critical habitat from ongoing agency activities or existing agency facilities that are not within the agency's discretion to modify are part of the environmental baseline (50 CFR 402.02).

The BE (pages 14–46) includes a thorough discussion of the environmental baseline, and is incorporated here by reference. We provide a more general overview of environmental baseline conditions below, including key aspects regarding the presence and condition of ESA-listed species and their designated critical habitats in the action area are described further in Sections 2.4.1 and 2.4.2.

2.4.1. Presence of ESA-listed Species and Designated Critical Habitat in the Action Area

Within Idaho, the action area is used by all freshwater life history stages of SR sp/su and fall Chinook salmon, SR sockeye salmon, and SRB steelhead. The action area encompasses habitat for many different populations of these species (Section 2.2.1). Reduction in abundance, productivity, spatial structure, or diversity for any populations due to pesticides in the action area in Idaho has the potential to reduce viability for these salmonid species, particularly for species that contain fewer populations or have a greater proportion of populations within the action area.

In the ocean, the action area is used by SRKW, where the whales' prey upon adult anadromous species. More specific details regarding the presence of these species in the action area are provided in Sections 2.4.1.2 through 2.4.1.5. Designated critical habitat for the four-salmonid species in the action area is illustrated in Figure 4. There is substantial overlap of designated critical habitat for all four species. While the status of designated critical habitat provides an overview of the environmental baseline conditions, more specific details regarding the current condition of designated critical habitat in Idaho are provided in Section 2.4.2.

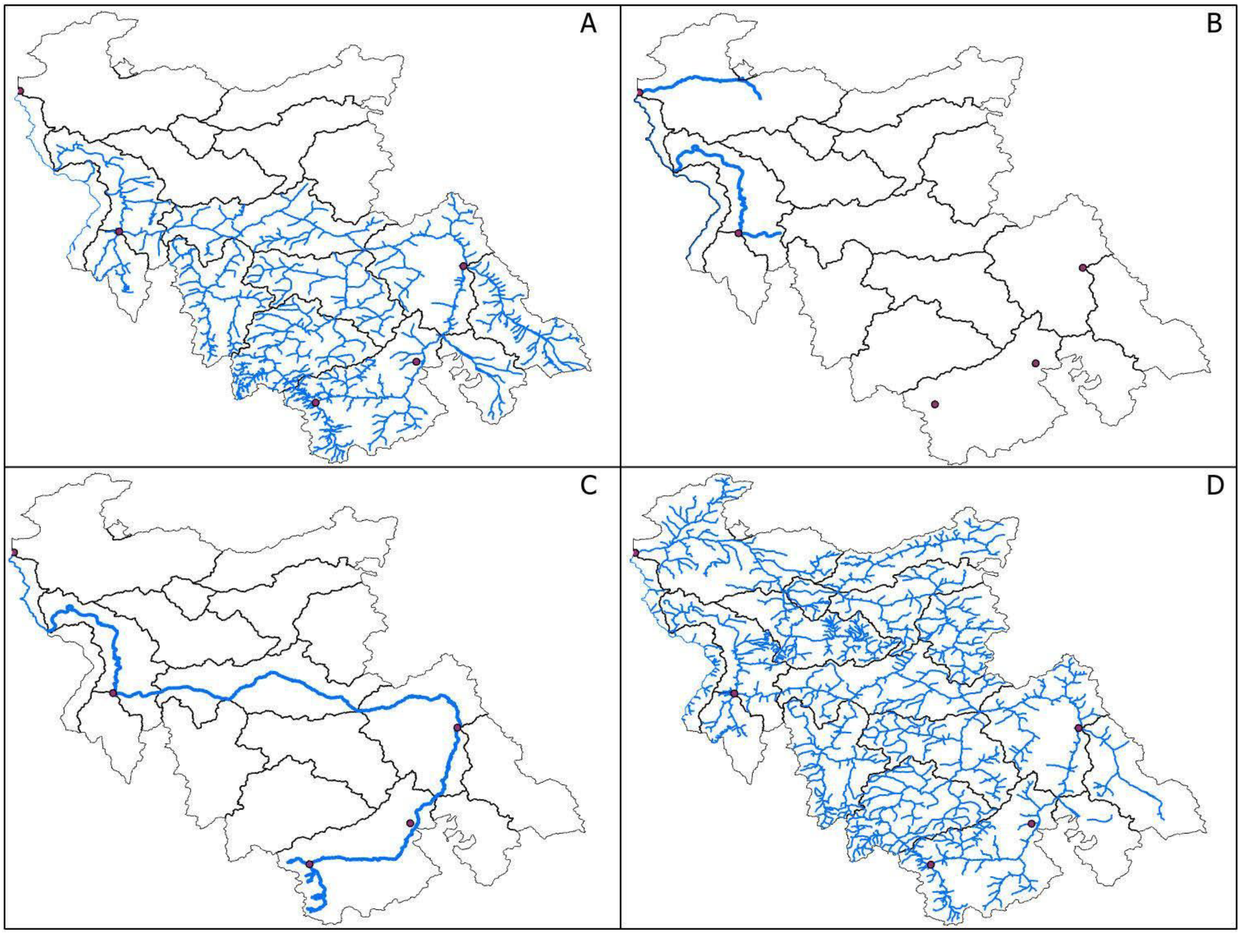

Figure 4. Designated critical habitat (blue lines) for: (A) Snake River spring/summer Chinook salmon; (B) Snake River fall Chinook salmon; (C) Snake River sockeye salmon; and (D) Snake River Basin Steelhead in Idaho.

2.4.1.1. Snake River Spring/Summer Chinook Salmon

All but one population (Tucannon River) in the SR sp/su Chinook salmon ESU may be affected by the proposed action. All populations in the ESU are vital for survival and recovery of the species (see status and recovery goals in Table 4). Adult SR sp/su Chinook salmon typically enter the Columbia River in late February and early March after 2 or 3 years in the ocean. SR sp/su Chinook salmon are characterized by their return times. Runs classified as spring Chinook salmon are counted at Bonneville Dam beginning in early March and ending the first week of June; summer runs are those Chinook salmon adults that pass Bonneville Dam from June through August (NMFS 2024a).

Passage of adult SR sp/su Chinook salmon (hatchery and wild) over Lower Granite Dam (LGD) is variable among years, and is generally concentrated from late May to mid-June (Columbia River DART 2024). The median passage timing for the 5th and 95th percentile of the annual counts for the period of record (1999 – 2023) is May 12 and July 18, respectively. While extended passage timing occurs, 95% of the annual counts have passed LGD on or before August 13 every year since 1998 (Columbia River DART 2024). LGD is a dam in Washington that is the last dam along the migration route before entering the action area. Passage through LGD therefore provides us with a timeframe of when fish are expected to be within the action area.

Returning adults will hold in deep mainstem and tributary pools until late summer, when they move up into tributary areas and spawn. Spawn timing varies among years, beginning as early as late July and finishing by October (Copeland et al. 2019; Kiefer et al. 1992; Venditti et al. 2008; USBWP 2005; Young and Busby 2018). In general, spring-run type Chinook salmon tend to spawn in higher-elevation reaches of major Snake River tributaries in mid- through late August, and summer-run Chinook salmon tend to spawn lower in Snake River tributaries in late August and September (although the spawning areas of the two runs may overlap) (NMFS 2024a).

The incubation period is variable and depends on stream temperatures and dissolved oxygen levels. Generally, incubation for sp/su Chinook salmon in Idaho is thought to occur in March through May, but fry emergence may extend into June in colder habitats (Kiefer et al. 1992; Herger et al. 2002; Cannamela 1992). SR sp/su Chinook salmon typically exhibit a stream-type life history, rearing for one year in freshwater before migrating to the ocean (Healey 1991; Myers et al. 1998). Some fish may disperse from natal streams shortly following emergence, during the fall or winter, or during the following spring of their first year. Fish that leave natal streams in the summer or fall following emergence may overwinter in larger Idaho rivers downstream of their natal habitats and a small proportion may pass over LGD to overwinter (Copeland and Venditti 2009; Connor et al. 2001). The majority of out-migrating juvenile SR sp/su Chinook salmon pass LGD from late-April through mid-May as yearlings (Columbia River DART 2024). While extended passage timing occurs (earliest detection dates in late March and last detection dates extending into November), 95% of the annual counts have passed LGD on or before June 1 every year since 1998 (Columbia River DART 2024).

2.4.1.2. Snake River Fall Chinook Salmon

The only extant population in the SR fall Chinook salmon ESU may be affected by the proposed action. As there is only one remaining population in the ESU, its success is vital to the survival and recovery of the species. SR fall Chinook salmon subadults and adults forage in coastal and offshore waters of the North Pacific Ocean prior to returning to spawn in their natal streams. Adults typically return to fresh water beginning in July, and the majority of SR fall Chinook salmon adults (hatchery and wild) typically pass LGD in September (Columbia River DART 2024). The median passage timing for the 25^{th} and 75^{th} percentile of the annual counts for the period of record (1999 – 2023) is September 15 and October 1, respectively. Although uncommon, adult fish have passed LGD as early as the spring and as late as early December (Columbia River DART 2024). During their upstream migration, adults make extensive use of cold-water patches, often at tributary confluences (Keefer et al. 2018).

In general, fall Chinook salmon are larger than sp/su Chinook salmon and spawn in larger, mainstem rivers and the lower sections of larger tributaries. Idaho contains three of the five major spawning areas for the SR fall species, including the Upper Hells Canyon reach (which includes the mainstem Snake River from Hells Canyon Dam downstream to the mouth of the Salmon River as well as the lower mainstem of the Salmon River), Lower Hells Canyon reach (including the mainstem Snake River from the Salmon River confluence downstream to the upper end of the Lower Granite reservoir), and the Clearwater River. Spawning generally does not occur until early-to-mid October, peaks in early-to-mid November and is generally complete by the beginning of December (Connor et al. 2019).

The incubation period is variable and depends on stream temperatures and dissolved oxygen levels. Generally, incubation extends through the winter into early spring. Fry emergence occurs from April through July, depending on the river. For example, Connor et al. (2002) documented fry emergence in the Snake and Clearwater Rivers from early April through late June and from early April through early July, respectively. The SR fall Chinook salmon ESU exhibits a diversity of juvenile migration strategies. The majority of both natural- (59%) and hatchery-origin (51%) SR fall Chinook salmon have an ocean-type migration strategy, and emigrate out of the action area rapidly after emergence, though the yearling-type migration strategy has become more common over the last two decades (Connor et al. 2005; Chittaro et al. 2019; Connor and Burge 2003; Coutant and Whitney 2006). Fish that exhibit a yearling life-strategy typically overwinter in lower Snake River reservoirs or other cool-water refuge areas and migrate to the ocean the following spring (NMFS 2017b). Peak passage of out-migrating juvenile SR fall Chinook salmon pass LGD generally occurs in May and June (Columbia River DART 2024). Given the variable life history, extended passage timing occurs, with earliest detection dates in late February and last detection dates extending into December. The median 95th percentile passage date for juveniles over the period of record is August 12, with a 95% confidence interval of July 6-September 15 (Columbia River DART 2024).

2.4.1.3. Snake River Sockeye Salmon

The single extant population (Redfish Lake) in the SR sockeye salmon ESU may be affected by the proposed action, and is essential to survival and recovery of the species. Snake River sockeye salmon usually spend 2 to 3 years in the Pacific Ocean and return in their fourth or fifth year of life. SR sockeye salmon adults enter the Columbia River primarily during June and July. The majority of SR sockeye salmon adults (hatchery and wild) typically pass LGD in July (Columbia River DART 2024). The median passage timing for the 25th and 75th percentile of the annual counts for the period of record (2000 – 2022) is July 8 and July 16, respectively. Although uncommon, adult fish have passed LGD as early as June 13 and as late as October 21 (Columbia River DART 2024). Details from the University of Washington DART passive integrator transponder (PIT) tag database show that only three PIT tagged adult sockeye salmon (out of 964 or 0.3%) have been detected passing LGD after mid-October in recent years. Most adults reach the Sawtooth Valley in late summer, peaking in August. Crozier et al. (2020) reported an average travel time of 39 days (standard deviation of 12.6 days) for sockeye salmon from LGD to the Sawtooth Valley for their period of study (2008 - 2017). Apparent adult survival through this migratory reach ranged from 33 - 75% during that same period of record (Crozier et al. 2020).

Five lakes in the Sawtooth Valley historically contained anadromous sockeye salmon: Alturas, Pettit, Redfish, Stanley, and Yellowbelly Lakes. Currently, natural production occurs in Redfish, Pettit, and Alturas Lakes. Spawning generally occurs in late October and November (Kozfkay et al. 2019) using areas of the shoreline with gravel substrate (Bjornn et al. 1968). There is also a residual component of sockeye salmon in Redfish Lake, which tend to spawn in either lake shorelines or in the adjacent Fishhook Creek.

Eggs hatch in the spring between 80 and 140 days after spawning. Fry remain in gravels for three to five weeks, emerge from April through May, and then move immediately into limnetic habitats. Once there, juveniles feed on plankton for one to three years before they rapidly migrate to the ocean, leaving their natal lake in the spring from late April through May (Bjornn et al. 1968; Kozfkay et al. 2019). SR sockeye salmon juveniles generally move downstream through the migration corridor quickly, reaching the ocean in the early summer months. Out-migrating juveniles pass LGD from late April to July, with peak passage occurring in May.

2.4.1.4. Snake River Basin Steelhead

All but one population (Tucannon River) in the SRB steelhead DPS may be affected by the proposed action. All populations in the DPS are vital for survival and recovery of the species (see status and recovery goals in Table 5). Passage of SRB steelhead adults (hatchery and wild) is generally concentrated from mid-September through late October (Columbia River DART 2024). The median passage timing for the 25th and 75th percentile of the annual counts for the period of record (1998 – 2022) is September 19 and November 5, respectively. While extended passage timing occurs, 95%of the annual visual counts have passed LGD on or before November 21 every year since 1998 (Columbia River DART 2024). Similar to Chinook salmon, migrating steelhead make extensive use of cold-water areas (Keefer et al. 2018). After holding over the fall and winter in mainstem reaches of larger rivers or in reservoirs, summer-run steelhead disperse into smaller tributaries to access spawning habitat in the spring (Busby et al. 1996; Thurow 1985). Typically, earlier dispersal occurs at lower elevations and later dispersal occurs at higher elevations.

Spawn timing generally occurs from March through early June, shortly after fish reach spawning areas, which is typically during a rising hydrograph and prior to peak flows (Thurow 1985; Thurow 1987). Because spawning occurs during periods of higher flows and greater turbidity, steelhead spawning surveys are difficult to perform with accuracy and index reach redd counts are not performed. Steelhead generally select spawning areas at the downstream end of pools, in gravels ranging in size from 0.5 to 4.5 inches in diameter (Pauley et al. 1986).

Depending on water temperature, steelhead eggs may incubate in redds for 1.5 to 4 months before hatching as alevins. Following yolk sac absorption, the alevins emerge from the gravel as young juveniles (fry) in July through September (four to eight weeks after hatching). Steelhead fry initially move from the gravel to low-velocity areas in side channels and along channel margins to escape high velocities and predators (Everest and Chapman 1972), and progressively move toward deeper water as they grow in size (Bjornn and Rieser 1991). Rearing steelhead remain in freshwater for one to four years before migrating toward the ocean during spring runoff, which occurs from March to mid-June depending on elevation. In the Snake River basin, most steelhead usually smolt as 2- or 3-year-olds, but 5-year-old smolts have been documented (Busby et al. 1996; Copeland et al. 2017). The majority of out-migrating juvenile SRB steelhead pass LGD from late-April through mid-May (Columbia River DART 2024). While extended passage timing occurs (earliest detection dates in late March and last detection dates extending into November), 95% of the annual counts have passed LGD on or before June 17 every year since 1998 (Columbia River DART 2024).

2.4.1.5. Southern Resident killer whale

SRKWs are highly mobile and can travel up to 86 miles (160 km) in a single day (Erickson 1978; Baird 2000), with seasonal movements likely tied to the migration of their primary prey, salmon. During the spring, summer, and fall months, the whales spend a substantial amount of time in the inland waterways of the Strait of Georgia, Strait of Juan de Fuca, and Puget Sound (Bigg 1982; Ford et al. 2000; Krahn et al. 2002; Hauser et al. 2007). During fall and early winter, SRKWs, and J pod in particular, expand their routine movements into Puget Sound, likely to take advantage of chum, coho, and Chinook salmon runs (Osborne 1999; Hanson et al. 2010; Ford et al. 2016). Although seasonal movements are somewhat predictable, there can be large inter-annual variability in arrival time and days present in inland waters from spring through fall (Olson et al. 2018; NMFS 2021a), with late arrivals and fewer days present in recent years (Hanson and Emmons 2010; NMFS 2021a; Ettinger et al. 2022).

Tagging data from a study conducted from 2012 to 2016 provided general information on the home range and overlap of each pod, and areas that are used more frequently during the winter than others by each pod (Hanson et al. 2017). The J pod had high use areas or hot spots in the northern Strait of Georgia and the west entrance to the Strait of Juan de Fuca where they spent approximately 30% of their time, but they spent relatively little time in other coastal areas. The K and L pods on the other hand occurred almost exclusively on the continental shelf during December to mid-May, primarily on the Washington coast, with a hot spot area between Grays Harbor and the Columbia River and off Westport, spending approximately 53% of their time there (Hanson et al. 2017; Hanson et al. 2018). Passive acoustic recorders have been deployed off the coasts of California, Oregon, and Washington in most years since 2006 to assess SRKW seasonal uses of these areas (Hanson et al. 2013; Emmons et al. 2019).

There were acoustic detections off of the Washington coast in all months of the year, with greater than 2.4 detections per month from January through June and a peak of 4.7 detections per month in both March and April, indicating that the SRKW may be present in Washington coastal waters at nearly any time of year, more often than previously believed (Hanson et al. 2013; Emmons et al. 2021). Also, SRKW were more frequently detected at inshore sites as compared to mid-shelf and offshore sites. Hanson et al. (2017) found that approximately 95% of the SRKW locations were within 34 kilometers (km) of the shore and 50% of these were within 10 km of the coast. Only 5% of locations were greater than 34 km from the coast, but no locations exceeded 75 km. Almost all (96.5%) outer coastal locations of satellite-tagged SRKWs occurred in continental shelf waters of 200 m (656.2 feet (ft)) depth or less, 77.7% were in waters less than 100 m (328.1 ft) depth, and only 5.3% were in waters less than 18 m (59 ft). Three primary hot spots identified through winter satellite tagging data were used to place multiple additional recorders; specifically, 1) the Washington coast, particularly between Grays Harbor and the mouth of the Columbia River (primarily for K/L pods); 2) the west entrance to the Strait of Juan de Fuca (primarily for J pod); and 3) the northern Strait of Georgia (primarily for J pod). It is important to note that recorders deployed within the sampling area were designed to assess spatial use off Washington coast and thus the effort was higher in this area (i.e., the number of recorders increased in this area) compared to off Oregon and California.

As discussed in the Status of the Species section, major threats to SRKW include 1) quantity and quality of prey, 2) toxic chemicals that accumulate in top predators, and 3) impacts from sound and vessels. Other threats include oil spills, disease, small population size, inbreeding, and other ecosystem-level effects (NMFS 2008b). It is likely that multiple threats act together to impact the whales, rather than any one threat being primarily responsible for the status of SRKWs. In this opinion, we focus on the baseline of SRKW as it relates to the quantity and quality of prey species, and in particular their primary prey, Chinook salmon. The abundance of Chinook salmon now is much less than historical abundance due to a number of human activities (section 2.2.1.1 and 2.2.1.2). Available data indicate lower prey availability for SRKW and poorer body condition in winter and early spring compared to summer (Durban et al. 2017; Fearnbach et al. 2018; Hanson et al. 2021). Human activities that likely have adverse effects on ESA-listed and non-ESA-listed salmon include: land use activities that result in habitat loss and degradation, contaminant exposure, hatchery practices, harvest, and hydropower systems. Changing ocean conditions driven by climate change (as described in section 2.2.3) may influence ocean survival and distribution of Chinook and other Pacific salmon further affecting the prey available to SRKWs. The effects of climate change described in section 2.2.3 would be expected to occur in the action area. These changes would likely have profound effects on marine productivity and food webs, including populations of salmon that serve as prey for SRKW.

2.4.2. Condition of Designated Critical Habitat in the Action Area

2.4.2.1. Land Cover and Human Activities

Designated critical habitat for SR sp/su Chinook salmon, SR fall Chinook salmon, SR sockeye salmon, and SRB steelhead overlap substantially in the action area, and the critical habitat PBFs for these species are similar, if not identical in many cases. Therefore, the environmental baseline is evaluated together here.

Land use data provides an indication of where acrolein, carbaryl, and diazinon are most likely to affect surface waters in the action area. Although the action area only includes anadromous watersheds in Idaho (and all areas of the Pacific Ocean where the marine ranges of prey species subject to this consultation overlap with SRKW), land use and pesticide use data are typically collected at the state scale. This statewide information for land use and pesticide use represents a larger geographic area than the action area, but provides useful context for anadromous watersheds in Idaho. Acrolein is typically used in irrigation canals, carbaryl is used on forested land (30.2% of land cover), rangeland (13.3%), and in agricultural areas (10.4%), and diazinon is primarily used in agricultural contexts (10.4%) (Table 8).

As shown in Figures 4 and 5, parts of the designated critical habitat of each of the ESA-listed salmonids considered in this opinion are in close proximity to several irrigation districts, where acrolein may reasonably be expected to be used. However, the vast majority of irrigation districts in Idaho are in the southern part of the state, away from waters that support ESA-listed salmon and steelhead. Although there may be spatial overlap between presence of ESA-listed salmonids and irrigation infrastructure, this does not necessarily indicate that acrolein is used in these areas.

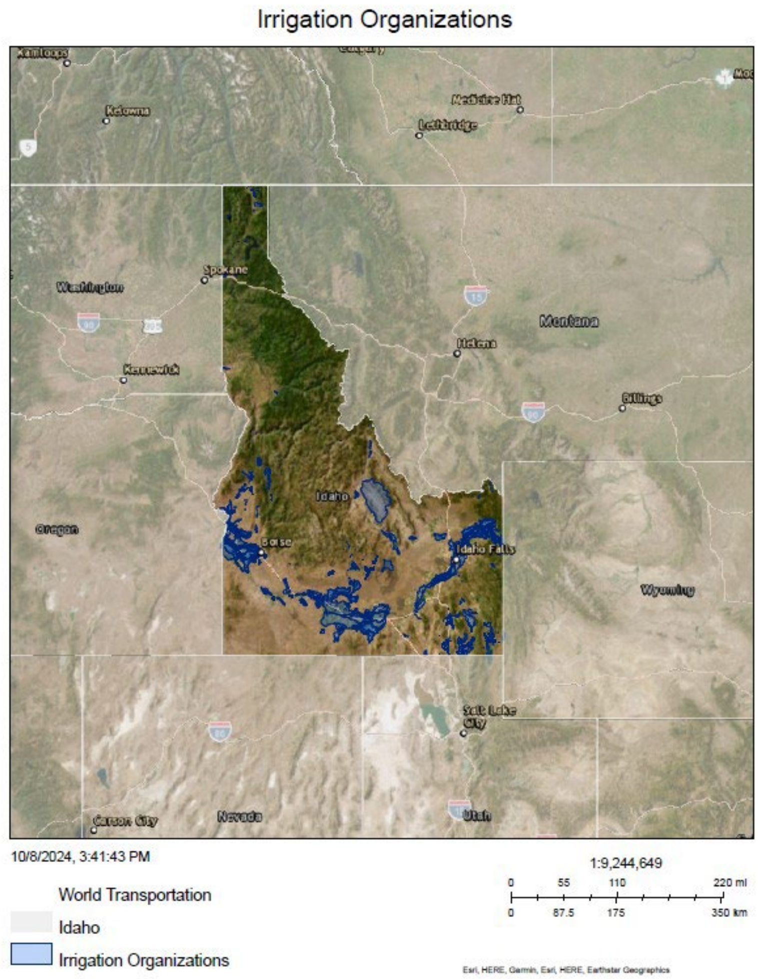

Figure 5. Irrigation organizations in Idaho, shown in blue.

Table 8. Land-use/cover composition in Idaho (USDA 2021).

Land-Use Class	Proportion (%)
Shrubland	42.11
Forest (evergreen, deciduous, mixed)	30.21
Grassland/Pasture	13.27
Crops (all crops/agricultural uses)	10.39
Developed (sum of all intensities)	1.78
Open Water	0.99
Herbaceous and Woody Wetlands	0.96
Barren	0.28
Perennial Ice/Snow	0.03

Species habitat is also variably distributed across land-use types. For example, SRB steelhead, SR sockeye salmon and SR sp/su Chinook salmon habitat mostly consists of forests and shrubland (open water is also a large component for sockeye salmon, which rear in lakes). In contrast, SR fall Chinook salmon habitat is majority grassland/pasture and agricultural uses (50.9%) (USEPA 2024).

Table 9. Proportion of land use types within habitat of salmonid species in Idaho. Where 0.0 is listed, values are much smaller than 1%, but not equal to 0%, whereas a (-) indicates no overlap with species habitat at all (USEPA 2024).

	Proportion (%) of species habitat			
Class Name	**SR sockeye**	**SRB steelhead**	**SR fall Chinook**	**SR sp/su Chinook**
Shrubland	36.5	33.5	29.1	43.7
Forests (evergreen, deciduous, mixed)	23.2	57.4	10.3	43.0
Grassland, pasture	4.8	7.4	29.2	11.9
Crops (all ag uses)	0.8	0.7	21.7	0.2
Developed (total of all densities)	6.6	0.4	8.1	0.4
Open Water	22.2	0.2	1.5	0.3
Herbaceous and woody wetlands	5.9	0.2	0.1	0.2
Barren	0.0	0.3	0.0	0.0
Perennial Ice/Snow	-	0.0	-	0.0

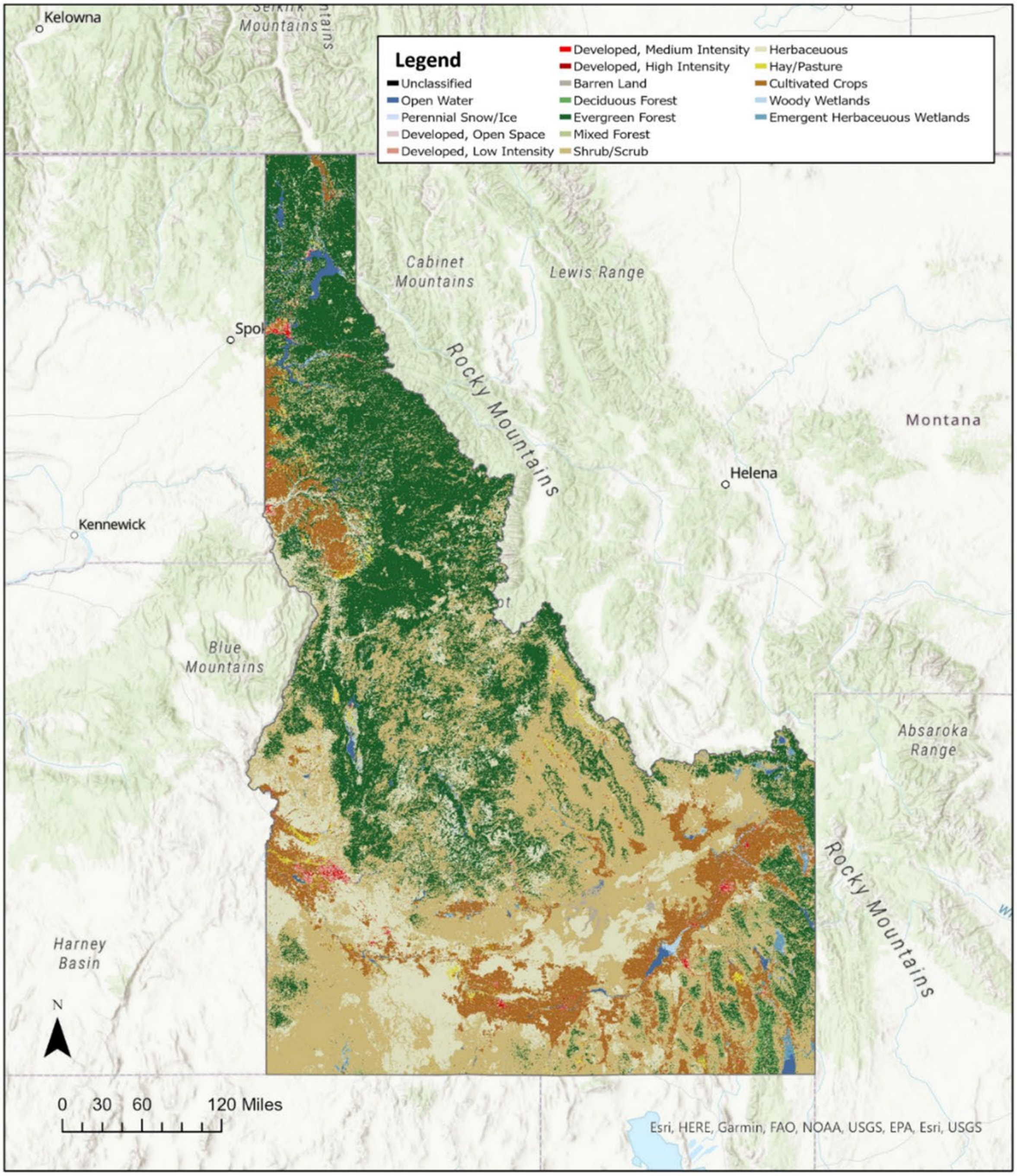

Figure 6. Land-use/cover classes across Idaho State (Dewitz 2021).

Of the cropland coverage in Idaho (~10.4% of total land-use/cover, Table 8), many types of crops may be treated with carbaryl or diazinon. Exact geographic areas of pesticide application are challenging to estimate, but we can make inferences based on where certain crops are grown, as some are more likely to be treated with carbaryl or diazinon than other types of crops or land cover. The cultivated crops that may be treated with carbaryl or diazinon that occupy the greatest proportion of cropland in Idaho include alfalfa (~30%), wheat (~22%), corn (7.8%), hay

(~6.1%), potatoes (~6.1%), sugar beets (~3.1%) and orchards/grapes (~0.01%). While these crops may be treated with carbaryl or diazinon, they are not necessarily the crops that are most commonly treated, or treated most heavily with these pesticides. The majority of agricultural areas in Idaho do not overlap with anadromous watersheds. The crops that are grown in proximity to anadromous watersheds are a mix of crops that may be treated with carbaryl and/or diazinon and those that are not (i.e., spring and winter wheat, alfalfa (may be treated), and canola, chick peas, lentils, barley (typically not treated with carbaryl and/or diazinon)).

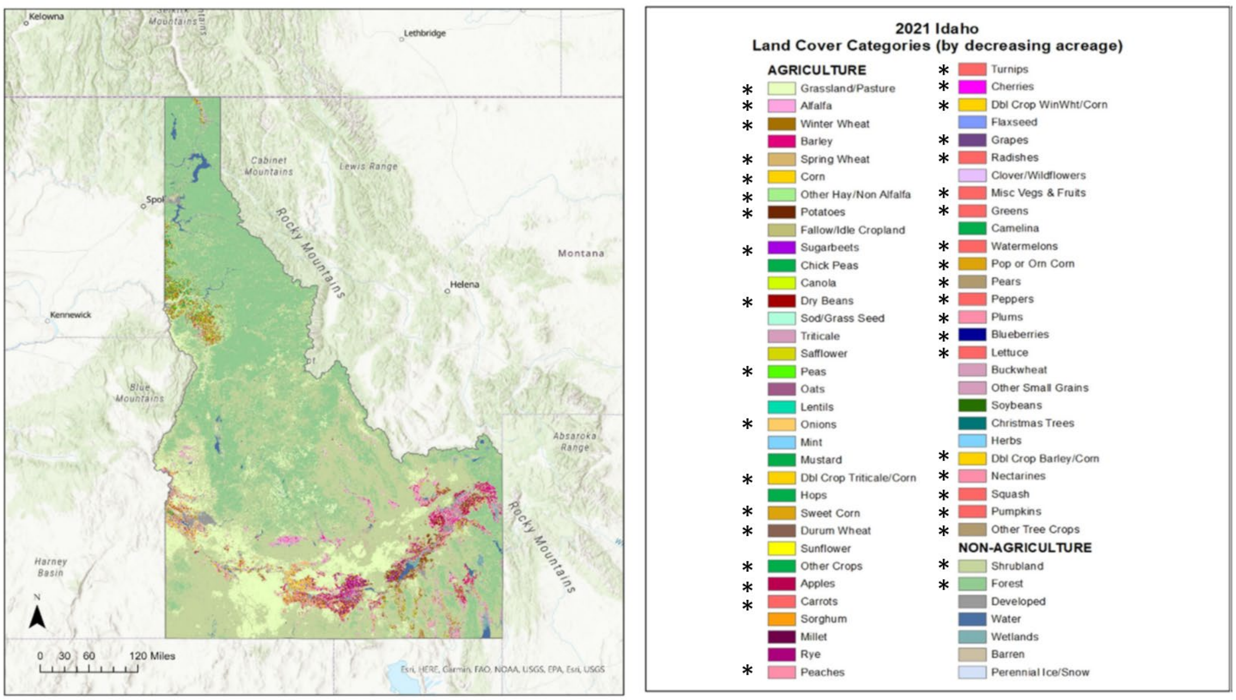

Figure 7. Cropland Data Layer across Idaho State based on USDA National Agricultural Statistics Service (USDA 2023). Land cover categories with an asterisk are most likely to be treated with carbaryl or diazinon (APHIS 2021; USEPA 2010; 2021d; Wieben 2021). These pesticides are approved to be applied to other fruits and vegetables, but were considered to contribute less to carbaryl/diazinon-treated acreage in Idaho.

Another way of the estimating pesticide application baseline is by weight applied to different types of crops in Idaho (Table 10). Based on estimated annual agricultural pesticide usage data spanning 1992-2019 for carbaryl and 1992-2018 for diazinon (Wieben 2021), carbaryl (by weight) is most applied to vegetable and fruits, followed by alfalfa, other crops, wheat, orchards, and grapes. By weight, diazinon is most applied to fruits and vegetables, other unreported other crops, followed by orchards and grapes, and pasture and hay. While fruits and vegetables make up a relatively small proportion of land cover, these small areas can be expected to be treated most heavily with carbaryl and diazinon. Some categories reported in the NAWQA dataset are broad, making it challenging to identify whether the small area of cropland in proximity to anadromous watersheds is planted with crops that are most heavily treated with carbaryl and diazinon. One crop that occurs in a relatively small area in proximity to anadromous watersheds in the lower Clearwater, lower Snake, and upper Salmon Rivers is alfalfa, which has a relatively high estimated weight of annual application in Idaho at 78,766 kg (Table 10). Given its relatively high application rate statewide, it is reasonable that alfalfa cropland in proximity to anadromous watersheds would be treated with carbaryl. This may also be true for wheat cropland in proximity to anadromous watersheds, though wheat has a lower estimated application statewide (30,615 kg annually).

Table 10. NAWQA high annual estimates for carbaryl and diazinon usage (total kilograms) major crop groups in Idaho. See Wieben (2021) for estimation methods.

Pesticide	Carbaryl (total kg, 1992-2019)	Diazinon (total kg, 1992-2018)
Vegetables and Fruit	126,840	180, 495
Alfalfa	78,766	2,233
Wheat	30,615	-
Orchards and Grapes	28,349	22,855
Pasture and Hay	623	17,203
Corn	332	654
Other Crops	43,990	46,057

Within the action area (anadromous waters in the state of Idaho, excepting waters under Nez Perce Tribe jurisdiction), there are three main anadromous basins: the Clearwater River Basin, the Salmon River Basin, and the Snake River Basin. The following sections describe the baseline of land cover and human activities that are relevant to the proposed action in each of these basins.

Clearwater River Basin: The Clearwater River basin, in north-central Idaho, is bracketed by the Salmon River basin to the south and St. Joe River subbasin to the north. The Clearwater River drains approximately a 9,645-mi^2 area, with four major tributaries including the Lochsa, Selway, South Fork Clearwater, and North Fork Clearwater Rivers.

More than two-thirds of the total acreage of the Clearwater River basin is evergreen forests (over 4 million acres), largely in the mountainous eastern portion of the basin. Most of the forested land within the Clearwater basin is owned by the federal government and managed by the USFS (over 3.5 million acres), but the State of Idaho and Potlatch Corporation also own extensive forested tracts. Private ownership by small forest landowners and timber companies becomes increasingly common in the more western forests of this basin, but accounts for a relatively small proportion of the forested land. The western third of the basin is composed almost entirely of crop and pastureland, owned by farming and ranching families and companies. Nez Perce Tribe lands are located primarily within or adjacent to Lewis, Nez Perce, and Idaho Counties within the current boundaries of the Nez Perce Indian Reservation, which is excluded from the action area. Other agencies managing relatively small land areas in the Clearwater basin include the National Park Service, the BLM, Idaho Transportation Department, and IDFG (Ecovista 2004a).

Salmon River Basin: The Salmon River flows through central Idaho to join the Snake River. The Salmon River is the largest subbasin in the Columbia River drainage, excluding the Snake River, and has the most stream miles of habitat available to anadromous fish. The total subbasin is approximately 14,000 mi^2 in size. Major tributaries include the Little Salmon River, South Fork

Salmon River, Middle Fork Salmon River, Panther Creek, Lemhi River, Pahsimeroi River, and East Fork Salmon River (IDFG 1990).

Public lands account for approximately 91% of the Salmon River Basin, with most of this being in federal ownership and managed by seven National Forests or the BLM. Public lands within the basin are managed to produce wood products, domestic livestock forage, and mineral commodities; and to provide recreation, wilderness, and terrestrial and aquatic habitats. Approximately 9% of the basin is privately owned (Ecovista 2004b). Private lands are primarily in agricultural cultivation, and are concentrated in valley bottom areas of the basin. The Salmon River Basin encompasses portions of five USFS wilderness areas. The Frank Church River of No Return Wilderness area, one of the five within the subbasin, is the largest wilderness area in the contiguous United States. Specific management guidelines for wilderness areas generally prohibit motorized activities and allow natural processes to function in an undisturbed manner.

The diversion of water, primarily for agricultural use within the Salmon River Basin, has a major impact on developed areas – particularly the Lemhi, Pahsimeroi, the mainstem Salmon, and several tributaries of the Salmon River. A major problem is localized stream dewatering. In addition to water diversions, numerous small pumping operations for private use occur throughout the subbasin. Impacts of water withdrawal on fish production are greatest during the summer months, when streamflows are critically low (IDFG 1990).

Snake River Basin: The Snake River is a large river that is one of the most important water resources in the State of Idaho. Anadromous salmonids occupy only a portion of the Snake River in Idaho, extending from near the confluence with the Clearwater River upstream to Hells Canyon Dam (a man-made barrier to upstream migration). Water quality conditions within the Snake River reach of the action area are influenced by the various agriculture, irrigation, and urban/industrial activities in the Snake River basin upstream of the Hells Canyon Dam. Agricultural runoff returns to the river and also recharges the aquifer. It can carry various contaminants from pesticides, fertilizers, and/or animal wastes. Water quality in the Snake River is also influenced by effluent from Boise, Idaho Falls, and Twin Falls. These population centers are sources of contaminants associated with urban and industrial activity that may influence contaminants in downstream anadromous waters. Downstream of Hells Canyon Dam, where there is ESA-listed salmonid habitat, the Snake River flows through forested areas before reaching another agricultural area and the population centers of Lewiston, Idaho and Clarkston, WA. The Snake River then crosses the Washington-Idaho border and out of the action area.

In summary, all three anadromous basins in the action area have mixed land cover, and may have been affected by the pesticides considered in this opinion in the past, given their widespread application for multiple land uses. Given the composition of land cover in each of these three basins and the association of these pesticides with agricultural areas, the Snake River Basin has likely been impacted by acrolein, carbaryl, and diazinon applications upstream of anadromous habitat and in anadromous habitat in the Snake River in northwestern Idaho. Anadromous waters in the Clearwater River Basin may have also been impacted where the lower reaches of the South Fork Clearwater River and the mainstem Clearwater pass through agriculture areas that include a mixture of crops that may be treated with carbaryl or diazinon and crops that are not treated. The Salmon River Basin has only a small area of cropland in anadromous habitat in the Upper

Salmon River, and this primarily consists of alfalfa, which is known to be treated with carbaryl (and diazinon to a lesser extent) in Idaho. Impacts have likely varied spatially and over time within these basins, correlating with land use category and crop type.

Maintaining the integrity of critical habitat and its PBFs is essential to meeting recovery goals for the ESA-listed species considered in this opinion. Overall, there is a large degree of variation in the level of degradation to critical habitat in the action area. While most designated wilderness areas and 1st-order streams have relatively little disturbance, many streams are impaired due to altered hydrology (e.g., dams, water allocation and use) and water quality (e.g., contaminants, nutrients, temperature, dissolved oxygen). Given the baseline conditions, temperature is a major limiting factor for many salmonid populations in Idaho. Climate change is expected to exacerbate these issues by reducing flows, warming stream temperatures (Isaak et al. 2016), and potentially enhancing the mobility, accumulation, and toxicity of contaminants (Kibria et al. 2021; Patra et al. 2015). Particularly in higher order streams, it is likely that salmonids are being exposed to pesticides and other contaminants. However, there is little information about the distribution and concentration of many pesticides, including carbaryl, diazinon, and particularly acrolein.

2.4.2.2. Water Quality

Pesticides in current use have been detected in the mainstem Columbia and Snake Rivers and estuary, downstream of the action area. NMFS has performed a series of consultations on the effects of commonly applied chemical insecticides, herbicides, and fungicides which are authorized for use per EPA label criteria (NMFS 2022a; 2023a, see discussion in section 2.5.1). In these opinions, all West Coast salmonids were identified as jeopardized by at least one of the analyzed chemicals; most are identified as being jeopardized by many of the chemicals.

NMFS also issued jeopardy biological opinions for Idaho (NMFS 2014) and Oregon (NMFS 2012) for water quality standards for multiple toxic substances. EPA and the states have since taken steps to update criteria for some of the contaminants that NMFS determined would jeopardize ESA-listed species.

Pesticides contribute to degradation of water quality in addition to many other contaminants and water quality stressors (e.g., temperature, dissolved oxygen, turbidity). Water quality limited segments are streams or lakes which are listed under section 303(d) of the CWA for either failing to support their designated beneficial uses, or for exceeding state water quality criteria. IDEQ monitors and periodically updates the 303(d) list of impaired waters, and did so most recently in the 2022 Integrated Report (IDEQ 2022). Of the 92,056 stream miles in Idaho, 32.2% are fully supporting their beneficial uses, 39.2% are not supporting beneficial uses and are considered impaired, and 28.6% have not been assessed. In Idaho, the leading cause of impairment is temperature, followed by biota/habitat, Escherichia coli, and sedimentation/siltation (IDEQ 2022). Each of the three anadromous basins in the action area (Clearwater River, Salmon River, and Snake River basins) have a number of impaired reaches. For example, the 2022 303(d) list includes 7 defined stream reaches within the Hells Canyon and Lower Snake River Asotin 4th-field HUCs. Reach-specific 303(d)-listed stream segments can be accessed at: https://www.deq.idaho.gov/water-quality/surface-water/monitoring-and-assessment/. Given that criteria for the three pesticides considered in this opinion have not previously been implemented, there are currently no water bodies that are considered to be impaired for acrolein, carbaryl, or diazinon. However, pesticides containing these active ingredients are in current use, and allowable application rates, estimated usage, land use, and water quality monitoring data provide some insight into the spatial and temporal context of occurrence of these compounds. The baseline for acrolein, carbaryl, and diazinon in the action area is discussed further in section 2.4.2.2.2.

Pesticides have a wide range of uses in residential, agricultural, and other land management practices. They may enter water bodies via multiple pathways, all anthropogenic in nature. Most often, pesticides enter water bodies through drift, runoff, or direct application (intentional or otherwise). Because many of the transport pathways of pesticides are diffuse on the landscape, identifying sources of pesticide contamination can be challenging for some types of application. Pesticides have a diversity of chemical properties, may degrade into other compounds in aquatic environments, and interaction with other water quality parameters (e.g., temperature, pH) may influence their availability and potency (Fishel and Farrell 2019; Laetz et al. 2014; Nowell et al. 2014; Patra et al. 2015). Monitoring data for pesticides can also be sparse, resulting in some uncertainty in characterizing the environmental baseline for the compounds considered in this opinion.

2.4.2.2.1 Acrolein

Acrolein, which is also known as acrylaldehyde, allyl aldehyde and 2-propenal, is registered as MAGNACIDE® H primarily for use in irrigation canals. Acrolein may be used for algae, weed and mollusk control in recirculating process water systems; for slime control in the paper industry; to protect liquid fuels against microorganisms; and to control sulfate reducing bacteria that produce corrosive hydrogen sulfide in oilfield water systems (IARC 1985; USEPA 2007). Sources of acrolein in the environment include emissions and effluents from its manufacturing and use facilities, emissions from combustion processes, direct application to water and waste water as a slimicide or aquatic herbicide, as a photooxidation product of various hydrocarbon pollutants found in air, and from land disposal of some organic waste materials (Faroon et al. 2008). It is most commonly applied for aquatic weed and pest control via direct injection into irrigation canals in Idaho; thus, irrigation activities can give a good indication of potential for acrolein use. There are 386 active irrigation organizations in Idaho (IDWR 2021, Figure 5) and 3 million acres of irrigated land (IDWR 2022), primarily in cultivated crop and pasture land use areas (Figure 6). The majority of agricultural land in Idaho, where most irrigation canals that may be treated with acrolein exist, is outside anadromous watersheds. However, there is some overlap, and the degree of overlap varies between the ESA-listed salmonid species considered in this opinion (Table 9).

Products containing acrolein are typically applied directly below the surface of water in irrigation systems. Magnacide H may be applied up to 26 times per year, but six applications per year is most common. Concentrations in the range of 1 to 15 mg/L are typically used for effective weed control, though the amount needed increases by as much as 100% when water temperature is below 10°C (USEPA 2007). According to the product label for Magnacide H, water treated with this pesticide may be used to irrigate fields at any time after treatment, or should be held for 6 days before being released into surface waters that contain or drain into waters that contain fish. While the 2016 PGP does not cover agricultural stormwater discharges and there are no active NPDES permittees with discharge limits or monitoring requirements for acrolein, the PGP does cover weed and algae pest control. In the 2016 PGP Annual Report (USEPA 2016a), applicators within the Pioneer Irrigation District registered notices of intent to use Magnacide H from 2017 – 2019 for controlling aquatic pests in irrigation canals near Caldwell (southwest Idaho, upstream of anadromous watersheds and the Hells Canyon dam complex). Around 4-5 treatments were applied across an area spanning 720,720 linear feet. Acrolein is a restricted use herbicide and can only be used by certified applicators. Baker Petrolite, the maker of Magnacide H, requires users to be trained by Baker in the use of acrolein (Turner and Erickson 2003; USEPA 2014).

Although the Pioneer Irrigation District has registered notices of intent for Magnacide H, currently no monitoring of acrolein in fish-bearing streams is required. However, it is likely that the notices of intent included in the 2016 PGP are outdated (USEPA 2024), making it challenging to accurately assess the usage of acrolein and its proximity to salmonid habitat. In addition, the only pesticide monitoring programs in Idaho (USGS-NAWQA, ISDA) have not measured acrolein in surface waters to our knowledge. Therefore, there is a large degree of uncertainty in our understanding of the occurrence of acrolein in aquatic habitats in Idaho.

2.4.2.2.2 Carbaryl

Carbaryl is an insecticide, molluscicide, and is used to control pests in a variety of land-use settings, and to thin fruit in orchards. It belongs to the N-methyl carbamate class of pesticides (USEPA 2012). Carbaryl is not managed under the PGP, and coverage for carbaryl discharges are obtained through individual permits. There is one individually-permitted facility (Henggeler Packing Co., Inc. in Fruitland, Idaho) that discharges carbaryl. The IPDES permit for this facility (Permit No. ID0027901) requires one monitoring sample per year for carbaryl, taken between July 1st and November 30th. There have been no carbaryl detections from this facility. To characterize baseline conditions of carbaryl in the action area, we rely upon water quality monitoring programs, and an understanding of application rates to characterize potential occurrence and concentrations of carbaryl in aquatic environments.

Carbaryl is typically applied for insect control to (in no particular order) lawns, home gardens, citrus, fruit, forage and field crops, forest, nuts, ornamentals, rangeland, turf, shade trees, poultry, and pets (USEPA 2010). In a 2013 – 2017 national survey of carbaryl agricultural usage by state, USEPA (2021d) found that carbaryl is reported to be used on dry beans and peas (200,000 acres), potato (300,000 acres), sugar beets (200,000 acres), field corn and alfalfa (no estimate of acreage) in Idaho (USEPA 2021d). The average annual rate of application across the state of Idaho is <500 lbs of active ingredient for each of the above listed crops, where an estimate was possible (no estimates for dry beans/peas, field corn, and alfalfa) (USEPA 2021d).

Carbaryl is also used in non-agricultural contexts to control a variety of pests including leaf beetle and bark beetle populations on USDA forest lands in Idaho (USDA 2008). The Animal Plant Health Inspection Service (APHIS) also distributes carbaryl bait to control cricket and grasshopper populations in rangelands across southern Idaho (APHIS 2021). APHIS applies the insecticide as bait, ultra-low-volume (ULV) spray formulations by ground-based equipment, or at reduced volumes by aerial application. These types of applications take place in rural rangeland areas where agriculture is a primary economic factor in the southern part of the state.

The program restricts insecticide applications directly into waterbodies and requires a no treatment buffer from water bodies (i.e., 500 feet buffer for aerial and 200 feet buffer for ground applications) to minimize drift from applications (USDA 2019). From 2010 to 2022, an average of 35,242 pounds (minimum = 150 lbs, maximum = 169,000 lbs) of carbaryl was applied in Blaine, Butte, Cassia, Clark, Elmore, Gooding, Jerome, Minidoka, Owyhee, Oneida, Twin Falls, and Washington counties for grasshopper and cricket control (APHIS personal communication as cited in EPA 2024), all in the southern portion of the state. A 2014 – 2018 national carbaryl survey for non-agricultural usage reported carbaryl treatment of over 57,600,000 acres of forest in Forest Service Regions 1 and 4, an area which encompasses Idaho and other surrounding states, as well as 53,500,000 acres of rangeland and pasture in Idaho (USEPA 2021d).

Carbaryl usage over the landscape can also be estimated using the USGS E-pest database, which contains extensive estimates of pesticide use from proprietary surveys for Crop Reporting Districts (USGS 2024d). The E-pest high method (shown in Figure 8) imputes an estimate based on reported use rates in nearby districts for those with missing data for a particular crop and pesticide. The available data from 2019 suggests that is prevalent in the agricultural areas in the southern part of the state, outside of anadromous watersheds. Some carbaryl use may occur in the central-eastern portion of the state, as well as in larger rivers in agricultural areas in the northwestern part of the state, overlapping to some degree with anadromous watersheds (Figure 8).

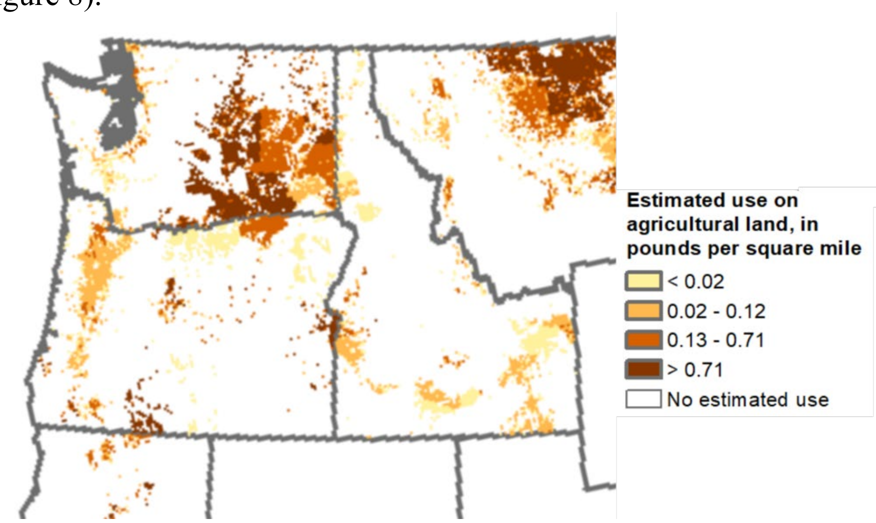

Figure 8. E-pest high estimated carbaryl use in pounds per square mile for 2019 in the Pacific Northwest.

Pesticide monitoring, which included testing for carbaryl and diazinon, was conducted by the USGS NAWQA program in most years from 1994 – 2019 and the ISDA Agricultural Water Quality Monitoring program from 2014 – 2019. For the NAWQA sites, samples collected spanned all months of the year at three sampling locations in the Snake River basin (Figure 9). Of all samples collected from 1994 – 2019, 51.9% of samples were from the Rock Creek at Twin Falls station, 37.5% from the Snake River at King Hill station, and 10.6% from the Henry's Fork near Rexburg, ID station (USGS 2024a; 2024b; 2024c). For the ISDA dataset (2014 – 2019), samples were taken at 57 different sites across southern Idaho, though season of sampling could not be determined, given that sample date was not always reported. Very few samples collected by these monitoring programs were from anadromous watersheds, and samples from nonanadromous waters may have different conditions than those experienced by ESA-listed fish. However, monitoring data from outside the action area can provide insight into pesticide levels in the state more broadly. In combination with land use and crop cover data, we can estimate how representative monitoring data in other parts of the state may be of Idaho's anadromous watersheds.

Monitoring for carbaryl by USGS-NAWQA and the ISDA pesticides monitoring program from 1994 – 2019 found a total of 53 samples were at detectable levels, with a median concentration of 0.010 µg/L and 10 statistical outliers (0.03 – 0.2 µg/L) (Figure 10). Even the outliers in this dataset were below the thresholds defined by the EPA Office of Pesticides Programs (OPP) (6.8 µg/L) and by the EPA's 304(a) aquatic life criterion and proposed Idaho criterion (2.1 µg/L).

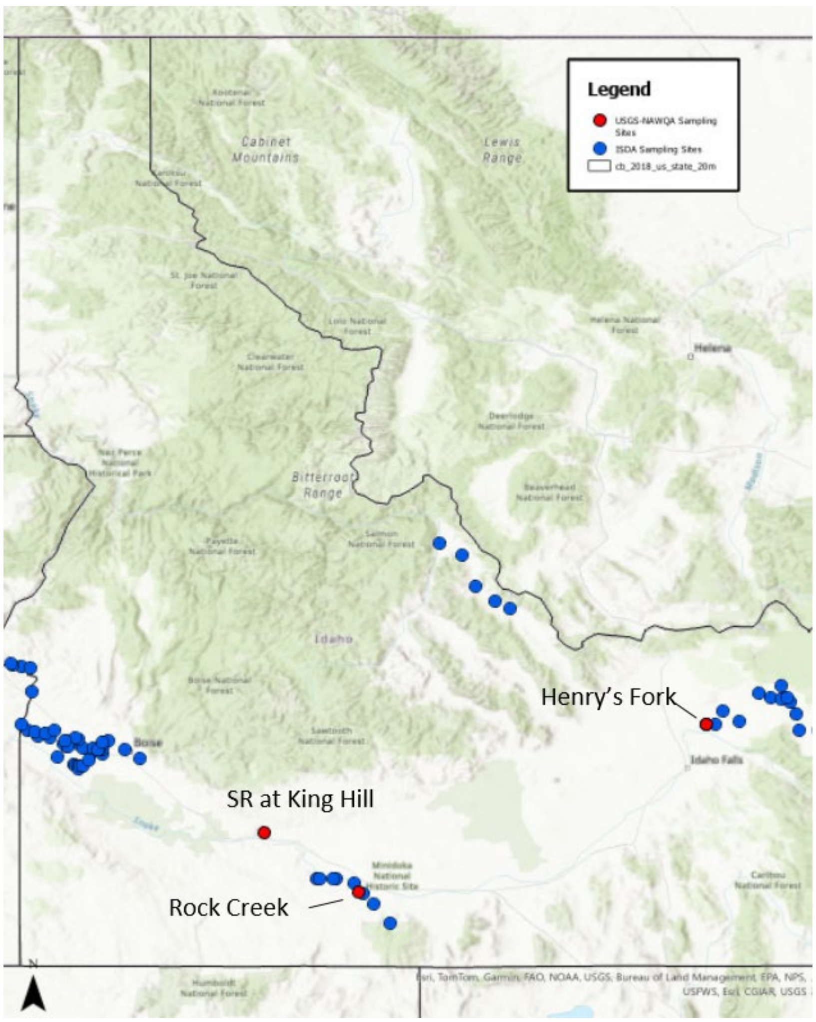

Figure 9. Idaho surface water pesticide monitoring locations for USGS-NAWQA (red points) and ISDA monitoring program (blue points).

Most of the samples (~95%) collected as a part of these monitoring programs had concentrations that were below analytical detection limits for both carbaryl and diazinon. For the NAWQA dataset, 929 discrete samples were collected and measured for both carbaryl and diazinon, but yielded concentrations below the lowest reporting limit for multiple analytical methods. In the ISDA dataset, 1,278 discrete samples were collected that had concentrations below the method detection limit. The detection limit varied by method and by compound measured. For carbaryl, the detection limit ranged from 0.002 µg/L to 0.06 µg/L for the NAWQA monitoring program methods and 0.025 µg/L to 0.14 µg/L for the ISDA methods. Some of the higher detection limits fall within the range of values shown in Figure 10. Because of this, it is possible that the median surface water concentration is underestimated here, as a result of variably sensitive analytical methods. For example, samples that fell below a 0.14 µg/L detection limit would not be included in Figure 10 or this calculation of median surface water concentration of carbaryl, despite the fact that the true concentration of this sample may fall anywhere from 0 – 0.14 µg/L, and might have been included had a more sensitive method been used.

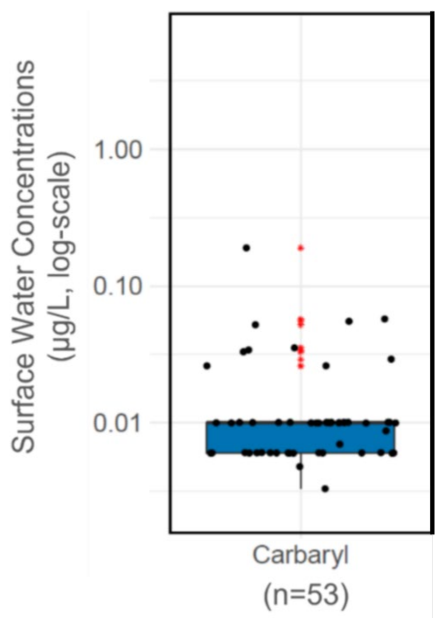

Figure 10. Box and whisker summary statistics for sampled surface water concentrations (µg/L on log-scale) of carbaryl exceeding analytical detection limits (n= 53 samples). The box denotes the interquartile range, and whiskers indicate minimum and maximum values. Individual data points are overlaid. Red asterisks indicate where along the y-axis statistical outliers occur.

As indicated in Figure 11, none of the detections of carbaryl were in or near ESA-listed salmonid critical habitat or range. However, as previously noted, salmonid habitat does occur downstream of the pesticide detections.

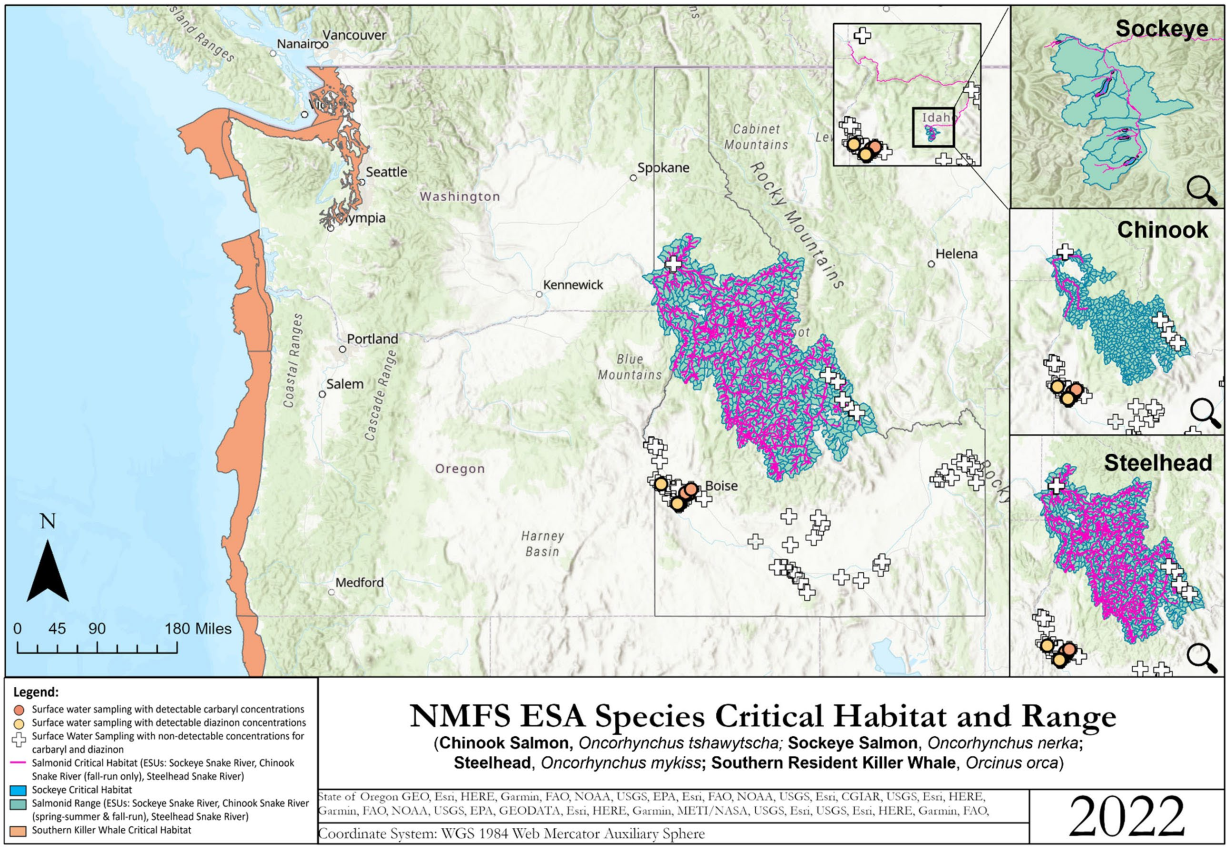

Figure 11. Surface water sampling with detectable concentrations overlaid on ESA species habitat (yellow circles = diazinon, orange circles = carbaryl, white + = pesticides below detection limits). Critical habitat (pink lines) for SR sockeye salmon, SR fall Chinook salmon, and SRB steelhead, and range (green polygons) for SR sockeye salmon, SR sp/su and fall Chinook salmon, SRB steelhead, and critical habitat for SRKW (orange polygons). Magnified panels show individual critical habitat (pink lines) and range (green polygons) for SR sockeye salmon, Chinook salmon, and SRB steelhead.

2.4.2.2.3 Diazinon

Diazinon is a broad-spectrum organophosphate insecticide used against adult and juvenile insects, acarians, and spiders (WHO 1998 as cited in USEPA 2005). It is most often applied to fruit, vegetables, tobacco, forage, field crops, range, pasture, grasslands, and ornamentals. It may also be used to treat ectoparasites on livestock. Use of diazinon for nonresidential agricultural or other uses in accordance with the product label has been approved by EPA under FIFRA (USEPA 2005).

Diazinon is not managed under the PGP. There are no active IPDES permittees with discharge limits or monitoring requirements for diazinon. To characterize diazinon occurrence and concentrations, we rely upon water quality monitoring programs, and estimates of application rates.

The national maximum annual rate of diazinon that may be applied to a crop site at a single time is 9 lbs of active ingredient per acre for cranberries (USEPA 2017). For some crops, the label use instructions allow for crop cycles with multiple applications per year. The highest yearly application rate allowed when accounting for multiple crop cycles is 15.5 lbs of active ingredient per acre, for squash and winter squash. Most applications are in liquid form, but can also be applied as a livestock ear tag. Ground applications of diazinon are most common (broadcast, soil incorporation, orchard airblast, chemigation), though aerial applications are allowed for lettuce (USEPA 2017). Diazinon was banned for residential use in 2004, and agricultural use has been declining in recent years. The total number of agricultural acres in the U.S. where diazinon is used has declined by 97% since the peak in 2005, and the weight applied annually has decreased by 85% since its peak in 2003 (USEPA 2016c).

Approximately 60% of diazinon nationwide is applied to five crops: apples, lettuce, onions, tomatoes, and cherries, with the remaining 40% spread over nearly 30 other crops. The EPA performed a survey of diazinon usage by crop and state for the time span of 2010 – 2014. The only crop that was surveyed and reported usage in Idaho was potatoes (318,800 acres of potatoes in Idaho). Crops that were surveyed for Idaho, but did not report usage during this timeframe include watermelons, pumpkins, onions, dry beans/peas, beans (snap, bush, pole, string), and cantaloupes. The crops that are most commonly treated with diazinon are not evenly distributed across Idaho. The five crops that most diazinon is applied to, as well as potatoes, are grown in the southern portion of the state, with almost none grown within anadromous watersheds (Figure 12). Diazinon may also be used on other crops that are grown in other parts of the state, but we expect usage to be lower in areas outside of those shown in Figure 12. Diazinon usage over the landscape can also be estimated using the USGS E-pest database, which contains extensive estimates of pesticide use from proprietary surveys for Crop Reporting Districts (USGS 2024d). The E-pest high method (shown in Figure 13) imputes an estimate based on reported use rates in nearby districts for those with missing data for a particular crop and pesticide. This information suggests that some diazinon use may occur in the central-eastern portion of the state in anadromous watersheds, but that the majority of use aligns with the crop cover data, in that it is primarily used in the southern part of the state (Figure 13). It is important to point out that the data mapped in Figures 12 and 13 only represent snapshots of one year (2023 and 2017, respectively).

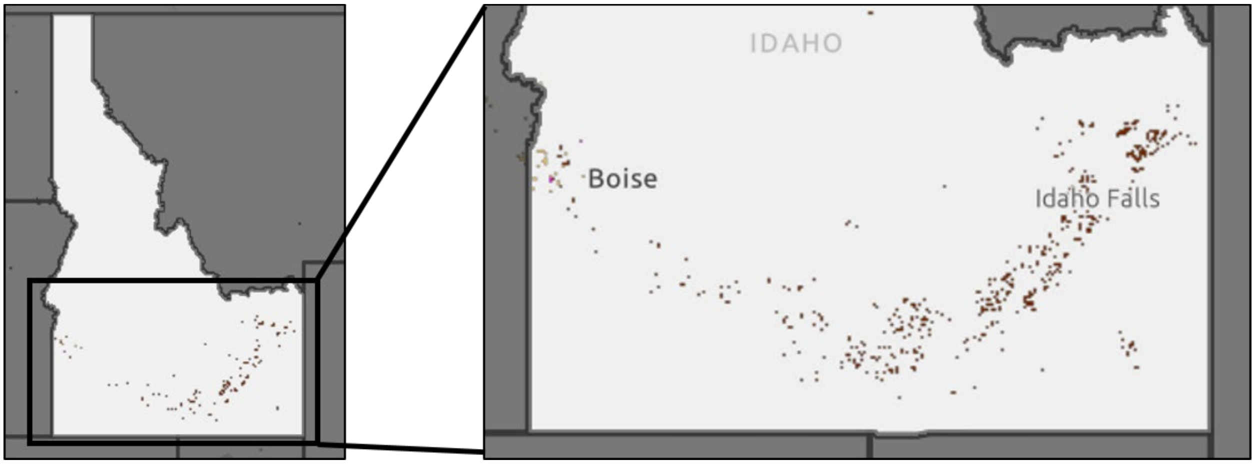

Figure 12. Spatial distribution of crops in Idaho that are most commonly treated with diazinon including apples, lettuce, onions, tomatoes, cherries, and potatoes. The inset shows the southern portion of Idaho, where most of these crops are grown.

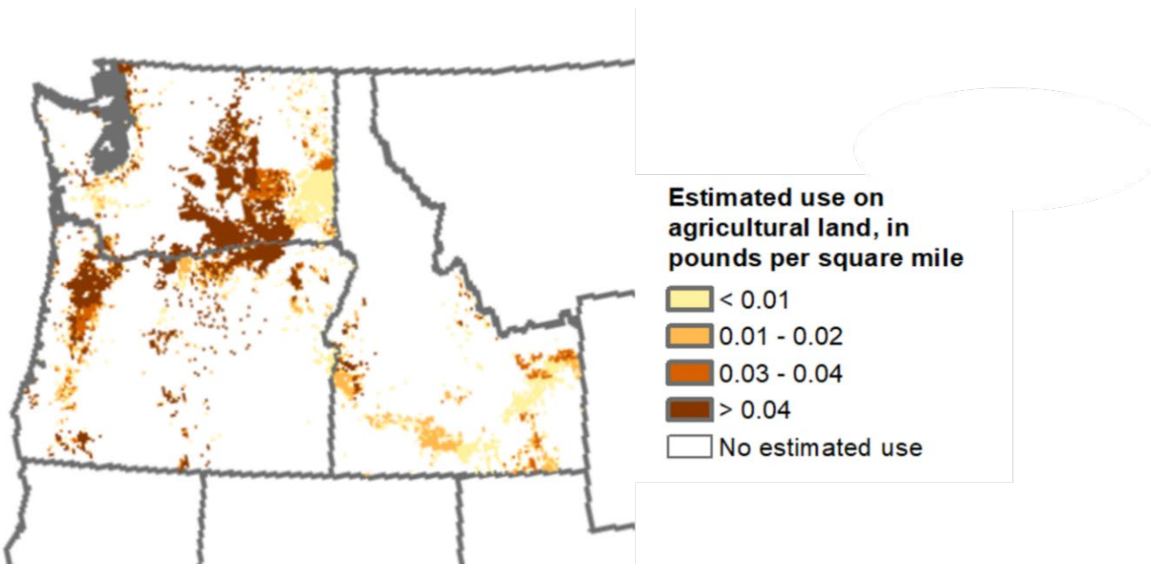

Figure 13. E-pest high estimated diazinon use in pounds per square mile for 2017 in the Pacific Northwest.

Monitoring for diazinon by USGS- NAWQA and the ISDA pesticides monitoring programs from 1994 – 2019 at three sampling locations in the Snake River basin found a total of 67 samples were at detectable levels, with a median concentration of 0.005 µg/L and 13 statistical outliers (0.01 – 6.3 µg/L) (Figure 14). The majority of outliers in this dataset were below the thresholds defined by the OPP (<0.55 µg/L) and by the EPA's 304(a) aquatic life criterion and proposed Idaho criterion (0.17 µg/L). There were, however, three detections that exceeded the proposed acute and chronic criterion concentration.

For diazinon, the detection limit ranged from 0.002 µg/L to 0.006 µg/L for the NAWQA monitoring program methods and 0.025 µg/L to 6.3 µg/L for the ISDA methods. Some of the higher detection limits fall within the range of values shown in Figure 14. It is possible that the elevated detection limits may reflect spiked samples for the method used (USEPA 2016b).

Similar to the carbaryl monitoring data, this variability in detection limit could potentially result in an underestimate of the median of surface water concentrations of diazinon in Idaho.

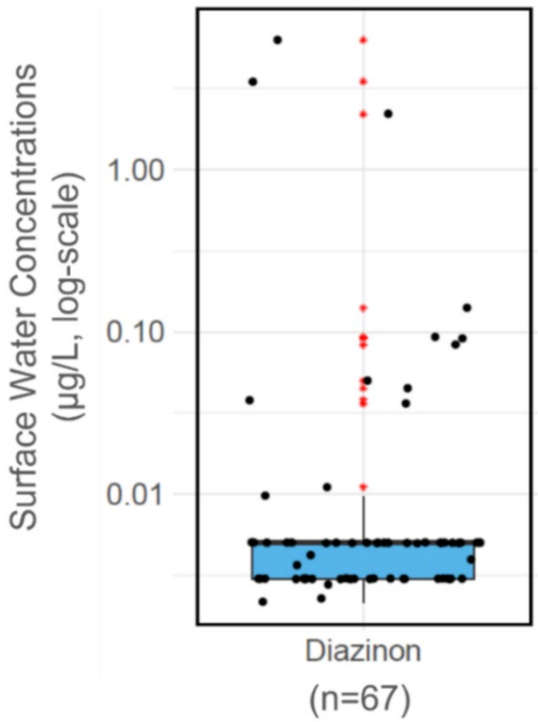

Figure 14. Box and whisker summary statistics for sampled surface water concentrations (µg/L on log-scale) of diazinon exceeding analytical detection limits (n= 67 samples). The box denotes the interquartile range, and whiskers indicate minimum and maximum values. Individual data points (black) are overlaid. Red asterisks indicate where along the y-axis statistical outliers occur.

As indicated in Figure 11, none of the detections of diazinon were in or near ESA-listed salmonid critical habitat or range. Salmonid habitat does occur downstream of the pesticide detections.

2.4.2.3. SRKW Critical Habitat

For SRKW, the most relevant critical habitat PBF to the proposed action includes prey and is the focus of this summary. As described in Section 2.2.1.5, salmon are preferred prey of SRKW although steelhead are also consumed. Recent research on SRKW fecal samples and prey remains from the Salish Sea and outer coast found Chinook salmon to be an important year-round prey item; Chinook salmon makes up the majority of their diet in late spring through summer and declines in proportion starting in fall through early spring, which varies by pod (Hanson et al. 2021, Van Cise et al 2024). About 34% of fecal and 35% of prey samples collected January-April in Hanson et al. (2021) were from the coastal waters (most off the coast of Washington) with the rest of the samples collected from the Salish Sea. Results from coastal fecal samples found Chinook salmon was the most common species (67.3% of coastal samples), followed by steelhead (8.7% of samples), compared to approximately 80% in summer (Ford and Ellis 2006, Ford et al. 2016, Hanson et al 2010). Results from the prey remains analysis were based on 55 prey items, 52 were collected from between northern Oregon and northern Washington. These samples were mostly Chinook salmon (78.2%), which is more similar to the percentage typically found in summer, followed by steelhead (18.2%) (Hanson et al. 2021).

Genetic stock origin could be determined for 33 of 44 Chinook salmon prey remains-samples collected from the outer coast waters (Hanson et al. 2021). The outer coast Chinook samples included 14 Chinook salmon stocks. From this limited number of samples, most (93.3%) had stock origin in four regions: Columbia River (53.6%), Central-Valley (19.0%), Puget Sound (14.2%) and Fraser River (6.5%). For the Columbia River origin samples, about a third were from spring runs (adults returning to freshwater in-spring) and the rest were summer or fall-runs (adults return to freshwater in the summer or fall). The representation of specific SR Chinook salmon stocks from the limited number of samples was relatively small. Only 2.2% (+/- 3.4) of samples were SR sp/su Chinook salmon origin and 0% (+/-2.4) were SR fall Chinook salmon (Hanson et al. 2021). In outer coast waters, the majority of Chinook salmon (60.0%) found in the samples were 4 years-old and most of the remaining were 5-year-olds. The steelhead were 5 or 6-year-olds.

Prey availability in the action area is influenced by a myriad of factors including commercial and recreational fisheries, hatchery actions, habitat actions, and hydropower projects that occur within and outside of the action area as well as predation by other predators (e.g., birds, pelagic fish and sharks, seals, and sea lions). Salmon fisheries intercepting fish that would otherwise pass through the action area and become available prey for SRKWs occurs all along the Pacific Coast. Non-salmon fisheries may also catch adult and juvenile salmon as bycatch – reducing the immediate (adults) and future (juveniles that will continue to grow in the ocean) prey availability. Hatchery production of salmonids contribute to the SRKW prey base in the action area. Activities that influence habitat conditions, as discussed in Section 2.4.2.1, limit the ability of the habitat in Idaho to produce salmon and contribute to reduced prey production for SRKW. The presence of hydropower facilities also results in loss of juvenile salmonids that would otherwise potentially be available as prey to SRKWs.

It is extremely difficult to precisely estimate how many salmon or what density of salmon, particularly Chinook, needs to be available to SRKWs to fully support their recovery and survival. Considering their highly mobile nature, the large ranges with variable seasonal overlap, and the many sources of mortality for salmon, SRKW likely need more fish available throughout their habitat than what is required metabolically to support their energetic needs. The abundance of Chinook salmon that originate in the Snake River basin is currently far below their historic, pre-ESA listing levels and is contributing to the reduced function of the SRKW prey PBF in the action area.

The quality of prey is an important component of the prey PBF as well. NMFS (2021a) identified contaminants as a threat to SRKW survival and recovery. As SRKW occupy a high trophic level, they are at risk of bioaccumulation of contaminants such as persistent organic pollutants, which can reduce fitness (NMFS 2021a). The pesticides considered in this opinion are not likely to bioaccumulate based on their chemical properties (EPA 2024; see section 2.5.1), so the baseline risk posed to SRKW by these compounds is low. Reduced size of Chinook salmon also has implications for the quality of prey available to SRKW because they are more likely to prey upon older adult fish (Ford and Ellis 2006) and length is associated with total energy value of fish (O'Neill et al. 2014), meaning SRKWs may need to consume more fish to meet their caloric needs. The size and age structure of Chinook salmon has changed significantly across the Northeast Pacific Ocean, with an increase in younger age classes and a decline in size of older fish, possibly due to size-selective removal by marine mammals and fisheries (Ohlberger et al. 2018). Mixtures of environmental contaminants may also impact growth of Chinook salmon (Lundin et al. 2023).

2.5. Effects of the Action

Under the ESA, "effects of the action" are 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 but that are not part of the 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 (see 50 CFR 402.02).

Our analysis and conclusions assume the proposed action will be implemented as described, including full implementation of the proposed conservation measures. We employ an exposure-response approach to evaluate the potential effects of implementation of the proposed action on species and their designated critical habitat. Because all four anadromous salmonids utilize the action area in a similar manner, and because these species have similar physiology, the exposure-response pathways are similar. As such, the analysis for each exposure pathway is similar for all ESA-listed anadromous salmonid species covered in this opinion, and we have explicitly noted any differences that exist (e.g., exposure potential given migration timing). Additionally, the critical habitat designations contain similar PBFs that are deemed necessary to support conservation of those species. As such, our analysis of the project's potential impacts on PBFs is similar for designated critical habitat of all four anadromous salmonid species. Again, any differences are noted where appropriate. We have conducted a separate analysis for SRKWs and their critical habitat, which is largely dependent on the effects of the action on SR sp/su and fall Chinook salmon, which are a proportionally more important food resource for SRKWs than SR sockeye salmon and SRB steelhead, though these species may make up a small portion of their diet as well.

We first evaluate the effects of the proposed criteria for acrolein, carbaryl, and diazinon separately on species and designated critical habitat in sections 2.5.1 and 2.5.2, respectively. The effects due to potential mixtures of these pesticides at criteria levels are discussed in sections 2.5.1.4 and 2.5.2.4.

The subsequent effects analysis must be considered against the backdrop of climate change. Climate change is expected to warm freshwater habitats, which may increase the bioavailability of contaminants and alter salmonid uptake and detoxification pathways (Noyes et al. 2009). This may result in higher potential for increased toxicity on already stressed individuals. Climate change may also lead to lower flows, elevating concentrations of discharged pollutants in waterbodies, and making it more challenging to achieve criteria. All of these factors result in additional risk to the species, which is likely to increase over time.

2.5.1. Effects of the Action on Salmonids

To assess the effects of Idaho's proposed criteria for acrolein, carbaryl, and diazinon for salmonids, we examine the best available ecotoxicological evidence concerning physiological and ecological tolerance to these pesticides, and combine this with an analysis of expected pesticide exposure. The BE (and BE attachments B and C) contains a list of literature reviewed on of acrolein, carbaryl, and diazinon effects to salmonids and their prey organisms, the literature review conducted as part of the BE is incorporated by reference. We also provide supplemental literature review where appropriate (e.g., mixture studies, toxicological endpoints not included by EPA).

Previous ESA Consultations for Acrolein, Carbaryl, and Diazinon

NMFS has previously completed national consultations specifically for registration of carbaryl and diazinon under FIFRA (NMFS 2022a; NMFS 2023). These consultations assessed the impacts of carbaryl and diazinon use as described in labeling requirements on ESA-listed species nationwide. These consultations are incorporated by reference in this opinion. NMFS has also completed a consultation for the approval of acrolein and carbaryl criteria for New Hampshire and Massachusetts. We first review the consultations relevant to acrolein and carbaryl, followed by those relevant to diazinon.

In a 2022 biological opinion (NMFS 2022f), NMFS determined that the same acute and chronic criteria for acrolein (3 µg/L) and carbaryl (2.1 µg/L) considered in this opinion that were proposed for approval in New Hampshire and Massachusetts were not likely to adversely affect shortnose sturgeon or Atlantic sturgeon. They stated that exposures to acrolein were extremely unlikely to occur and were therefore discountable, based on the reasoning that there were no acrolein-containing products registered for use as a biocide and no permitted dischargers for acrolein in these states, and the half-life of acrolein is on the order of hours. This situation differs slightly from Idaho, where acrolein-containing products are registered for use as a biocide and several irrigation districts have filed NOIs for use of acrolein. Carbaryl was not expected to adversely affect sturgeon because the proposed criteria for these states were orders of magnitude lower than the lowest endpoint indicating adverse effects for freshwater and saltwater fish. This opinion also determined that exposures of sturgeon prey species to carbaryl at criteria levels would not result in limitation of prey quantity or quality for sturgeon, given their generalist feeding strategy.

EPA's registration of all pesticide products containing carbaryl was recently reviewed in a nationwide 2023 biological opinion (NMFS 2023) that updated a previous 2009 opinion. The 2023 opinion found that the registration of carbaryl products as described by product labels was likely to jeopardize the continued existence of 37 species and to destroy or adversely modify the designated critical habitat of 36 listed species, including SR sp/su Chinook salmon, SR fall Chinook salmon, SR sockeye salmon, SRB steelhead, and SRKW and their designated critical habitats. In their effects analysis, NMFS rated the risk of adverse effects from the registration of carbaryl at the population and species level as high, medium, or low, and assigned a confidence level to each risk assessment. SR sp/su Chinook salmon were rated as having medium risk (high confidence), SR fall Chinook salmon were rated as having high risk (medium confidence), SR sockeye salmon were rated at high risk (medium confidence), SRB steelhead were rated at medium risk (high confidence), and SRKW rated as high risk (medium confidence). These risk assessments were made based on the best available science on toxicity of carbaryl to salmonids and surrogate species (considered mortality, growth, reproduction, and behavioral endpoints), as well as estimates of potential exposure levels. The estimated potential exposure levels were above the proposed acute and chronic criteria for carbaryl. The risk posed to SRKW was predicated upon effects caused to salmonids that would reduce SRKW prey quantity or quality. For critical habitat, SR sp/su Chinook salmon were determined to have medium risk (high confidence), SR fall Chinook salmon were rated as having high risk (medium confidence), SR sockeye salmon were rated at high risk (medium confidence), SRB steelhead were rated at medium risk (high confidence), and SRKW rated as high risk (medium confidence). This opinion provided an RPA which included measures to be incorporated into carbaryl product use requirements to reduce pesticide loading into ESA-listed salmonid habitat (e.g., implement runoff reduction measures, do not apply within 40 feet of ESA-listed species habitats or 55 feet if wind is blowing toward the habitat).

EPA's registration of pesticide products containing diazinon was reviewed in 2008 and 2017 opinions (NMFS 2008a) which have since been replaced by a 2022 opinion (NMFS 2022a). The original 2008 opinion concluded that the registration of diazinon (and chlorpyrifos and malathion) was likely to jeopardize all but one of the listed salmon ESUs and likely to adversely modify their designated critical habitat. This opinion included an RPA which included no-application buffers and other measures that would avoid jeopardy and adverse modification of critical habitat. The most recent opinion for diazinon registration (NMFS 2022a) resulted in EPA adopting conservation measures into the proposed action that would avoid "jeopardy" and "adverse modification". The conservation measures focused on reducing exposure potential to ESA-listed species and their habitats by targeting risk reduction measures that effectively reduce drift and runoff, and include pesticide use restrictions for FIFRA labels of all products containing diazinon. These use restriction measures included:

- a prohibition on aerial applications of diazinon
- restrictions on ground broadcast and airblast applications
- restrictions on non-broadcast applications within 300 m of listed species habitat
- geographically-specific restrictions to address potential loading from runoff

With the implementation of these conservation measures, the NMFS (2022a) effects analysis determined that all four Snake River basin ESA-listed salmonids and SRKWs were rated as having high risk (medium confidence) of adverse effects, but would not jeopardize the continued existence nor destroy or adversely modify the designated critical habitat of these species.

The described national FIFRA registration consultations are part of the baseline conditions considered for this opinion. Therefore, in our analysis we make the assumption that any use restrictions and runoff reduction measures will be implemented where these pesticides are applied. The previous biological opinions reviewed above also provide context for effects that can reasonably be expected due to exposure to acrolein, carbaryl, or diazinon.

Limitations of Available Data

In general, ecotoxicology data specific to ESA-listed salmonids, or the biological species to which they belong, are sparse. Therefore, our effects analysis largely relies on studies conducted with *Oncorhynchus mykiss* (rainbow trout), as well as other surrogate species for which more studies have been conducted. *O. mykiss* is a biological species match for SRB steelhead and is in the same genus as the other ESA-listed salmonids considered in this opinion; thus, it is likely to have conserved (i.e., shared) physiological traits. Therefore, we give more weight to *O. mykiss* studies, and decreasing weight to more distantly related species in consideration of the toxicological response caused by the pesticides of interest.

There are also fairly limited data on occurrence and concentrations of these pesticides in the environment, particularly for acrolein. Thus, in estimating the likelihood of exposure to these pesticides, we must at times rely on proxies, such as irrigation infrastructure, land-use data regarding where certain crops are cultivated, and estimated application rates.

Interpreting Toxicity Data

Although LC50 (lethal concentration for 50% of test subjects) data are abundant, an exposure in which half of exposed organisms die or are otherwise affected is clearly a consequential effect. As demonstrated in prior NMFS' Opinions for EPA approval of Oregon and Idaho water quality standards (NMFS 2012, 2014, 2020b), the validity of the commonly made assumption that one half an LC50 is a safe exposure is reliant on the slope of the exposure-response relationship. A pattern observed with metals data analyzed for a previous water quality consultation was that half an LC50 concentration would probably result in about a 5% death rate in salmon (NMFS 2012). Testing with cutthroat trout and cadmium, lead, and zinc singly and in mixtures, Dillon and Mebane (2002) found that the LC50/2 concentration corresponded with death rates of 0% to 15%. EPA's BE analysis (USEPA 2024) uses the lowest, most related value to select as or transform into a LC_{low} (concentration at which organism mortality is indistinguishable from control mortality, or the minimum effect level (MEL)). For example, when a NOEC (no observed effect concentration) was the lowest toxicity value in an acute dataset (i.e., no LC values were lower), it was selected as the LC_{low} (or the acute MEL) with no adjustment to the value. However, most acute studies report LC50s, which would not be used as a minimum effect level, but would rather be transformed into a LC_{low} (i.e., an acute MEL). If transformation is necessary, the estimated LC50 is divided by 2.27 (acute adjustment factor), providing a slightly more conservative assumption than assessed by Dillon and Mebane (2002), that would likely result in very low death rates. Where there were multiple reported NOEC or LC50 values for a species, EPA selected the lowest reported value to be used as or transformed (respectively) into the LC_{low} for that species. EPA also used the most sensitive endpoint from the most closely related species for which data were available, typically from *O. mykiss* for the salmonids considered in this opinion.

A few studies reported NOECs (no observed effects concentration) and LOECs (lowest observed effects concentration), which can provide a more sensitive endpoint than an LC50. However, use of these metrics can still lead to less-than-protective decisions. For example, in many of the acrolein toxicity studies reviewed, test exposures exceeded the acrolein criterion concentration of

3 μg/L. Study design and the test concentrations chosen may not provide detailed information about toxicity at concentrations of interest for decision-making, and instead rely on inference. A LOEC typically indicates the lowest concentration tested where a statistically significant effect was observed, and may not truly represent the lowest concentrations that may cause an effect. NOECs are similarly dependent on study design and test concentrations chosen, but can provide a conservative effects threshold in a rigorously designed study. It can be more accurate to estimate a dose-response relationship to estimate effective concentration values (i.e., EC_x) which reports a concentration that causes a x% effect. These estimates can report effects that are smaller than an LC50, while avoiding some of the pitfalls of reporting NOECs and LOECs. However, such estimates are not reported in the literature nearly as often as LC50s, NOECs, and LOECs, so much of our discussion still focuses on these metrics.

The EPA also calculated mean acute and chronic values for a given species or genus (i.e., SMAV, GMAV, SMCV, or GMCV), which are the means of the LC50s reported for a given species or genus. Other toxicology terms that may be used in the following discussion include:

- Species sensitivity distribution (SSD): used to estimate the proportion of species affected by a certain concentration of a toxicant. This can be based on NOEC values for a more conservative estimate of impacts to prey species.
- Hazardous concentration for 5% of species (HC5): used when determining how potential prey items for salmonids might be affected, calculated from the SSD.
- Acute to chronic ratio (ACR; the ratio of LC50 to NOEC values): used to translate from an acute value to a chronic MEL.
- Maximum acceptable toxicant concentration (MATC): geometric mean of the NOEC and LOEC.
- MEL: a general term for an effect level that is not expected to cause adverse effects that are distinct from a control group. In EPA's BE analysis, NOECs, or LC50s that have been transformed into LC_{low} are considered MELs.

In order to assess the risk of an adverse response due to exposure to pesticides at criteria concentrations, we also considered a set of thresholds developed by the EPA's OPP. When evaluating acute exposures for nontarget aquatic animals using LC50 data the OPP considers a risk quotient greater than 0.5 as warranting concern. That is to say, EPA expects exposures that are less than half of an LC50 to cause minimal adverse effects. However, for threatened and endangered aquatic animals OPP's level of concern for acute exposures is an order of magnitude more protective, with risk quotients (calculated from an LC50) greater than 0.05 posing a concern (USEPA 2004). For this threshold to be met, the proposed criteria must be approximately two orders of magnitude higher than the threshold of expected adverse effects. For chronic exposures, OPP bases risk on the lowest early life-stage or full life cycle NOEC for freshwater fish and invertebrates and estuarine/saltwater fish and invertebrates, where a risk quotient greater than 1.0 is of concern for all aquatic species, regardless of ESA-listing status. We utilize these risk quotient thresholds as a line of evidence, providing a shared scale of comparison between the proposed pesticide criteria and the expected threshold of adverse responses in salmonids. While the OPP threshold for nontarget aquatic animals (0.5) and for chronic exposures (1.0) are likely not protective enough to ensure that only minimal adverse effects occur, the OPP threshold for endangered species (0.05) is much more conservative.

Salmon Translator Model

In this effects analysis, we evaluate the impact of carbaryl and diazinon on ESA-listed salmonids via reductions in prey organisms. Acrolein is not included in the salmon translator model analysis, as adverse effects to salmonid prey under adherence to prescribed label instructions would be extremely limited in scope. One line of evidence used in this analysis is a "salmon translator model", which was presented in the EPA's BE (EPA 2024, Appendix E). This model was developed by EPA from a previous fish translator model (Pollesch et al. 2022), and parameterized on SR sp/su Chinook salmon in 15 stream reaches. EPA found high concurrence between modeled and observed growth and survival for these SR sp/su Chinook salmon juveniles. It is very similar to models used in other NMFS pesticide biological opinions (NMFS 2022a, 2023a), with minor methodological differences and a focus on exposure scenarios with lower concentrations, in keeping with the proposed criteria. There are limitations of this model, which does not statistically differentiate between a 10% reduction in survival and the control. It was also parameterized on SR sp/su Chinook salmon juveniles and may not represent the response of other species considered in this opinion, which have variable life history (e.g., SRB steelhead rear much longer in freshwater). However, we use this model as a best available surrogate for the other species. In addition, there are a relatively small number of studies available that met EPA's inclusion criteria that could be used to estimate the potential reduction in prey organisms due to carbaryl and diazinon exposure. While there are limitations, this model provides valuable estimates of potential indirect impacts of pesticide exposure to salmonids.

In essence, the salmon translator model relates reductions in prey abundance as a result of pesticide exposure to fish growth rate. Because survival of juvenile salmon is strongly influenced by fish size, a size-survival function was used to estimate reductions in survival. Thus, reductions in survival of salmonids can be estimated from pesticide exposure scenarios. The exposure scenarios EPA used (Table 11) were meant to represent likely environmental conditions if the proposed criteria were implemented, as well as some conservative scenarios that likely overestimate the concentration or frequency of pesticide occurrence in anadromous watersheds. The exposure scenarios shown in Table 11 consist of four characteristics: concentration relative to the chronic criterion (or CCC), the duration of the exposure to the pesticide, the interval of recurrence of the exposure, and the age of the fish at first exposure. NMFS only considered results for scenarios at or below the chronic criterion for our analysis, as these are the only scenarios that would be expected in streams under full implementation of the proposed action.

The "A" family of scenarios evaluated the impact of fish age on effects, and found that a single exposure at the chronic criterion concentration had a small likelihood of affecting salmon growth and survival at any age, with non-statistically-significant variability in survival compared to the control. The "B" family of scenarios evaluates a continuous 427-day exposure, which is extremely unlikely to occur in Idaho, given our evaluation of the environmental baseline (Section 2.4). The "C", "D", and "E" families of scenarios evaluate the effect of a pulsed exposure every 30, 60, and 120 days, respectively. These scenarios (excluding those with a relative concentration higher than the CCC) are plausible based on the proposed criterion and the environmental baseline for these pesticides.

Table 11. Exposure scenarios used to estimate reductions in salmonid survival as part of the salmon translator model. Reproduced from EPA (2024).

Simulation ID	Relative CCC	Exposure Duration (days)	Recurrence (days)	Age at First Exposure (dph)
A1	1	4	1	4
A2	1	4	1	30
A3	1	4	1	60
A4	1	4	1	120
A5	1	4	1	240
B1	0.5	427	1	1
B2	0.75	427	1	1
B3	0.9	427	1	1
B4	1	427	1	1
C1	0.5	4	30	4
C2	0.75	4	30	4
C3	1	4	30	4
C4	1.25	4	30	4
C5	1.5	4	30	4
C6	2	4	30	4
D1	0.5	4	60	4
D2	0.75	4	60	4
D3	1	4	60	4
D4	1.25	4	60	4
D5	1.5	4	60	4
D6	2	4	60	4
E1	0.5	4	120	4
E2	0.75	4	120	4
E3	1	4	120	4
E4	1.25	4	120	4
E5	1.5	4	120	4
E6	2	4	120	4

2.5.1.1. Approval of Acrolein Criteria

The proposed acute and chronic criteria for acrolein are 3 μg/L over one hour and over four days, respectively. The data available for calculating a recommended chronic water quality guideline had similar threshold concentrations for lethal and sublethal responses. In such cases, instructions in EPA's 1985 guidance for calculating recommended chronic guideline concentrations result in identical concentrations for both acute and chronic exposures (Stephen et al. 1985). Since the acute and chronic criteria for acrolein are identical, our evaluation addresses the exposure concentration irrespective of exposure duration.

Acrolein can enter the aquatic environment through its use as an aquatic herbicide, from industrial discharges, and from the chlorination of organic compounds in wastewater and drinking water treatment (USEPA 2009a). Acrolein is volatile (experimental Henry's Law constant = 0.00012, varies with temperature (CompTox v. 2.4.1)), highly soluble in water

(~ 237.6 g/L at 25C) (MRID 40840602 as cited in USEPA 2008b), and has a low octanol–water partition coefficient (recommended Kow = -0.01 (USEPA 2009a)). These properties indicate that acrolein dissolves well in water, may volatilize into the air, and has a low likelihood of adsorbing to sediments or organic solids (Canada 2000).

Once in freshwater, acrolein degrades relatively rapidly. In laboratory studies, acrolein persisted in a large tank for up to 150 hours (Bowmer and Higgins, 1976). When applied as an herbicide in irrigation canals, it typically dissipates faster, with the observed dissipation half-life ranging from 3-10.2 hours (Canada 2000; WHO 1998). EPA's CompTox knowledgebase uses a biodegradation half-life calculation that estimates the half-life to be 3.7 days (CompTox v. 2.4.1), which is a very conservative estimate compared to other research. In natural waters, acrolein degrades to aldehydes that do not persist, with dissipating reactions typically occurring to completion within 30 to 100 hours, though this rate is dependent on initial concentration, temperature, pH, and microbial activity (Canada 2000, USEPA 2009a, Turner and Erickson 2003). Acrolein does not persist for long periods of time in surface water, therefore considerable transport downstream is not likely. However, transport would be expected to increase in faster moving waters.

The labels for products containing acrolein dictate that treated water must be used on cropland or held for 6 days prior to releasing treated water into nearby streams. Treatment concentrations of acrolein are often up to 15 mg/L (though this may be lowered as part of the acrolein proposed interim registration review (USEPA 2024a), section 1.3.2), which is several orders of magnitude above the proposed criteria and would be expected to cause an acute response in salmonids. However, if acrolein-treated water is held in irrigation canals for the prescribed 6 days, we expect dissipation will occur to the extent that concentrations of acrolein will be well below the proposed criteria of 3 µg/L.

Toxicity to salmonids

We do not have sufficient information to suggest that any degradates or additives in acrolein formulations would increase the toxicity to salmonids. Acrolein degradates of potential concern include glycidol and 3-hydroxypropanal (USEPA 2008b). Glycidol is a metabolite of acrolein that is mainly found in fish tissue, and is reasonably anticipated to be a human carcinogen based on evidence of carcinogenicity in mice (USEPA 2008b). This metabolite depurates from fish tissue quickly, and its effects on fish have not been studied to our knowledge. The degradate 3-hydroypropanal is formed in equilibrium with acrolein independent of pH, and is dissipated relatively rapidly by other processes (USEPA 2008b). Thus, it is not expected to be a concern for risk assessment. Acrolein formulations may contain small amounts (0.25%) of hydroquinone to prevent spontaneous reactivity of acrolein. The estimated 96-hour LC50 for hydroquinone is 97 µg/L for rainbow trout (De Graeve et al. 1980), indicating that it is less toxic than acrolein. Given the lower toxicity and small proportion of this compound in acrolein formulations, this non-active ingredient does not increase the risk posed by acrolein product applications.

Acrolein's pesticidal mode of action involves binding to organic material and cross-linking proteins, resulting in degradation of cellular structures, and reducing the cell's ability to inactivate toxic chemicals (USEPA 2008b). This cross-linking is thought to be irreversible, though there is not sufficient evidence to suggest that this process immobilizes or uses up the acrolein as it kills target plants and algae in irrigation canals. Acrolein can also reduce myocyte beating activity in rats, which affects muscle contraction (USEPA 2003), and can reduce intracellular adenosine triphosphate (ATP), which is needed for most cellular functions. While acrolein is known to have diverse toxic effects in humans, toxicity to fish is less studied, particularly chronic toxicity. To our knowledge, no relationships have been demonstrated between acrolein toxicity and water quality characteristics (e.g., hardness, pH) (USEPA 2009a).

Based on the available data, acrolein is considered to be very highly toxic to rainbow trout and highly toxic or very highly toxic to several other freshwater fish and invertebrates (Turner and Erickson 2003). Species-specific data were available to estimate the acute MEL for SRB steelhead (rainbow trout, *Oncorhynchus mykiss*), which also served as genus-specific data for SR Chinook salmon and SR sockeye salmon. The estimated acute MEL for all salmonid species was 10 µg/L, which is higher than the proposed chronic and acute criteria (3 µg/L). This was based on a NOEC for *O. mykiss* (Venturino et al. 2007). Chronic toxicity data was not available for fish that were taxonomically similar to salmonids (i.e., lower than Class level), so the chronic MEL had to be estimated. The BE (USEPA 2024) estimated a MEL from LC50s generated from the Web-ICE model (Web-based Interspecies Correlation Estimation: estimates toxicity based on a closely related taxon), which included studies on freshwater fish species. In this case, the lowest chronic LC50 was 17.4 µg/L for fathead minnow after a 32-day exposure, which is similar, but on the low end of the acute LC50s we reviewed for the *Oncorhynchus* genus (Table 12). The lowest acute LC50 for the *Oncorhynchus* genus was also used in a Web-ICE model and transformed by an ACR to calculate a chronic MEL. The chronic MELs were conservatively estimated using the lower confidence interval generated from the Web-ICE model to be 6.21 µg/L for Chinook salmon, 4.23 µg/L for sockeye salmon, and 6.45 µg/L for steelhead, which all exceed the proposed criteria as well. This analysis indicates that the criteria are protective of salmonids.

In general, trout and other teleosts are poorly adapted to detoxify acrolein and other xenobiotic aldehydes (Parker et al. 1990). To understand potential toxicity to SR Chinook salmon, SR sockeye salmon, and SRB steelhead, we conducted a literature review of references identified from the BE (USEPA 2024), ECOTOX searches, and an open literature search. Table 12 summarizes the literature investigating the toxicity of acrolein to salmonids. The majority of information available is for rainbow trout, with one study each on Chinook and coho salmon. The majority of ecotoxicology studies have been performed in a lab setting on juvenile fish, with mortality endpoints. For rainbow trout, reported LC50s ranged from 16 – 140 µg/L (mean of reported LC50s = 60 µg/L). The only reported LC50 for Chinook salmon was 80 µg/L, and 68 µg/L for coho salmon. This endpoint, while common in ecotoxicology literature, is not the most useful metric for determining criteria levels that will be protective of ESA-listed salmonids, as the LC50 denotes the concentrations at which 50% of fish may be expected to die. Others reported more sensitive endpoints including a LC20 of 25 µg/L and NOEC of 10 µg/L (Venturino et al. 2007), and a LC32 of 48 µg/L and NOEC of 8 µg/L (Bartley and Hattrup 1975).

The majority of studies shown in Table 12 were performed with juvenile salmonids. This is an informative life stage for understanding the effects of acrolein, as rearing juveniles may be exposed to this herbicide via exposure to contaminated media or through consumption of contaminated prey. However, we were unable to find studies that examined growth of juvenile salmonids as an endpoint, or reproduction (either due to exposure of spawning adults or incubating embryos). There is a dearth of information concerning non-mortality endpoints to assess sublethal effects of acrolein on fish, with only two studies addressing this topic in salmonids to our knowledge. Lorz et al. (1979) performed smoltification tests with coho salmon after exposure to acrolein below lethal levels and found no effect on sodium or potassium ion-stimulated ATPase activity of gills, and little effect on seawater tolerance. They also observed some dose-related histological effects in the gills, kidneys, livers of exposed fish. Although acrolein was among the most toxic of the 12 water soluble herbicides tested in this study, it seemed to produce little or no dose-related mortality when exposed fish were subsequently challenged with seawater. Folmar (1976) tested for a behavioral avoidance response, and found that fry may avoid acrolein at concentrations exceeding 100 µg/L, though significant avoidance did not occur at concentrations below the 96-hour LC50 (140 µg/L). This indicates that many fish would likely die before exhibiting an avoidance response.

McKim et al. (1987) reported on physiological response of rainbow trout (life stage not reported) to acrolein in addition to performing a mortality-based experiment. At 77 µg/L (acutely lethal concentration), the surviving fish showed respiratory distress and a general hypoxic effect, with a mean survival time of 21 hours. The respiratory responses included a steady increase in cough rate; decreases in ventilation rate, oxygen utilization, and heart rate; increases in hematocrit; and decreases in total arterial oxygen, carbon dioxide, and pH.

For the purpose of comparison with the proposed acrolein acute and chronic criteria of 3 µg/L, we calculated a risk quotient from each measured endpoint (i.e., LC_x, LOEC, NOEC). These risk quotients and comparison with OPP's levels of concern provide a line of evidence for evaluating the protectiveness of the proposed acrolein criteria. Most risk quotients indicate that the criteria are an order of magnitude lower than most reported LC50s. Even the risk quotients for the lowest reported lethal doses and more sensitive endpoints (i.e., NOEC) were below 0.5 and 1, the OPP's acute and chronic levels of concern for aquatic species. However, three of the eight risk quotients calculated from salmonid LC50s exceed the OPP's threshold of concern (0.05) for threatened and endangered aquatic animals (USEPA 2004). Even when test species and ESA-listed species have comparable sensitivities, the loss of an individual from an imperiled population has greater consequences than the loss of an individual from healthy populations. The proposed acrolein criteria are lower than the OPP acute aquatic life benchmarks for freshwater vertebrates (5.4 and 11.4 µg/L acute and chronic respectively), and may indicate that the proposed acrolein criteria are protective. This assessment mirrors the conclusion from the BE that the criteria are likely to be protective of endangered salmonid species. However, using OPP risk quotients as a guide provides a more uncertain conclusion. The magnitude of some of the risk quotients calculated from more conservative salmonid LC50 estimates indicate that there may be some risk to threatened and endangered species at the proposed acute and chronic criteria levels.

Table 12. Toxicity of acrolein to salmonids. Information gathered from literature review and risk quotients calculated based on the proposed acute and chronic acrolein criteria of 3 µg/L.

Species	Endpoint Concentration (µg/L)	Endpoint	Life stage	Risk Quotient	Reference
Rainbow trout (*Oncorhynchus mykiss*)	29	LC50	NR	0.10	McKim et al. 1987
	89	LC95	Juvenile	0.034	Venturino et al. 2007
	38	LC50	Juvenile	0.079	
	25	LC20 (LOEC)	Juvenile	0.12	
	10	NOEC (mortality)	Juvenile	0.30	
	65	LC50	Fingerling	0.046	Bond et al. 1960
	16	LC50	NR	0.19	Holcombe et al. 1987
	74	LC50	Juvenile	0.041	Birge et al. 1982
	100	Avoidance	Fry	0.030	Folmar 1976
	140	LC50	Fry	0.021	
	150	Lethal	NR	0.020	Kissel et al. 1987
	48	LC32	Fry	0.063	Bartley and Hattrup 1975
	8	NOEC (mortality)	Fry	0.38	
Chinook salmon (*Oncorhynchus tshawytscha*)	80	LC50	Fingerling	0.038	Bond et al. 1960
Coho salmon (*Oncorhynchus kisutch*)	68	LC50	Yearling	0.044	Lorz et al. 1979

Due to the small number of studies investigating the effects of acrolein on salmonid species, which are most directly relevant to the ESA-listed species considered in this opinion, we also reviewed toxicity information for other fish species. While not as closely related, it is reasonable to base judgements of toxicity on studies of other fish species for which information is available, when species-specific information is sparse, as they share many physiological traits with salmonids. Different species of scaled fish have been found to have similar sensitivity to acrolein, and several studies have indicated that endangered and threatened fish have similar sensitivity to several toxicants as non-endangered counterparts (Sappington et al. 2001; Dwyer et al. 1999). While effects to fish can have a more significant impact on threatened and endangered species, toxicology studies on non-listed species can still provide useful context for understanding toxicity to the species of interest, (i.e., by providing more data or different endpoints). However, we give more weight to studies of more closely related fish.

Most acrolein toxicity data available for other Actinopterygii fish species was for the fathead minnow (*Pimephales promelas)*. Macek et al. (1976) reported the lowest chronic value at 11.4+/- 8.3 µg/L based on survival of newly hatched fry during the continuous exposure of fathead minnows. While this reported "low effect" threshold is nearly fourfold the criterion concentration of 3 µg/L, the wide confidence interval accompanying this data indicates a range from 3 to 32 µg/L (Table 10 in Macek et al. 1976). Other studies reported LC50s for fathead minnows ranging from 14 - 150 µg/L (mean LC50 of surveyed studies = 44.7 µg/L), with lower LC50s for younger fish when tested (Birge et al. 1982; Geiger et al. 1988, 1990; Sabourin 1986, 1987; Spehar 1989; Turner 1982). Not all of these studies reported a NOEC or LOEC, but values ranged from 9.1 – 73 µg/L for NOECs and 30.8 – 120 µg/L for LOECs (Sabourin 1986, 1987; Spehar 1989; Turner 1982). Fathead minnows exposed to acrolein lost schooling behavior, were hyperactive and overreactive to external stimuli, and exhibited increased respiration (Geiger 1988). Fish also lacked an avoidance response to acrolein prior to lethal exposure (Louder and McCoy 1962).

For the endangered bluegill (*Lepomis macrochirus*), the LC50 ranged from 22 µg/L (Turner and Erickson 2003) to 140 µg/L (Louder and McCoy 1962). Barrows et al. (1978) also determined the half-life of acrolein in bluegill fish tissue to be greater than seven days, with a bioconcentration factor (BCF) of 344 L/kg. Spehar (1989) also examined acrolein toxicity to embryos and fry of the flagfish (*Jordanella floridae*). Percent hatch was not affected by any of five acrolein concentrations ranging from 1.4- 42 µg/L. Survival was not reduced at end of trial, but growth (weight) was reduced in the highest exposure concentration (42 µg/L) compared to the control. The resultant chronic value for flagfish was 25.92 µg/L (MATC for growth). The LC50 was determined to be 51 µg/L (35-74 µg/L CI) for 30d old fish or 60 µg/L (43-97 CI) for 1-d old fish. The 32-day NOEC and LOEC were 16 µg/L and 42 µg/L, respectively. This study provides important context for understanding the potential effects of acrolein to fish at sensitive life stages. It indicates that while exposure as embryos may not affect survival directly at concentrations of 42 µg/L, it may lead to decreases in growth, which are known to reduce survival of juvenile fish. This also indicates that the proposed chronic criterion is likely protective for ESA-listed salmonids.

Acrolein acute toxicity data are relatively sparse for salmonids, and chronic toxicity data are not available for salmonids. Because of this, there is a higher level of uncertainty in our analysis of the proposed acrolein criteria than for the other pesticides assessed in this opinion. We did not find any studies that demonstrated adverse effects as a result of direct exposures to concentrations at or below the proposed acute and chronic criteria level of 3 µg/L. While the majority of data suggest that the proposed criteria would be protective of salmonids, a few relevant studies suggested there is some risk of toxic responses if exposed at criteria concentrations. Although irrigation canals must be screened to prevent fish entrainment (Idaho Code § 36-906), salmonids may on rare occasion enter irrigation canals treated with acrolein. These instances are rare, but small numbers of salmonids entering irrigation canals could be exposed to acrolein concentrations at and above the criteria levels. Outside of irrigation canals, acrolein concentrations are expected to be below criteria levels when required application instructions are followed. Given this relatively low likelihood of exposure coupled with a small risk of toxicity at criteria concentrations, we expect that only a small number individual fish would be adversely affected by the proposed action.

Toxicity to salmonid prey

Salmonids feed in freshwater as juveniles and are opportunistic feeders. They may consume insect larvae, zooplankton, benthic amphipods, insects, crustaceans, mollusks (Scott and Crossman 1973), and other fish as they grow in size (Staley and Mueller 2000). USEPA (2024) found only three studies on acrolein toxicity to potential prey items. From these studies, they estimated a genus mean chronic value (GMCV) based on NOECs of 12.7 µg/L for *Daphia* spp., 141.4 µg/L for *Ceriodaphnia* spp., and 240 µg/L for *Hyalella* spp. The lowest NOEC observed for fish was 9.1 µg/L for fathead minnow (Sabourin 1986; 1987). All of these values are higher than the acrolein criteria, and were therefore determined not to have a significant effect on prey items available for salmonids.

Other studies conducted in situ or that considered community composition (as opposed to a single species) largely confirmed that significant effects to prey organisms would not be expected at 3 µg/L. Albarino et al. (2007) found that the benthic assemblage was affected by direct application of Magnacide H (active ingredient is acrolein) at typical treatment levels in an irrigation channel. They observed a significant reduction in the number of taxa (58%), abundance (57%), and community diversity (67%) compared to untreated control channels. However, the assemblage recovered these biotic characteristics to levels similar to controls after two months. On the other hand, Hayworth and Melwani (2004) did not observe an effect of acrolein treatment (treatment level not reported) on downstream benthic communities. Similarly, Snyder-Conn (1997) found no evidence of acrolein-related mortality among fathead minnows, *Daphnia magna*, or the snail *Planorvella (Pierosoma) subcrenaum* in the Tule Lake National Wildlife Refuge downstream of irrigation canals that had been treated with acrolein. Limited evidence also suggests that aquatic vertebrates tend to be just as or more sensitive to acrolein than invertebrates in a survey of acrolein toxicity across multiple species (Eisler 1994). While not specific to prey items of salmonids, this suggests that acrolein criteria that are protective of salmonids would also be protective of invertebrate prey organisms. Taken together, these studies indicate that while acrolein can have adverse effects on potential prey species at treatment levels (which would also be toxic for salmonids), the effects are not long-lasting, and do not typically extend beyond the treated irrigation channel into downstream habitat if best practices are followed.

Although the data are very limited, we expect the generalist feeding strategy typical of juvenile salmonids to be protective against effects of acrolein on prey items. Species tend to vary in their response to pesticides and benthic species composition has been observed to recover relatively quickly from acrolein exposure in a natural stream environment (Albarino et al. 2007). Given this and the fact that available GMCVs indicate 3 µg/L would be protective of three zooplankton species (GMCVs range from 12.7 - 240 µg/L for *Daphnia, Ceriodaphnia,* and *Hyalella* genera), it is unlikely that a majority of potential prey items would be affected simultaneously or permanently by acrolein at criteria concentrations.

Relevance of fish effects to population/ MPG viability

As shown in Figure 4 and 5, the designated critical habitats of each of the ESA-listed salmonids considered in this opinion are in proximity to several irrigation districts, where acrolein may reasonably be expected to be used. Because there is no monitoring data for acrolein, our understanding of the seasonality of acrolein use is limited. Acrolein could be applied as a biocide or for other purposes at any time of year, but is most likely to be applied during the irrigation season. Given that it is most often used for aquatic plants, it is reasonable that acrolein would be applied more frequently during the growing season (spring, summer, early fall). Although there may be spatial and temporal overlap between presence of ESA-listed salmonids and operation of irrigation infrastructure and possible applications timeframes, this does not necessarily indicate that acrolein is used in these areas or during these timeframes.

Considering the relatively rapid degradation of acrolein and the requirement to hold treated water for 6 days prior to release to fish-bearing streams, we believe it would be unlikely for fish to be exposed to acrolein concentrations equivalent to the criteria. Although typical treatment concentrations are well above the criteria and may be lethal to fish and their prey, treatment occurs in irrigation canals, which are not intended to function as habitat for salmonids. Fish kills may occur if spills or leaks of treated water enter fish-bearing streams before the appropriate holding period has expired. Fish entrained in irrigation canals may also result in mortality (Walters et al. 2012), but this is expected to be rare, given that entrances to irrigation canals should be screened in a manner consistent with NMFS passage guidelines (NMFS 2022g). Though fish kills have occurred in the past due to spills, leaks, or early releases (Ewing 1999), adverse effects in streams/rivers are expected to be avoided with proper application and following previously instated best practices for irrigation canal use.

Given the short half-life of acrolein in natural streams, we find that with prescribed label use, spills or leaks that would result in contamination of salmonid-bearing streams would be very rare and unlikely to occur. With proper use, we also expect concentrations of acrolein in salmonid-bearing streams at the proposed criteria (3 µg/L) to be rare. Based on our analysis of acrolein toxicity studies on fish and their prey, which indicate a relatively low risk of response given exposure, and considering the low risk of exposure to acrolein at criteria concentrations, we only expect adverse effects to a very small number of individual SR sp/su Chinook salmon, SR fall Chinook salmon, SR sockeye salmon, or SRB steelhead. Only those individuals that are present in irrigation canals when and where acrolein is applied are expected to experience adverse effects. We also do not expect individual juvenile salmonid forage behavior to be reduced by acrolein concentrations at or below 3 µg/L. Therefore, based on the effects of the proposed action alone, we do not expect reductions to the survival, reproduction, diversity, or spatial structure of any population, MPG, or ESU/DPS for SR sp/su Chinook salmon, SR fall Chinook salmon, SR sockeye salmon, or SRB steelhead due to the proposed acrolein criteria. Since we do not expect population-scale effects, we do not expect the proposed acrolein criteria to limit recovery of the species either. Impacts at the population, MPG, and ESU/DPS scale are considered alongside the status of the species, environmental baseline, and cumulative effects in the Integration and Synthesis (Section 2.7).

2.5.1.2. Approval of Carbaryl Criteria

The proposed acute and chronic criteria for carbaryl are 2.1 µg/L over one hour and over four days, respectively. This is consistent with the EPA's 304(a) criteria for carbaryl. The proposed criteria are more protective than the OPP's freshwater vertebrate benchmarks (110 µg/L acute, 6.8 µg/L chronic), but less protective than the OPP's freshwater invertebrate benchmarks (0.85 µg/L acute, 0.5 µg/L chronic). Carbaryl may be used for insect control on lawns, home gardens, citrus, fruit, forage and field crops, forest, nuts, ornamentals, rangeland, turf, shade trees, poultry, and livestock (USEPA 2010). It is typically applied as liquid sprays, dusts, and granular formulations. Carbaryl can be transported from the original use site and enter surface waters through runoff, spray drift, and atmospheric transport and deposition. While transport in air and precipitation is not a major transport pathway, carbaryl has been detected at concentrations up to 0.756 µg/L in precipitation and 4 µg/L in fog (Waite et al. 1995; Foreman et al. 2000; Sanusi et al. 2000; Mast et al. 2007; Vogel et al. 2008). Carbaryl is more likely to enter aquatic habitat when it is applied during or approximately contemporaneous with precipitation events, during high wind or inversion conditions, and in closer proximity to surface waters. Aerial modes of application are also more likely to result in drift into aquatic environments.

Carbaryl is classified as non-volatile, poorly soluble in water (~ 0.04 – 0.12 g/L at 30°C) (PubChem CID 6129), and has a low octanol–water partition coefficient (log Kow = 2.39 (CompTox v. 2.4.1), indicating that it has a low likelihood of adsorbing to sediments or organic solids. Carbaryl also does not readily bioaccumulate (BCF = 498, below what is considered bioaccumulative).

The half-life of carbaryl in soil depends on conditions, and can range from 4 – 72 days (NPIC 2003), indicating it may persist for days or a few months at most at typical use sites. The EPA's BE reports that carbaryl has a half-life on the order of hours in the air, as it reacts with photochemically-generated hydroxyl radicals in the atmosphere. The degradation rate of carbaryl in water is relatively slow under anaerobic conditions (half-life = 68.9 days), but more rapid under aerobic conditions (half-life = 2.0 – 18.2 days) (USEPA 2024). Since salmonids generally occupy aerobic aquatic environments, we would expect carbaryl to dissipate on the order of days in anadromous waters.

For carbaryl, three major degradates (1-naphthol, 1, 4-napthoquinone, and carbon dioxide) were detected in various environmental fate studies (NMFS 2023). Acute fish and invertebrate toxicity data are available for 1-napthol, the main hydrolysis degradate of carbaryl. The LC50s for aquatic invertebrates range from 700-730 µg/L for *D. magna* (freshwater organism), 200-210 µg/L for *M. bahia* (estuarine organism) and 2,100 µg/L for *C. virginica* (estuarine organism). In goldfish (*Carassius auratus*) and killifish (*Fundulus heteroclitus*), 1-naphthol was significantly more toxic than carbaryl based on 10-day acute lethality tests (Shea and Berry 1983). The degradate 1-naphthol was approximately five times more toxic than carbaryl in goldfish, and in killifish twice as toxic as carbaryl (Shea and Berry 1983). Additionally, fish exposed to 1-naphthol showed neurological trauma including pronounced erratic swimming behaviors and increased opercula beats following exposure to 5 and 10 mg/L. None of these symptoms were observed in the carbaryl treatments (Shea and Berry 1983). The volatility of 1-napthol is greater than carbaryl, and it is expected to be less persistent in air, with an estimated 0.7 hour estimated half-life in air and total transformation between 3-20 days (Rogers et al. 1984). We were unable to find information about the half-life of 1-napthol in freshwater, but in seawater exposed to sunlight, the half-life was 7 days, and increased to 15 days in the absence of sunlight (Lamberton and Claeys 1970).

The degradate 1, 4-napthoquinone is also considered to be very toxic to aquatic organisms (MSDS), though ecotoxicological data are limited. It has a biodegradation half-life of 4.07 days, and a fish biotransformation half-life of 0.107 days (CompTox v. 2.4.1).

Carbaryl is a part of a group known as N-methyl carbamates, which act as neurotoxicants by impairing nerve cell transmission in vertebrates and invertebrates. They inhibit the enzyme acetylcholinesterase (AChE), which is present in cholinergic synapses. The normal function of AChE is to break down (hydrolyze) the neurotransmitter, acetylcholine, thereby serving as an "off-switch" for the electrochemical signal transmissions along nerve cells and neuromuscular junctions. In a reversible reaction, carbamates bind to AChE, thereby inhibiting AChE's normal activity to hydrolyze the neurotransmitter acetylcholine at nerve synapses. This reaction is similar to organophosphorus insecticides with the main exception being a carbamylation of AChE instead of a phosphorylation. Carbamate inhibition of AChE is "reversible" in cases of sublethal exposure and recovery of N-methyl carbamate-inhibited AChE is typically rapid compared to OP-inhibited AChE, usually within a few hours. The key result of AChE inhibition by carbamate and OP insecticides is accumulation of acetylcholine in a cholinergic synapse. The buildup of acetylcholine causes continuous nerve firing and eventual failure of nerve impulse propagation.

AChE is prevalent in a variety of cell and organ types throughout the body of vertebrates and invertebrates (Walker 1991). A variety of adverse effects to organisms due to AChE inhibition range from sublethal behavioral effects to death (Mineau 1991). Numerous reports, peer-reviewed journal articles (Antwi 1985; Coppage 1974; Haines 1981; Holland 1967; Williams 1966) as well as multiple reviews, text books (Geisy 1999; Mineau 1991; Smith 1993), and wildlife poisoning cases document inhibition of AChE activity in invertebrates (Detra 1986; Detra 1991) and vertebrates including salmonids following exposures to carbamates and OPs (Beyers and Sikoski 1994; Grange 2002; Hoy 1991).

Toxicity to salmonids

Of the studies reviewed for NMFS's biological opinion on the FIFRA registration of carbaryl, response values for fish ranged from 0.6 µg/L (Mdegela et al. 2010) to 12,250 µg/L (Pereira et al. 2019). The majority of these endpoints were acute, in vitro exposures of brain and/or muscle homogenate. This review found that 96-hour LC50s for fish exposed to carbaryl ranged from 140 µg/L – 1,188 mg/L. This wide span of values indicates a range of sensitivity to carbaryl among fish. The most sensitive endpoint this review found for a closely related fish species (rainbow trout) exposed to a formulated product containing carbaryl was an LC50 value of 440 µg/L.

EPA's BE assessed toxicity data from salmonid species including Chinook salmon (Mayer and Ellersieck 1986) and rainbow trout (Boran et al. 2010), as well as other closely related fish, all in juvenile life stages (fry, fingerling, juvenile). For their analysis, LC50 values were transformed into LC_{low} values by dividing LC50s by 2.27, which provide a more conservative estimate of the level of effect. As discussed earlier (Section 2.5.1), we would expect between 0-15% mortality of salmonids when LC50s are modified by a safety factor of 0.5 (Dillon and Mebane 2002; NMFS 2012). The transformation EPA used is more conservative, but we may still expect a small amount of mortality at the LClow concentrations (estimated at <15% based on previous analysis of metals toxicity).

The selected LC50s for transformation into LClow values ranged from 522 – 2,400 µg/L and were from *O. mykiss, Salvelinus fontinalis* (brook trout), *Acipenser brevirostrum* (shortnose sturgeon)*,* and *O. tshawytscha* in order from most to least sensitive*.* EPA also reviewed other studies on carbaryl toxicity to fish within the same genus as those considered in this opinion, which yielded a range of LC50 values ranging from 780 – 7,100 µg/L from *O. mykiss¸ O. clarkii, O. kisutch* that varied depending on the exposure time used in the study.

Estimated acute minimum effect levels (transformed LC_{low} values) were 229.96 µg/L for steelhead and sockeye salmon (both based on rainbow trout surrogate data), and 1,057.27 µg/L for Chinook salmon. All assessed MELs were above the proposed criteria of 2.1 µg/L (Figure 15). Risk quotients for these LC_{low} values were 0.0091 and 0.0020, which both fall below the 0.5 and 1, the OPP's acute and chronic levels of concern for aquatic species, as well as OPP's threshold of concern for threatened and endangered animals, 0.05 (USEPA 2004). EPA's acute toxicity analysis only included mortality as an endpoint, so we examine studies that were not included in the BE, which measured other acute physiological and behavioral endpoints in the *Oncorhynchus* genus below.

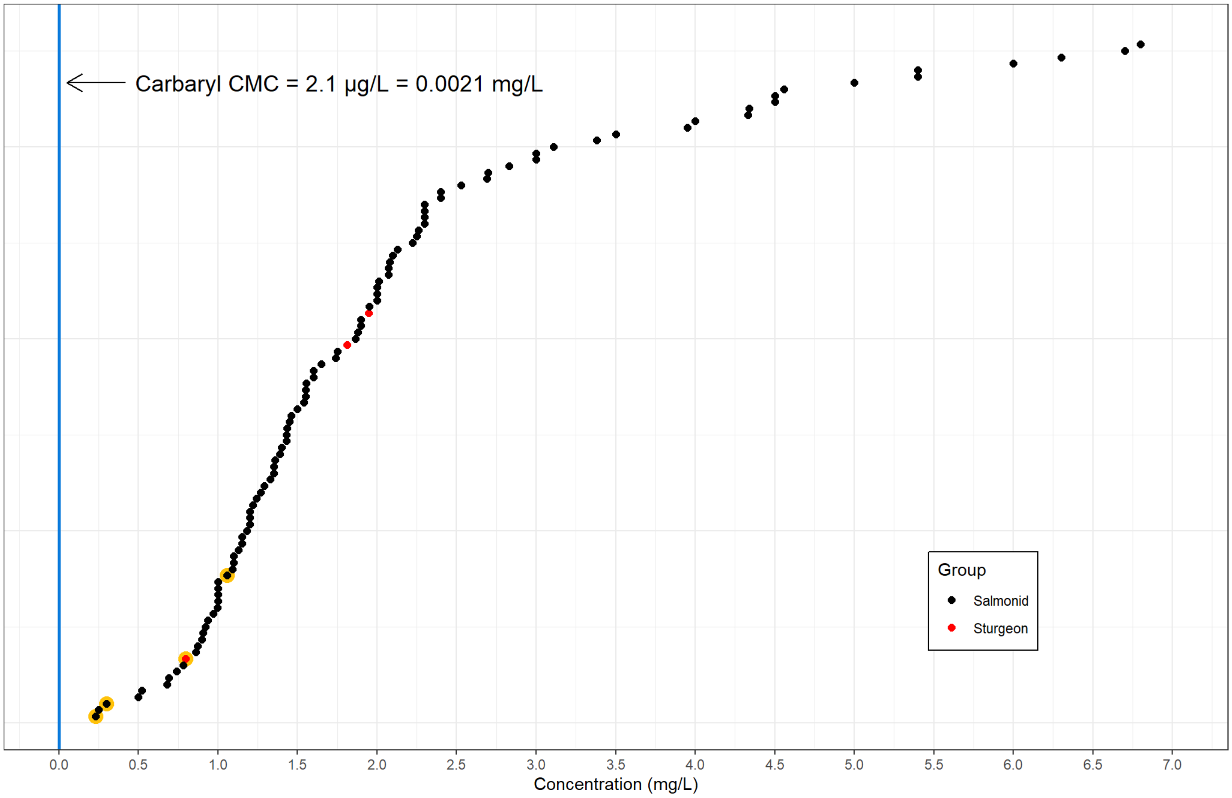

Figure 15. Salmonid and Sturgeon 96-hour LC_{50} values following acute exposure to carbaryl. Blue line represents the proposed acute carbaryl CMC (0.0021 mg/L). LC_{low}-based minimum effect levels are highlighted with yellow. Because of the high number of points, labels were left off for clarity and readability of the figure. Reproduced from EPA 2024.

One study relevant to our effects analysis measured inhibition of brain AChE, duration of recovery, survival at 24 hours, and tissue concentrations in juvenile rainbow trout (O. mykiss) following exposure to carbaryl at 0, 250, 500, 1,000, 2,000, and 4,000 µg/L (Zinkl 1987). Rainbow trout showed dose-dependent AChE inhibition from 61 - 91% when exposed to 250 – 4,000 µg/L for 24 hours. Most trout that died had 85% or greater inhibition. Trout recovered AChE activity following 24 h in uncontaminated water, indicating that fish recover if given the opportunity following carbamate exposures (Zinkl 1987). This study showed that carbaryl is acutely toxic to rainbow trout in a matter of hours (incidences of death at 1.5 – 4 h) at concentrations at or above 1,000 µg/L.

Carbaryl exposure has been found to have both physiological and behavioral impacts, which has been documented for AChE inhibitors, including carbaryl (Beauvais et al. 2001). Larval rainbow trout swimming speed was correlated with ChE activity (the family of enzymes AChE belongs to), which both decreased under carbaryl exposure, indicating both physiological and behavioral impacts. Carbaryl concentration levels of exposure were 188, 375, and 750 µg/L, and the latter two treatment levels differed from the control in ChE activity. Mean inhibition of ChE activity ranged 14-38% at 24 hours, 32-41% at 96 hours, and 7-14% following 48-hour recovery. Reductions in swimming speed may impair critical behaviors for salmonids including foraging, predator evasion, schooling, and migration. Little et al. (1990) also found that exposure to carbaryl inhibited spontaneous swimming activity and influenced swimming capacity. As the concentrations that caused physiological and behavioral impairment are orders of magnitude above the proposed acute criteria, the risk quotients for this endpoint are well below the OPP's thresholds of concern for threatened and endangered species.

Using a model based on empirical data that linked brain AChE activity, feeding behavior, food uptake, and growth rate in subyearling Chinook salmon, Baldwin et al. (2009) found that 4-day pulsed exposures to AChE inhibitors (such as carbaryl), may be sufficient to reduce growth and size at ocean entry. This relationship between AChE inhibition and growth is likely to be temperature-mediated, but temperature was not considered as a variable in this model. This study also found that reduction in individual survival due to AChE inhibition over successive years reduced the intrinsic productivity of a modeled Chinook salmon population. It is important to note that impacts of AChE inhibition and consequent reductions in growth may be delayed, and are particularly influential as salmon migrate to the ocean. The authors of this study concluded that even short-term (four-day) OP and carbamate pesticide exposures at levels representative of seasonal pesticide use that result in 50% reduction in AChE activity can influence growth and survival, and may limit the conservation and recovery of threatened and endangered salmonids.

Estuarine cutthroat trout were exposed in a lab setting to environmentally relevant concentrations of carbaryl for application to estuarine oyster beds to control burrowing shrimp populations (Labenia et al. 2007). This study found that a 6-hour carbaryl exposure reduced brain and muscle AChE activity in a dose-dependent manner, and swimming was impaired at concentrations above 750 µg/L. Predation rates were also significantly higher for trout exposed to carbaryl concentrations above 500 µg/L. The concentrations at which effects were observed were orders of magnitude higher than the proposed criteria, providing further confirmation that they are protective of fish. Juvenile Chinook salmon in the same estuarine environment as Labenia et al. (2007) showed brain AChE enzyme activity was decreased by 8 -14% 24 hours after a carbaryl spray event to control burrowing shrimp, and returned to normal levels within 48 hours (Troiano et al. 2013). Carbaryl concentrations in the estuary ranged from 15 - 800 µg/L 6 hours after the spray, depending on location within the application area, and concentrations decreased to less than 7 µg/L after 24 hours. Given that this was an *in-situ* study, it is difficult to estimate the true exposure concentrations that caused a decline in enzyme activity. Laetz et al. (2009) also showed AChE inhibition in coho salmon brains after exposure to carbaryl in combination with other carbamate and OP pesticides.

In addition to impairment of AChE, carbamates can also affect detoxifying responses in fish. Juvenile rainbow trout exposed to concentrations of carbaryl from 1,000 – 3,000 µg/L for 24, 48, and 96 hours showed early induction of cytochrome P450-1A, catalase, and glutathione S-transferase, followed by inhibition of these enzymes in response to carbaryl exposure (Ferrari et al. 2007). This indicates that exposure to carbaryl may cause delayed oxidative stress, and a reduction in the detoxification response of rainbow trout. This may lead to cell damage, and has the potential to reduce the ability of fish to detoxify other contaminants. Another study that used Gulf killifish (*Fundulus grandis*) as a test organism found that carbaryl metabolic activity increased by 350 – 500% five days after an embryo exposure to carbaryl, suggesting an improvement in the detoxification response (Oziolor et al. 2017). However, this effect disappeared after ten days, suggesting that induction of this defense mechanism is short-lived.

Given that this study was conducted with a non-salmonid species, we give less weight to this finding in our consideration.

Several salmonid species were found to have reduced olfactory function after exposure to carbaryl for 30 minutes at 100 µg/L (Tierney et al. 2007). For salmon, olfaction forms the basis of important behaviors including predator evasion and conspecific recognition, and pesticides can impair olfactory functions. This study found that electro-olfactogram response (indicator of olfactory pesticide toxicity) was 49.7%, 60.3% and 62.3% of the control for sockeye, rainbow trout, and coho, respectively. This suggests that there is some interspecific variation in olfactory toxicity between salmonids, as sockeye salmon appeared more sensitive. The fish exposed to carbaryl in this study had not recovered olfactory function 15 minutes after exposure, suggesting that impairment may be persistent. However, it is not clear from this study, whether reductions in electro-olfactogram response of this magnitude would result in impairment of olfaction-based behaviors, so we give less weight to this study than a study of whole organisms. Effects were observed at 100 µg/L, resulting in a risk quotient for this endpoint of 0.021, which is below the OPP's thresholds of concern for threatened and endangered species. Given that this is a relatively conservative threshold indicating that the criteria are two orders of magnitude lower than the adverse effect level, it is unlikely that olfactory function would be impaired after exposure to carbaryl at the proposed criteria concentrations.

The BE's chronic toxicity analysis included mortality, growth, reproduction, behavior, or AChE activity as endpoints (Figure 16). In general, the sublethal endpoints were much more sensitive than the mortality endpoint. The BE assessed one study on chronic impacts to a salmonid species, *O. nerka* (Kennedy and Ross 2012), with most information about chronic toxicity from studies with fathead minnow and other surrogate species.

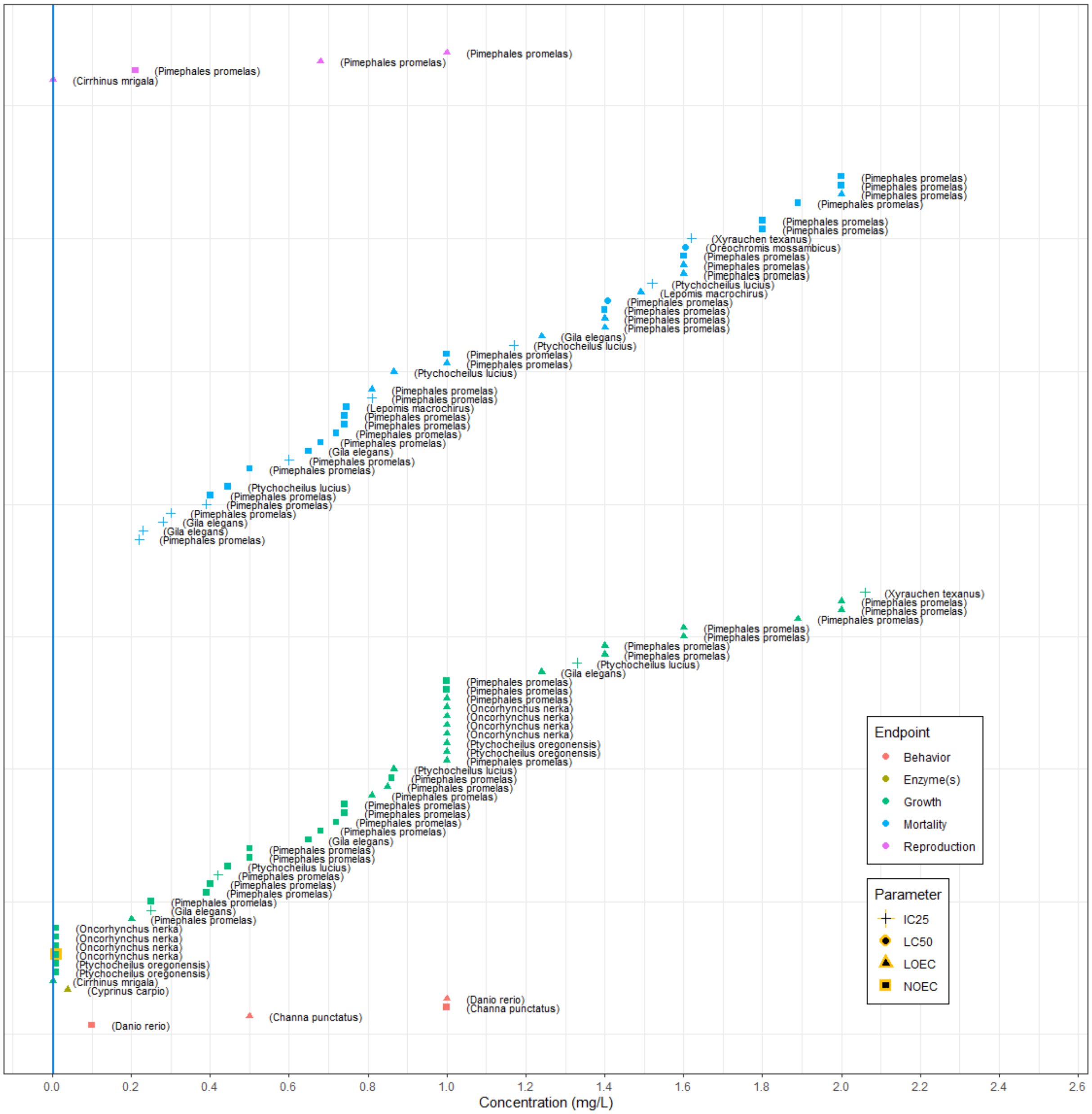

Figure 16. Fish carbaryl chronic toxicity endpoints are displayed. The blue line represents the proposed carbaryl CCC (0.0021 mg/L or 2.1 µg/L). The salmonid minimum effect levels (i.e lowest NOECs) are highlighted with yellow. Points are labeled with the scientific name of the fish and the type of parameter that was measured for that endpoint. Reproduced from EPA 2024.

Kennedy and Ross (2012) found that at warmer temperatures reflective of summer conditions, body mass, organ and body condition indices and energy stores in both species (juvenile sockeye salmon (*O. nerka*), Northern pike minnow (*Ptychocheilus oregonensis*)) were significantly more reduced under limited food conditions when fish were concurrently exposed to carbaryl at 1,000 µg/L for 12 weeks. There was no such difference when the exposure concentration of carbaryl was 10 µg/L, which was the lowest NOEC for chronic exposure in the literature reviewed in

EPA's BE. This study only used two concentrations of carbaryl, and therefore, could not be used to calculate a dose-response relationship.

Because of the scarcity of chronic data available for salmonids, EPA also assessed carbaryl chronic toxicity to other fish, a comparison which has been supported in the literature, though it is acknowledged that rainbow trout provide the best commonly used surrogate for salmonids (Sappington et al. 2001; Dwyer 1999). Jones et al. (1998) found that surrogate species were useful for assessing sublethal physiological responses to carbaryl, particularly because it has a clear mechanism of action. NOECs included in the BE's review ranged as high as 4,000 µg/L for fathead minnow (Pickering et al. 1996). The lowest concentration at which growth and reproductive effects were observed in the literature surveyed was 2 µg/L following a 60-day exposure for *Cirrhinus mrigala* (a species of carp) (Kaur and Dhawan 1996), while the highest LOEC was an effect on growth observed at 5,000 µg/L for *Mystus vittatus* exposed for 27 days, and for *Oryzias latipes* exposed for 14 days (Arunachalam et al. 1980; Kashiwada et al. 2008). Two studies reported low growth-related endpoint values for carbaryl. In the first study, a NOEC value of 250 µg/L and LOEC of 500 µg/L was reported based on dry weight reductions in 4-day old fathead minnow larvae (*Pimephales promelas*) exposed to carbaryl for 7 days (Pickering et al. 1996). In a 7-day study, an EC25 of 250 µg/L was based on the reduction of biomass (using an inhibition concentration methodology) for bonytail freshwater fish following exposure to carbaryl (Dwyer et al. 2005). However, both studies contained limitations (including limited information on methodology, nonstandard endpoint analysis, and lack of raw data), and therefore were not considered as the growth endpoint threshold for freshwater fish. Overall, there appeared to be a range of inter- and intraspecific variation in sensitivity to carbaryl at chronic timescales. Because there was little chronic data specific to salmonids, estimates of chronic toxicity for the listed species are fairly uncertain.

To provide an additional species-specific estimate of chronic carbaryl toxicity, EPA calculated a SMAV for each listed species, which was divided by an ACR (acute to chronic ratio, the ratio of LC50 to NOEC values), resulting in a calculated chronic MEL (i.e., a NOEC). These values for each salmonid species considered in this opinion are shown in Table 13. These calculated NOEC values are higher than the NOEC reported in Kennedy and Ross (2012), but without a dose-response relationship from this study, it is unclear how much of an underestimate their NOEC may be. Using the calculated chronic MELs, risk quotients for the proposed criteria would range from 0.017 - 0.025, which is below the OPP's acute and chronic levels of concern for aquatic species, as well as OPP's threshold of concern for threatened and endangered animals, 0.05 (USEPA 2004), and indicates that the chronic criteria would be protective based on this calculation.

Table 13. Summary of carbaryl chronic NOEC values calculated from the MAV and ACR for each ESA-listed fish (USEPA 2024).

Family	Species	MAV (LC_{50} in µg /L)	ACR (LC_{50}/NOEC)	Calculated NOEC (µg/L)
Salmonidae	*Oncorhynchus mykiss*	1,670	20.19	82.71
Salmonidae	*Oncorhynchus tshawytscha*	2,540	20.19	125.80
Salmonidae	*Oncorhynchus nerka*	1,970	20.19	97.57

In summary, carbaryl is known to produce lethal and sublethal effects to salmonids, but the available evidence suggests that the proposed acute and chronic criteria (2.1 µg/L) is low enough to protect against most adverse effects via direct exposure of fish. However, salmonids rely on functioning ecosystems for growth and survival, and carbaryl may affect the quality and quantity of prey organisms. The next section examines the effects of the proposed criteria on prey organisms and the resulting effects to salmonid growth and survival.

Secondary exposure to salmonids and toxicity to salmonid prey species

Anticholinesterase insecticides can reduce benthic densities of aquatic invertebrates and alter the composition of aquatic communities (Chang et al. 2005; Fleeger et al. 2003; Liess and Schulz 1999; Relyea 2005; Schulz 2004; Schulz and Liess 1999). Juvenile salmonids are largely opportunistic, feeding on a diverse community of aquatic and terrestrial invertebrate taxa that are entrained in the water column or on the surface and that have a wide range of sensitivities to carbaryl (Higgs et al. 1995). However, carbaryl is known to be highly toxic to aquatic crustaceans and macroinvertebrates; concentrations that are not expected to kill salmonids are often lethal for their invertebrate prey (e.g., 1.8 – 3.7 µg/L in Toumi et al. 2016). In particular, prey items that are preferred by small juvenile salmonids (including midge larvae, water fleas, mayflies, caddisflies, and stoneflies) are among the most sensitive aquatic macroinvertebrates (NMFS 2023). Effects of other types of pesticides on the prey community have been shown to persist for extended periods of time (Colville et al. 2008; Liess and Schulz 1999; Van den Brink et al. 1996; Ward et al. 1995). After pesticide exposure, the prey community can take weeks to months to fully reestablish, depending on the species composition, life cycle length of the affected species, and presence of nearby reestablishing source populations), If preferred prey items do not reestablish quickly, this may result in effects on fish feeding and growth after an exposure has ended. Therefore, in combination with the direct stressor of carbaryl exposure, there may also be significant indirect effects to individuals via their prey (Peterson et al. 2001). Salmon are often found to be food limited (Quinn 2005), suggesting that a reduction in prey number or size due to insecticide exposure may further stress salmon and lead to reduced growth rates.

In addition to reduction in the quantity or composition of available prey organisms, exposure to carbaryl can further reduce the ability of salmonids to successfully feed. Sandahl et al. (2005) showed that juvenile salmonids had reduced feeding success following exposures to AChE inhibitors (Sandahl et al. 2005), though this typically occurs at concentrations above 2.1 µg/L. This may be linked to reduced swimming ability caused by AChE inhibitors (Baldwin et al. 2009; Beauvais et al. 2001; Little et al. 1990). Reduced feeding success due to physiological impairment of fish has the potential to interact with ecological factors such as reductions in prey quantity or quality.

One likely biological consequence of reduced feeding, foraging, and prey availability is a reduction in food uptake and, subsequently, a reduction in somatic growth of exposed fish. For example, juvenile growth is a critical determinant of freshwater and marine survival for Chinook salmon (Higgs et al. 1995; Mebane and Arthaud 2010). Reductions in the somatic growth rate of salmon fry and smolts are believed to result in increased size-dependent mortality (Healey 1982; West and Larkin 1987; Zabel and Achord 2004). Zabel and Achord (2004) observed size-dependent survival for juvenile salmon during the freshwater phase of their outmigration. Mortality is also higher among smaller and slower growing salmon because they are more susceptible to predation during their first winter (Beamish and Mahnken 2001; Healey 1982; Holtby et al. 1990). These studies suggest that factors affecting the organism and reducing somatic growth, such as anticholinesterase insecticide exposure, could result in decreased first-year survival and, thus, reduce population productivity.

One uncertainty in the effects analysis is the degree to which secondary poisoning of listed species may occur from feeding on contaminated prey (e.g., dead and dying drifting insects). Secondary poisoning is a frequent occurrence with OPs and carbamates in bird deaths (Mineau 1991), yet is much less studied in fish. Juvenile brook trout gorged on drifting insects following applications of carbaryl, showed reduced AChE activity (15-34%) (Haines 1981). However, it is not possible to differentiate the contribution to AChE inhibition measured in this study from the aqueous and dietary routes because concentrations were not measured in the water, prey, or fish. Uptake, metabolism, and accumulation of carbaryl by a salmonid prey item, *Chironomus riparius* (midge), exposed for 24 hours indicated significant uptake over the first 8 hours, significant metabolism (more than 85-99%) of parent carbaryl to metabolites, and low bioconcentration factors (5-10) (Lohner and Fisher 1990). These results suggest that contaminated prey items, take up carbaryl, but it does not tend to accumulate due to rapid metabolism.

Using a SSD based on NOEC values, the BE found that the HC5 was lower than the chronic carbaryl criterion of 2.1 µg/L, indicating that the most sensitive species considered would not be protected by the proposed criterion. Approximately 94% of the GMCVs based on NOECs for prey species were above the criterion level, and would likely not be significantly impacted. In their analysis, invertebrates tended to be more sensitive to carbaryl than fish, which is consistent with previous assessments. It is important to consider that *Daphnia magna*, which was found to be one of the most sensitive organisms to carbaryl (GMCV of 2.6 µg/L), can be considered a keystone species in aquatic food webs (particularly in lakes). Reductions in *Daphnia* spp. may impact the myriad of other organisms that feed on it, potentially magnifying the effects of carbaryl exposure on prey availability.

The BE also conducted an assessment of salmonid growth based on reductions in prey items using a salmon translator model (USEPA 2024). Under the most severe scenario of continuous exposure at or below criteria levels for 427 days, the model predicted up to a 43% reduction in the survival of a salmonid due to exposure of their prey to carbaryl. This scenario is quite unlikely, given carbaryl's short half-life in aerobic environments. Most scenarios of prey exposures to carbaryl below the chronic criterion at recurring intervals, which may be more reflective of exposures in the environment, showed at or below 10% impact on salmonids, which is within the range accepted for control mortality during laboratory experiments. For scenarios with recurring exposure of the prey to carbaryl at or below the chronic criterion, the only scenarios with an impact greater than 10% was the recurrence of exposure at the chronic criterion every 30 days. The model predicted an impact on the survival of 15 - 20% of salmonids due to reductions in growth under these potential scenarios. For this to occur, the juvenile salmon would have to encounter reduced prey daily during rearing and/or as they migrate down river/stream repeatedly for up to three months. The likelihood that any of the above-described scenarios occur is dependent on the frequency of the exposure, which is based on pesticide and land use that coincides with the timing and duration of salmon rearing and migration. Given that carbaryl is not persistent in the environment, and has only rarely been detected, it is unlikely that prey would be reduced throughout salmonid rearing habitat, and therefore unlikely salmonid survival would be as reduced as predicted under the 30-day recurring exposure scenario of the salmon translator model.

Relevance of fish effects to population/ MPG viability

As shown in Table 9, the designated critical habitats of each of the ESA-listed salmonids considered in this opinion overlap to some degree with agricultural and forested land cover, where carbaryl may reasonably be expected to be used. Overall, SR sockeye salmon tend to have less overlap with agricultural and forested lands than the other three species considered, and SR fall Chinook salmon have the most overlap. Populations most likely to be affected by the proposed action are those that spend more time in agricultural areas. For example, fish that tend to rear as juveniles in agricultural areas may have greater exposure to pesticides. In general, the fish that spend more time in larger, lower elevation rivers are more likely to be exposed to carbaryl, as these habitats tend to be in closer proximity or downstream of agricultural areas where carbaryl may be more commonly used. There were no detections of carbaryl within the designated critical habitat for any of the listed salmonids considered in this opinion (Figure 11). Of the NAWQA samples (ISDA data were unavailable), detections of carbaryl were not localized in one season of the year, indicating that carbaryl may be applied at any time and its use is not necessarily tied only to seasonal crops.

Based on the available, albeit limited, data there appears to be no spatial overlap between carbaryl presence in aquatic habitat and SR sp/su Chinook salmon, SR fall Chinook salmon, SR sockeye salmon, or SRB steelhead critical habitat. However, carbaryl sampling in critical habitat has been so limited that we cannot rule out that exposures may occur in these areas. Sampling also did not occur in the more agricultural areas within critical habitat, particularly of SR sp/su and fall Chinook salmon and SRB steelhead, potentially causing an underestimation of carbaryl exposures. In general, toxics monitoring in the Columbia Basin has been concentrated primarily in the lower Columbia River and estuary, and data for the middle and upper Columbia, Snake River and Salmon River basins are lacking (USEPA 2009b). Based on land use and crop cover data (section 2.4.2.1 and 2.4.2.2.2), we know there is less agricultural area with a limited number of crops that are treated with carbaryl in anadromous watersheds compared to the areas of the state that have been monitored for carbaryl. This suggests that carbaryl concentrations in anadromous waters are unlikely to be higher than what has been observed at monitoring sites in southern Idaho (Figure 9). Species may be more likely to encounter these pesticides outside their critical habitat in migration corridors, but concentrations in the action area appear to be below the proposed criteria. The limited monitoring data we have suggest that it is unlikely fish will be exposed to carbaryl concentrations that exceed the proposed criteria of 2.1 μg/L.

At concentrations below this proposed level, we expect only a very small number of individual fish to be adversely affected directly by acute or chronic carbaryl toxicity. However, even low concentrations (at or below 2.1 μg/L) may cause indirect effects on salmonid growth and survival via toxicity to prey organisms. Given these indirect effects of carbaryl on salmonid growth and size-mediated survival, the juvenile rearing and migration life stages are of primary concern. We do not have sufficient information to understand the effects of carbaryl on salmonid embryos and spawning adults. Migrating adults typically do not consume food on their route to spawn, and would not be likely to be impacted by reductions in prey due to carbaryl toxicity. Therefore, we focus on the potential for exposure during juvenile life stages, and assess the potential effects at the population level for each species.

Although it appears possible that all of the listed salmonid species considered in this opinion could be exposed to low concentrations of carbaryl, the diverse life history strategies of SR Chinook sp/su salmon, SR fall Chinook salmon, SR sockeye salmon, and SRB steelhead may result in differential likelihood of exposure. This analysis relies on the best available information for salmonid presence in certain land-use areas. Carbaryl is a widely used pesticide for multiple applications. There remains substantial uncertainty regarding the actual application rates (as opposed to allowable application rates) of carbaryl for the various land-use categories and crop areas that are registered for carbaryl use. We also do not have sufficient pesticide monitoring information to model in-stream concentrations based on application rates. Because of the lack of data at multiple levels, we use a qualitative approach to assessing salmonid exposure potential. We have qualitatively estimated potential exposure that is reasonable based on land use, prescribed carbaryl use, estimated application rates, and limited monitoring data, but recognize that this may over- or underestimate true salmonid exposure, and therefore effects to salmonids in some cases.

<u>SR sp/su Chinook salmon:</u> Juvenile SR sp/su Chinook salmon may emigrate shortly following emergence, during the fall or winter, or during the following spring. Most SR sp/su Chinook salmon exhibit a stream-type strategy, rearing for one year in freshwater before migrating to the ocean in the spring, typically April - May. The fish that overwinter either do so in natal streams, larger Idaho rivers downstream of their natal habitat, or outside of the action area, downstream of LGD. This diversity of life-history strategies can create differential exposure potential, with the juveniles that overwinter downstream, more likely to be exposed to contaminants than individuals that overwinter in more remote natal streams. Because SR sp/su Chinook salmon juveniles may spend a year (or more) in larger downstream rivers, they may be exposed to carbaryl multiple times during their rearing. However, carbaryl is relatively short-lived in the environment, which likely reduces the chances of fish exposure.

The salmon translator model found that under a scenario where fish were exposed to carbaryl concentrations at 2.1 µg/L or at 75% of the criterion every 30 days, a 15-20% reduction in survival was expected. For stream-type SR sp/su Chinook salmon that rear in larger rivers, which are more likely to contain contaminants at higher concentrations due to their proximity to agricultural land uses, exposure to carbaryl once every 30 days may be a reasonable assumption for some individuals, as it is widely used in agricultural contexts. Exposure to carbaryl at concentrations at or below 2.1 µg/L every 30 days would be allowable under the proposed chronic criterion, but only one exposure above 2.1 µg/L every three years would be allowable under the proposed chronic criterion. Therefore, the proposed action could result in up to a 15 – 20% reduction in survival for the regularly exposed SR sp/su Chinook salmon. These are likely to be over-estimates of population-level effects, as it is reasonable that some individuals could be exposed to a pulse of carbaryl at least once per month, but unlikely that this would apply to a large number of fish in a population. The majority of fish would likely experience less frequent exposure scenarios, and would therefore experience reductions in survival of less than 10%. Our reasoning is that carbaryl does not persist in the environment, meaning contamination events would be localized. There also have been no detections of carbaryl at concentrations above the proposed criteria, and most detections (median = 0.010 µg/L) were substantially below 2.1 µg/L.

Baldwin et al. (2009) demonstrated for a modeled Chinook salmon population that reductions in survival due to representative carbamate exposure could result in spawner abundance that was 56.4 – 85.6% of the control after 20 years. This was based on exposure to a different carbamate, at concentrations that cause AChE inhibition; thus, this is likely an overestimate of the reductions in survival and productivity compared to what we would observe for the proposed action. At carbaryl concentrations of 2.1 µg/L (proposed acute and chronic criteria), we do not expect AChE inhibition to occur for salmonids, so we do not expect the same population-scale effects as observed in Baldwin et al. (2009). This study provides an indication that reductions in survival due to the pesticide exposure can translate to reductions in productivity. We also expect the proposed action to differentially impact different life-histories of the species, as juveniles that overwinter downstream of natal habitats are more likely to be exposed to carbaryl. Populations in some geographic areas may be differentially impacted if carbaryl is applied more heavily or frequently in certain parts of SR sp/su Chinook salmon habitat. While we do expect adverse effects to some individuals via reductions in prey, we do not expect the VSP criteria (abundance, productivity, spatial structure, and diversity) to be negatively affected at the population scale, as it is unlikely that a significant number of individuals would be exposed to carbaryl at criteria levels given current information regarding land use, application of carbaryl, and available water quality data. As we do not expect population-scale effects, the proposed action would not reduce the viability or recovery trajectory of the affected MPGs and ESU. Impacts at the population, MPG, and ESU scale are considered alongside the status of the species, environmental baseline, and cumulative effects in the Integration and Synthesis (Section 2.7).

<u>SR fall Chinook salmon:</u> A slight majority of SR fall Chinook salmon juveniles have an ocean-type migration strategy and migrate to the ocean rapidly after emergence. The yearling-type strategy is becoming more common, and many migrate downstream from natal streams into reservoirs (some in Idaho, some in Washington) (Tiffan and Connor 2012; Tiffan et al. 2014). Some yearling-type SR fall Chinook salmon juveniles may overwinter near natal streams or in the upper reaches of the Lower Granite pool in Idaho before leaving the action area in May-June. We expect the juveniles that rear in freshwater for a longer period of time are more likely to be repeatedly exposed to carbaryl than ocean-type juveniles. The lower Snake River and Columbia River reservoirs, where many SR fall Chinook salmon overwinter, are in or downstream of agricultural areas and all of the carbaryl detections found in the action area (Figures 6 and 11), though carbaryl's short half-life would likely limit the extent of downstream effects.

Because of the higher likelihood of exposure for the yearling-type fall Chinook salmon that rear for an extended period in Idaho, we expect the proposed action could potentially result in up to a 15 – 20% reduction in survival for some regularly exposed fish (upper-bound estimate, derived from an assumption of exposure equal to or at 75% of the criteria every 30 days). The majority of yearling-type SR fall Chinook salmon would likely experience less frequent exposure scenarios, and would therefore experience reductions in survival of less than 10%. Reductions in survival for ocean-type SR sp/su Chinook salmon are also expected to be less than 10%, as it seems unlikely that any fish would be exposed on such a regular basis (i.e., every 30 days) given their short duration in the action area. Fish in certain geographic areas may be more impacted if carbaryl is disproportionately applied in these areas of SR fall Chinook salmon habitat. While we expect adverse effects to some individuals, we do not expect the VSP criteria (abundance, productivity, spatial structure, and diversity) to be negatively affected at the population scale, as it is unlikely that a significant number of SR fall Chinook salmon individuals would be exposed to carbaryl at criteria levels. Our reasoning for this is similar to the reasoning described for SR sp/su Chinook salmon. A relatively small proportion of anadromous watersheds flow through agricultural areas. Those agricultural areas that do surround anadromous watersheds tend to include only a small proportion of crops that may be treated with carbaryl, compared to agricultural areas in southern Idaho (section 2.4.2.1). Given the relative rarity of carbaryl detections in southern Idaho (section 2.4.2.2.2), where monitoring occurs and where we would expect carbaryl detections to be more common, we do not expect carbaryl to reach criteria levels in anadromous watersheds very frequently. As we do not expect population-scale effects based on the proposed action, it would not result in reduced viability of the ESU, which consists of only one extant population. Similarly, we also would not expect the carbaryl criteria to limit recovery of SR fall Chinook salmon. Impacts at the population and ESU scale are considered alongside the status of the species, environmental baseline, and cumulative effects in the Integration and Synthesis (Section 2.7).

SR sockeye salmon: SR sockeye salmon rear primarily in remote, high-elevation lakes that are unlikely to be affected by agricultural activities, such as pesticide use. However, carbaryl has been used on forested land for bark beetle control. This is a less prevalent use of the pesticide, but cannot be discounted. SR sockeye salmon would be less likely to be exposed to carbaryl in the lakes where they rear than along their migration route. Very little is known about actual exposure to and uptake of contaminants in outmigrant juvenile SR sockeye salmon, or returning adults, and no data are available on contaminant body burdens in this species. Moreover, water quality data for much of this ESU's habitat is incomplete. For example, there are only three NAWQA monitoring sites within the migration corridor of SR sockeye salmon, and no sites within the spawning and rearing habitat (NMFS 2011). Water quality assessments are lacking for several lakes that comprise historical spawning habitat.

Sockeye salmon likelihood of exposure would increase for only a short window of time when they migrate rapidly to the ocean through waters in the action area that may be impacted by agricultural activities for a few weeks between April and July. Because of the short time frame of passage through waters in agricultural areas, it is unlikely that SR sockeye salmon would be exposed to carbaryl at concentrations at or below 2.1 µg/L frequently or long enough to cause a reduction in growth via reductions in feeding success. As demonstrated by the salmon translator model, only continuous exposure at criteria levels for over a year and repeated exposure every 30 days would be likely to result in reductions in survival of more than 10%. Due to the nature of the salmon translator model, "less than 10%" cannot be distinguished from the control. Given the very limited timeframe for exposure, we expect SR sockeye salmon survival declines to be well under 10%. While some individual fish may be impacted, we do not expect population-level impacts because SR sockeye salmon life history, land use data, estimated carbaryl application rates, and available water quality information suggest widespread and frequent exposures of aquatic ecosystems to concentrations near the criteria are unlikely to occur. SR sockeye salmon are already at high risk for all four VSP variables, but we do not expect impacts to the VSP criteria as a result of the proposed action that would reduce the overall viability of the single remaining MPG and therefore the ESU. We also do not expect the carbaryl criteria to limit recovery of the species. Impacts at the population, MPG, and ESU scale are considered alongside the status of the species, environmental baseline, and cumulative effects in the Integration and Synthesis (Section 2.7).

SRB steelhead: Rearing SRB steelhead typically remain in freshwater for two to three years (up to five years has been documented) before migrating toward the ocean in spring to early summer, typically leaving the action area by April to May. Younger fish tend to rear in smaller, low velocity streams and channels, and older fish may venture into deeper waters. The relatively long tenure of SRB steelhead juveniles in freshwater presents more opportunity for repeated carbaryl exposures. The rivers and tributaries where SRB steelhead most commonly rear overlap somewhat with agricultural land uses, particularly in the more western part of their range, and overlap significantly with forested and shrub/scrub areas. We expect SRB steelhead populations that spend more time in the western part of their Idaho range (i.e., lower Snake, Salmon, and Clearwater Rivers) to be more likely to experience adverse effects from carbaryl exposure (Figure 8), though this pesticide is used in other areas, less prevalently, in a variety of contexts including forest management. In agricultural areas it is reasonable to estimate that carbaryl exposure at or below 2.1 µg/L could occur once every 30 days for some individuals, but unlikely this would be true for a large number of individuals in a population due to the short half-life of carbaryl and the lack of detections of this compound in monitoring data. Using the salmon translator model, this scenario could result in up to a 15-20% reduction in survival for regularly exposed steelhead in agricultural areas. We expect exposure to be less likely outside of agricultural contexts, and would result in less than a 10% reduction in survival of SRB steelhead in most of its range. While we do expect adverse effects to some individuals, we do not expect the VSP criteria (abundance, productivity, spatial structure, and diversity) to be negatively affected at the population scale, as it is unlikely that a significant number of SRB steelhead individuals would be exposed to carbaryl at criteria levels on a regular basis, based on land-use information, estimated application rates, and the available monitoring data. As we do not expect population-scale effects, the proposed action would not result in significantly reduced viability of the affected MPGs and DPS. We also do not expect the carbaryl criteria to limit recovery of the species. Impacts at the population, MPG, and DPS scale are considered alongside the status of the species, environmental baseline, and cumulative effects in the Integration and Synthesis (Section 2.7).

2.5.1.3. Approval of Diazinon Criteria

The proposed acute and chronic criteria for diazinon are 0.17 µg/L over one hour and over four days, respectively. This is consistent with the EPA's 304(a) criteria for diazinon. The proposed criteria are more protective than the OPP's freshwater vertebrate benchmarks (45 µg/L acute, <0.55 µg/L chronic), and as or less protective than the OPP's freshwater invertebrate benchmarks (0.105 µg/L acute, 0.17 µg/L chronic). Diazinon was first registered in 1956 as an insecticide for use on fruit, vegetables, and forage and field crops. Diazinon has veterinary uses for fleas and ticks, and has also been used for control of household insects, grubs, nematodes in turf, seed treatments, and fly control. As of March 29, 1988, diazinon uses on golf courses and sod farms were canceled due to numerous bird kills. Residential use of diazinon was also cancelled in 2004. Diazinon is registered for use on multiple food crops, outdoor ornamentals grown in nurseries, and cattle ear tags (NMFS 2022a). Formulations include wettable powder, emulsifiable concentrate, and ear tags, and it is most often applied in liquid form. Aerial and ground application methods (including broadcast, soil incorporation, orchard airblast, and chemigation) are allowed (aerial applications only allowed for lettuce). Diazinon can be transported from the original use site and enter surface waters through runoff, spray drift, and volatilization. It is more likely to enter aquatic habitat when it is applied during precipitation events or when soil is saturated, during high wind or inversion conditions, and in closer proximity to surface waters. Aerial modes of application are also more likely to result in drift into aquatic environments.

Diazinon is not expected to volatilize, is poorly soluble in water (~60 mg/L at 20°C) (PubChem CID 3017), and has a fairly low octanol–water partition coefficient (log Kow = 3.81 (CompTox v. 2.4.1), indicating that it may moderately adsorb to sediments or organic solids. Diazinon does not readily bioaccumulate (BCF = 161, below what is considered bioaccumulative), and is metabolized in animals rapidly (USEPA 2017).

The half-life of diazinon in air is estimated to be 1.8 hours (PubChem CID 3017), and in nonsterile soils half-life estimates range from less than 1 week to 5 weeks, and may persist in soils from 3 to 14 weeks. In water at pH 7.0, diazinon is stable and can persist in the environment for as long as six months (USEPA 2005). Diazinon degradation is regulated by chemical hydrolysis and microbial degradation, both of which are influenced by various water quality parameters (e.g., pH, temperature, organic content of water).

Degradates of diazinon include diazoxon and oxypyrimidine. Oxypyrimidine is less toxic to fish and invertebrates than diazinon with acute toxicity endpoints greater than 101 – 109 mg/L (White and Steeger 2012). Diazoxon is ten times more toxic than diazinon to amphibians (Sparling and Fellers 2007), but has a much shorter half-life (4.17 days) (CompTox v. 2.4.1). Tsuda et al. (1997) found that the 48-hour LC50 for diazinon in the killifish (*Oryzias latipes*) was 4.4 mg/L, while the diazoxon LC50 was 0.22 mg/L.

Diazinon is a part of the organophosphate (OP) group of pesticides, which act as neurotoxicants by impairing nerve cell transmission in vertebrates and invertebrates in a manner similar to carbamates (Section 2.5.1.2). They inhibit the enzyme AChE, which is present in cholinergic synapses. Unlike carbamates, OPs irreversibly bind to AChE, inhibiting its function at nerve synapses. This irreversible binding makes recovery time from OP exposure longer than for carbamates because new cholinesterase enzyme must be synthesized, which can take up to several weeks (Ferrari et al. 2004). As described in section 2.5.1.2, AChE inhibition can cause a number of adverse neurological effects ranging from sublethal behavioral effects to death in vertebrates and invertebrates. For freshwater fish, the primary route of exposure is through contact with surface water, as diazinon is transported through the gills.

Of the studies reviewed for NMFS's biological opinion on the FIFRA registration of diazinon (NMFS 2022a), the majority of available toxicity data were for the mortality endpoint, but sublethal endpoints were also considered. This opinion estimated the LC50 for fish and aquatic-phase amphibians to be 237.9 µg/L. The LC50 for fish prey (including freshwater, estuarine, and marine species) was 0.5 µg/L. Reported LOECs for growth ranged from 0.55 – 4,074 µg/L, LOECs for behavior ranged from 1- 3,044 µg/L, and the estimated LOEC for reproduction was 0.47 µg/L. The EC50 for AChE effects was estimated to be 66 µg/L. The 2022 biological opinion also determined that the concentrations of diazinon (1.0 µg/L or greater) that elicit reductions in population growth rate were likely to occur in salmonid habitats without implementation of the draft opinion's prescribed RPA, which was adopted into the proposed action. These estimated concentrations were based on expected usage, sales, and crop/land-use in salmonid habitat, and were expected to be higher than the proposed criteria evaluated in this opinion if the RPA was not adopted. The degree to which a threatened or endangered population is affected will depend on a host of factors including the proportion of individuals exposed, the duration of exposure, when they are exposed during their life cycle, and if they are exposed more than once.

EPA's BE assessed toxicity data from surrogate salmonid species from the *Oncorhynchus* genus, including Chinook salmon, sockeye salmon, rainbow trout, and cutthroat trout, as well as other closely related salmonids, in juvenile or unreported life stages (Allison and Hermanutz 1977; Banaee et al. 2011; Bathe et al. 1975; Beliles 1965; Mayer and Ellersieck 1986; Meier et al. 1979). For their analysis, LC50 values were transformed into LC_{low} values, as described in section 2.5.1.2. The transformation EPA used is more conservative, but we may still expect a small amount of mortality at the LC_{low} concentrations (estimated at <15% based on previous analysis of metals toxicity).

The selected LC50s for transformation into LClow values ranged from 90 – 450 µg/L and were from *O. mykiss* and *Salvelinus fontinalis* (brook trout) in order from most to least sensitive. A LC5 of 4,990 µg/L for *Huso huso* (Beluga sturgeon) was also considered as a minimum effect level. EPA also reviewed other studies on diazinon toxicity to fish within the same genus as those considered in this opinion, which yielded a range of LC50 values ranging from 90 – 3,200 µg/L from *O. mykiss* and *O. clarkii*. Other sources not included in the BE, which tested for acute mortality dose-response reported a range of effects. The 96-hour LC50 was reported to be 2,760 µg/L for cutthroat trout (life stage not reported) (Swedburg 1973), and 545,000 µg/L and 29,500 µg/L for Chinook salmon eyed eggs and alevins, respectively (Viant et al. 2006). This study suggests that salmonid eggs and alevins may be less sensitive to diazinon than other life stages. All assessed MELs were above the proposed criteria of 0.17 µg/L (Figure 17).

Many of the studies reviewed used 96-hour LC50s, but even very short-term exposures to diazinon can cause mortality in rainbow trout, when present in high concentrations. Matsuo and Tamura (1970) observed 30% mortality one hour after exposure to 5,000 µg/L and 20% mortality after exposure to 15,000 µg/L for just 30 minutes. These trials were conducted with either five or ten fish, and due to the small sample size, come with uncertainty in understanding short-term toxicity more broadly. It is also important to note that the concentrations tested are several orders of magnitude above the proposed diazinon criteria.

Estimated acute minimum effect levels (LClow values) were 39.64 µg/L for Chinook salmon, steelhead, and sockeye salmon (all based on rainbow trout surrogate data). The risk quotients for the LClow values are 0.0043, which both fall below the 0.5 and 1, the OPP's acute and chronic levels of concern for aquatic species, as well as OPP's threshold of concern for threatened and endangered animals, 0.05 (USEPA 2004). EPA's acute toxicity analysis only included mortality as an endpoint, so we examine studies that were not included in the BE, which measured other acute physiological and behavioral endpoints of whole organisms for diazinon in the *Oncorhynchus* genus below.

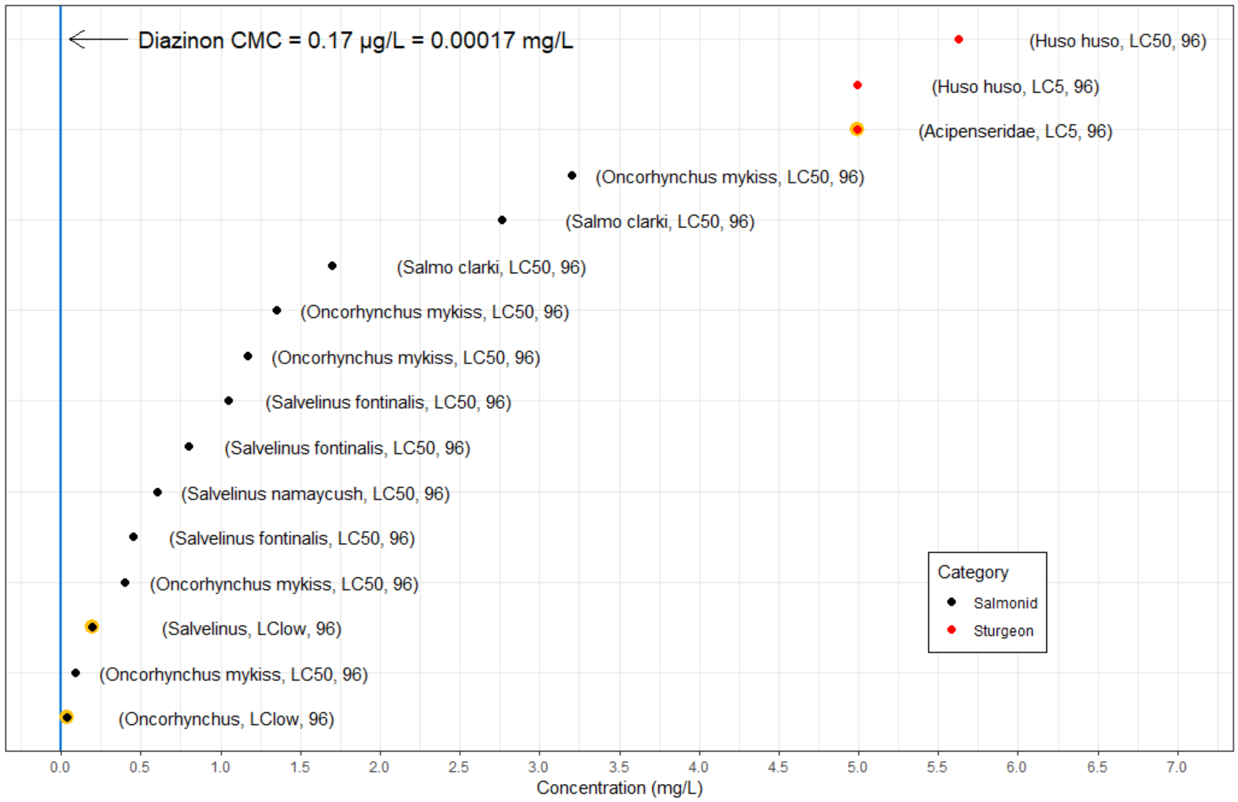

Figure 17.Salmonid and sturgeon 96-hour LC50 values following acute exposure to diazinon. Blue line represents the proposed acute diazinon CMC (0.00017 mg/L or 0.17 µg/L). LClow minimum effect levels are highlighted with yellow.

Several studies have suggested linkage between diazinon-inhibited ChE activity and decreased swimming ability. Beauvais (2009) reported that rainbow trout juvenile ChE activity decreased significantly with increasing diazinon concentration and differed significantly with exposure duration (i.e., 24-hour and 96-hour ChE activity means were lower than after 48 hours of recovery). Changes in swimming speed and swimming distance were significantly correlated with changes in ChE activity. Another study observed reductions in fingerling rainbow trout's distance traveled and speed of movement after 24-hour exposures to 500 and 1,000 µg/L of diazinon (Brewer et al. 2001). Fish exposed to diazinon also tended to have a more linear swimming path compared to controls after 96 hours of exposure to 250 and 500 µg/L diazinon. As noted in other previously reviewed studies on carbaryl toxicity (Ferrari et al. 2007; Oziolor et al. 2017), a short-term compensatory effect was observed, in this case where swimming mirrored control characteristics for a short time before returning to the slower, more linear swimming associated with diazinon exposure. Brewer et al. (2001) found that ChE activity was positively correlated with greater swimming distances and faster swimming, and accounted for 44 and 41%

of variation, respectively. Brewer et al. (2001) also found that swimming characteristics had not returned to control levels after 48 hours of recovery in clean water. The most sensitive of these physiological and behavioral endpoints were observed when exposure concentrations were several orders of magnitude above the proposed acute and chronic diazinon criteria of 0.17 µg/L, indicating that swimming impairment from ChE inhibition is unlikely to occur at criteria levels.

Pesticides may also cause oxidative stress, and Isik and Celik (2008) observed an increase in one biomarker of stress (malondialdehyde) and fluctuations in rainbow trout antioxidant defense systems (reduced glutathione and other enzymes) after exposure to 500 and 1,000 µg/L diazinon for 24, 48, and 72 hours. Pincetich (2004) observed that phosphocreatine, an indicator of sublethal metabolic stress, decreased with eyed egg exposure to 100,000 µg/L diazinon, indicating the potential for changes in metabolism during salmonid embryogenesis in Chinook salmon. The observed effects on stress hormones occurred at concentrations several orders of magnitude above the proposed criteria levels, indicating such effects would be unlikely to occur at criteria concentrations.

Delayed effects and mortality after short-term exposure to diazinon may also be of concern during adaptation to sea-water through osmoregulation and entry into the ocean (Baldwin et al. 2009; Hajirezaee et al. 2016). One study of endangered Persian sturgeon (*Acipenser persicus*) exposed fingerlings to diazinon concentrations of 0, 180, 540, and 900 µg/L for 96 hours and 12 days in freshwater before exposing them to brackish water to emulate entry into estuaries. The fish treated with 540 and 900 µg/L diazinon in both short- and long-term trials were less able to acclimate to brackish water, as measured by biomarkers (e.g., cortisol, T3, T4, K+, Na+, Cl-, and gill Na+/K+-ATPase activity) than the control and 180 µg/L treatment groups. Although data on the toxic role of diazinon on osmoregulation for the species considered in this opinion, or for the *Oncorhynchus* genus, are not available, seawater challenges presented by exposure to pesticides such as diazinon are likely to hinder salmonids at concentrations ranging from 180 – 900 µg/L, as they undergo an adaptation to seawater that is similar to sturgeon. Given that the proposed criteria are several orders of magnitude below these concentrations, exposures to 0.17 µg/L of diazinon is not likely to result in delayed effects on salmonid osmoregulation.

The most sensitive endpoint that was not assessed in the BE involves the effect of diazinon on salmonid olfactory function. Juvenile salmonids rely upon olfaction for a variety of reasons including predator evasion, sensing conspecific alarm chemicals, and feeding (also influenced by sight). Scholz et al. (2000) exposed hatchery Chinook salmon parr to 0.1, 1.0, and 10.0 µg/L diazinon for 24 hours. The concentrations selected in this study were based on findings of environmental concentrations in western streams. At these concentrations, diazinon did not affect swimming behavior or visually-guided food capture. However, olfactory-mediated alarm responses, in which fish reduce feeding in response to an alarm chemical that is released via the skin and detectable by fish of the same species, were inhibited at concentrations as low as 1.0 µg/L. Alarm-response behaviors reduce the likelihood that a fish will succumb to predation, and impairment of this behavior is likely to reduce survival. In contrast, Palm and Powell (2010) did not observe significant differences in predator evasion of juvenile Chinook salmon based on olfactory response between the control and test groups, which had diazinon concentrations of 0.04, 1.8, 17, and 183 µg/L. The authors noted that this could have been because there was no effect of diazinon on olfaction at these relatively low concentrations, or because visual cues were more important to predator avoidance, which was not controlled in this study as it was in Scholz et al. (2000). While data are limited, these results suggest that there is a small margin between the proposed criterion concentration of 0.17 µg/L and the concentrations of diazinon that cause impairment of predator evasion behavior. Although the lowest effect level observed (1.0 µg/L) is higher than 0.17 µg/L, the NOEC from Scholz et al. (2000) (0.1 µg/L) was below the proposed criterion concentration. This NOEC could be used as a conservative MEL. Given these results, which are limited due to the tested concentrations, it is possible that olfaction may be impaired at the proposed criteria concentration of 0.17 µg/L. It is within reason that diazinon concentrations could reach the proposed criteria within the action area given prescribed use. Therefore, there is potential to cause adverse effects.

Scholz et al. (2000) also found that homing behavior of adult Chinook salmon that had been exposed as juveniles was impaired at 10.0 µg/L. This may indicate that relatively low concentrations of diazinon, even in early life stages, influence the ability of salmonids to navigate to their natal streams to spawn, but the study design and conditions make it difficult to confirm this hypothesis. The authors note that returns were lower than usual, even in the control, suggesting another unmeasured factor could have influenced the results. The study also did not measure delayed mortality of diazinon-exposed salmonids, which could have accounted for the difference in returns between exposed and control fish. Whether fish experienced higher delayed mortality, impaired homing, or some other mediating factor, the diazinon-treated fish had lower return rates than the control. The observed neurotoxic effects on homing behaviors occur at lower concentrations than other sublethal and lethal effects. Based on this study, the risk quotient for impaired homing behavior would be 0.017, which is just below the OPP's threshold (0.05) for threatened and endangered species, indicating the criteria are most likely protective for this endpoint.

Olfaction also plays an important role in successful salmonid reproduction. Moore and Waring (1996) found that olfactory response of Atlantic salmon to prostaglandin F2a, which helps synchronize spawning physiology between male and female salmonids, was significantly reduced when fish were exposed for 30 minutes to nominal diazinon concentrations of 1.0 µg/L, and olfactory detection was reduced tenfold at 2.0 µg/L. Reproductively mature males also showed decreased levels of a number of reproductive steroids and gonadotrophin levels in response to ovulated female urine (which helps prime male reproductive hormones) after exposure to diazinon for 120 hours. The observed reduction in the ability of this salmonid to detect odors and pheromones involved in reproduction due to diazinon exposure at levels near the proposed diazinon criteria has potential to interfere with successful reproduction. In this study, olfactory rosettes of test organisms were directly exposed, which differs from the manner of exposure in the natural environment, though environmentally relevant diazinon concentrations were used. Based on this study, the risk quotient for impaired olfactory detection in reproduction would be 0.17. If these results are comparable for Pacific salmonids, then this would indicate that the proposed criteria are not protective of threatened and endangered species, based on OPP's threshold of concern. A similar study has not been conducted with Pacific salmonids to our knowledge, but we expect reliance on olfaction for reproduction, and its mechanism of diazinon impairment to be similar. While not we cannot directly translate these results to the ESA-listed salmonids considered in this opinion in their natural habitat, there is risk of some interference with spawning adults if concentrations are at criteria levels. Given the design of this study, we give less weight to their conclusion.

The BE's chronic toxicity analysis included mortality, growth, reproduction, behavior, or AChE activity as endpoints with exposures of seven days or longer (Figure 18). In general, the sublethal endpoints were much more sensitive than the mortality endpoint. The BE assessed one study on chronic impacts to a salmonid, brook trout (*Salvelinus fontinalis*) (Allison and Hermanutz 1977), with most information about chronic toxicity from studies with other surrogate species. Allison and Hermanutz (1977) tested diazinon toxicity to multiple fish species including *S. fontinalis* and *Pimephales promelas* and observed the lowest LOECs for behavior, reproduction, and growth of any of the other studies reviewed in the BE. This study found the NOEC for growth and behavioral endpoints was 2.4 µg/L (tetanic convulsions), and the LOEC for reproduction was 0.8 µg/L (progeny of exposed adults were smaller). This suggests that effects to reproduction may be among the most sensitive endpoint for salmonids. The proposed chronic criterion is lower than both of these values, suggesting it would be protective of salmonids.

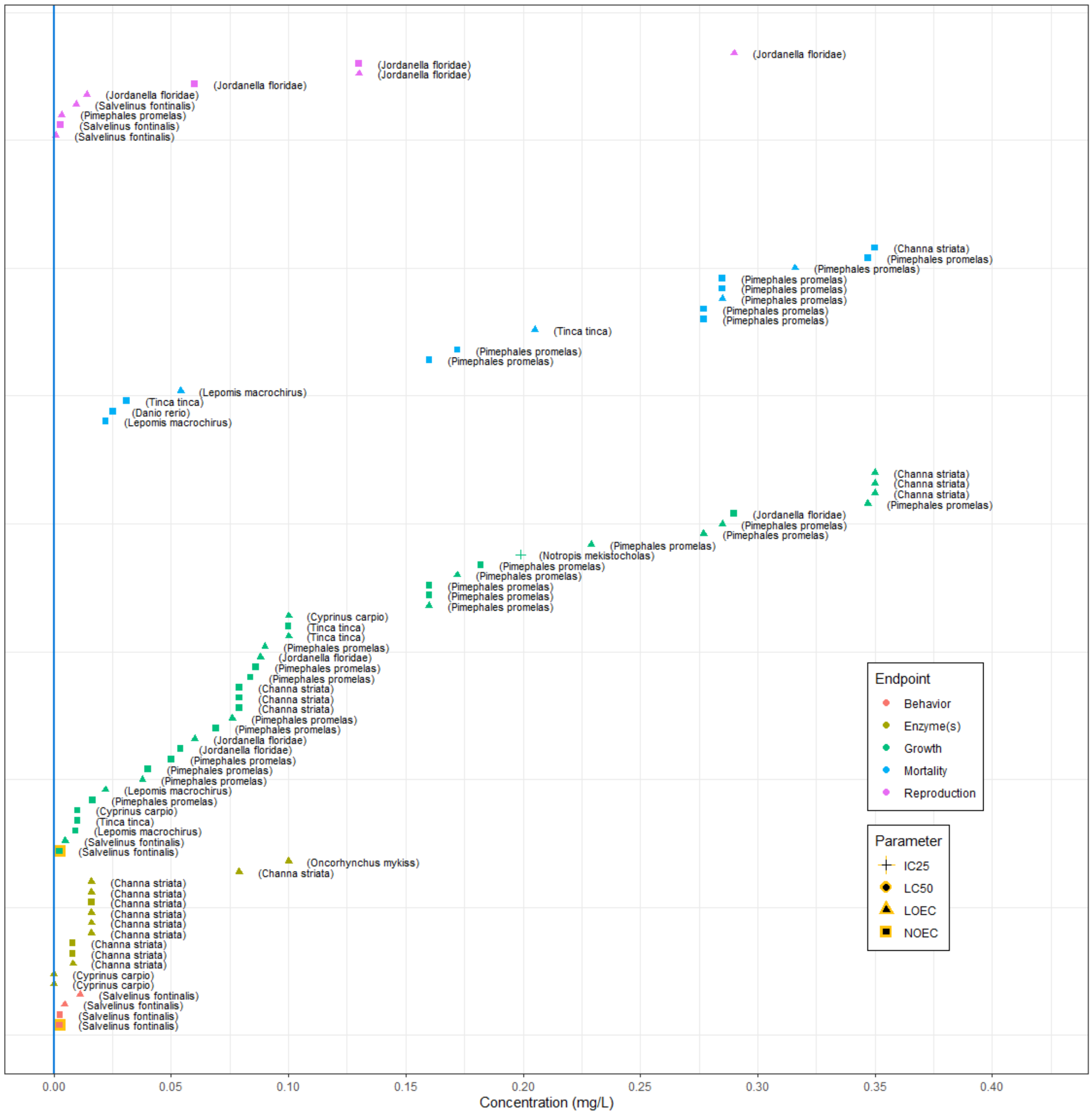

Figure 18. Fish diazinon chronic toxicity endpoints are displayed. The blue line represents the proposed diazinon CCC (0.00017 mg/L or 0.17 µg/L). The salmonid minimum effect levels (i.e lowest NOECs) are highlighted with yellow. Points are labeled with the scientific name of the fish and the type of parameter that was measured for that endpoint.

The BE did not review any chronic diazinon toxicity data for fish within the genus of the ESA-listed species considered in this opinion, and there was only a single study on a salmonid species. Because of the scarcity of chronic data available for salmonids, EPA also assessed diazinon chronic toxicity to other fish. This provides useful context, though it is acknowledged that rainbow trout provide the best commonly used surrogate for salmonids (Sappington et al. 2001; Dwyer 1999). The NOECs included in the BE's review ranged from 2.4 µg/L for cutthroat trout (Allison and Hermanutz 1977) to as high as 2,500 µg/L for mortality to sexually mature fathead minnow (Chappel 2001). The highest non-mortality NOEC was 290 µg/L for larval *Jordanella floridae* growth and reproduction (Allison and Hermanutz 1977). The lowest concentration at which impacts to AChE activity were observed was reported for *Cyprinus carpio* (common carp) exposed to 0.0036 µg/L for 30 days (Oruc 2011). The highest mortality-based LOEC was 5,000 µg/L observed for sexually mature fathead minnow exposed for seven days (Chappel 2001), while the highest non-mortality LOEC was 1,000 µg/L for *Tinca tinca* (tench) eggs exposed to diazinon for 11 days. There was a significant amount of variation in the reported sensitivity of fish to diazinon at chronic timescales, and the lack of chronic data specific to salmonids makes estimates of chronic toxicity for the listed species fairly uncertain.

To provide an additional species-specific estimate of chronic diazinon toxicity, EPA calculated a GMAV for the *Oncorhynchus* genus from seven genus-specific acute LC50 values (0.98 mg/L), and if species-specific information was available as it was for *O. mykiss*, a SMAV could be calculated (0.71 mg/L). The acute value (GMAV or SMAV) was divided by an ACR (acute to chronic ratio, the ratio of LC50 to NOEC values), resulting in a calculated chronic MEL (i.e., a chronic NOEC). These values for each salmonid species considered in this opinion are shown in Table 14. These calculated NOEC values are higher than the NOEC reported in Allison and Hermanutz (1977), but this study was not specific to any of the species considered in this opinion. Using the calculated chronic MELs, risk quotients for the proposed chronic criterion would range from 0.028 - 0.039, which is below the OPP's acute and chronic levels of concern for aquatic species, falls just below OPP's threshold of concern for threatened and endangered animals, 0.05 (USEPA 2004), and indicates that the chronic criterion would be protective based on this calculation.

Table 14. Summary of diazinon chronic NOEC values calculated from the MAV and ACR for each ESA-listed fish.

Family	Species	MAV (LC_{50} in mg/L)	ACR (LC_{50}/NOEC)	Calculated NOEC (µg/L)
Salmonidae	*Oncorhynchus mykiss*	0.71	162.19	4.38
Salmonidae	*Oncorhynchus tshawytscha*	0.98	162.19	6.04
Salmonidae	*Oncorhynchus nerka*	0.98	162.19	6.04

Though chronic diazinon toxicology data for salmonids are sparse, we found two studies on rainbow trout and one study on an endangered sturgeon (*Acipenser*) with information about chronic toxicity of diazinon that had not been included in the BE's analysis. Bresch (1991) assessed the growth response of rainbow trout fingerlings that were exposed to diazinon for 4 weeks, and found no significant effects on growth at 8-200 µg/L. Ahmadi et al. (2014) observed markers of immunosuppression (e.g., significant decrease in white blood cells, ACH50, lysozyme activity, globulin and total protein levels in fish plasma) and anemia (e.g., significant decrease in red blood cells, hematocrit, and hemoglobin levels) in rainbow trout after a 30-day exposure to diazinon at 100 and 200 µg/L, in comparison with the control. Hajirezaee et al. (2016) also found *Acipenser persicus* fingerlings' osmoregulation was impaired after a 12-day exposure to diazinon at 180, 540, and 900 µg/L. All of the chronic toxicology studies we were able to find for diazinon on salmonids and sturgeon, which share an anadromous life history strategy, suggested that sublethal effects typically occur at chronic concentrations that are orders of magnitude above 0.17 µg/L, the chronic criterion level. The lowest effect level observed for growth was 8 µg/L, which results in a risk quotient of 0.021, which is just below the OPP threshold of concern for threatened and endangered species.

In summary, diazinon is known to produce lethal and sublethal effects to salmonids. The available evidence suggests that the proposed acute and chronic criteria (0.17 µg/L) is low enough to protect against many adverse effects via direct exposure of fish, but may not protect against olfactory impairment, which at criteria levels could lead to reduced predator evasion. In addition, salmonids rely on functioning ecosystems for growth and survival, and diazinon may affect the quality and quantity of prey organisms. The next section examines the effects of the proposed criteria on prey organisms and the resulting effects to salmonid growth and survival.

Secondary exposure and toxicity to prey species

Anticholinesterase insecticides can reduce benthic densities of aquatic invertebrates and alter the composition of aquatic communities (Chang et al. 2005; Fleeger et al. 2003; Liess and Schulz 1999; Relyea 2005; Schulz 2004; Schulz and Liess 1999). Juvenile salmonids are largely opportunistic, feeding on a diverse community of aquatic and terrestrial invertebrate taxa that are entrained in the water column or on the surface and that have a wide range of sensitivities to pesticides (Higgs et al. 1995). Diazinon is known to be highly toxic to aquatic crustaceans and macroinvertebrates; concentrations that are not expected to kill salmonids are often lethal for their invertebrate prey (e.g., 1.8 – 3.7 µg/L in Toumi et al. 2016). In particular, prey items that are preferred by small juvenile salmonids (including midge larvae, water fleas, mayflies, caddisflies, and stoneflies) are among the most sensitive aquatic macroinvertebrates. In addition, effects on the prey community can persist for extended periods of time (weeks to months), resulting in effects on fish feeding and growth long after an exposure has ended (Colville et al. 2008; Liess and Schulz 1999; Van den Brink et al. 1996; Ward et al. 1995). Therefore, in combination with the direct stressor of diazinon exposure, there may also be significant indirect effects to individuals via their prey (Peterson et al. 2001). Salmon are often found to be food limited (Quinn 2005), suggesting that a reduction in prey number or size due to insecticide exposure may further stress salmon and lead to reduced growth rates.

Anticholinesterase insecticides can reduce benthic densities of aquatic invertebrates and alter the composition of aquatic communities (see section 2.5.1.2 for discussion of toxicity to prey species, effects on salmonid growth and mortality). Exposure to diazinon (an OP pesticide), unlike exposure to carbamates, results in much longer recovery times, often on the order of days to weeks. It is also more persistent in the environment. The bioaccumulation factor for diazinon in rainbow trout is between 57-92 L/kg for exposures between one and seven days in length (Seguchi and Asaka 1981), and is considered to be marginally bioaccumulative. In combination, these qualities indicate that diazinon may pose more threats to salmonid prey species than carbaryl and other carbamates. In addition, swimming impairments caused by diazinon exposure can impact the ability of fish to successfully feed. This may interact with ecological factors such as reductions in prey quantity or quality.

Using a SSD based on NOEC values, the BE found that the HC5 (0.069 µg/L) was lower than the chronic diazinon criterion of 0.17 µg/L, indicating that the most sensitive species considered would not be protected by the proposed criterion. It should be noted that the HC5 was based on

NOEC values, meaning it is a conservative estimate. Approximately 80% (4 out of 5 genera) of the GMCVs based on NOECs for prey species were above the criterion level, and would likely not be significantly impacted. The only GMCV below the criterion level was for *Daphnia* (GMCV of 0.116 µg/L). In their analysis, invertebrates tended to be more sensitive to diazinon than fish, and all fish GMCVs were above the proposed diazinon criterion of 0.17 µg/L. As discussed in section 2.5.1.1, *Daphnia magna* can be considered a keystone species in some aquatic food webs, meaning reductions in this taxon could have outsized effects.

The BE also conducted an assessment of salmonid growth based on reductions in prey items using a salmon translator model. Under the most severe scenario of continuous exposure at criteria levels for 427 days, the model predicted up to a 43% reduction in the survival of fish due to exposure of their prey to diazinon. While this scenario is unlikely to occur, the long half-life of diazinon in the environment and its widespread use (Table 9, Figure 13) means that fish could potentially be exposed on a regular basis. Most scenarios of prey exposures to diazinon below the chronic criteria at recurring intervals, which may be more reflective of exposures in the environment, showed at or below 10% impact of salmonids, which is within the range accepted for control mortality during laboratory experiments. For scenarios with recurring exposure of the prey to diazinon at or below the chronic criteria, the only scenarios with an impact greater than 10% was the recurrence of exposure at 100% or 75% of the chronic criteria concentration every 30 days (as compared to 60- or 120-day recurrence). The model predicted an impact on the survival of 16% and 12%, respectively, of salmonids due to reductions in growth under these potential scenarios. The likelihood that any of the above-described scenarios occur is dependent on the frequency of the exposure, which is based on pesticide and land use that coincides with the timing and duration of salmon migration.

NMFS (2022a) conducted a similar analysis for the FIFRA registration of diazinon, and found that salmonid species can be severely affected by changes in juvenile growth resulting from reduced prey availability and reduced feeding due to AChE inhibition. With implementation of the conservation measures described in this opinion, concentrations of diazinon would be reduced to a point that would not cause declines in a population's intrinsic growth rate, which NMFS found would be achieved at concentrations of 0.5 µg/L or less. The degree to which an actual threatened or endangered population is affected will depend on a host of factors including the number of individuals exposed, the duration of exposure, when they are exposed, and if they are exposed more than once.

While salmonids may be impacted by reductions in quantity or quality of forage, we do not expect a significant risk from secondary poisoning due to bioaccumulation of diazinon in prey organisms. Diazinon is readily metabolized and excreted by most animals (USEPA 2017) and the BCF is not considered to be very accumulative.

Relevance of fish effects to population/ MPG viability

As shown in Table 9, the designated critical habitats of each of the ESA-listed salmonids considered in this opinion overlap to some degree with rangeland and agricultural land cover, where diazinon may reasonably be expected to be used. In general, the species that spend more time in larger, lower elevation rivers are more likely to be exposed to diazinon, as these habitats tend to be in closer proximity or downstream of agricultural areas where diazinon is most often used. For example, the SR fall Chinook salmon ESU has significantly more overlap with agricultural and pasture land covers than the other three species considered. Fish that tend to rear as juveniles in agricultural areas have a greater risk of exposure to pesticides, and populations within a species that spend more time in agricultural areas will be more at risk. There were no detections of diazinon within the designated critical habitat for any of the listed salmonids considered in this opinion (Figure 11). Of the NAWQA samples (ISDA data were unavailable), detections of diazinon were not localized in one season of the year, indicating that diazinon may be applied at any time and its use is not necessarily tied only to certain seasonal crops.

Similar to carbaryl, diazinon monitoring data are limited, making it difficult to rule out exposures (above or below the criteria) in critical habitat, though available data suggest no overlap between diazinon presence and habitat occupied by SR sp/su Chinook salmon, SR fall Chinook salmon, SR sockeye salmon, or SRB steelhead. Sampling did not occur in the more agricultural areas within critical habitat, particularly of SR Chinook salmon and SRB steelhead, potentially causing an underestimation of diazinon exposures. Diazinon sampling was concentrated in the agricultural southern portion of Idaho, where the majority of detections were below the proposed criteria, with three exceptions. In general, toxics monitoring in the Columbia Basin has been concentrated primarily in the lower Columbia River and estuary, and data for the middle and upper Columbia, Snake River and Salmon River basins are lacking (USEPA 2009b). Species may be more likely to encounter these pesticides outside their critical habitat in migration corridors.

The crops that are most commonly treated with diazinon are very rarely grown in critical habitat areas in Idaho (Figure 12). The E-pest database (USGS 2024d) indicates that diazinon use does occur in the central-eastern portion of the state and overlaps somewhat with designated critical habitat, but the vast majority occurs in the southern portion of the state (Figure 13). The E-pest data also show no use of diazinon in the region of the lower Snake River reservoirs within Idaho or larger downstream rivers in the northwestern part of the state, where some stream-type SR fall and sp/su Chinook salmon may spend a significant proportion of the rearing life stage.

The limited monitoring data we have suggest that it is unlikely fish will be exposed to diazinon concentrations at the proposed criteria of 0.17 µg/L. At concentrations below this level, we expect olfaction (and therefore predator evasion) may be impaired as a result of direct diazinon toxicity, with the number of fish affected dependent on the extent of exposure. A conservative MEL for predator evasion based on olfaction was 0.10 µg/L. Approximately 6% of diazinon detections exceeded 0.10 µg/L (in the Snake River Basin, many in the upper Snake River, see Figure 11), indicating that while uncommon, concentrations that may cause direct sublethal effects to salmonids have occurred in other parts of the state. The sampling sites where these detections occurred in the upper Snake River are in an agricultural area where crops that are more commonly treated with diazinon occur (e.g., apples, cherries, onions, tomatoes, lettuce, potatoes). These crops, and reported diazinon usage (Figure 12 and 13) are much less common in areas where SR salmonid juveniles rear. Therefore, we expect diazinon detections to be even less common in anadromous watersheds. Although there are uncertainties about exposure due to a lack of monitoring data in anadromous watersheds, this suggests that only a small proportion of juveniles would experience direct sublethal effects that can influence survival.

In addition, low concentrations (at or below 0.17 µg/L) may cause indirect effects on salmonid growth and subsequent size-mediated survival via toxicity to prey organisms. Given these effects of diazinon, the juvenile rearing and migration life stages are of primary concern. The two endpoints that are most likely to be impacted at concentrations below 0.17 µg/L, olfaction and feeding, do not play a role in survival of incubating embryos, so this life stage is not likely to be significantly impacted. Migrating adults typically do not consume food on their route to spawn, and would not be likely to be impacted by reductions in prey due to diazinon toxicity. Diazinon exposure can impair olfaction used for detecting spawning cues, but the available evidence suggests this occurs at levels marginally above the proposed criteria. Therefore, we focus on the potential for exposure during juvenile life stages, and assess the potential effects at the population level for each species.

Although it is reasonable that all of the listed salmonid species considered in this opinion could be exposed to low concentrations of diazinon, the diverse life history strategies of SR Chinook sp/su salmon, SR fall Chinook salmon, SR sockeye salmon, and SRB steelhead and different habitat ranges may result in differential likelihood of exposure. Similar to carbaryl, the available data are scarce or limited at multiple levels (actual application rates, in-stream concentrations from monitoring), so we use a qualitative approach to assessing salmonid exposure potential. We have qualitatively estimated potential exposure scenarios that are reasonable based on land use, prescribed diazinon use, reported diazinon use, and limited environmental monitoring data, but recognize that this may over- or underestimate true salmonid exposure, and therefore effects to salmonids in some cases.

SR sp/su Chinook salmon: Most juvenile SR sp/su Chinook salmon exhibit a stream-type strategy, rearing for one year in freshwater before migrating to the ocean in the spring, typically April - May. Depending on the natal tributary and its specific habitat conditions, some fish that overwinter may do so in natal streams, larger Idaho rivers downstream of their natal habitat, or rivers outside the action area, downstream of LGD. This diversity of life-history strategies can create differential exposure potential, with the juveniles that overwinter in larger downstream rivers, more likely to be exposed to contaminants than individuals that overwinter in more remote natal streams. About 12.1% of SR sp/su Chinook salmon habitat lies within agricultural areas, and this area largely includes downstream, larger rivers such as the lower Snake, lower Clearwater, or lower Salmon Rivers. However, the E-pest database does not have reports of diazinon use in this area. It does show usage in the western portion of SR sp/su critical habitat (Figure 13).

Because some stream-type SR sp/su Chinook salmon juveniles may spend up to a year in larger downstream rivers, they have more opportunity to be exposed to diazinon multiple times during their rearing. Most of these exposures would likely be below the proposed criteria of 0.17 µg/L, based on monitoring data from other agricultural areas (there has been very little diazinon monitoring in SR sp/su Chinook salmon critical habitat). Given that a small number of detections in Idaho exceeded 0.10 µg/L, it is possible that some juveniles could be exposed to diazinon at concentrations that impair predator evasion via olfaction. We do not expect a substantial number of juveniles to be affected in this manner, but those in more agricultural areas would be more likely to experience direct, sublethal effects.

In addition to effects from direct exposure, SR sp/su Chinook salmon may also be impacted by reductions in prey exposed to diazinon. The salmon translator model analysis in the BE found that under a scenario where fish were exposed to diazinon concentrations of 0.13 µg/L or 0.17 µg/L (75% and 100% of criterion) every 30 days, a 12-16% reduction in survival for individual stream-type fish over the time period of typical freshwater rearing was expected. Exposure to diazinon once every 30 days may be a reasonable assumption for the proportion of stream-type SR sp/su Chinook salmon that rear in close proximity to diazinon use sites. Because diazinon is commonly used in agricultural contexts, moderately mobile (low to moderate sorption expected), and stable in aquatic environments for up to six months, it may impact aquatic organisms downstream and for extended time periods (USEPA 2005). However, reported diazinon use and crops that are typically treated with diazinon are much more common in the upper Snake River and areas outside SR sp/su Chinook salmon critical habitat than they are where juveniles typically rear. Given that diazinon detections in the areas more likely to experience diazinon contamination were rarely detected at levels comparable to the criteria, it is unlikely that many juvenile stream-type SR sp/su Chinook salmon would experience the 30-d recurring exposure scenario. Thus, the described exposure scenarios are possible, but not likely to occur for a significant proportion of stream-type juveniles. As such, while modeling suggests that any regularly-exposed juvenile Chinook salmon could experience a 12-16% reduction in survival, we do not expect population-level effects for the reasons above.

Baldwin et al. (2009) demonstrated for a modeled Chinook salmon population that small reductions in size-mediated survival (13-21%) due to pulsed or continuous organophosphate exposure can result in reduced intrinsic growth rates and spawner abundances at 27.0 – 47.3% of the control after a modeled 20-year period. This reduction in survival is similar to that predicted by the salmon translator for regular diazinon exposures at 75% or 100% of the criterion level. However, population-scale effects are unlikely for SR sp/su Chinook salmon, as we expect only a small number of fish are likely to be exposed to diazinon on such a regular basis. Some geographic areas with more agricultural land uses, and the SR sp/su Chinook salmon populations in those areas may be differentially impacted if diazinon is more heavily applied on average per unit area.

The proposed action is likely to cause adverse effects to some SR sp/su Chinook salmon juveniles from reductions in prey combined with effects to a small number of juveniles with impaired predator evasion from direct toxicity. Given land use, estimated diazinon application rates, and available water quality information, we do not expect the proposed action to negatively affect the VSP criteria (abundance, productivity, spatial structure, or diversity) at the population level. Because the VSP criteria would not be affected, the proposed action would not significantly reduce the viability or recovery potential of the affected MPGs and ESU. Impacts at the population, MPG, and ESU scale are considered alongside the status of the species, environmental baseline, and cumulative effects in the Integration and Synthesis (Section 2.7).

<u>SR fall Chinook salmon:</u> A slight majority (59% of natural origin and 51% of hatchery origin) of SR fall Chinook salmon juveniles have an ocean-type migration strategy and migrate to the ocean rapidly after emergence. The yearling-type strategy is becoming more common, and these fish typically overwinter in lower Snake River reservoirs and migrate to the ocean the following spring (Connor et al. 2005; Tiffan and Connor 2012; Tiffan et al. 2014). One contingent of SR

fall Chinook salmon juveniles overwinters in the upper reaches of the Lower Granite pool in Idaho (an agricultural area), and therefore could be exposed to diazinon on a regular basis. However, reported diazinon use and crops that are typically treated with diazinon are much more common in the upper Snake River and areas outside anadromous watersheds than they are where SR fall Chinook salmon juveniles typically rear. Given that diazinon detections in the areas more likely to experience diazinon contamination (i.e., upper Snake River) were rarely measured at levels comparable to the criteria, it is not likely that many juvenile stream-type SR fall Chinook salmon would experience the 30-d recurring exposure scenario. Thus, the described exposure scenarios are possible, but not likely to occur for a significant proportion of stream-type juveniles.

About 50.9% of SR fall Chinook salmon habitat lies within agricultural areas, indicating potential for diazinon exposure. Similar to SR sp/su Chinook salmon, we expect the juveniles that rear in freshwater for a longer period of time to be more likely to be repeatedly exposed to diazinon. The lower Snake River reservoirs, where more than 40% of SR fall Chinook salmon overwinter, are in or downstream of agricultural areas. However, the crops grown in this area are not typically treated with diazinon, and there was essentially no reported use of diazinon in the area immediately upstream of these reservoirs in Idaho in 2017 (Figure 12 and 13). While data are sparse, these findings suggest diazinon is less prevalent than in other parts of the state. Considering the available information about diazinon occurrence and SR fall Chinook salmon life history, it is possible that juveniles could be exposed to diazinon multiple times during their rearing. Most of these exposures are expected to be below the proposed criteria of 0.17 µg/L. Given that some detections in Idaho have exceeded 0.10 µg/L, it is possible that some juveniles will be exposed to diazinon at concentrations that impair predator evasion via olfaction. We do not expect a substantial number of juveniles to be affected in this manner, but those in more agricultural areas are at greater risk of experiencing direct, sublethal effects.

Diazinon exposure may also impact SR fall Chinook salmon via reductions in prey that have been exposed to this pesticide. Yearling-type Chinook salmon rear for a longer period in fresh water, and therefore are at higher risk of impacts from prey reduction. Because of this, we would expect the proposed action to result in up to a 12-16% reduction in survival for yearling-type SR fall Chinook salmon that are exposed to 75% or 100% of the criteria every 30 days. The scenario of exposure every 30 days is possible because yearling-type Chinook salmon tend to overwinter in reservoirs that are in close proximity to agricultural land uses where diazinon could be used. Diazinon is also relatively stable in the environment, and may be transported downstream. However, we do not expect a significant number of fish to experience this exposure scenario due to the relative rarity of diazinon detections in other agricultural areas and the types of crops grown around SR fall Chinook salmon juvenile rearing habitat. Reductions in survival for ocean-type SR sp/su Chinook salmon are expected to be less than 10%, as it is unlikely that this life history strategy would be exposed on such a regular basis. SR fall Chinook salmon that occupy waters in more agricultural areas are at greater risk of being adversely affected due to the higher potential of diazinon use in these areas.

In summary, the proposed action is likely to cause adverse effects to some SR fall Chinook salmon juveniles (with yearling-type fish more affected) from reductions in prey as well as effects to a small number of juveniles with impaired predator evasion from direct toxicity. While some individuals may be impacted, we do not expect population-level impacts because land use data, estimated application rates, and available water quality information suggest widespread and frequent exposures to concentrations near the criteria are unlikely to occur. We do not expect the VSP criteria to be negatively affected at the population scale. Consequently, the proposed action would not significantly reduce viability or impede recovery of the ESU, which consists of only one extant population. Impacts at the population and ESU scale are considered alongside the status of the species, environmental baseline, and cumulative effects in the Integration and Synthesis (Section 2.7).

SR sockeye salmon: SR sockeye salmon rear primarily in remote, high-elevation lakes. As diazinon is mainly used on crops, pasture, and livestock, it is unlikely to be used in proximity to SR sockeye salmon rearing habitat. Only 5.6% of SR sockeye salmon habitat falls within crop or pasture land-uses. SR sockeye salmon juveniles typically migrate rapidly to the ocean, passing through areas more prone to diazinon contamination and exiting the action area in a matter of weeks. Very little is known about actual exposure to and uptake of contaminants in outmigrant juvenile SR sockeye salmon, or returning adults, and no data are available on contaminant body burdens in this species. Moreover, water quality data for much of this ESU's habitat is incomplete. For example, there are only three NAWQA monitoring sites within the migration corridor of SR sockeye salmon, and no sites within the spawning and rearing habitat (NMFS 2011).

Sockeye salmon likelihood of exposure would increase for only a short window of time when they migrate rapidly through waters in the action area that may be impacted by agricultural activities to the ocean. Exposures during outmigration are expected to be mostly below the proposed criteria of 0.17 µg/L. Given that some detections in Idaho surface waters exceeded 0.10 µg/L, it is possible that some juveniles will be exposed to diazinon at concentrations that impair predator evasion via olfaction. We do not expect a substantial number of juveniles to be affected in this manner, but any individuals that are slower to migrate through more agricultural areas would be more likely to experience direct, sublethal effects.

Because of the short time frame of passage through waters in agricultural areas, it is unlikely that SR sockeye salmon would be exposed to diazinon at concentrations at or below 0.17 µg/L frequently enough to cause a significant reduction in growth via reductions in forage. As demonstrated by the salmon translator model, only continuous exposure at criteria levels for over a year and repeated exposure every 30 days would be likely to result in reductions in survival of more than 10%. Therefore, we find that the proposed action is likely to reduce exposed SR sockeye salmon survival by less than 10%. For SR sockeye salmon a 10% reduction in survival could have drastic effects, given their high risk for extinction. It is important to note that the salmon translator model cannot statistically distinguish <10% from the control. It is also probable that the exposure scenario the model uses is a significant overestimate of actual exposure for sockeye salmon which would only be exposed for a very short timeframe. Therefore, actual impacts to SR sockeye salmon survival would be substantially less than 10%.

In summary, although some individual fish will likely be exposed and adversely affected via reductions in prey because of the proposed action, we do not expect a significant number of individuals to be affected because sockeye salmon do not linger in habitats where we expect diazinon to occur. Therefore, reductions in sockeye salmon growth as a result of any reduced prey are expected to be small and short-lived. SR sockeye salmon are at high risk for all four VSP variables, but we do not expect further impacts to the VSP criteria as a result of the proposed action that would reduce the overall viability or recovery potential of the single remaining MPG and therefore the ESU. Impacts at the population, MPG, and ESU scale are considered alongside the status of the species, environmental baseline, and cumulative effects in the Integration and Synthesis (Section 2.7).

SRB steelhead: Rearing SRB steelhead typically remain in freshwater for two to three years (up to five years has been documented) before migrating toward the ocean in spring to early summer, typically leaving the action area by April to May. Younger fish tend to rear in smaller, low velocity streams and channels, and older fish may venture into deeper waters. The relatively long tenure of SRB steelhead juveniles in freshwater presents more opportunity for repeated diazinon exposures. The rivers and tributaries where SRB most commonly rear overlap somewhat with agricultural land uses. Approximately 8.1% of SRB steelhead habitat falls within crop and pasture land-uses, where diazinon may be used. There has been some reported usage of diazinon in the eastern portion of SRB steelhead critical habitat, but is much less than in other parts of the state (i.e., upper Snake River). There may be diazinon usage in other agricultural areas in the SRB steelhead range as well, though many of the crops in these areas are less likely to be treated with diazinon. It is reasonable to conclude that SRB steelhead may experience diazinon exposures, but most of these exposures are expected to be below the proposed criteria of 0.17 µg/L, based on limited detections in monitoring data from the upper Snake River. Given that some detections in the action area exceeded 0.10 µg/L, it is possible that some juveniles could be exposed to diazinon at concentrations that impair predator evasion via olfaction. We do not expect a substantial number of juveniles to be affected in this manner, but those in more agricultural areas are at greater risk of experiencing direct, sublethal effects, with some populations more prone than others.

In agricultural areas it may be reasonable to estimate that diazinon exposure at 0.13 µg/L or 0.17 µg/L (75% and 100% of criteria concentration) could occur at least once every 30 days for individuals rearing in, or immediately downstream of, agricultural areas. Using the salmon translator model, this scenario could result in up to a 12-16% reduction in survival for regularly exposed steelhead. Diazinon is commonly used in agricultural areas and may be stable for up to six months in aquatic environments. However, reported diazinon use is lower in SRB steelhead critical habitat than in other agricultural areas of the state where monitoring indicates detections at criteria concentrations are relatively rare. This suggests it is unlikely that many juvenile SRB steelhead would experience the 30-d recurring exposure scenario. There may be variation in exposure, with fish rearing in smaller tributaries or areas with less dense agricultural activity less likely to be exposed to diazinon as frequently. We expect exposure to be less likely outside of agricultural contexts, and would likely result in <10% reduction in survival of SRB steelhead in most of its range and for the majority of populations within this DPS.

In summary, the proposed action is likely to cause adverse effects to some SRB steelhead juveniles (with fish in agricultural areas more affected) from reductions in prey as well as effects to a small number of juveniles with impaired predator evasion from direct toxicity. While some individuals may be impacted, we do not expect population-level impacts because land use data, estimated application rates, and available water quality information suggest widespread and frequent exposures to concentrations near the criteria are unlikely to occur. We do not expect the VSP criteria to be negatively affected at the population scale. Consequently, the proposed action would not result in significantly reduced viability or limit recovery of the affected MPGs and DPS. Impacts at the population, MPG, and DPS scale are considered alongside the status of the species, environmental baseline, and cumulative effects in the Integration and Synthesis (Section 2.7).

2.5.1.4. Environmental Mixtures

Ambient monitoring data shows that pesticide contamination in the nation's freshwater habitats is ubiquitous, and that pesticides usually occur in the environment as mixtures (Gilliom 2007). For example, NAWQA monitoring detected two or more pesticides in more than 90% of samples from urban, agricultural, and mixed-use streams nationwide (Gilliom 2007). Environmental mixtures result from unrelated pesticide use over the landscape and are typically detected in ambient water quality monitoring efforts. Performing a robust, quantitative mixtures analysis of all environmental mixtures containing acrolein, carbaryl, and diazinon would be difficult. This is due in part to a lack of adequate exposure data, no reporting of the frequency and magnitude of mixture concentrations, changes in pesticide use over time, and the long temporal duration of the action (i.e., criteria are set indefinitely until revised). However, failing to consider mixtures may underestimate pesticide risk to such an extent as to lead to erroneous conclusions and ineffective protections for ESA-listed species. It is reasonable to expect that carbaryl and diazinon may mix with with other chemicals not part of the proposed action in anadromous waters, and may result in additional toxicity to salmonids and their prey, though information on all possible environmental mixtures and the potential effects is unavailable.

Given the different uses and application methods for acrolein as compared to diazinon and carbaryl, it is unlikely that acrolein would occur in salmonid habitat at the same time as the other two pesticides. However, diazinon and carbaryl are both commonly used in agricultural practices, and may even be applied to some of the same crops. Particularly in agricultural areas, it is possible salmonids could be exposed to both diazinon and carbaryl at the same time. The USGS NAWQA monitoring program did not always sample for both carbaryl and diazinon at the same site on the same day (see Figure 9 for site map). However, the subset of monitoring data that measured concentrations of both pesticides can provide insight into how common mixtures are in Idaho. At the Snake River at King Hill, ID site, only 1.1% of concurrently collected samples (n=92) had detections of both carbaryl and diazinon. At the Rock Creek at Twin Falls, ID site, 57% of a small number of concurrently collected samples (n=7) had detections of both pesticides. At the Henry's Fork near Rexburg, ID site, 20% of concurrently collected samples (n=20) had detections of both pesticides. These data are limited, as only a relatively small number of samples were collected for both pesticides at the same time. Estimates of mixture frequency should be interpreted with caution, especially for the Rock Creek and Twin Falls and Henry's Fork near Rexburg sites. However, this does provide confirmation that mixtures of carbaryl and diazinon occur in Idaho, with a variable frequency depending on the site. These monitoring sites are not within anadromous watersheds and, as discussed previously (in this section and Section 2.4), are likely characterized by greater pesticide use than areas where ESA-listed salmonids live. Salmon and steelhead may also be exposed to other pesticides, including other organophosphates and carbamates with the same mode of toxicity, but evaluating all possible mixture combinations falls outside the scope of this document.

The pesticides considered in this opinion also produce degradates that can be toxic to salmon and steelhead (section 2.5.1). It is very difficult to estimate the potential concentrations of these degradates in the environment given the complexities of factors influencing the rate of degradation reactions of both the parent compound and degradates of concern, and variation in the initial concentrations of parent compounds in the environment. Carbaryl degradates of concern include 1-napthol, which is about five times more toxic than its parent compound. If we conservatively assume 1:1 conversion, the proposed carbaryl criteria would still be protective, as they are several orders of magnitude above the levels at which fish toxicity is observed. It is unclear how this degradate would affect prey organisms for salmonids. Another carbaryl degradate, 1, 4-napthoquinone, is also considered to be very toxic to aquatic organisms, but ecotoxicological data are limited. Diazinon can degrade into diazoxon, which is an order of magnitude more toxic than the parent compound, with some variation depending on the test organism. It is unclear whether the mode of toxicity of diazoxon is the same as diazinon; thus, endpoints affected may or may not be the same as diazinon. While it is likely this degradate will cause some additional toxicity, it has a much shorter half-life than diazinon, so any effects would be more short-lived than effects due to the parent compound. Ecotoxicological data for degradates of common pesticides are very limited, so quantitative estimates of additional toxicity come with a large degree of uncertainty. Qualitatively, we do not expect additional toxicity from acrolein or carbaryl degradates, but there may be some additional, short-lived toxicity from diazinon degradates.

Current methodologies for calculating mixture toxicity indicate that additivity is the appropriate initial assumption (Cedergreen 2014). Of note, diazinon and carbaryl are known to produce additive and synergistic (i.e., greater-than-additive) toxicity in coho salmon (Laetz et al 2009, 2013), highlighting the overall relevance of an environmental mixtures analysis to this opinion. For example, Laetz et al. (2009) found several combinations of OP pesticides were lethal at concentrations that were sublethal in single-chemical trials. For chemicals with similar modes of action (i.e., organophosphate and carbamate pesticides that inhibit AChE), dose-addition is appropriate (Scholz et al. 2006). Conversely, response-addition is appropriate for chemicals with dissimilar modes of action (Rodney et al. 2013). Because diazinon and carbaryl have similar modes of action, dose-addition is most appropriate.

We assess the risk posed by a mixture of carbaryl and diazinon by calculating a hazard index, as recommended by the EPA for assessment of chemical mixtures (USEPA 1986). For additive toxicity, the hazard index can be calculated simply by adding the risk quotients for each chemical. Scholz et al. (2006) suggests that this approach is appropriate for carbaryl and diazinon, as they found their toxicity in terms of AChE inhibition to be non-interactive. The additive hazard index is shown for acute toxicity, chronic toxicity, and olfaction (the most sensitive direct endpoint) in Table 15. These are based on risk quotients calculated in previous sections (2.5.1.2 and 2.5.1.3) of this opinion's analysis of effects.

Other studies (Laetz et al. 2009; 2013) found that mixtures of organophosphate and carbamate pesticides, including carbaryl and diazinon, displayed additive and synergistic interactions.

Therefore, we also include a “weight-of-evidence” (WOE) modification to the hazard index, which includes a weighting factor for the type of interaction expected between the chemicals, based on the available evidence (Mumtaz and Durkin 1992). This calculation is as follows:

$HI_I = HI_{add} \times UF_I^{WOE}$

Where HI_I is the interactions-adjusted hazard index and HI_{add} is the hazard index based on additivity. UF_I is an uncertainty factor (recommended factor of 10), which is modified by a weight-of-evidence factor (WOE). The WOE is qualitatively determined by applying weights based on the quality of the available data including mechanistic understanding, toxicological significance, among other considerations (Mumtaz and Durkin 1992). We find that a WOE of 0.32 is most appropriate, given that there is mechanistic data available that does not clearly indicate the direction of interaction for diazinon and carbaryl (i.e., additive, or synergistic), but similar chemicals tend to have more-than additive interactions. There is also a strong understanding of the significance of the toxicity pathway for organophosphates and carbamates. If the weight of evidence unambiguously suggested that organophosphates and carbamates interact synergistically (i.e., more than additively), a WOE of 1.0 would be warranted. Table 15 shows the interactions-adjusted hazard indexes for acute and chronic toxicity and olfaction, which we found to be the most sensitive endpoint. Risk quotients for effect levels for the species considered in this opinion were used where possible, and where risk quotients varied between species, we selected the value for the most sensitive species. When risk quotients were not based solely on the species, they are based on similar fish taxa.

Table 15. Additive hazard indexes and interactions-adjusted hazard indexes for general acute toxicity, general chronic toxicity, and olfaction (most sensitive endpoint) for salmonids exposed to carbaryl and diazinon in environmental mixture. For comparison, OPP’s thresholds of concern: acute = 0.5, chronic = 1, threatened and endangered species = 0.05.

Endpoint	**HI for carbaryl and diazinon[1]**	**HI_I for carbaryl and diazinon[2]**
Acute toxicity	0.013	0.028
Chronic toxicity	0.064	0.134
Olfaction	0.609	1.272

[1] $HIadd = RQ_{carbaryl} + RQ_{diazinon}$
[2] $HII = HI_{add} \times UF_I^{WOE}$

The OPP’s acute and chronic levels of concern for aquatic species are 0.5 and 1, respectively, and the threshold of concern for threatened and endangered animals is 0.05 (USEPA 2004). When considering each chemical in isolation, the risk quotients for acute and chronic toxicity did not exceed OPP’s level of concern for threatened and endangered animals. The HI and HI_I for chronic toxicity exceed the threshold of concern for threatened and endangered species. However, they do not exceed the thresholds (acute or chronic) for aquatic species more generally. The individual risk quotient for the olfaction endpoint exceeded the OPP’s acute thresholds for diazinon, but not carbaryl. Unsurprisingly, when accounting for an additive or more-than-additive interaction between these two compounds, the hazard index exceeds the OPP’s thresholds. These estimates of mixture toxicity indicate that when carbaryl and diazinon occur together in environmental contexts, the proposed chronic criteria may not be protective of threatened and endangered species, based on the EPA's OPP benchmark.

These pesticides are both used in agricultural contexts, but it is very difficult to characterize whether they are applied at the same time or in the same area. While mixtures are known to occur widely in aquatic habitats, information specifically concerning mixtures of diazinon and carbaryl in aquatic habitats in Idaho is not available. Although mixtures of carbaryl and diazinon have the potential to render the proposed criteria not sufficiently protective, we find that it is unlikely these two chemicals will occur in the same salmonid habitat, at the same time, for an extended period. Diazinon can remain in aquatic environments for up to six months, but the half-life of carbaryl in aerobic aquatic environments (most streams where salmonids occur can be considered aerobic) is on the order of 2.0 – 18.2 days. Carbaryl may persist long enough to cause chronic toxic effects, but its relatively shorter half-life reduces the likelihood of it co-occurring with diazinon. There may be short periods of time when fish will encounter mixtures of these two pesticides, but it is not expected to be the norm.

In summary, mixtures of these chemicals, particularly diazinon and carbaryl, at the criteria concentrations considered for the proposed action, have the potential to cause adverse effects to salmonids (chronic toxicity, and more sensitive endpoints) beyond what would be expected for each chemical individually. While we do not foresee mixtures of these pesticides being widespread, information about mixtures in natural environments is extremely limited. Our understanding of the effects of many contaminants on aquatic life, alone or in combination with other chemicals (e.g., potential for synergistic effects), is incomplete. The toxic effects of various chemicals and pesticides could also indirectly affect viability by reducing nontarget insect species that are important food for juvenile salmonids. Research on the effects of chemical mixtures to salmonid prey is even more limited than for salmonids themselves. More information is needed to determine if these chemical contaminants are limiting salmon and steelhead population viability.

2.5.2. Effects to Designated Critical Habitat of Anadromous Salmonids

In this section we summarize the effects of the proposed action on the critical habitats of the subject ESA-listed species. The durations of the effects are likely to reflect the period of time that the WQS provisions are in effect, which would be in perpetuity unless revised in the future. The proportion of critical habitat that will be exposed to effects of the proposed action varies by species. All of the species considered have some of their critical habitat outside of Idaho, but only the portion of their critical habitat that occurs in or very near Idaho will be exposed to the effects of the proposed action.

Table 6 lists the PBFs of designated critical habitat for each species considered in this opinion. For the three salmon species (SR sp/su Chinook salmon, SR fall Chinook salmon, and SR sockeye salmon) the most relevant critical habitat PBFs to the proposed action include water quality, forage, and cover/shelter to support spawning, rearing, and/or migration life history stages. For SRB steelhead, the most relevant critical habitat PBFs to the proposed action include water quality, forage, and natural cover. Because these PBFs are similar for all the anadromous species, our analysis applies to each species' critical habitat PBFs. This analysis draws on literature reviewed in depth in Section 2.5.1.

2.5.2.1. Approval of Acrolein Criteria

The PBFs relevant to the approval of acrolein acute and chronic criteria (3 µg/L) include water quality, forage/food, and natural cover/shelter for juvenile and adult SR sp/su Chinook, SR fall Chinook, SR sockeye salmon, and SRB steelhead. The water quality PBF applies in freshwater spawning, juvenile rearing, and adult and juvenile migration habitats for all four salmonid species. The forage/food PBF applies for freshwater juvenile rearing and migration sites. The natural cover/shelter PBF applies to freshwater rearing sites for SRB steelhead and SR Chinook salmon, to spawning sites for SR Chinook salmon, and to juvenile migration corridors for all four species.

The proposed acrolein criteria are expected to maintain the conservation value of the water quality PBF. There may be some variation in the degree to which the proposed action may impact the critical habitat for the species considered in this opinion. For example, SR fall Chinook salmon critical habitat contains a higher proportion of agricultural land. Because agricultural areas are correlated with higher pesticide loads, we might expect the risk of reduced water quality to be higher in SR fall Chinook salmon critical habitat. However, the risk posed by the proposed acrolein criteria is likely very small for all species. As reviewed in Section 2.5.1, acrolein concentrations of 3 µg/L are not likely to cause adverse effects to salmonids, and we expect exposures to acrolein concentrations that approach the criteria to be rare, given the prescribed label use instructions and rapid degradation of acrolein. Acrolein may be used in irrigation channels, but treated water must either be used on cropland or held for 6 days prior to release into nearby surface waters that may contain fish. Safe use depends on proper screening of irrigation canals to prevent fish entry and prevention of spills and leaks that could result in early release to nearby fish-bearing streams. Given prior screening efforts and application instructions, we expect ecological incidents to be very rare. Acrolein dissipates quickly (hours) in aquatic environments, would be expected to dissipate during the holding period, and would also not be likely to result in long-term impacts to water quality. In addition, any degradates or additives of acrolein formulations are not expected to reduce water quality.

Ecotoxicological data on salmonid prey items is sparse, but the available evidence indicates that acrolein concentrations of 3 µg/L are also not expected to result in substantial impacts to salmonid prey species. As previously described, we expect the instances of acrolein concentrations reaching 3 µg/L in fish-bearing streams to be rare given the prescribed label use instructions and acrolein's short half-life. In situ studies have also demonstrated that any effects to invertebrates and zooplankton (potential prey items for salmonids) do not extend beyond a month, even when exposed to concentrations well above the proposed criteria, which is an unlikely scenario with proper use as described on product labels. For these reasons, the proposed acrolein criteria are expected to maintain the conservation value of the forage/food PBF.

The proposed acrolein criteria are expected to maintain the conservation value of the natural cover/shelter PBF. Although acrolein is most often used as a herbicide for aquatic plants, its use is restricted to irrigation channels, and we expect instances when concentrations in salmonid designated critical habitat to reach 3 µg/L to be rare. Therefore, it is unlikely to impact submerged aquatic vegetation in salmonid critical habitat. In addition, acrolein was found to have limited toxicity to emergent macrophytes and riparian vegetation (Eisler 1994), indicating a very low probability that they will be impacted by the proposed action. This study also found that any vegetation destruction peaks one week after application and plants typically return within one month, so any vegetation destruction, if it were to occur, would not be long-lived.

2.5.2.2. Approval of Carbaryl Criteria

The PBFs relevant to the approval of carbaryl acute and chronic criteria (2.1 μg/L) include water quality and forage/food for juvenile and adult SR sp/su Chinook salmon, SR fall Chinook salmon, SR sockeye salmon, and SRB steelhead. The water quality PBF applies in freshwater spawning, juvenile rearing, and adult and juvenile migration habitats for all four salmonid species. The forage/food PBF applies for freshwater juvenile rearing and migration sites.

As outlined in section 2.5.1.2, rearing habitats for stream-type SR sp/su Chinook salmon, yearling-type SR fall Chinook salmon, and SRB steelhead in agricultural areas are the most likely critical habitat areas where fish and their prey may be exposed to carbaryl. There have not been any detections of carbaryl in designated critical habitat for any of the salmonids considered in this opinion, but data are limited.

As outlined in section 2.5.1, we do not expect the proposed carbaryl criteria to result in adverse effects to listed species as a result of direct toxicity. This includes sublethal endpoints, such as AChE inhibition, olfactory impairment, and reduced swimming ability, for which effects have only been observed at concentrations orders of magnitude larger than the criteria. For this reason, the proposed carbaryl criteria are expected to maintain the conservation value of the water quality PBF for salmonids in the action area.

The proposed carbaryl criteria are expected to maintain the conservation value of the forage/food PBFs in rearing habitat in the action area, though localized areas of forage reductions may occur. At carbaryl concentrations of 2.1 μg/L, approximately 6% of salmonid prey genera are expected to experience acute and chronic toxicity. Many of these sensitive species are preferred salmonid prey items, and loss of high-quality prey is likely to cause reductions in feeding success and growth for the ESA-listed salmonids considered in this opinion to some degree (see section 2.5.1). However, due to the relatively short half-life of carbaryl, and the low concentrations and frequency observed in monitoring data, we do not expect carbaryl to impact a significant portion of forage available to the species.

2.5.2.3. Approval of Diazinon Criteria

The PBFs relevant to the approval of diazinon acute and chronic criteria (0.17 μg/L) include water quality and forage/food for juvenile and adult SR sp/su Chinook salmon, SR fall Chinook salmon, SR sockeye salmon, and SRB steelhead. The water quality PBF applies in freshwater spawning, juvenile rearing, and adult and juvenile migration habitats for all four salmonid species. The forage/food PBF applies for freshwater juvenile rearing and migration sites.

As outlined in section 2.5.1.3, juvenile rearing habitats for stream-type SR sp/su Chinook salmon, yearling-type SR fall Chinook salmon, and SRB steelhead in agricultural areas are the most likely critical habitat areas where fish and their prey may be exposed to diazinon. There have not been any detections of diazinon in designated critical habitat for any of the salmonids considered in this opinion, but there are very few sampling locations within these species' designated critical habitats. There have been detections of diazinon (with a small number above the proposed criteria) outside of designated critical habitat, mostly in agricultural areas that are expected to have greater use of diazinon than areas nearby salmonid critical habitat.

As outlined in section 2.5.1.3, we do not expect the proposed diazinon criteria to adversely affect a significant number of individuals of the listed species as a result of direct toxicity. This includes sublethal endpoints, such as AChE inhibition and reduced swimming ability, for which effects have only been observed at concentrations orders of magnitude larger than the criteria. However, olfactory impairment may occasionally occur at concentrations below the proposed criteria. There may be some temporary and/or spatially isolated negative impacts to the water quality PBF, but this is not expected to be widespread or common. For this reason, the proposed diazinon criteria are expected to maintain the conservation value of the water quality PBF for salmonids in the action area.

The proposed diazinon criteria are expected to maintain the conservation value of the forage/food PBFs in rearing habitat in the action area. At diazinon concentrations of 0.17 μg/L, as many as 20% of salmonid prey genera (for which toxicity data were available) may experience acute and/or chronic toxicity (section 2.5.1.3). Many of the sensitive species are preferred salmonid prey items, or are important in the diet of other salmonid prey. Loss of high-quality prey may cause reductions in feeding success and growth for the ESA-listed salmonids considered in this opinion (section 2.5.1). While infrequent, localized reductions in forage may occur, we do not expect exposure to diazinon at 0.17 μg/L to be a common occurrence in salmonid critical habitat due to the declining use of diazinon overall, the low rate of reported use in critical habitat areas, and rarity of detections at criteria levels in other agricultural areas of the state. Because of the limited expected exposure, the proposed action is not likely to impact a significant portion of forage available to the species and the conservation value of this PBF will be maintained in the action area.

2.5.2.4. Environmental Mixtures

As described in Section 2.5.1.4, mixtures of these chemicals, particularly diazinon and carbaryl, at the criteria concentrations considered for the proposed action, have the potential to adversely affect the water quality PBF. If carbaryl and diazinon occurred together at proposed criteria concentrations, salmonids could experience sublethal effects when encountering areas of reduced water quality. Although mixtures of these chemicals can produce additive or more-than-additive effects on salmonids (as described in section 2.5.1.4), degrading the water quality of their habitat, we expect the extent of critical habitat experiencing mixtures of these chemicals on a regular basis to be limited. This reasoning is based on the relatively low frequency of carbaryl and diazinon detections co-occurring at the King Hill site (higher frequency at Rock Creek and Henry's Fork, but these only had a few concurrent samples) (Section 2.5.1.4), in a more agricultural area of the state outside anadromous watersheds. For this reason, we find that mixtures of diazinon, carbaryl, and their degradates are not likely to reduce the conservation value of the water quality PBF in the action area.

Mixtures of diazinon and carbaryl at criteria concentrations may lead to localized reductions in forage. While we do not have sufficient information to determine the nature of interactive toxicity to salmonid prey items, it is likely the interaction is at least additive, if not synergistic. If carbaryl and diazinon occurred together at proposed criteria concentrations, this could significantly impact forage in localized areas. However, as we do not expect significant exposures to either diazinon or carbaryl in salmonid critical habitat (when considering rarity of detections at criteria levels, low rate of reported use in critical habitat, relatively low proportion of agricultural land use in critical habitat, and the short half-life of carbaryl), the occurrence of these two chemicals together in salmonid is expected to be rare. Because mixtures of these chemicals are not expected to occur regularly, mixtures that could result from the proposed action are not expected to significantly reduce available prey for salmonids. It is reasonable to expect that carbaryl and diazinon may mix with with other chemicals not part of the proposed action in anadromous waters, and may result in additional toxicity to salmonids and their prey. However, information on all possible environmental mixtures and the potential effects is unavailable.

2.5.3. Effects to SRKW and Designated Critical Habitat

NMFS designated critical habitat for SRKW in 2021, which included marine waters between the 6.1 m (20 ft) depth contour and the 200 m (656.2 ft) depth contour from the U.S. international border with Canada south to Point Sur, California (NMFS 2021b). PBFs essential to conservation of SRKWs that are relevant to this opinion include prey species of sufficient quantity, quality, and availability to support individual growth, reproduction, and development, as well as overall population growth.

Our analysis for SRKWs is focused on the proposed action's potential effects on prey abundance, as SRKWs inhabit deeper marine waters outside the area where the subject water quality criteria would apply. In addition, direct toxicity to SRKWs is not expected because the pesticides considered in this opinion do not significantly accumulate in fish tissue. Similarly, our analysis for SRKW critical habitat is focused solely on the prey PBF because the proposed action has the potential to affect prey abundance. Our analysis uses a qualitative WOE approach, as there is currently no supported analytical approach that could be used to statistically quantify effects of declines in Chinook salmon abundance to individual SRKW survival and fecundity (i.e., mortality and reproduction). The proposed action is likely to reduce survival for some individual juvenile salmonids. These reductions have the potential to decrease the abundance of prey for SRKWs, which may consume multiple salmonid species, but focus predation primarily on Chinook salmon.

The proposed criteria for acrolein, carbaryl, and diazinon in Idaho would also affect non-listed sp/su Chinook salmon in the Clearwater basin as well as coho salmon. During the time of year when SRKWs expand their diet beyond Chinook salmon, they may consume coho salmon from the Snake River basin. Although this species is not ESA-listed, it may also be impacted by this action. Available information suggests that coho make up only a very small fraction of SRKW diet. Furthermore, coho from Idaho make up a very small fraction of the overall coho available for SRKW consumption.

In the summer, SRKWs primarily feed on Chinook salmon, and in other months expand their diet to include other salmon such as chum, coho, and steelhead as well as a small amount of bottomfish (Hanson et al. 2010, 2021, Van Cise et al. 2024). However, availability of other salmonids and bottomfish are not considered a limiting factor for SRKWs (NMFS 2021a).

Switching to other prey items may indicate a lack of their preferred prey, Chinook salmon. When prey availability is low enough that whales are not eating regularly, their body condition may decline and they use blubber stores for energy. Though it is difficult to find quantitatively statistically significant relationships between prey abundance and SRKW demographics, nutritional stress as a chronic condition can lead to reduced body size and condition of individuals (e.g., Trites and Donnelly 2003) and whales in poor body condition have a higher likelihood of mortality, while accounting for age and sex (Stewart et al. 2021). In addition, blubber stores that are used during nutritional stress may be contaminated by pollutants in coastal waters, and use of these contaminated energy stores can threaten whales' long-term health and reproductive success (Mongillo et al. 2016). Increasing time spent searching for prey during periods of reduced prey availability may decrease the time spent socializing; potentially reducing reproductive opportunities. Also, low abundance across multiple years may have even greater effect because SRKWs likely require more food consumption during certain life stages, female body condition and energy reserves potentially affect reproduction and/or result in reproductive failure at multiple stages of reproduction (e.g. failure to ovulate, failure to conceive, or miscarriage, successfully nurse calves, etc.), and effects of prey availability on reproduction should be combined across consecutive years. Good fitness and body condition coupled with stable group cohesion and reproductive opportunities are important for reproductive success.

Recent photogrammetry work by Fearnbach and Durban (2024) found that body condition has continued to decline. In 2023, 32% of J pod and 40% of L pod were in the poorest body condition (out of five body condition groups), with 48% and 67% below normal, respectively. K pod, though the smallest with the lowest birth rate, was last sighted for body condition measurements in 2022 with 19% below normal, only 6% in the poorest condition (Fearnbach and Durban 2023). This evidence suggests prey limitation may already be impacting SRKW health, making them vulnerable to continued reduction in Chinook salmon prey, particularly during winter and spring. In the non-summer months where SRKWs need to expand their diet to include prey species other than Chinook salmon, it is especially important that they have sufficient prey to ensure their body condition is not further degraded.

NMFS (2021a) identified several challenges to estimating the total amount of Chinook salmon needed by SRKWs to meet their metabolic needs. Estimates may vary depending on several factors, including the size of the whale population, the caloric density of the salmon, and foraging efficiency (which can be affected by other environmental factors such as vessel presence). The whales and prey are both highly mobile and have large ranges with variable overlap seasonally. New analysis by Holt et al. (2021) found that the probability of prey capture for SRKWs increased as prey abundance increased (both Chinook and coho salmon), highlighting that the more prey available may allow for higher likelihood of meeting caloric needs. Though there are general estimates of how many Chinook salmon need to be consumed to meet the biological needs of the whales, we do not have estimates of the total amount needed in their environment or what density is needed for the population to be able to consume this amount.

There are limited data on the proportional contribution of SR Chinook salmon to SRKW diet, but Hanson et al. (2021) demonstrated that SR sp/su Chinook salmon made up a small (2.2% +/- 3.4) proportion of the samples collected in mid-winter through early spring to analyze the diet of whales. SR sp/su Chinook salmon have been observed in SRKW prey tissue and fecal samples. They also overlap somewhat in space and time with SRKW range, and are a food source in

October to May when SRKW body condition is reduced and diet is diversified. While this ESU is not the most important stock for SRKWs, it is identified within the top ten priority Chinook stocks for SRKW (NMFS and WDFW 2018) and provides a food source during the most vulnerable time of year, particularly for the K and L pods that spend more time near the Columbia River in spring (Hanson et al. 2013).

Snake River fall Chinook salmon are thought to be in the top five Chinook stocks for SRKW. They have been observed in SRKW prey tissue and fecal samples, and are an important food source outside the summer months, when SRKWs are more vulnerable, body conditions decline, and whales rely more on Chinook stocks from outside of the Salish Sea (Durban et al. 2017; Fearnbach et al. 2018; Hanson et al. 2021).

Given that SR sp/su and fall Chinook salmon are the primary stocks considered in this opinion that could impact SRKW prey availability, our subsequent analysis is focused solely on these ESUs. As we do not anticipate an appreciable long-term increase in the risk of extinction of SR sp/su Chinook salmon and SR fall Chinook salmon as a result of the proposed action, this analysis focuses on the short-term or annual reduction in Chinook salmon available to whales due to adverse effects of the proposed action on juveniles.

Deaths of juvenile Chinook salmon due to exposure to carbaryl, and/or diazinon following implementation of the criteria EPA is proposing to approve could affect the annual prey availability to SRKWs where the marine ranges of the affected Chinook salmon populations and the whales overlap. Mortality to some juvenile Chinook salmon is expected as a result of direct toxicity or via reductions in growth caused by declines in salmonid prey quantity or quality exposed to pesticides (more so for Chinook that exhibit the yearling strategy than the ocean-type) (section 2.5.1). This would equate to a relatively small loss of adult-equivalent Chinook salmon available as SRKW prey for each ESU because exposures are expected to be infrequent due to the relatively small proportion of agricultural land in SR sp/su Chinook salmon habitat (somewhat more in SR fall Chinook salmon habitat), the low prevalence of crops that are treated with carbaryl and/or diazinon in anadromous watersheds, declining usage rates, and the rarity of carbaryl or diazinon detections in monitoring programs in more agricultural areas of the state. The impact of this juvenile mortality for SRKWs would be expressed 3 to 5 years after the fact, as this is the amount of time it would have taken for those juveniles to mature and become prey. Other salmonid life stages (embryo incubation, adults, spawning) are not expected to be significantly impacted by pesticide exposures at criteria concentrations, and therefore would not result in a loss of prey for SRKW.

Given that prey abundance is already a limiting factor, additional annual reductions in prey availability have the potential to place further strain on SRKW.The SR Chinook salmon primarily occupy marine areas near the Columbia River, and in the coastal waters of the Pacific Northwest (Weitkamp 2010). Because research has recently identified the area near the Columbia River plume as particularly important for K and L pods of SRKWs, they may consume more Chinook from the Columbia River than previously understood (Hanson et al. 2021). The best available information suggests that both SR sp/su Chinook salmon and SR fall Chinook salmon are an important part of the SRKW diet when they occupy the outer coast region. In fact, Hanson et al. (2013) found that Chinook salmon that migrate out to the ocean from the Columbia

River are likely a more important food resource than previously recognized, as SRKWs (particularly the smaller K and L pods) spend a significant amount of time offshore of this river (Hanson et al. 2021). Preserving each of the SRKW pods is necessary for the recovery of the SRKW DPS overall. Recent research also suggests that there is large inter-annual variability in the timing of SRKW movement to inland waters, with later arrival and fewer days present in inland waters in recent years (Olson et al. 2018; NMFS 2021a). This suggests a greater reliance on SR sp/su and fall Chinook salmon in the outer coast region in some years more than others, as well as an increasing importance of SR Chinook salmon stocks in outer coast waters, such as near those near the mouth of the Columbia River. The effect of reduced prey abundance on SRKW may also vary from year to year because of changes in pesticide use rates and application locations in the action area.

The proposed action would affect SR Chinook salmon at the juvenile life stage, which results in a relatively small reduction of adult fish available to SRKWs in later years (low adult prey equivalent). According to the BE's evaluation based on the salmon translator results, Chinook salmon biomass available for SRKW forage could be reduced by 0.05 – 0.33% for periodic carbaryl exposures at or below the criterion (excluding the continuous exposure scenario, which is very unlikely). For diazinon exposure scenarios (excluding continuous exposure), forage could be reduced by 0.26 – 0.4%. SR Chinook salmon do not exclusively make up the SRKW diet, so this would result in even smaller proportional reductions of salmonid forage overall. Although we expect the reductions in SR sp/su and fall Chinook salmon available as prey for SRKW to be relatively small, these ESUs are important stocks for SRKWs, particularly during vulnerable times of year. Therefore, we find that annual reductions in SR sp/su and fall Chinook salmon due to the proposed action would have only affect a small number of individuals in the SRKW DPS, and the forage PBF of their designated critical habitat.

2.6. Cumulative Effects

"Cumulative effects" are those effects of future State or private activities, not involving federal activities, that are reasonably certain to occur within the action area of the federal action subject to consultation (50 CFR 402.02). Future federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the ESA.

Some continuing non-federal activities are reasonably certain to contribute to climate effects within the action area. However, it is difficult if not impossible to distinguish between the action area's future environmental conditions caused by global climate change that are properly part of the environmental baseline versus cumulative effects. Therefore, all relevant future climate-related environmental conditions in the action area are described earlier in the discussion of environmental baseline (Section 2.4).

A large proportion of land in Idaho is federally managed, particularly around the Salmon River basin. However, human activities that are not federally authorized do occur in the action area and contribute to cumulative adverse effects on ESA-listed species and critical habitat PBFs. Many of these activities are ongoing and have negatively affected the environmental baseline. These activities are expected to continue into the future, some may increase while others may decrease. Within the action area, non-federal actions are likely to include activities tied to human population growth, water withdrawals (i.e., those pursuant to state water rights) and various land uses (e.g., agriculture, timber harvest). In the action area, state, tribal, and local government actions that do not have a federal nexus are likely to be in the form of legislation, administrative rules, or policy initiatives, infrastructure development, maintenance, or upgrades, and resource permitting (e.g., state issuance of IPDES permits, nonpoint source management programs). Absent adequate zoning regulations, future development in riparian areas and floodplain corridors will continue to degrade water quality and reduce habitat resilience to climate change. We also expect to see impacts to salmon and steelhead from continued state and tribal fisheries targeting non-listed salmonids that will result in similar level of mortalities to ESA-listed stocks (TAC 2008).

As many cities border rivers, and considering Idaho has been one of the fastest growing states in the nation in recent years, growth likely will increase contaminant loading from wastewater treatment plants and input of sediments from urban and suburban development into streams and rivers. Urban runoff from impervious surfaces and roadways often contains oil, heavy metals, pesticides, tire wear particles, and other chemical pollutants that flow into surface waters, which are managed under both the IPDES program (for large enough municipalities; e.g., City of Lewiston) and the state nonpoint source management program. Inputs of these point and nonpoint pollution sources into numerous rivers and their tributaries will continue to degrade water quality in available migratory, spawning, and rearing habitat for salmon and steelhead. Based on the increase in human population expected in Idaho (28% over the next two decades) (Mahler 2019), NMFS expects an associated increase in the number or size of discharges and a concomitant increase of pollutant loading.

Mining has historically been a major component of western state economies. National non-fuel mineral output has been steadily increasing, up 6% in 2023 from the previous year (USGS 2024e). Increases in mining will add to existing significant levels of mining contaminants entering rivers. Mining will also contribute to altered hydrologic regimes (through water use) and thermal loading. While major mining activities are expected to occur on federal lands and therefore have a federal nexus, we cannot discount mining on patented or state lands. Given this trend, we expect existing water degradation in Idaho streams that feed into or provide spawning habitat for threatened and endangered species to be exacerbated.

As Idaho's population grows, agricultural land will increasingly be converted to urban land uses. In 2018, agriculture used 84% of the state's water resources. This percentage is expected to drop somewhat as conversion from agricultural to urban land use continues (Mahler 2019). While the impact of agriculture is decreasing, it remains a significant contributor of harmful effects to listed species. One of the main impacts of agriculture is increased concentrations of pesticides, fertilizers, and herbicides in rivers due to agricultural runoff and drift during application. Surface and groundwater withdrawals for agriculture can also negatively impact ESA-listed species. Increased water diversions may reduce stream flows and the amount of habitat available for spawning and rearing. As water is drawn off, contaminants will become more concentrated in these waterways and temperatures will increase, exacerbating toxicity and susceptibility to disease.

Approximately 26% of Idaho timber land is non-federally managed (Idaho Department of Lands 2023). Timber harvest on state- or privately-owned lands may result in modification to riparian habitats, potentially reducing shading of streams in forested areas and leading to elevated stream temperatures. Forestry activities may also cause runoff of herbicides, pesticides, fertilizers, and increased sediment and nutrient loads. These changes to stream water quality can all have adverse effects on listed species.

In coastal waters where the range of SRKW overlaps with SR sp/su and fall Chinook salmon, non-federal actions may apply that would influence these species. In this part of the action area, state, tribal, and Canadian government actions are likely to be in the form of legislation, administrative rules, or policy initiatives, infrastructure development, maintenance, or upgrades, and resource permitting related to coastal resources and habitat, such as those that regulate fishing, boating, water quality, construction or removal of structures, shoreline growth, alternative energy development, aquaculture/mariculture, dredging, and other activities that could impact SRKWs. Private activities are primarily associated with recreational and sport fisheries, recreational vessel traffic and sound, resource extraction, and marine pollution. The most recent action is Washington State's legislation creating a mandatory 1,000-yard vessel buffer around SRKW that went into effect at the beginning of January 2025 (WDFW 2023). This action is likely to reduce adverse impacts to SRKW from vessel noise and disturbance.

The above non-federal actions are likely to impose continuous but unquantifiable negative effects on the ESA-listed species and critical habitats addressed in this opinion. These effects include increases in stream temperature, increased sedimentation, increased point and nonpoint pollution discharges, and decreased infiltration of rainwater (leading to decreases in shallow groundwater recharge, hyporheic flow, and summer low flows). Some non-federal actions likely to occur in or near surface waters in the action area, such as riparian improvement actions and fish habitat restoration projects, are likely to have beneficial effects on the ESA-listed species and critical habitats addressed in this opinion, at least at a stream-reach scale.

When considered together, we expect the discussed cumulative effects to exert minor to moderate negative effects on salmon and steelhead population abundance and productivity, and minor, short-term negative effects on spatial structure (due to temporary blockages of fish passage related to altered stream flows). Similarly, the condition of critical habitat PBFs likely will be slightly to moderately degraded by cumulative effects. These effects will in turn exert a negative effect on SRKW that depend on these species for forage.

2.7. Integration and Synthesis

The Integration and Synthesis section is the final step assessing the risk that the proposed action poses to species and critical habitat. In this section, we add the effects of the action (Section 2.5) to the environmental baseline (Section 2.4) and the cumulative effects (Section 2.6), taking into account the status of the species and critical habitat (Section 2.2), to formulate the agency's biological opinion as to whether the proposed action is likely to: (1) reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing its numbers, reproduction, or distribution; or (2) appreciably diminish the value of designated or proposed critical habitat as a whole for the conservation of the species.

2.7.1. Species

As discussed in the Effects of the Action section (2.5), the water quality criteria for carbaryl and diazinon that EPA proposes to approve are likely to result in mortality or injury to individuals of each of the species considered in this opinion. The water quality criteria for acrolein is also expected to adversely affect individual organisms of each of the species considered in this opinion, though in much smaller numbers than the other two pesticides. Below we describe whether these impacts would cause adverse effects at the population and species level. The anadromous salmon considered in this opinion spawn, incubate, rear, and migrate in partially overlapping areas of the action area (Figure 3). The SRKWs forage on salmon and steelhead that originate from within and migrate through the action area.

The method for determining whether adverse effects will cause impact at the population and species scale is discussed in detail in Section 2.1 (Analytical Approach) and in Section 2.5 (Effects of the Action). Our analysis considers the effects of approving the acute and chronic criteria for three pesticides: acrolein, carbaryl, and diazinon, in addition to environmental mixtures that would result from the proposed criteria. For all effects on species, unless stated otherwise, our analysis reflects the period of time that the component of the standard is in effect, which is indefinite since there is no requirement in the CWA to update specific WQS on any specific schedule.

The salmonids considered in this opinion are listed as either threatened or endangered. The SR sockeye salmon is listed as endangered, and is at high risk of extinction in the next 100 years. The single remaining population of SR fall Chinook salmon is currently listed as threatened and is not yet meeting recovery goals (NMFS 2024a-d). Similarly, SR sp/su Chinook salmon and SRB steelhead are both listed as threatened, and are at a moderate-to-high and moderate risk of extinction in the next 100 years, respectively. Currently, none of the SR sp/su Chinook salmon populations are meeting recovery goals (refer to Table 4). Some, but not all, steelhead populations are meeting recovery goals (refer to Table 5). In the Lower Snake MPG, no steelhead populations are meeting recovery goals, three of five extant steelhead populations in the Clearwater River MPG are meeting recovery goals, and six out of twelve extant steelhead populations in the Salmon River MPG are meeting recovery goals. Populations of all four species may have different baselines of exposures to pesticides, depending on their proximity to pesticide use areas.

The SRKW DPS is at high risk of extinction considering its endangered status and declining population trend. The population has relatively high mortality and low reproduction rate compared to other killer whale populations which have generally been growing since the 1970s (Carretta et al. 2022). Factors that are limiting to SRKW recovery include reduced prey availability and quality, bioaccumulation of toxic chemicals, inbreeding, and disturbance from vessels and sound.

The environmental baseline is generally degraded for all species addressed in this opinion, although there is substantial variation depending on the amount and nature of human and natural disturbance. Some areas within wilderness or other protective designations have good-to-excellent conditions for creating and maintaining fish habitat, while many mainstem valley bottom areas are much less equipped to sustain fish production due to growing human development and land use. This development has had impacts to stream and river hydrology and temperature, and is expected to continue due to the growing population trend of Idaho. Of previously assessed Idaho streams, about 37% do not fully support one or more of their beneficial uses. As the pesticides considered in this opinion have not previously had water quality standards, no streams are known to be impaired for these contaminants. The environmental baseline for SRKW is also degraded, with Chinook salmon (primary food source) below historic numbers, and lower prey quality due to reduced size and contaminant loading.

Climate change is likely to exacerbate several of the previously described ongoing habitat issues, including increased summer temperatures, decreased summer flows in freshwater environments, ocean acidification, and sea level rise in the marine environment. Climate change is also expected to increase the impact of toxic pollutants, including pesticides, due to reduced flows leading to higher pollutant concentrations and increased toxicity of many pollutants at higher temperatures. Cumulative effects are likely to exert a minor but increasingly negative effect on abundance and productivity of salmon and steelhead populations. This will in turn exert a negative effect on SRKW that depend on them for forage.

2.7.1.1. Snake River spring/summer Chinook salmon ESU

The approval of acute and chronic water quality criteria for acrolein (3 µg/L) is not expected to reduce the viability of the SR sp/su Chinook salmon ESU. We do not expect adverse effects to any life stage at the proposed criteria concentrations from either direct toxicity to fish or reductions in forage. While fish occasionally become entrained in irrigation canals, we expect exposures at the proposed criteria levels for SR sp/su Chinook salmon to be rare, provided label use instructions are followed and canals are properly screened. A small number of individuals may be affected, but would not be large enough to affect any of the VSP variables at the population scale.

The approval of acute and chronic water quality criteria for carbaryl (2.1 µg/L) is not expected to reduce the viability of the SR sp/su Chinook salmon ESU. We expect some adverse effects to individual juvenile fish at the proposed criteria concentrations as a result of carbaryl exposures, namely, reducing available forage and subsequent growth and survival. The salmon translator model demonstrated that implementation of the carbaryl criteria could result in up to a 15-20% reduction in survival for individuals subject to reasonable, but upper-bound estimates of, potential exposure (Section 2.5.1). Based on the rarity of detections (and low concentration of the few detections) even in the most agricultural parts of the state, carbaryl's short half-life, and the low prevalence of estimated carbaryl use in SR sp/su Chinook salmon designated critical habitat within the action area, the number of individual juvenile SR sp/su Chinook salmon adversely affected will not be large enough to affect any of the VSP variables at the population scale.

The approval of acute and chronic water quality criteria for diazinon (0.17 µg/L) is not expected to reduce the viability of the SR sp/su Chinook salmon ESU. We expect some adverse effects to individual juvenile fish at the proposed criteria concentrations as a result of diazinon exposures: reducing available forage and subsequent growth and survival and impairing olfaction-based predator evasion. The salmon translator model demonstrated that implementation of the diazinon criteria could result in up to a 12-16% reduction in survival for individuals subject to reasonable, but upper-bound estimates of, potential exposure (Section 2.5.1). Based on the rarity of detections and criteria exceedances even in the most agricultural parts of the state and the low prevalence of estimated diazinon use in SR sp/su Chinook salmon designated critical habitat within the action area, the number of juvenile SR sp/su Chinook salmon adversely affected will not be large enough to affect any of the VSP variables.

We also expect adverse effects of environmental mixtures of carbaryl, diazinon, and their degradates, as these pesticides may co-occur in the anadromous habitat. When exposed to both pesticides at criteria concentrations, we expect at least additive adverse effects, potentially reducing forage for juvenile salmonids and causing chronic toxicity to sensitive physiological functions (e.g., olfaction-based predator evasion). Given the frequency with which these two pesticides have been observed together through Idaho pesticide monitoring programs at typically low concentrations, the probability of SR sp/su Chinook salmon encountering these pesticides together at criteria concentrations is relatively low. Although mixtures will only increase the adverse effects discussed in this opinion, we do not expect mixtures of carbaryl and diazinon to reduce the viability of SR sp/su Chinook salmon ESU.

Overall SR sp/su Chinook salmon are at moderate to high risk of extinction. The vast majority of populations were rated as "high risk" in NMFS's most recent 5-year review, and none were meeting recovery goals (NMFS 2022b). All populations will therefore need to improve their viability rating to meet overall recovery goals for this species. We do not anticipate the proposed action will prevent progress toward these recovery goals, given we do not expect population-scale impacts to the VSP variables. Considering these effects in concert with the environmental baseline and cumulative effects, as well as the status of the species, the proposed action is not likely to appreciably reduce the likelihood of survival and recovery of this species in the wild.

2.7.1.2. Snake River fall Chinook salmon ESU

The approval of acute and chronic water quality criteria for acrolein (3 µg/L) is not expected to reduce the viability of the SR fall Chinook salmon ESU. We do not expect adverse effects to any life stage at the proposed criteria concentrations from either direct toxicity to fish or reductions in forage. While fish occasionally become entrained in irrigation canals, we expect exposures at the proposed criteria levels for SR fall Chinook salmon to be rare, provided label use instructions are followed and canals are properly screened. A small number of individuals may be affected, but would not be large enough to affect any of the VSP variables at the population scale.

The approval of acute and chronic water quality criteria for carbaryl (2.1 µg/L) is not expected to reduce the viability of the SR fall Chinook salmon ESU. We expect some adverse effects to individual juvenile fish at the proposed criteria concentrations as a result of carbaryl exposures, namely, reducing available forage and subsequent growth and survival. The salmon translator model demonstrated that implementation of the carbaryl criteria could result in up to a 15-20% reduction in survival for individuals subject to reasonable, but upper-bound estimates of, exposure frequency (Section 2.5.1). Although a majority of SR fall Chinook salmon habitat is in agricultural land-use zones, carbaryl use occurs but is not estimated to be widespread in SR fall Chinook salmon habitat. Based on the rarity of detections (and low concentration of the few detections, all below 2.1 µg/L) even in the most agricultural parts of the state, as well as carbaryl's short half-life, the number of individual juvenile SR fall Chinook salmon adversely affected will not be large enough to affect any of the VSP variables.

The approval of acute and chronic water quality criteria for diazinon (0.17 μg/L) is not expected to reduce the viability of the SR fall Chinook salmon ESU. We expect some adverse effects to individual juvenile fish at the proposed criteria concentrations as a result of diazinon exposures; reducing available forage and subsequent growth and survival and impairing olfaction-based predator evasion. The salmon translator model demonstrated that implementation of the diazinon criteria could result in up to a 12-16% reduction in survival for individuals subject to reasonable, but upper-bound estimates of, potential exposure (Section 2.5.1). Based on the rarity of detections and criteria exceedances even in the most agricultural parts of the state, the low prevalence of estimated diazinon use in SR fall Chinook salmon designated critical habitat, and the diversity of SR fall Chinook salmon rearing strategies (i.e. yearling and sub-yearling migrations), the number of individual juvenile SR fall Chinook salmon adversely affected will not be large enough to affect any of the VSP variables.

We also expect adverse effects (similar to effects described for SR sp/su Chinook salmon, Section 2.7.1.1) of environmental mixtures of carbaryl, diazinon, and their degradates as these toxicants may occasionally co-occur in anadromous habitat. Given the frequency with which these two pesticides have been observed together through Idaho pesticide monitoring programs at typically low concentrations, the probability of SR fall Chinook salmon encountering these pesticides together at criteria concentrations is relatively low. Mixtures will only increase the adverse effects discussed in this opinion and may be more commonly encountered by SR fall Chinook salmon, which have proportionally more critical habitat in agricultural areas than other ESA-listed Idaho salmonids. However, we do not expect mixtures of carbaryl and diazinon to reduce the viability of SR fall Chinook salmon ESU due to the low probability of fish encountering both pesticides at the proposed criteria levels.

The extant population of SR fall-run Chinook salmon is the only remaining population from an historical ESU that also included large mainstem populations upstream of the current location of the Hells Canyon Dam complex (ICTRT 2003; McClure et al. 2005). The population is at "moderate-to-low" risk for all four VSP variables, with an overall status of "maintained (Ford 2022)." Improved viability of this population will be necessary for the ESU to meet its recovery goals. We do not anticipate the proposed action will prevent progress toward these recovery goals, given that we do not expect population-scale impacts to the VSP variables. Considering these effects in concert with the environmental baseline and cumulative effects, as well as the status of the species, the proposed action is not likely to appreciably reduce the likelihood of survival and recovery of this species in the wild.

2.7.1.3. Snake River sockeye salmon ESU

The approval of acute and chronic water quality criteria for acrolein (3 μg/L) is not expected to reduce the viability of the SR sockeye salmon ESU. We do not expect adverse effects to any life stage at the proposed criteria concentrations from either direct toxicity to fish or reductions in forage. While fish occasionally become entrained in irrigation canals, we expect exposures at the proposed criteria levels for SR sockeye salmon to be rare, provided label use instructions are followed and canals are properly screened. A small number of individuals may be affected, but would not be large enough to affect any of the VSP variables at the population scale.

The approval of acute and chronic water quality criteria for carbaryl (2.1 µg/L) is not expected to reduce the viability of the SR sockeye salmon ESU. We expect some adverse effects to individual juvenile fish at the proposed criteria concentrations as a result of carbaryl exposures, namely, reducing available forage and subsequent growth and survival for the short window of time during their seaward migration. Reasonable exposure scenarios of the salmon translator model for sockeye salmon indicate that survival would be reduced by less than 10% with implementation of the proposed carbaryl criteria (Section 2.5.1). Based on the short window of time when SR sockeye salmon juveniles could be exposed, the rarity of detections (and low concentration of the few detections) even in the most agricultural parts of the state, and carbaryl's short half-life, the number of juvenile SR sockeye salmon adversely affected will not be large enough to affect any of the VSP variables.

The approval of acute and chronic water quality criteria for diazinon (0.17 µg/L) is not expected to reduce the viability of the SR sockeye salmon ESU. We expect some adverse effects to individual juvenile fish at the proposed criteria concentrations as a result of diazinon exposures; reducing available forage and subsequent growth and survival and impairing olfaction-based predator evasion. Reasonable exposure scenarios of the salmon translator model for sockeye salmon indicate that survival would be reduced by less than 10% with implementation of the proposed diazinon criteria (Section 2.5.1). Based on the rarity of detections and criteria exceedances even in the most agricultural parts of the state, the low prevalence of estimated diazinon use in SR sockeye salmon designated critical habitat, and the short duration of potential for exposure during their migration through areas with potential diazinon use, the number of juvenile SR sockeye salmon adversely affected will not be large enough to affect any of the VSP variables.

We also expect adverse effects (similar to effects described for SR sp/su Chinook salmon, Section 2.7.1.1) of environmental mixtures of carbaryl, diazinon, and their degradates, as these toxicants may occasionally co-occur in anadromous habitat. Given the frequency with which these two pesticides have been observed together through Idaho pesticide monitoring programs at typically low concentrations, the probability of SR sockeye salmon encountering these pesticides together at criteria concentrations is relatively low. Although mixtures will only increase the adverse effects discussed in this opinion, we do not expect mixtures of carbaryl and diazinon to reduce the viability of SR sockeye salmon ESU due to the low probability of fish encountering both pesticides at the proposed criteria levels.

This species is at extremely high risk across all four VSP measures (abundance, productivity, spatial structure, and diversity). We do not anticipate the proposed action will cause additional population-scale impacts to the VSP variables. The majority of SR sockeye salmon spawning and rearing life stages take place in areas where pesticide use is unlikely. Exposures may occur in the juvenile migration corridor, but are expected to affect only a small number of fish, given the short duration of SR sockeye salmon outmigration. Considering these effects in concert with the environmental baseline and cumulative effects, as well as the status of the species, the proposed action is not likely to appreciably reduce the likelihood of survival and recovery of this species in the wild.

2.7.1.4. Snake River Basin steelhead DPS

The approval of acute and chronic water quality criteria for acrolein (3 µg/L) is not expected to reduce the viability of the SRB steelhead DPS. We do not expect adverse effects to any life stage at the proposed criteria concentrations from either direct toxicity to fish or reductions in forage. While fish occasionally become entrained in irrigation canals, we expect exposures at the proposed criteria levels for SRB steelhead to be rare, provided label use instructions are followed and canals are properly screened. A small number of individuals may be affected, but would not be large enough to affect any of the VSP variables at the population scale.

The approval of acute and chronic water quality criteria for carbaryl (2.1 µg/L) is not expected to reduce the viability of the SRB steelhead DPS. We expect some adverse effects to individual juvenile fish at the proposed criteria concentrations as a result of carbaryl exposures, namely, reducing available forage and subsequent growth and survival of juveniles. The salmon translator model demonstrated that implementation of the carbaryl criteria could result in up to a 15-20% reduction in survival for steelhead individuals subject to exposure frequencies that are reasonable (especially in more agricultural areas), but upper-bound estimates (Section 2.5.1). Carbaryl use occurs, but is not estimated to be widespread, in the majority SRB steelhead habitat. Some populations in more agricultural areas may be more strongly impacted than others. Based on the rarity of detections (and low concentration of the few detections) even in the most agricultural parts of the state, as well as carbaryl’s short half-life, the number of juvenile SRB steelhead adversely affected will not to be large enough to affect any of the VSP variables.

The approval of acute and chronic water quality criteria for diazinon (0.17 µg/L) is not expected to reduce the viability of the SRB steelhead DPS. We expect some adverse effects to individual juvenile fish at the proposed criteria concentrations as a result of diazinon exposures: reducing available forage and subsequent growth and survival and impairing olfaction-based predator evasion. The salmon translator model demonstrated that implementation of the diazinon criteria could result in up to a 12-16% reduction in survival for individuals subject to reasonable, but upper-bound estimates of, potential exposure (Section 2.5.1). Although SRB steelhead can rear for several years in freshwater habitat and therefore have more opportunities for exposure, diazinon detections and criteria exceedances even in the most agricultural parts of the state are relatively rare, and estimated prevalence of diazinon use in most of the SRB steelhead designated critical habitat is low. For these reasons, the number of juvenile SRB steelhead adversely affected will not be large enough to affect any of the VSP variables.

We also expect adverse effects (similar to effects described for SR sp/su Chinook salmon, Section 2.7.1.1) of environmental mixtures of carbaryl, diazinon, and their degradates, as these toxicants may occasionally co-occur in anadromous habitat. Given the frequency with which these two pesticides have been observed together through Idaho pesticide monitoring programs at typically low concentrations, the probability of SRB steelhead encountering these pesticides together at criteria concentrations is relatively low. Although mixtures will only increase the adverse effects discussed in this opinion, we do not expect mixtures of carbaryl and diazinon to reduce the viability of SRB steelhead DPS.

Overall, SRB steelhead are at moderate risk of extinction within the next 100 years. The viability ratings for SRB steelhead populations range from "high risk" to "highly viable", with some populations meeting or exceeding recovery goals, and several populations falling short of these goals. Just under half of the extant populations in the action area will need to improve their viability rating to meet overall recovery goals for this species. The populations likely to be affected most severely are the ones that rear and migrate through more agricultural portions of the action area, and juveniles that rear for a longer time (i.e., four years vs one year) would be more prone to pesticide exposure. We do not anticipate the proposed action will prevent progress toward species recovery goals, given we do not expect population-scale impacts to the VSP variables. Considering these effects in concert with the environmental baseline and cumulative effects, as well as the status of the species, the proposed action is not likely to appreciably reduce the likelihood of survival and recovery of this species in the wild.

2.7.1.5. Southern Resident killer whale DPS

We expect short-term reductions in SR sp/su and fall Chinook salmon (preferred prey), as well as SR sockeye salmon and SRB steelhead, as a result of the proposed pesticide criteria and any resulting mixtures to reduce a small amount of forage available for SRKWs. The status of the species, environmental baseline, and cumulative effects show that SRKW recovery is limited by prey availability, among other environmental and human-caused factors. SR Chinook salmon is an important dietary component during a more vulnerable time of year for SRKWs, and significant reductions could result in poor body condition, increased prey searching, increased mortality, and reduced reproductive success. However, we do not expect reductions in abundance or productivity of the salmonid species in the action area at the population scale. Therefore, the number of fish adversely affected by the proposed action and the subsequent reductions in available forage would be relatively small. While this is likely to adversely affect SRKWs, we expect the effect to be small enough not to appreciably reduce the survival and recovery of the species in the long term.

2.7.2. Designated Critical Habitat

In this section, we consider the effects of the proposed criteria for three pesticides (acrolein, carbaryl, and diazinon) together. For all effects on critical habitats, unless stated otherwise, the duration of the criteria application reflects the period of time that the component of the standard is in effect, which is indefinite. While the proposed criteria may be applied as long as they are not revised, we do not expect criteria concentrations to be realized in critical habitat indefinitely, as the pesticides considered in this opinion are currently only rarely detected at these concentrations.

The quality of critical habitat varies substantially depending on the amount and nature of human and natural disturbance. Some areas with wilderness or other protective designations have good-to-excellent conditions for creating and maintaining fish habitat, while many downstream areas are much less equipped to sustain fish production due to growing human development and land use. This development has had impacts to stream and river hydrology and temperature. Dams also exert negative effects on the quality of critical habitat for the listed anadromous species considered in this opinion. The PBFs have been degraded to various extents, but many streams (particularly those in wilderness areas) still exhibit optimal water quality, forage, and shelter.

The current conservation value of many areas of critical habitat is high. Effects of climate change likely will result in generally negative trends for stream flow and water temperature conditions, which may impact the toxicity of the pesticides considered in this opinion.

Approval of aquatic life criteria for acrolein, carbaryl, and diazinon will adversely affect the following critical habitat PBFs:

- SR sp/su Chinook salmon: freshwater rearing sites (water quality, food), freshwater migration sites (water quality, food).
- SR fall Chinook salmon: freshwater rearing sites (water quality, food), freshwater migration sites (water quality, food).
- SR sockeye salmon: freshwater rearing sites (water quality, food), freshwater migration sites (water quality, food).
- SRB steelhead: freshwater rearing sites (water quality, forage), freshwater migration sites (water quality).
- SRKW: offshore coastal habitat (prey).

We consider the effects of the approval of acrolein, carbaryl, and diazinon on the PBFs together as one action, even though the effects of each pesticide varies. Implementation of the diazinon and carbaryl criteria may negatively affect the water quality and forage PBFs localized areas within designated critical habitat for the four salmonid species; however, the value of the water quality and food/forage PBFs within the action area will be maintained. A small portion of the SRKW forage PBF will be adversely affected as a result of declines in survival of SR sp/su and SR fall Chinook salmon due to carbaryl and diazinon exposure; however, the overall conservation value of the prey PBF is expected to be maintained. Considering these effects in concert with the environmental baseline and cumulative effects, as well as the status of designated critical habitat, the proposed action is not likely to appreciably reduce the conservation value of the designated critical habitats.

2.8. Conclusion

After reviewing and analyzing the current status of the listed species and critical habitat, the environmental baseline within the action area, the effects of the proposed action, the effects of other activities caused by the proposed action, and the cumulative effects, it is NMFS' biological opinion that the proposed action is not likely to jeopardize the continued existence of SR sp/su Chinook salmon ESU, SR fall Chinook salmon ESU, SR sockeye salmon ESU, SRB steelhead DPS, and SRKW DPS or destroy or adversely modify their designated critical habitats.

2.9. Incidental Take Statement

Section 9 of the ESA and Federal regulations pursuant to section 4(d) of the ESA prohibit the take of endangered and threatened species, respectively, without a special exemption. "Take" is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. "Harm" is further defined by regulation to include significant habitat modification or degradation that actually kills or injures fish or wildlife by significantly impairing essential behavioral patterns, including breeding, spawning, rearing, migrating, feeding, or sheltering (50 CFR 222.102). “Harass” is further defined by interim guidance as to “create the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavioral patterns, which include but are not limited to, breeding, feeding, or sheltering.” “Incidental take” is defined by regulation as takings that result from, but are not the purpose of, carrying out an otherwise lawful activity conducted by the federal agency or applicant (50 CFR 402.02). Section 7(b)(4) and section 7(o)(2) provide that taking that is incidental to an otherwise lawful agency action is not considered to be prohibited taking under the ESA if that action is performed in compliance with the terms and conditions of this ITS. The proposed action does not require an authorization under section 101(a)(5) of the Marine Mammal Protection Act for Southern Resident killer whales. The proposed action will result in take under the ESA, but the harm caused by the proposed action would not constitute take under the Marine Mammal Protection Act (MMPA).

2.9.1. Amount or Extent of Take

The proposed criteria for acrolein, carbaryl, and diazinon apply to all freshwater habitats in Idaho, a subset of which contain ESA-listed SR sp/su Chinook salmon, SR fall Chinook salmon, SR sockeye salmon, and SRB steelhead. As described below, the proposed action is reasonably certain to cause incidental take of one or more of these fish species. In particular, the carbaryl and diazinon criteria are likely to result in incidental take of individulas. The acrolein criteria may result in some take, but we expect take to be relatively rare and the number of individuals affected smaller than for the carbaryl and diazinon criteria. Therefore, we place more emphasis on carbaryl and diazinon in this ITS. Both adult and juvenile life stages have the potential to be exposed to these pesticides at concentrations equivalent to the proposed criteria. Juvenile life stages are expected to be more sensitive than adults, and juvenile fish exposed to criteria concentrations for sufficient periods of time may experience sublethal effects such as reduced growth due to reductions in prey availability and impaired olfaction-based predator evasion, which can both result in reduced survival. The potential reduction of juvenile Chinook salmon reaching the ocean is likely to result in some level of harm to SRKW. Reduced prey availability may cause SRKWs to forage for longer periods, travel to alternate locations, or abandon foraging efforts. All individuals of the SRKW DPS have the potential to be adversely affected in the action area. However, the K and L pods are known to use coastal waters off Washington, Oregon, and California where greater prey reduction may occur than in inland waters of the Salish Sea where the J pod primarily occurs. NMFS is unable to quantify the amount of take that is associated with implementation of the acrolein, carbaryl, and diazinon criteria for the reasons listed below.

1. It is not possible to predict the spatial distribution of these pesticides that could be discharged into the environment from nonpoint sources (which make up a majority of carbaryl and diazinon sources).

2. It is not possible to predict the number of individuals of a species exposed to these pesticides at criteria concentrations. Furthermore, it is not possible to count the number of fish that may be adversely affected by such exposures as the majority of effects are anticipated to be sublethal or behavioral in nature.

3. The actual exposure of ESA-listed fish to harmful concentrations of acrolein, carbaryl, diazinon, and mixtures of these pesticides and other contaminants, and the duration of such exposures, is unpredictable. Available monitoring information is not sufficient to reasonably estimate exposure concentrations or duration. Furthermore, there is a large degree of variability in the effects that could occur as a result of these exposures.

4. There are no data available to help NMFS quantify impacts to foraging behavior or any changes to health of individual killer whales in the population from a specific amount of removal of potential prey resulting from the proposed criteria.

Because it is not practicable to quantify an amount of take, we will use the following surrogates for take that is directly related to the potential for exposure to acrolein, carbaryl, and diazinon at criteria concentrations.

1. Water body impairments (i.e., 303(d) listing) for acrolein, carbaryl, or diazinon in ESA-listed salmonid critical habitat.

Our estimate of the extent of take is that which would occur when acrolein, carbaryl, and diazinon concentrations in ESA-listed salmonid critical habitat are consistent with the proposed criteria. If acrolein concentrations regularly exceed the acute and chronic criteria of 3.0 µg/L, carbaryl concentrations regularly exceed the acute and chronic criteria of 2.1 µg/L, or if diazinon concentrations regularly exceed the acute and chronic criteria of 0.17 µg/L (duration and frequency components described in section 1.3.1), take would be exceeded. This is representative of the amount of take of the species because carbaryl or diazinon concentrations that exceed the criteria may cause additional adverse effects to juvenile and adult salmonids including AChE inhibition, impaired swimming, feeding, homing, and predator evasion, reduced reproductive success and growth, and mortality. If the carbaryl and diazinon criteria were exceeded, this would result in less protective water quality conditions, causing more take of listed species to occur than we anticipated, triggering the need for EPA to determine whether to reinitiate consultation.

This surrogate is quantifiable and may be monitored, serving its intended role as clear reinitiation triggers. Monitoring and reporting requirements included in this ITS will provide opportunities to check throughout the course of the proposed action whether the surrogate is exceeded.

2. The number of point source discharges of carbaryl and diazinon to waters supporting ESA-listed species and/or critical habitat will serve as a surrogate.

There is currently one individual IPDES permit for a discharge containing carbaryl. This discharge is from a fruit processing facility, outside of ESA-listed salmonid designated critical habitat. There are currently no permits for discharges containing diazinon. For the sake of the ITS we will assume potential for three new individual point source discharges of carbaryl and/or diazinon may be permitted in the future which discharge to waters supporting ESA-listed salmon and steelhead. As such, our estimate of the extent of take for EPA’s approval of aquatic life criteria for carbaryl and diazinon is three permitted point source discharges of these pesticides into waters supporting ESA-listed salmon and steelhead. If this number of point source discharge permits were exceeded, this could result in less protective water quality conditions causing more take (e.g., AChE inhibition, impaired swimming, feeding, homing, and predator evasion, reduced reproductive success and growth, mortality) of listed species to occur than we anticipated, possibly triggering the need for EPA to reinitiate consultation. This surrogate is quantifiable and may be monitored, serving its intended role as a clear reinitiation trigger.

3. The number of fish mortality incidents of ESA-listed species in irrigation canals that have been treated with acrolein-containing products over a ten-year period.

Our estimate of the extent of take is that which would occur when irrigation canals are properly screened as required by Idaho state law. If irrigation canals are properly screened, we expect fish mortality incidents to be rare, such that these events are limited to once in every ten years. If ESA-listed salmonid mortality as a result of acrolein treatment in irrigation canals occurs more frequently than once in every ten years in the state of Idaho, take would be exceeded. If this frequency of acrolein-related fish mortality events were exceeded, this could result in additional mortality of listed species to occur than we anticipated, possibly triggering the need for EPA to reinitiate consultation. This surrogate is quantifiable and may be monitored, serving its intended role as a clear reinitiation trigger.

2.9.2. Effect of the Take

In the opinion, NMFS determined that the amount or extent of anticipated take, coupled with other effects of the proposed action, is not likely to result in jeopardy to the species or destruction or adverse modification of critical habitat.

2.9.3. Reasonable and Prudent Measures

"Reasonable and prudent measures" are measures that are necessary or appropriate to minimize the impact of the amount or extent of incidental take (50 CFR 402.02).

The EPA and IDEQ shall:

1. Minimize the potential for adverse effects associated with exposures to the proposed pesticide criteria; and

2. Ensure completion of monitoring and reporting to confirm that the terms and conditions in the ITS are effective in avoiding and minimizing incidental take and ensuring the extent of incidental take is not exceeded.

2.9.4. Terms and Conditions

In order to be exempt from the prohibitions of section 9 of the ESA, the federal action agency must comply (or must ensure that any applicant complies) with the following terms and conditions. The EPA or any applicant has a continuing duty to monitor the impacts of incidental take and must report the progress of the action and its impact on the species as specified in this ITS (50 CFR 402.14). If the entity to whom a term and condition is directed does not comply with the following terms and conditions, protective coverage for the proposed action would likely lapse.

1. The following terms and conditions implement RPM 1:
   a. Any new IPDES permitted discharges of carbaryl or diazinon discharging to receiving waters where anadromous fish may be present shall be evaluated as a pollutant of concern during permit development. These discharges will be subject to applicable effluent limits in accordance with the EPA *Technical Support Document for Water Quality-based Toxics Control (TSD)* and the *IPDES Effluent Limit Development Guidance*. The resulting permit will require monitoring for these compounds in both the receiving water and effluent, as applicable. Monitoring methods must be sufficiently sensitive to determine whether either compound is detected at or below the effluent limits, as well as at criteria concentrations after mixing within the receiving water during or shortly after discharge events. If discharge monitoring results indicate either compound exceeds the effluent limit, the permittee will be considered noncompliant and must take corrective actions to return to compliance. If carbaryl or diazinon are found exceeding thresholds in receiving waters, the data will be reported in the subsequent cycle of the Integrated Report, and EPA or IDEQ must identify and implement additional point source management measures to reduce risk of criteria exceedance where possible.

2. The following terms and conditions implement RPM 2 (monitoring and reporting program):
   a. IDEQ shall perform biomonitoring as described in Biological Assessment Frameworks and Index Development for Rivers and Streams in Idaho (IDEQ 2011) and report on results of this monitoring in IDEQ's Integrated Reports (submitted to EPA approximately every two years). Where macroinvertebrate index ratings in streams or rivers adjacent to, or immediately downstream of, agricultural areas in anadromous watersheds score a 2 or less, the IDEQ shall investigate whether pesticides could be a cause of reduced macroinvertebrate community health and report any instances where discharges of carbaryl or diazinon appear to be a cause in the Integrated Report.

   b. IDEQ shall report any known fish kills in irrigation canals following acrolein application. This report shall consist of an email to NMFS (nmfswcr.srbo@noaa.gov) providing all available information regarding the fish kill. Information may include, but is not limited to, number of dead salmonids observed, location of observations, application timing, and rate of application.

2.10. Conservation Recommendations

Section 7(a)(1) of the ESA directs federal agencies to use their authorities to further the purposes of the ESA by carrying out conservation programs for the benefit of the threatened and endangered species. Specifically, "conservation recommendations" are suggestions regarding discretionary measures to minimize or avoid adverse effects of a proposed action on listed species or critical habitat or regarding the development of information (50 CFR 402.02). The following recommendations should be carried out by the EPA to achieve these purposes:

1. To improve the potential for recovery of ESA-listed species in the State of Idaho, the EPA should carry out management actions to reverse threats to survival as identified in the recovery plans for each species (e.g., clean up mines, manage toxic pollutants, temperature, and other limiting water quality factors).

2. To reduce nonpoint source pesticide loading to water bodies supporting ESA-listed species, the EPA should collaborate with federal and state agencies to ensure the most effective best management practices to reduce and treat stormwater runoff from nonpoint sources of pesticide pollution (e.g., agriculture, forestry) are implemented. IDEQ should inform Watershed Advisory Groups of the risks of pesticide runoff to aquatic communities, and should strive to influence implementation of BMPs and local regulations which are designed to reduce pesticide contamination of surface waters.

3. Given that pesticide monitoring in Idaho is very sparse, the EPA should work with the State of Idaho to develop a monitoring protocol for pesticides that establishes a consistent monitoring program across the state, with particular emphasis on gathering data in areas that have not been monitored for pesticides in the past but are near known pesticide usage sites and that intersect with ESA-listed salmonid critical habitat. This effort should also include a monitoring program to assess pesticide contamination from agricultural applications in irrigation return drains. Such a monitoring program will help gather information concerning water body impairment relative to the proposed criteria for the pesticides considered in this opinion, providing a pathway to minimize effects of acrolein, carbaryl, and diazinon on ESA-listed species.

4. The EPA and IDEQ should target sampling of streams for bioassessment nearby and downstream of agricultural areas where acrolein, carbaryl, and/or diazinon are likely to be used. This biomonitoring will provide an indicator of possible pesticide effects to salmonids and their prey for further investigation.

5. EPA and IDEQ should develop and implement a pesticide monitoring program by 2030 to gather information concerning carbaryl and diazinon occurrence and concentrations in Idaho waters that support ESA-listed salmon and steelhead.

6. Given the paucity of toxicity studies for the pesticides considered in this opinion, EPA should fund or conduct additional acrolein, carbaryl, and diazinon toxicity testing to examine potential lethal and sublethal effects. In particular EPA should examine acrolein chronic toxicity in salmonids (which has less available toxicity information overall), and certain chronic effects to salmonids exposed to carbaryl and diazinon (e.g., survival after entry to seawater, olfaction, impacts on growth due to prey reductions).

7. The EPA should collaborate with relevant partners to implement monitoring of agricultural return flows for acrolein concentrations discharged to waters where anadromous fish may be present.

8. The EPA should revise its 1985 *Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses* to reflect more recent scientific advancements in the fields of ecotoxicology and salmon biology. As part

of this effort, the EPA should collaborate with NMFS scientists to ensure the most sensitive and relevant toxicological endpoints (e.g., behavioral effects, olfaction, etc.), assessment methodologies (e.g., inclusion of mixture studies), and effects thresholds are incorporated into the criteria development procedures.

2.11. Reinitiation of Consultation

This concludes formal consultation for EPA's proposed approval of Idaho's water quality standards for acrolein, carbaryl, and diazinon.

Under 50 CFR 402.16(a): "Reinitiation of consultation is required and shall be requested by the federal agency, where discretionary federal involvement or control over the action has been retained or is authorized by law and: (1) If the amount or extent of incidental taking specified in the ITS is exceeded; (2) If new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not previously considered; (3) If the identified action is subsequently modified in a manner that causes an effect to the listed species or critical habitat that was not considered in the biological opinion or written concurrence; or (4) If a new species is listed or critical habitat designated that may be affected by the identified action."

3. MAGNUSON–STEVENS FISHERY CONSERVATION AND MANAGEMENT ACT ESSENTIAL FISH HABITAT RESPONSE

Section 305(b) of the MSA directs federal agencies to consult with NMFS on all actions or proposed actions that may adversely affect EFH. Under the MSA, this consultation is intended to promote the conservation of EFH as necessary to support sustainable fisheries and the managed species' contribution to a healthy ecosystem. For the purposes of the MSA, EFH means "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity", and includes the associated physical, chemical, and biological properties that are used by fish (50 CFR 600.10). Adverse effect means any impact that reduces quality or quantity of EFH, and may include direct or indirect physical, chemical, or biological alteration of the waters or substrate and loss of (or injury to) benthic organisms, prey species and their habitat, and other ecosystem components, if such modifications reduce the quality or quantity of EFH. Adverse effects on EFH may result from actions occurring within EFH or outside of it and may include direct, indirect, site-specific, or habitat-wide impacts, including individual, cumulative, or synergistic consequences of actions (50 CFR 600.810). Section 305(b) of the MSA also requires NMFS to recommend measures that can be taken by the action agency to conserve EFH. Such recommendations may include measures to avoid, minimize, mitigate, or otherwise offset the adverse effects of the action on EFH (CFR 600.905(b)).

This analysis is based, in part, on the EFH assessment provided by EPA and descriptions of EFH for Pacific Coast salmon (PFMC 2014) contained in the fishery management plans developed by the Pacific Fishery Management Council (PFMC) and approved by the Secretary of Commerce.

3.1. Essential Fish Habitat Affected by the Project

The action area, as described in Section 2.3 of the above opinion, except for areas above natural barriers to fish passage, is also EFH for Chinook salmon and coho (PFMC 2014). The PFMC designated the following five habitat types as habitat areas of particular concern (HAPCs) for salmon: complex channel and floodplain habitat, spawning habitat, thermal refugia, estuaries, and submerged aquatic vegetation (PFMC 2014). HAPCs are described in the regulations as subsets of EFH which are rare, particularly susceptible to human-induced degradation, especially ecologically important, or located in an environmentally stressed area. Designated HAPCs are not afforded any additional regulatory protection under the MSA; however, federal projects with potential adverse impacts on HAPCs will be more carefully scrutinized during the consultation process. The proposed action may adversely affect water quality in the action area, which is an integral component of the complex channel and floodplain habitat, spawning habitat, and thermal refugia HAPCs.

3.2. Adverse Effects on Essential Fish Habitat

Considering the information provided in EPA's BE and the analysis of effects presented in the ESA portion of this document, NMFS concludes that implementation of the proposed action will have adverse effects on EFH designated for Pacific Coast salmon in freshwater. Because the properties of EFH that are necessary for the spawning, breeding, feeding, or growth to maturity of managed species in the action are the same or similar to the biological requirements of the ESA-listed species analyzed above, we rely on the Effects Analysis carried out in Section 2.5 of this document to assess adverse effects on EFH. The impacts of the proposed action include adverse effects to the following elements of EFH:

1. Water quality (rearing and migration). EPA's proposed approval of acute and chronic criteria for acrolein, carbaryl, and diazinon establishes numeric limits of these pesticides in surface waters of Idaho. As described in Section 2.5.1 of this document, the proposed criteria would result in water quality conditions incapable of fully supporting Chinook and coho salmon, as they would lead to some toxicity to aquatic organisms. However, it is unlikely that water quality will be degraded by high concentrations of these pesticides throughout EFH all of the time. Rather, these effects are anticipated to occur in localized areas and will most likely be influenced by human activities, such as agriculture and forestry management. Furthermore, acrolein and carbaryl are short-lived in aquatic environments and therefore typical use of these pesticides is not expected to result in extensive exposures in EFH. Best management practices and usage instructions that are required on labels of products containing these compounds are also expected to minimize the potential for adverse effects.

2. Forage (rearing and migration). Prey organisms may experience adverse effects when exposed to these pesticides (particularly carbaryl and diazinon) at proposed criteria concentrations. Thus, forage may be impacted in localized areas, as described in Section 2.5.1. Reductions in growth as a result of reduced forage may affect Chinook salmon and coho, as juvenile survival is mediated by size.

3.3. Essential Fish Habitat Conservation Recommendations

Because the properties of EFH that are necessary for the spawning, breeding, feeding, or growth to maturity of managed species in the action are the same or similar to the biological requirements of the ESA-listed species analyzed above, the following conservation recommendations are based on our analysis of ESA-listed species. NMFS determined that the following conservation recommendations are necessary to avoid, minimize, mitigate, or otherwise offset the impact of the proposed action on EFH.

a. Any new IPDES permitted discharges of carbaryl or diazinon discharging to receiving waters where anadromous fish may be present shall be evaluated as a pollutant of concern during permit development. These discharges will be subject to applicable effluent limits in accordance with the EPA *Technical Support Document for Water Quality-based Toxics Control (TSD)* and the *IPDES Effluent Limit Development Guidance*. The resulting permit will require monitoring for these compounds in both the receiving water and effluent, as applicable. Monitoring methods must be sufficiently sensitive to determine whether either compound is detected at or below the effluent limits, as well as at criteria concentrations after mixing within the receiving water during or shortly after discharge events. If discharge monitoring results indicate either compound exceeds the effluent limit, the permittee will be considered noncompliant and must take corrective actions to return to compliance. If carbaryl or diazinon are found exceeding thresholds in receiving waters, the data will be reported in the subsequent cycle of the Integrated Report, and EPA or IDEQ must identify and implement additional point source management measures to reduce risk of criteria exceedance where possible.

Fully implementing this EFH conservation recommendation would protect, by avoiding or minimizing the adverse effects described in section 2.5, above, for Pacific Coast salmon. Implementation of this conservation recommendation would benefit the complex channel and floodplain habitat and spawning habitat HAPC and address adverse effects to both water quality and forage elements of EFH. This would be achieved by gathering information to understand pesticide discharges, and creating accountability to minimize pesticide loading to EFH.

3.4. Statutory Response Requirement

As required by section 305(b)(4)(B) of the MSA, the EPA must provide a detailed response in writing to NMFS within 30 days after receiving an EFH conservation recommendation. Such a response must be provided at least 10 days prior to final approval of the action if the response is inconsistent with any of NMFS' EFH conservation recommendations unless NMFS and the federal agency have agreed to use alternative timeframes for the federal agency response. The response must include a description of the measures proposed by the agency for avoiding, minimizing, mitigating, or otherwise offsetting the impact of the activity on EFH. In the case of a response that is inconsistent with the conservation recommendations, the federal agency must explain its reasons for not following the recommendations, including the scientific justification for any disagreements with NMFS over the anticipated effects of the action and the measures needed to avoid, minimize, mitigate, or offset such effects (50 CFR 600.920(k)(1)).

3.5. Supplemental Consultation

The EPA must reinitiate EFH consultation with NMFS if the proposed action is substantially revised in a way that may adversely affect EFH, or if new information becomes available that affects the basis for NMFS' EFH conservation recommendations (50 CFR 600.920(l)).

4. Data Quality Act Documentation and Pre-Dissemination Review

The Data Quality Act (DQA) specifies three components contributing to the quality of a document. They are utility, integrity, and objectivity. This section of the opinion addresses these DQA components, documents compliance with the DQA, and certifies that this opinion has undergone pre-dissemination review.

4.1. Utility

Utility principally refers to ensuring that the information contained in this consultation is helpful, serviceable, and beneficial to the intended users. The intended users of this opinion are the EPA and IDEQ. Other interested users could include permit or license applicants, citizens of affected areas, others interested in the conservation of the affected ESU/DPS. Individual copies of this opinion were provided to the EPA. The document will be available within 2 weeks at the NOAA Library Institutional Repository (https://repository.library.noaa.gov/welcome). The format and naming adhere to conventional standards for style.

4.2. Integrity

This consultation was completed on a computer system managed by NMFS in accordance with relevant information technology security policies and standards set out in Appendix III, 'Security of Automated Information Resources,' Office of Management and Budget Circular A-130; the Computer Security Act; and the Government Information Security Reform Act.

4.3. Objectivity

Information Product Category: Natural Resource Plan

Standards: This consultation and supporting documents are clear, concise, complete, and unbiased; and were developed using commonly accepted scientific research methods. They adhere to published standards including the NMFS ESA Consultation Handbook, ESA regulations, 50 CFR 402.01 et seq., and the MSA implementing regulations regarding EFH, 50 CFR 600.

Best Available Information: This consultation and supporting documents use the best available information, as referenced in the References section. The analyses in this opinion and EFH consultation contain more background on information sources and quality.

Referencing: All supporting materials, information, data, and analyses are properly referenced, consistent with standard scientific referencing style.

Review Process: This consultation was drafted by NMFS staff with training in ESA and MSA implementation, and reviewed in accordance with West Coast Region ESA quality control and assurance processes.

5. References

Ahmadi, K., Mirvaghefei, A. R., Banaee, M., & Vosoghei, A. R. 2014. Effects of long-term diazinon exposure on some immunological and haematological parameters in rainbow trout Oncorhynchus mykiss (Walbaum, 1792). *Toxicology and environmental health sciences*, *6*, 1-7.

APHIS. 2021. Grasshopper and Mormon Cricket Control 2021 Program Summary. Invasive Species of Idaho. Report accessed September 2024 at: https://invasivespecies.idaho.gov/ghmc-information

Albariño, R., Venturino, A., Montagna, C. M., and de D'Angelo, A. M. P. 2007. Environmental effect assessment of Magnacide® H herbicide at Río Colorado irrigation channels (Argentina). tier 4: In situ survey on benthic invertebrates. Environmental Toxicology and Chemistry 26(1): 183-189.

Allison, D. T., and R. O. Hermanutz. 1977. Toxicity of Diazinon to Brook Trout and Fathead Minnows. EPA-600/3-77-060, U.S.EPA, Duluth, MN: 69 p.

Antwi, L. A. K. 1985. Effects of aerial spraying of chlorphoxin on the brain acetylchloinesterase activity of fish from three rivers in the Ivory Coast, West Africa. Environmental Pollution 39:151-159.

Arunachalam, S., Jeyalakshmi, K., and Aboobucker, S. 1980. Toxic and sublethal effects of carbaryl on a freshwater catfish, *Mystus vittatus* (Bloch). Archives of environmental contamination and toxicology, 9, 307-316.

Au, W. W. L., J. K. Horne, and C. Jones. 2010. Basis of acoustic discrimination of Chinook salmon from other salmons by echolocating *Orcinus orca*. The Journal of the Acoustical Society of America 128(4):2225-2232.

Bain, D. 1990. Examining the validity of inferences drawn from photo-identification data, with special reference to studies of the killer whale (*Orcinus orca*) in British Columbia. Report of the International Whaling Commission, Special 12 12:93-100.

Baird, R. W. 2000. The killer whale. Cetacean societies: Field studies of dolphins and whales, pages 127-153.

Baker, D. Hatchery Manager, Idaho Department of Fish and Game, October 19, 2023. Personal communication, email to Johnna Sandow, NMFS Fish Biologist, regarding sockeye returns to the Sawtooth Valley.

Baldwin, D. H., Spromberg, J. A., Collier, T. K., & Scholz, N. L. 2009. A fish of many scales: extrapolating sublethal pesticide exposures to the productivity of wild salmon populations. Ecological Applications, 19(8), 2004-2015.

Banaee, M., A. Sureda, A. R. Mirvaghefi, and K. Ahmadi. 2011. Effects of Diazinon on Biochemical Parameters of Blood in Rainbow Trout (Oncorhynchus mykiss). Pestic. Biochem. Physiol. 99 (1): 1-6.

Barrows, M.E., S.R Petrocelli and K.J. Macek. 1978. Bioconcentration and elimination of selected water pollutants by bluegill sunfish *(Lepomis macrochirus).* In: Dynamic Exposure Hazard Assessment of Toxic Chemicals. R Haque (ed.). Ann Arbor Science, Ann Arbor, MI. pp. 379-392.

Bartley, T. R., and A. R. Hattrup. 1975. Acrolein residues in irrigation water and effects on rainbow trout. U.S. Department of the Interior, Denver Engineering and Research Center, Bureau of Reclamation Report REC-ECR-75-8.11 pp.

Bathe, R., K. Sachsse, L. Ullmann, W. D. Hormann, F. Zak, and R. Hess. 1975. The Evaluation of Fish Toxicity in the Laboratory. Proc. Eur. Soc. Toxicol.16:113-124.

Beamish, R. J., D. J. Noakes, G. A. McFarlane, L. Klyashtorin, V. V. Ivanov, and V. Kurashov. 1999. The regime concept and natural trends in the production of Pacific salmon. Canadian Journal of Fisheries and Aquatic Sciences. 56: 516-526.

Beamish, R. J., and C. Mahnken. 2001. A critical size and period hypothesis to explain natural regulation of salmon abundance and the linkage to climate and climate change. Progress in Oceanography 49:423-437.

Beauvais, S. L., Jones, S. B., Parris, J. T., Brewer, S. K., and Little, E. E. 2001. Cholinergic and behavioral neurotoxicity of carbaryl and cadmium to larval rainbow trout (*Oncorhynchus mykiss*). Ecotoxicology and environmental safety, 49(1), 84-90.

Beauvais, S. L., Jones, S. B., Brewer, S. K., and Little, E. E. 2009. Physiological measures of neurotoxicity of diazinon and malathion to larval rainbow trout (*Oncorhynchus mykiss*) and their correlation with behavioral measures. Environmental Toxicology and Chemistry: An International Journal, 19(7), 1875-1880.

Beliles, R. 1965. Diazinon Safety Evaluation on Fish and Wildlife: Bobwhite Quail, Goldfish, Sunfish, and Rainbow Trout. U.S.EPA-OPP Registration Standard.

Benson, A. J., and A. W. Trites. 2002. Ecological effects of regime shifts in the Bering Sea and eastern North Pacific Ocean. Fish and Fisheries. 3(2): 95-113.

Beyers, D. W., and P. J. Sikoski. 1994. Acetylcholinesterase inhibition in federally endangered Colorado squawfish exposed to carbaryl and malathion. Environmental Toxicology and Chemistry 13(6):935-939.

Bigg, M. 1982. An assessment of killer whale (*Orcinus orca*) stocks off Vancouver Island, British Columbia. Report of the International Whaling Commission 32(65):655-666.

Bigg, M. A., P. F. Olesiuk, G. M. Ellis, J. K. B. Ford, and K. C. Balcomb. 1990. Social organization and genealogy of resident killer whales (*Orcinus orca*) in the coastal waters of British Columbia and Washington State. Report of the International Whaling Commission 12:383-405.

Birge, W. J., J. A. Black, S. T. Ballard, and W. E. McDonnell. 1982. Acute Toxicity Testing with Freshwater Fish.

Bjornn, T. C., D. R. Craddock, and D. R. Corley. 1968. Migration and survival of Redfish Lake, Idaho, sockeye salmon, *Oncorhynchus nerka*. Transactions of the American Fisheries Society. 97:360–373.

Bjornn, T.C. and D.W. Reiser. 1991. Habitat requirements of salmonids in streams. Pages 83-138 *in* W. R. Meehan, editor. *Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society Special Publication 19*, Bethesda, MD.

Bond C.E., Lewis R.H., Fryer J.L. 1960. Toxicity of various herbicidal materials to fishes. Pp96-101 *in* Tarzwell CM (ed.) Biological problems in water pollution. Trans. 1959 Semin., Robert A. Taft Sanit. Eng. Cent. Tech Rept W60-3.

Boran, H., Altinok, I., and Capkin, E. 2010. Histopathological changes induced by maneb and carbaryl on some tissues of rainbow trout, *Oncorhynchus mykiss*. Tissue and Cell, 42(3), 158-164.

Bowerman, T., M. L. Keefer, and C. C. Caudill. 2021. Elevated stream temperature, origin, and individual size influence Chinook salmon prespawn mortality across the Columbia River Basin. Fisheries Research 237:105874.

Bowmer, K.H. and Higgins, M.L. 1976. Some aspects of the persistence and fate of acrolein herbicide in water: Archives of Environmental Contamination and Toxicology, v. 57, p. 87-96.

Brewer, S. K., Little, E. E., DeLonay, A. J., Beauvais, S. L., Jones, S. B., and Ellersieck, M. R. 2001. Behavioral dysfunctions correlate to altered physiology in rainbow trout (*Oncorynchus mykiss*) exposed to cholinesterase-inhibiting chemicals. Archives of Environmental Contamination and Toxicology, 40, 70-76.

Bresch, H. 1991. Early life-stage test in zebrafish versus a growth test in rainbow trout to evaluate toxic effects. Bulletin of Environmental Contamination and Toxicology; (United States), 46(5).

Busby, P. J., T. C. Wainwright, G. J. Bryant, L. J. Lierheimer, R. S. Waples, F. W. Waknitz, and I. V. Lagomarcino. 1996. Status review of West Coast steelhead from Washington, Idaho, Oregon, and California. NOAA-NWFSC-27. Available from NOAA Fisheries, Northwest Fisheries Center, Coastal Zone and Estuaries Studies Division, 2725 Montlake Blvd., E., Seattle, Washington 98112-2097.

Canada, E. 2000. Priority Substances List Assessment Report Acrolein. Page 62. Environment Canada.

Cannamela, D. A. 1992. Potential impacts of release of hatchery steelhead smolts on wild and natural juvenile Chinook and sockeye salmon. White paper prepared by the Idaho Department of Fish and Game. 26 pp.

Carretta, J. V., E. M. Oleson, K. A. Forney, M. M. Muto, D. W. Weller, A. R. Lang, J. Baker, B. Hanson, A. J. Orr, J. Barlow, J. E. Moore, and R. L. Brownell Jr. 2022. Draft U.S. Pacific Marine Mammal Stock Assessments: 2022. NOAA Fisheries. Revised 9/13/2022. Available at: https://www.fisheries.noaa.gov/s3/2023-01/Draft%202022%20Pacific%20SARs_final.pdf.

Caudill, C. C., M. L. Keefer, T. S. Clabough, G. P. Naughton, B. J. Burke, and C. A. Peery. 2013. Indirect effects of impoundment on migrating fish: temperature gradients in fish ladders slow dam passage by 37 adult Chinook Salmon and steelhead. PLoS ONE 8: e85586. DOI: 10.1371/journal.pone.0085586.

Cedergreen N. 2014. Quantifying Synergy: A Systematic Review of Mixture Toxicity Studies within Environmental Toxicology. PLoS ONE 9(5): e96580. doi:10.1371/journal.pone.0096580

Center for Whale Research. 2023. Southern Resident Orca (SRKW) Population; J, K, and L Pod Census, at https://www.whaleresearch.com/orca-population. Website accessed October 20, 2024.

Center for Whale Research (CWR). 2024. Report of 2024 Southern Resident Killer Whale Census and Photo-ID Catalogue. Narrative Report for 1305M319DNFFP0009 Item No. 0009 and 0010. Center for Whale Research. 3 pages.

Chang, K., M. Sakamoto, and T. Hanazato. 2005. Impact of pesticide application on zooplankton communities with different densities of invertebrate predators: an experimental analysis using small-scale mesocosms. Aquatic Toxicology 72(4):373-382.

Chappel, M. J. 2001. Evaluation of the Toxicity of Pesticide Mixtures to Fathead Minnows (*Pimephales Promelas*) Using Probabilistic Ecological Risk Assessment and Toxic Equivalent Techniques. National Library of Canada, Ottawa.

Chittaro, P. M., J. C. Hegg, B. P. Kennedy, L. A. Weitkamp, L. L. Johnson, C. Bucher, and R. W. Zabel. 2019. Juvenile river residence and performance of Snake River fall Chinook salmon. Ecology of freshwater fish, 28(3), 396-410.

Columbia River DART, Columbia Basin Research, University of Washington. 2024. Columbia Basin ESU/DPS Historical Run Timing. Available from https://www.cbr.washington.edu/dart/query/esu_hrt

Colville, A., Jones, P., Pablo, F., Krassoi, F., Hose, G., and Lim, R. 2008. Effects of chlorpyrifos on macroinvertebrate communities in coastal stream mesocosms. Ecotoxicology 17(3):173-180.

Connor, W. P., and H. L. Burge. 2003. Growth of wild subyearling fall Chinook salmon in the Snake River. North American Journal of Fisheries Management 23:594–599.

Connor, W.P., Marshall, A.R., Bjornn, T.C., and Burge, H.L. 2001. Growth and long-range dispersal by wild subyearling spring and summer Chinook salmon in the Sanke River basin. Trans. Am. Fish. Soc. 130(6): 1070–1076. doi:10.1577/1548-8659(2001) 1302.0.CO;2.

Connor, W. P., H. L. Burge, R. Waitt, and T. C. Bjornn. 2002. Juvenile life history of wild fall Chinook salmon in the Snake and Clearwater Rivers. North American Journal of Fisheries Management 22:703–712.

Connor, W. P., J. G. Sneva, K. F. Tiffan, R. K. Steinhorst, and D. Ross. 2005. Two alternative juvenile life history types for fall Chinook salmon in the Snake River basin. Transactions of the American Fisheries Society 134:291–304.

Connor, W. P., K. F. Tiffan, J. A. Chandler, D. W. Rondorf, B. D. Arnsberg, and K. C. Anderson. 2019. Upstream migration and spawning success of Chinook salmon in a highly developed, seasonally warm river system. Reviews in Fisheries Science & Aquaculture, 27(1), 1-50.

Copeland, T., and D. A. Venditti. 2009. Contribution of three life history types to smolt production in a Chinook salmon (*Oncorhynchus tshawytscha*) population. Canadian Journal of Fisheries and Aquatic Sciences 66: 1658-1665.

Copeland, T., M. W. Ackerman, K. K. Wright, and A. Byrne. 2017. Life history diversity of Snake River steelhead populations between and within management categories. North American Journal of Fisheries Management. 37(2):395-404. DOI: 10.1080/02755947.2016.1264506.

Copeland, T., W. Schrader, B. Barnett, M. T. Davison, K. A. Apperson, M. Belnap, E. Brown, E. A. Felts. 2019. Idaho Chinook Salmon Spawning Ground Surveys: Protocol and Historic Trends. Idaho Department of Fish and Game, Report Number 19-16. October. 109 pp.

Coppage, D. L., E. Matthews. 1974. Short-term effects of organophosphate pesticides on cholinesterases of estuarine fishes and pink shrimp. Bulletin of Environmental Contamination and Toxicology 11:483-488.

Coutant, C. C., and R. R. Whitney. 2006. Hydroelectric system development: effects on juvenile and adult migration. Pages 249–324 *in* R. N. Williams, editor. Return to the River-Restoring Salmon to the Columbia River. Elsevier Academic Press, Amsterdam.

Crozier, L. G., A. P. Hendry, P. W. Lawson, T. P. Quinn, N. J. Mantua, J. Battin, R. G. Shaw, and R. B. Huey. 2008. Potential responses to climate change in organisms with complex life histories: evolution and plasticity in Pacific salmon. Evolutionary Applications 1:252-270.

Crozier, L.G., M. M. McClure, T. Beechie, S. J. Bograd, D. A. Boughton, M. Carr, T. D. Cooney, J. B. Dunham, C. M. Greene, M. A. Haltuch, E. L. Hazen, D. M. Holzer, D. D. Huff, R. C. Johnson, C. E. Jordan, I. C. Kaplan, S. T. Lindley, N. J. Mantua, P. B. Moyle, J. M. Myers, M. W. Nelson, B. C. Spence, L. A. Weitkamp, T. H. Williams, and E. Willis-Norton. 2019. Climate vulnerability assessment for Pacific salmon and steelhead in the California Current Large Marine Ecosystem: PLoS ONE, https://doi.org/10.1371/journal.pone.0217711.

Crozier, L. G., J. E. Siegel, L. E. Wiesebron, E. M. Trujillo, B. J. Burke, B. P. Sandford, and D. L. Widener. 2020. Snake River sockeye and Chinook salmon in a changing climate: Implications for upstream migration survival during recent extreme and future climates. PLoS One. 2020 Sep 30;15(9).

Crozier, L. G., B. J. Burke, B. E. Chasco, D. L. Widener, and R. W. Zabel. 2021. Climate change threatens Chinook salmon throughout their life cycle. Communications biology, 4(1), 222.

Dalton, M., P. W. Mote, and A. K. S. [Eds.]. 2013. Climate Change in the Northwest, Implications for Our Landscapes, Waters, and Communities. Washington, DC: Island Press. 271p.

DeGraeve, G. M., Geiger, D. L., Meyer, J. S., & Bergman, H. L. 1980. Acute and embryo-larval toxicity of phenolic compounds to aquatic biota. Archives of environmental contamination and toxicology, 9(5), 557-568.

Detra, R. L., W. J. Collins. 1986. Characterization of Cholinesterase Activity in Larval *Chironomus-Riparius* Meigen (Thummi Kiefer). Insect Biochemistry 16(4):733-739.

Detra, R. L., W. J. Collins 1991. The Relationship of Parathion Concentration, Exposure Time, Cholinesterase Inhibition and Symptoms of Toxicity in Midge Larvae (Chironomidae, Diptera). Environmental Toxicology and Chemistry 10(8):1089-1095.

Dewitz, J. 2021. National Land Cover Database (NLCD) 2019 Products (ver. 3.0, February 2024) [Data set]. U.S. Geological Survey. https://doi.org/10.5066/P9KZCM54

Dillon, F. S., and C. A. Mebane. 2002. Development of site-specific water quality criteria for the South Fork Coeur d'Alene River, Idaho: application of site-specific water quality criteria developed in headwater reaches to downstream waters. Prepared for and in conjunction with the Idaho Department of Environmental Quality. Windward Environmental, Seattle, WA. 95 pp.

Durban, J. W., H. Fearnbach, L. Barrett-Lennard, M. J. Groskreutz, W. L. Perryman, K. C. Balcomb, D. Ellifrit, M. Malleson, J. Cogan, M. Ford, and J. R. Towers. 2017, November 15. Photogrammetry and Body Condition. Availability of Prey for Southern Resident Killer Whales. Technical Workshop Proceedings.

Dwyer FJ, Hardesty DK, Henke CE, Ingersoll CG, Whites GW, Mount DR, Bridges CM. 1999. Assessing contaminant sensitivity of endangered and threatened species: Toxicant classes. U.S. Environmental Protection Agency Report No. EPA/600/R-99/098, Washington, DC. 15 p.

Dwyer, F. J., F. L. Mayer, L. C. Sappington, D. R. Buckler, C. M. Bridges, I. E. Greer, D. K. Hardesty, C. E. Henke, and C. G. Ingers. 2005. Assessing Contaminant Sensitivity of Endangered and Threatened Aquatic Species: Part I. Acute Toxicity of Five Chemicals. Arch. Environ. Contam. Toxicol. 48(2): 143-154.

Ecovista. 2004a. Clearwater Subbasin Assessment. In Intermountain Subbasin Plan prepared for the Northwest Power and Conservation Council. Portland, Oregon, May 2004. http://www.nwcouncil.org/fw/subbasinplanning/admin/level2/intermtn/plan/

Ecovista. 2004b. Salmon Subbasin Assessment. In Intermountain Subbasin Plan, prepared for the Northwest Power and Conservation Council. Portland, Oregon, May 2004. http://www.nwcouncil.org/fw/subbasinplanning/admin/level2/intermtn/plan/

Eisler, R., National Biological Survey (U.S.). 1994. Acrolein hazards to fish, wildlife, and invertebrates: a synoptic review. Washington, D.C.: U.S. Dept. of the Interior, National Biological Survey.

Emmons, C. K., M. B. Hanson, and M. O. Lammers. 2019. Monitoring the Occurrence of Southern Resident Killer Whales, Other Marine Mammals, and Anthropogenic Sound in the Pacific Northwest. Final Report for the U.S. Navy under MIPR Number N00070-17-MP-4C419. Prepared for: U.S. Navy, U.S. Pacific Fleet, Pearl Harbor, HI. Prepared by: NOAA, Northwest Fisheries Science Center, Seattle, WA. February 25, 2019. 32 pages.

Emmons, C. K., M. B. Hanson, and M. O. Lammers. 2021. Passive acoustic monitoring reveals spatiotemporal segregation of two fish-eating killer whale *Orcinus orca* populations in proposed critical habitat. Endangered Species Research 44:253-261.

Erickson, A. W. 1978. Population studies of killer whales (*Orcinus orca*) in the Pacific Northwest: a radio-marking and tracking study of killer whales. September 1978. U.S. Marine Mammal Commission, Washington, D.C.

Ettinger, A., C. Harvey, C. Emmons, M. Hanson, E. Ward, J. Olson, and J. Samhouri. 2022. Shifting phenology of an endangered apex predator mirrors changes in its favored prey. Endangered Species Research 48:211-223.

Everest, F. H., and D. W. Chapman. 1972. Habitat selection and spatial interaction by juvenile Chinook salmon and steelhead trout in two Idaho streams. Journal of the Fisheries Research Board of Canada 29(1):91-100.

Ewing, R. 1999. Diminishing Returns: Salmon Decline and Pesticides. 55 p.

Fagan, W. F., and E. E. Holmes. 2006. Quantifying the extinction vortex. Ecology Letters 9(1):51-60.

Faroon, O., N. Roney, J. Taylor, A. Ashizawa, M. Lumpkin, and D. Plewak. 2008. Acrolein environmental levels and potential for human exposure. Toxicology and Industrial Health 24:543-564.

Fearnbach, H., J. Durban, D. Ellifrit, and K. Balcomb. 2018. Using aerial photogrammetry to detect changes in body condition of endangered southern resident killer whales. Endangered Species Research 35:175–180.

Fearnbach, H., and J. Durban. 2023. Body Condition of Southern Resident Killer Whales in late 2022.

Fearnbach, H., and J. Durban. 2024. Body Condition of Southern Resident Killer Whales in late 2023.

Ferrari, A., Anguiano, O. L., Soleño, J., Venturino, A., & de D'Angelo, A. M. P. 2004. Different susceptibility of two aquatic vertebrates (Oncorhynchus mykiss and Bufo arenarum) to azinphos methyl and carbaryl. Comparative Biochemistry and Physiology Part C: Toxicology & Pharmacology, 139(4), 239-243.

Ferrari, A., Venturino, A., & de D’Angelo, A. M. P. 2007. Effects of carbaryl and azinphos methyl on juvenile rainbow trout (*Oncorhynchus mykiss*) detoxifying enzymes. Pesticide Biochemistry and Physiology, 88(2), 134-142.

Fishel, Frederick M., and Jason A. Ferrell. 2010. Managing Pesticide Drift: PI232 PI232, 9 2010. *EDIS* 2010 (7). Gainesville, FL. https://doi.org/10.32473/edis-pi232-2010.

Fleeger, J. W., K. R. Carman, and R. M. Nisbet. 2003. Indirect effects of contaminants in aquatic ecosystems. Science of the Total Environment 317(1-3):207-233.

Folmar, L. C. 1976. Overt avoidance reaction of rainbow trout fry to nine herbicides. Bulletin of Environmental Contamination and Toxicology 15:509-514.

Ford, M. J., editor. 2022. Biological Viability Assessment Update for Pacific Salmon and Steelhead Listed Under the Endangered Species Act: Pacific Northwest. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-171.

Ford J. K. B., G. M. Ellis, P. F. Olesiuk, K. C. Balcomb. 2010. Linking killer whale survival and prey abundance: food limitation in the oceans' apex predator? Biology Letters.

Ford, M. J. (ed.) 2011. Status review update for Pacific salmon and steelhead listed under the Endangered Species Act: Pacific Northwest. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-113, 281 p. https://www.westcoast.fisheries.noaa.gov/publications/status_reviews/salmon_steelhead/multiple_species/5-yr-sr.pdf

Ford, J. K. B., and G. M. Ellis. 2006. Selective foraging by fish-eating killer whales *Orcinus orca* in British Columbia. Marine Ecology Progress Series 316:185–199.

Ford, J. K. B., G. M. Ellis, and K. C. Balcomb. 2000. Killer Whales: The Natural History and Genealogy of *Orcinus orca* in British Columbia and Washington State. Second edition. University of British Columbia Press, Vancouver, British Columbia.

Ford, J. K. B., G. M. Ellis, L. G. Barrett-Lennard, A. B. Morton, R. S. Palm, and K. C. B. III. 1998. Dietary specialization in two sympatric populations of killer whales (*Orcinus orca*) in coastal British Columbia and adjacent waters. Canadian Journal of Zoology 76(8):1456-1471.

Ford, M. J., J. Hempelmann, B. Hanson, K. L. Ayres, R. W. Baird, C. K. Emmons, J. I. Lundin, G. S. Schorr, S. K. Wasser, and L. K. Park. 2016. Estimation of a killer whale (*Orcinus orca*) population's diet using sequencing analysis of DNA from feces. PLoS One 11(1):1-14.

Foreman, W., M. Majewski, D. Goolsby, F. Wiebe, and R. Coupe. 2000. Pesticides in the atmosphere of the Mississippi River Valley, Part II - Air. Science of the Total Environment 248:213-266.

Francis, D., and H. Hengeveld. 1998. Extreme Weather and Climate Change. 34p. Geiger, D., L. Brooke, and D. Call. 1988. Acute toxicities of organic chemicals to fathead minnows (*Pimephales promelas*) Volume IV. 0961496851.

Geiger, D., L. Brooke, and D. Call. 1990. Acute toxicities of organic chemicals to fathead minnows (*Pimephales promelas*) Volume V. 0961496851.

Geiger, D. L., L. T. Brooke, and D. J. Call. 1988. Acute toxicities of organic chemicals to fathead minnows (*Pimephales promelas*). Vol IV. Center for Lake Superior Environmental Studies University of Winsconsin-Superior.

Geisy, J. P., K. R. Solomon, et al. 1999. Chlorpyrifos: Ecological Risk Assessment in North American Aquatic Environments. Springer-Verlag, New York City.

Gilliom RJ. 2007. Pesticides in U.S. streams and groundwater. Environmental Science and Technology 41(10):3407-3414.

Gilpin, M. E., and S. Michael. 1986. Minimum Viable Populations: Processes of Species Extinction. Conservation biology: The science of scarcity and diversity Sunderland, Massachusetts. Pages 19-34.

Grange, G. F. 2002. Organophosphate insecticides and in-situ inhibition of acetylcholine esterase activity in steelhead (*Oncorhynchus mykiss*). Environmental Sciences and Resources. Portland, Portland State University. Master of Science: 104.

Haines, T. A. 1981. Effects of an application of carbaryl on brook trout (*Salvellinus fontinalls*). Bulletin of Environmental Contamination and Toxicology 27:534-542.

Hajirezaee, S., Mirvaghefi, A. R., Farahmand, H., and Agh, N. 2016. Effects of diazinon on adaptation to sea-water by the endangered Persian sturgeon, *Acipenser persicus*, fingerlings. Ecotoxicology and environmental safety, 133, 413-423.

Hanson, M. B., and C. K. Emmons. 2010. Annual Residency Patterns of Southern Resident Killer Whales in the Inland Waters of Washington and British Columbia. Revised Draft - 30 October 10. 11p.

Hanson, M. B., R. W. Baird, J. K. B. Ford, J. Hempelmann-Halos, D. M. V. Doornik, J. R. Candy, C. K. Emmons, G. S. Schorr, B. Gisborne, K. L. Ayres, S. K. Wasser, K. C. Balcomb, K. Balcomb-Bartok, J. G. Sneva, and M. J. Ford. 2010. Species and stock identification of prey consumed by endangered Southern Resident Killer Whales in their summer range. Endangered Species Research 11(1):69-82.

Hanson, M. B., C. K. Emmons, E. J. Ward, J. A. Nystuen, and M. O. Lammers. 2013. Assessing the coastal occurrence of endangered killer whales using autonomous passive acoustic recorders. The Journal of the Acoustical Society of America 134(5):3486–3495.

Hanson, M. B., E. J. Ward, C. K. Emmons, and M. M. Holt. 2018. Modeling the occurrence of endangered killer whales near a U.S. Navy Training Range in Washington State using satellite-tag locations to improve acoustic detection data. Prepared for: U.S. Navy, U.S. Pacific Fleet, Pearl Harbor, HI. Prepared by: National Oceanic and Atmospheric Administration, Northwest Fisheries Science Center under MIPR N00070-17-MP-4C419. 8 January 2018. 41p.

Hanson, M. B., E. J. Ward, C. K. Emmons, M. M. Holt, and D. M. Holzer. 2017. Assessing the movements and occurrence of Southern Resident Killer Whales relative to the U.S. Navy's Northwest Training Range Complex in the Pacific Northwest. Prepared for: U.S. Navy, U.S. Pacific Fleet, Pearl Harbor, HI. Prepared by: National Oceanic and Atmospheric Administration, Northwest Fisheries Science Center under MIPR N00070-15-MP-4C363. 30 June 2017. 32p.

Hanson, M. B., C. K. Emmons, M. J. Ford, M. Everett, K. Parsons, L. K. Park, J. Hempelmann, D.M. Van Doornik, G. S. Schorr, J. K. Jacobsen, M. F. Sears, M. S. Sears, J. G. Sheva, R. W. Baird, and L. Barre. 2021. Endangered predators and endangered prey: seasonal diet of Southern Resident killer whales. PLoS One 16(3):e0247031.

Hauser, D. D. W., M. G. Logsdon, E. E. Holmes, G. R. VanBlaricom, and R. W. Osborne. 2007. Summer distribution patterns of southern resident killer whales *Orcinus orca*: core areas and spatial segregation of social groups. Marine Ecology Process Series 351:301-310.

Hayworth, J. and A Melwani. 2004. Aquatic pesticide monitoring program: Phase 3 (2004) bioassessment of waterbodies treated with aquatic pesticides. SFEI Contribution #393. San Francisco Estuary Institute, Oakland, CA 120 p.

Healey, M. C. 1982. Juvenile Pacific salmon in estuaries: the life support system. Pages 315-341 in V. S. Kennedy, editor. Estuarine Comparisons. Academic Press, New York, NY.

Healey, M.C. 1991. The life history of Chinook salmon (*Oncorhynchus tshawytscha*). *In* C. Groot and L. Margolis (eds.), Life history of Pacific salmon, p. 311-393. Univ. B.C. Press, Vancouver, B.C.

Herger, L., A. Storrar and T. Dechert. 2002. Appendix D. Fisheries Resources In: South Fork Clearwater River subbasin assessment and TMDLs, 2003.

Herring, S. C., N. Christidis, A. Hoell, J. P. Kossin, C. J. Schreck III, and P. A. Stott, Eds. 2018: Explaining Extreme Events of 2016 from a Climate Perspective. Bulletin of the American Meteorological Society. 99(1): S1–S157.

Higgs, D. A., J. S. Macdonald, C. D. Levings, and B. S. Dosanjh. 1995. Nutrition and feeding habits in relation to life history stage. Pages 159-315 in C. Groot, L. Margolis, and W. C. Clarke, editors. Physiological Ecology of Pacific Salmon. University of British Columbia Press, Vancouver, Canada.

Holcombe, G. W, G. L. Phipps, A. H. Sulaiman, and A. D. Hoffman. 1987. Simultaneous multiple species testing: acute toxicity of 13 chemicals to 12 diverse freshwater amphibian, fish, and invertebrate families. Archives of Environmental Contamination and Toxicology 16:697-710.

Holland, H. T., D. L. Coppage, et al. 1967. Use of fish brain acetylcholinesterase to monitor pollution of organophosphate pesticides. Bulletin of Environmental Contamination and Toxicology 2:156-162.

Holt, M. M., J. B. Tennessen, E. J. Ward, M. B. Hanson, C. K. Emmons, D. A. Giles, and J. T. Hogan. 2021. Effects of vessel distance and sex on the behavior of endangered killer whales. Frontiers in Marine Science 7:1211.

Holtby, L. B., B. C. Andersen, and R. K. Kadowaki. 1990. Importance of smolt size and early ocean growth to interannual variability in marine survival of coho salmon (*Oncorhynchus kisutch*). Canadian Journal of Fisheries and Aquatic Sciences 47(11):2181-2194.

Hoy, T., T. E. Horsberg, et al. 1991. Inhibition of Acetylcholinesterase in Rainbow-Trout Following Dichlorvos Treatment at Different Water Oxygen Levels. Aquaculture 95:33-40.

IARC (1985) *IARC Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans*, Vol. 36, *Allyl Compounds, Aldehydes, Epoxides and Peroxides*, Lyon, pp. 133–161.

ICTRT (Interior Columbia Technical Recovery Team). 2003. Working draft. Independent populations of Chinook, steelhead, and sockeye for listed evolutionarily significant units within the Interior Columbia River domain. NOAA Fisheries. July.

ICTRT. 2007. Viability Criteria for Application to Interior Columbia Basin Salmonid ESUs, Review Draft March 2007. Interior Columbia Basin Technical Recovery Team: Portland, Oregon. 261 pp.

Idaho Department of Lands. 2023. About Forestry. https://www.idl.idaho.gov/about-forestry/

IDEQ (Idaho Department of Environmental Quality). 2001. Middle Salmon River–Panther Creek Subbasin Assessment and TMDL. IDEQ: Boise, Idaho. 114 p.

IDEQ. 2011. Biological Assessment Frameworks and Index Development for Rivers and Streams in Idaho. Boise, Idaho. 229 p.

IDEQ. 2017. 2017 Triennial Review of Water Quality Standards. IDEQ. Available at https://www2.deq.idaho.gov/admin/LEIA/index.html?view=folder&id=2537

IDEQ. 2019. Idaho Pollutant Discharge Elimination System, DEQ, 2019. Available at https://www2.deq.idaho.gov/admin/LEIA/api/document/download/4812

IDEQ. 2022. Idaho's 2022 Integrated Report, Final. IDEQ. Boise, Idaho. 114 p. https://mapcase.deq.idaho.gov/wq2022/

IDEQ. 2024. Enforcement and Compliance History Online Facility Report. Accessed February 29, 2024 at https://echo.epa.gov/facilities/facility-search

IDFG (Idaho Fish and Game); Nez Perce Tribe and Shoshone-Bannock Tribes. 1990. Salmon River Subbasin Salmon and Steelhead Production Plan, September 1, 1990. Northwest Power Planning Council, Portland, Oregon.

IDFG (Idaho Department of Fish and Game). 2022. Sockeye salmon hatchery returns. Available at https://idfg.idaho.gov/conservation/sockeye/returns. Accessed November 22, 2022.

IDWR (Idaho Department of Water Resources). 2021. Active Irrigation Organizations. Accessed September 6, 2024. https://idwr.idaho.gov/water-rights/irrigation-organizations/active/

IDWR. 2022. Idaho Water Facts. Accessed September 6, 2024. https://idwr.idaho.gov/water-data/idaho-water-facts/

ISAB (Independent Scientific Advisory Board). 2007. Climate change impacts on Columbia River Basin fish and wildlife. ISAB Climate Change Report, ISAB 2007-2, Northwest Power and Conservation Council, Portland, Oregon.

Isaak, D. J., S. J. Wenger, E. E. Peterson, J. M.Ver Hoef, S. W. Hostetler, C. H. Luce, J. B. Dunham, J. L. Kershner, B. B. Roper, D. E. Nagel, G. L. Chandler, S. P. Wollrab, S. L. Parkes, and D. L. Horan. 2016. NorWeST modeled summer stream temperature scenarios for the western U.S. Fort Collins, CO: Forest Service Research Data Archive. https://doi.org/10.2737/RDS-2016-0033.

Isaak, D. J., C. H. Luce, D. L. Horan, G. L. Chandler, S. P. Wollrab, and D. E. Nagel. 2018. Global warming of salmon and trout rivers in the northwestern U.S.: road to ruin or path through purgatory? Transactions of the American Fisheries Society 147:566–587.

Isik, I., and Celik, I. 2008. Acute effects of methyl parathion and diazinon as inducers for oxidative stress on certain biomarkers in various tissues of rainbowtrout (*Oncorhynchus mykiss*). Pesticide biochemistry and physiology, 92(1), 38-42.

Johnson, E., K. Plaster, and J. Powell. 2021. Snake River sockeye salmon captive broodstock program. 2020 Annual Report. IDFG Report Number 21-10.

Jones, S. B., King, L. B., Sappington, L. C., Dwyer, F. J., Ellersieck, M., and Buckler, D. R. 1998. Effects of carbaryl, permethrin, 4-nonylphenol, and copper on muscarinic cholinergic receptors in brain of surrogate and listed fish species. Comparative Biochemistry and Physiology Part C: Pharmacology, Toxicology and Endocrinology, 120(3), 405-414.

Jorgensen, J.C., C. Nicol, C. Fogel, and T. J. Beechie. 2021. Identifying the potential of anadromous salmonid habitat restoration with life cycle models. PLoS ONE 16(9): e0256792.

Kashiwada, S., Tatsuta, H., Kameshiro, M., Sugaya, Y., Sabo-Attwood, T., Chandler, G. T., and Goka, K. 2008. Stage-dependent differences in effects of carbaryl on population growth rate in Japanese medaka (*Oryzias latipes*). Environmental Toxicology and Chemistry: An International Journal, 27(11), 2397-2402.

Kardos, M., Y. Zhang, K. M. Parsons, Y. A, H. Kang, X. Xu, X. Liu, C. O. Matkin, P. Zhang, E. J. Ward, M. B. Hanson, C. Emmons, M. J. Ford, G. Fan, and S. Li. 2023. Inbreeding depression explains killer whale population dynamics. Nature Ecology and Evolution.

Kaur, K., and Dhawan, A. 1996. Effect of carbaryl on tissue composition, maturation, and breeding potential of *Cirrhina mrigala* (Ham.).

Keefer M. L., T. S. Clabough, M. A. Jepson, E. L. Johnson, C. A. Peery, and C. C. Caudill. 2018. Thermal exposure of adult Chinook salmon and steelhead: Diverse behavioral strategies in a large and warming river system. PLoS ONE 13(9): e0204274. https://doi.org/10.1371/journal.

Kennedy, C. J., and Ross, P. S. 2012. Stress syndromes: heightened bioenergetic costs associated with contaminant exposure at warm temperatures in teleosts. Integrated Environmental Assessment and Management, 8(1).

Kibria, G., D. Nugegoda, G. Rose, A. K. Y. Haroon. 2021. Climate change impacts on pollutants mobilization and interactive effects of climate change and pollutants on toxicity and bioaccumulation of pollutants in estuarine and marine biota and linkage to seafood security. Marine Pollution Bulletin 167: 112364.

Kiefer, S., M. Rowe, and K. Hatch. 1992. Stock Summary Reports for Columbia River Anadromous Salmonids. Volume V, Idaho Subbasins for the coordinated information system. Annual Report. Prepared or U.S. Department of Energy, Bonneville Power Administration, Division of Fish and Wildlife, Project No. 88-108, Contract No. DE-FC79-89BP94402. BPA Report DOE/BP-94402-4. 845 pp.

Kilduff, D. P., E. Di Lorenzo, L. W. Botsford, and S. L. H. Teo. 2015. Changing central Pacific El Niños reduce stability of North American salmon survival rates. Proceedings of the National Academy of Sciences 112 (35): 10962-10966.

Kissel, C. L., J. L. Brady, A. M. Guerra, M. J. Meshishnek, B. A. Rockie, and F. F. Caserio, Jr. 1981. Monitoring acrolein in naturally occurring systems. Pages 102-116 *in* J. L. Johnson, J. R. Stanford, C. C. Wright, and A. G. Ostroff, editors. Water for subsurface injection: proceedings of the second symposium. ASTM STP 735, American Society for Testing and Materials, Philadelphia, Pennsylvania.

Kozfkay, C. C., M. Peterson, B. P. Sandford, E. L. Johnson, and P. Kline. 2019. The productivity and viability of Snake River sockeye salmon hatchery adults released into Redfish Lake, Idaho. Transactions of the American Fisheries Society. 148:303-323.

Krahn, M. M., P. R. Wade, S. T. Kalinowski, M. E. Dahlheim, B. L. Taylor, M. B. Hanson, G. M. Ylitalo, R. P. Angliss, J. E. Stein and R. S. Waples. 2002. Status Review of Southern Resident Killer Whales (*Orcinus orca*) under the Endangered Species Act. U.S. Department of Commerce, NOAA Technical Memorandum, NMFS-NWFSC-54. 133 pp.

Labenia, J. S., Baldwin, D. H., French, B. L., Davis, J. W., and Scholz, N. L. 2007. Behavioral impairment and increased predation mortality in cutthroat trout exposed to carbaryl. Marine Ecology Progress Series, 329, 1-11.

Laetz, C. A., Baldwin, D. H., Collier, T. K., Hebert, V., Stark, J. D., and Scholz, N. L. 2009. The synergistic toxicity of pesticide mixtures: implications for risk assessment and the conservation of endangered Pacific salmon. Environmental health perspectives, 117(3), 348-353.

Laetz, C. A., Baldwin, D. H., Hebert, V., Stark, J. D., & Scholz, N. L. 2013. Interactive neurobehavioral toxicity of diazinon, malathion, and ethoprop to juvenile coho salmon. Environmental science & technology, 47(6), 2925-2931.

Laetz CA, Baldwin DH, Hebert VR, Stark JD, Scholz NL. Elevated temperatures increase the toxicity of pesticide mixtures to juvenile coho salmon. Aquat Toxicol. 2014 Jan;146:38-44. doi: 10.1016/j.aquatox.2013.10.022. Epub 2013 Oct 30. PMID: 24270668.

Lamberton JG, Claeys. 1970. Degradation of 1-napthol in seawater. J Agr Food Chem 18: 92-6.

Liess, M., and R. Schulz. 1999. Linking insecticide contamination and population response in an agricultural stream. Environmental Toxicology and Chemistry 18:1948-1955.

Lindsey, R., and L. Dahlman. 2024. Climate change: Global temperature. https://www.climate.gov/news-features/understanding-climate/climate-change-globaltemperature

Little, E. E., Archeski, R. D., Flerov, B. A., and Kozlovskaya, V. I. 1990. Behavioral indicators of sublethal toxicity in rainbow trout. Archives of Environmental Contamination and Toxicology, 19, 380-385.

Lohner, T. W., and S. W. Fisher. 1990. Effects of pH and temperature on the acute toxicity and uptake of carbaryl in the midge, *Chironomus riparius*. Aquatic Toxicology 16:335-354.

Lorz HW, Glenn SW, Williams RH, Kunkel CM, Norris LA, Loper BR. 1979. Effects of selected herbicides on smolting of coho salmon. Environmental Research Report EPA-600/3-79-071. U. S. EPA, Corvallis, Oregon. 103 p.

Louder, D.E. and E.G. McCoy. 1962. Preliminary investigations of the use of aqualin for collecting fishes. Proc. Annu. Conf. Southeast. Assoc. Game Fish Comm. 16: 240-242.

Lundin, J. I., Chittaro, P. M., Schultz, I. R., Arkoosh, M. R., Baker, M. C., Baldwin, D. H., ... & Dietrich, J. P. 2023. Dietary Exposure to Environmentally Relevant Levels of Chemical Contaminants Reduces Growth and Survival in Juvenile Chinook Salmon. Environmental Science & Technology, 58(1), 132-142.

Macek, K.J., M.A. Lindberg, S. Sauter, K.S. Buxton and P.A. Costa. 1976. Toxicity of four pesticides to water fleas and fathead minnows: Acute and chronic toxicity of acrolein, heptachlor, endosulfan, and trifluralin to the water flea *(Daphnia magna)* and the fathead minnow *(Pimephales promelas)*. EPA-600/3-76-099, U.S. EPA, Duluth, MN. 68 p. https://www.google.com/books/edition/Toxicity_of_four_pesticides_to_water_fle/sb5zR4_I2GoC?hl=enandgbpv=1andbsq=growth

Mahler, R. L. 2019. The impact of agriculture on the waters of the Idaho portion of the Snake River Basin, USA. International Journal of Sustainable Development and Planning, 14(2), 93-104.

Mantua, N. J., S. R. Hare, Y. Zhang, J. M. Wallace, and R. C. Francis. 1997. A Pacific interdecadal climate oscillation with impacts on salmon production. Bulletin of the American Meteorological Society. 78(6): 1069-1079.

Mast, M. A., W. T. Foreman, and S. V. Skaates. 2007. Current-use pesticides and organochlorine compounds in precipitation and lake sediment from two high-elevation national parks in the western United States. Archives of Environmental Contamination and Toxicology **52**:294-305.

Matsuo, K., and Tamura, T. 1970. Laboratory Experiments on the Effect of Insecticides against Black fly Larvae (Diptera: Simuliidae) and Fishes. *防虫科学*, *35*(4), 125-130.

Mayer, F. L., Jr., and M. R. Ellersieck. 1986. Manual of Acute Toxicity: Interpretation and Data Base for 410 Chemicals and 66 Species of Freshwater Animals. USDI Fish and Wildlife Service, Publication No.160, Washington, DC: 505 p.

McClure, M., T. Cooney, and ICTRT. 2005. Updated population delineation in the interior Columbia Basin. May 11, 2005 Memorandum to NMFS NW Regional Office, Co-managers, and other interested parties. NMFS: Seattle. 14 p.

McElhany, P., M. H. Ruckelshaus, M. J. Ford, T. C. Wainwright, and E. P. Bjorkstedt. 2000. Viable salmonid populations and the recovery of evolutionarily significant units. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-42, Seattle, 156 p.

Mdegela, R. H., R. D. Mosha, M. Sandvik, and J. U. Skaare. 2010. Assessment of acetylcholinesterase activity in *Clarias gariepinus* as a biomarker of organophosphate and carbamate exposure. Ecotoxicology 19(5):855-863.

Mebane, C. A., & Arthaud, D. L. 2010. Extrapolating growth reductions in fish to changes in population extinction risks: copper and Chinook salmon. *Human and Ecological Risk Assessment*, *16*(5), 1026-1065.

Meier, E. P., W. H. Dennis, A. B. Rosencrance, W. F. Randall, W. J. Cooper, and M. C. Warner. 1979. Sulfotepp, a Toxic Impurity in Formulations of Diazinon. Bull. Environ. Contam. Toxicol. 23(1-2): 158-164.

Mineau, P. 1991. Cholinesterase-inhibiting Insecticides: Their Impact on Wildlife and the Environment, volume 2. Elsevier, Amsterdam.

Melbourne, B. A., and A. Hastings. 2008. Extinction risk depends strongly on factors contributing to stochasticity. Nature 454(7200):100-103.

Mckim, J. M., P. K. Schmieder, G. J. Niemi, R. W. Carlson, and T. R. Henry. 1987. Use of Respiratory Cardiovascular Responses of Rainbow trout (*Salmo gairdneri*) in Identifying Acute Toxicity Syndromes in Fish .2. Malathion, Carbaryl, Acrolein and Benzaldehyde. Environmental Toxicology and Chemistry **6**:313-328.

Mongillo, T. M., G. M. Ylitalo, L. D. Rhodes, S. M. O'Neill, D. P. Noren, and M. B. Hanson. 2016. Exposure to a Mixture of Toxic Chemicals: Implications to the Health of Endangered Southern Resident Killer Whales. NOAA Technical Memorandum NMFS-NWFSC-135. National Marine Fisheries Service. November 2016. 118 pages.

Moore, A., and Waring, C. P. 1996. Sublethal effects of the pesticide diazinon on olfactory function in mature male Atlantic salmon parr. Journal of Fish Biology, 48(4), 758-775.

Mumtaz MM, Durkin PR. 1992. A weight-of-evidence approach for assessing interactions in chemical mixtures. Toxicol Ind Health 8:377-406.

Murray, C. C., L. C. Hannah, T. Doniol-Valcroze, B. M. Wright, E. H. Stredulinsky, J. C. Nelson, A. Locke, and R. C. Lacy. 2021. A Cumulative Effects Model for Population Trajectories of Resident Killer Whales in the Northeast Pacific. Biological Conservation 257(109124):1-10.

Myers, J. M., R. G. Kope, G. J. Bryant, D. Teel, L. J. Lierheimer, T. C. Wainwright, W. S. Grant, F. W. Waknitz, K. Neely, S. T. Lindley, and R. S. Waples. 1998. Status Review of Chinook Salmon From Washington, Idaho, Oregon, and California. NMFS-NWFSC-35. Available from National Marine Fisheries Service, Northwest Fisheries Science Center, Coastal Zone and Estuaries Studies Division, 2725 Montlake Blvd. E., Seattle, Washington 98112-2097. 443 p. http://www.nwfsc.noaa.gov/publications/techmemos/tm35/index.htm

Nelson, B. W., E. J. Ward, D. W. Linden, E. Ashe, and R. Williams. 2024. Identifying drivers of demographic rates in an at-risk population of marine mammals using integrated population models. Ecosphere 15, e4773.

NMFS (National Marine Fisheries Service). 2008a. Endangered Species Act section 7 consultation: biological opinion on Environmental Protection Agency registration of pesticides containing chlorpyrifos, diazinon, and malathion (Biological Opinion). Silver Spring, Maryland: U.S. Department of Commerce.

NMFS. 2008b. Recovery Plan for Southern Resident Killer Whales (*Orcinus orca*). National Marine Fisheries Service, Northwest Regional Office. January 17, 2008. 251 pages.

NMFS. 2010. Endangered Species Act Section 7(a)(2) Consultation, Supplemental Biological Opinion on Remand for Operation of the Federal Columbia River Power System, 11 Bureau of Reclamation Projects in the Columbia Basin and ESA Section 10(a)(1)(A) Permit for Juvenile Fish Transportation Program. National Marine Fisheries Service, Portland, Oregon, 5/20/2010.

NMFS. 2011. Endangered Species Act – Section 7 Consultation Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation. Consultation on Fisheries Management and Evaluation Plan for IDFG Recreational Fisheries for Spring/Summer Chinook Salmon. October 19, 2011.

NMFS. 2012. Jeopardy and Adverse Modification of Critical Habitat Biological Opinion for the Environmental Protection Agency's Proposed Approval of Certain Oregon Administrative Rules related to Revised Water Quality Criteria for Toxic Pollutants

NMFS. 2014. Endangered Species Act Section 7 Formal Consultation and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation for Water Quality Toxics Standards for Idaho.

NMFS. 2015. ESA Recovery Plan for Snake River Sockeye Salmon (*Oncorhynchus nerka*), June 8, 2015. NOAA Fisheries, West Coast Region. 431 p. https://www.westcoast.fisheries.noaa.gov/publications/recovery_planning/salmon_steelhead/domains/interior_columbia/snake/snake_river_sockeye_recovery_plan_june_2015.pdf

NMFS. 2017a. ESA Recovery Plan for Snake River Spring/Summer Chinook and Steelhead. NMFS. https://www.fisheries.noaa.gov/resource/document/recovery-plan-snake-river-spring-summer-chinook-salmon-and-snake-river-basin#:~:text=About%20Us-,Recovery%20Plan%20for%20Snake%20River%20Spring%2FSummer%20Chinook,and%20Snake%20River%20Basin%20Steelheadandtext=The%20goal%20of%20ESA%20recovery,no%20longer%20require%20ESA%20protection.

NMFS. 2017b. ESA Recovery Plan for Snake River Fall Chinook Salmon (*Oncorhynchus tshawytscha*). https://www.westcoast.fisheries.noaa.gov/publications/recovery_planning/salmon_steelhead/domains/interior_columbia/snake/Final%20Snake%20Recovery%20Plan%20Docs/final_snake_river_fall_chinook_salmon_recovery_plan.pdf

NMFS. 2020a. Endangered Species Act Biological Opinion on the Continued Operation of the Columbia River System. West Coast Region, NMFS. 1500 p.

NMFS. 2020b. Endangered Species Act Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response for the proposed EPA promulgation of freshwater aquatic life criteria for aluminum in Oregon.

NMFS. 2021a. Southern Resident Killer Whales (*Orcinus orca*) 5-Year Review: Summary and Evaluation. National Marine Fisheries Service, West Coast Region, Seattle, WA. December, 2021. 103 pages. Available at: https://media.fisheries.noaa.gov/2022-01/srkw-5-year-review-2021.pdf

NMFS. 2021b. Endangered Species (ESA) Section 7(a)(2) Biological Opinion, Conference Opinion, and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response for the BP Cherry Point Refinery Pier Reauthorization, Whatcom County, Washington. (Terrell Creek Frontal Birch Bay, 6th Field HUC 171100020203). NMFS Consultation Number: WRCO-2014-00005. Portland, OR. September 30, 2021. 349 pp.

NMFS. 2021c. Revision of the Critical Habitat Designation for Southern Resident Killer Whales: Final Biological Report (to Accompany the Final Rule). National Marine Fisheries Service, West Coast Region, Seattle, WA. July 2021. 142 pp.

NMFS. 2022a. Revised Conference and Biological Opinion on the Environmental Protection Agency's Registration Review of Pesticide Products containing Chlorpyrifos, Malathion, and Diazinon.*in* Office of Protected Resources, editor. US Department of Commerce, National Marine Fisheries Service National Oceanic and Atmospheric Administration.

NMFS. 2022b. 2022 5-Year Review: Summary and Evaluation of Snake River Spring/Summer Chinook Salmon. NMFS. West Coast Region. 101 pp.

NMFS. 2022c. 2022 5-Year Review: Summary and Evaluation of Snake River Fall-Run Chinook Salmon. NMFS. West Coast Region. 87 pp.

NMFS. 2022d. 2022 5-Year Review: Summary and Evaluation of Snake River Sockeye Salmon. NMFS. West Coast Region. 93 pp.

NMFS. 2022e. 2022 5-Year Review: Summary and Evaluation of Snake River Basin Steelhead. NMFS. West Coast Region. 95 pp.

NMFS. 2022f. Biological Opinion on EPA Approval of Water Quality Criteria Proposed for Adoption by Massachusetts and New Hampshire. NMFS Consultation Number: OPR-2022-00203. Office of Protected Resources. August 31, 2022. 167 pp.

NMFS. 2022g. Guidelines for Salmonid Passage at Stream Crossings in Oregon, Washington, and Idaho. NMFS. WCR. Portland, Oregon

NMFS. 2023. Conference and Biological Opinion on the Environmental Protection Agency's Registration Review of Pesticide Products containing Carbaryl and Methomyl. NMFS Consultation Number: OPR-2021-01400; OPR-2021-01401. March 9, 2023. 781pp.

NMFS. 2024a. Status of the Species Snake River Spring/Summer Chinook Salmon. July 2024 Accessed September 3, 2024. Available: www.fisheries.noaa.gov/s3/2024-08/status-species-snake-river-spring-summer-chinook-salmon-july-2024.pdf. 7 pages.

NMFS. 2024b. Status of the Species Snake River Fall Chinook Salmon. July 2024. Accessed September 3, 2024. Available: www.fisheries.noaa.gov/s3/2024-08/status-species-snake-river-fall-chinook-salmon-jul-2024.pdf. 5 pages.

NMFS. 2024c. Status of the Species Snake River Sockeye Salmon. February 2023 Accessed September 3, 2024. Availablewww.fisheries.noaa.gov/s3/2024-08/status-species-snake-river-sockeye-salmon-july-2024.pdf. 4 pages.

NMFS. 2024d. Status of the Species Snake River Basin Steelhead. February 2023. Accessed September 3, 2024. Available: www.fisheries.noaa.gov/s3/2024-08/status-species-snake-river-basin-steelhead-july-2024.pdf. 6 pages.

NMFS and WDFW. 2018. Southern Resident Killer Whale Priority Chinook Stocks Report. June 22, 2018. 8p.

NOAA (National Oceanic and Atmospheric Administration). 2024. Ocean Conditions Indicators Trends web page. https://www.fisheries.noaa.gov/content/ocean-conditions-indicators-trends.

Nowell, L. H., Norman, J. E., Moran, P. W., Martin, J. D., & Stone, W. W. 2014. Pesticide toxicity index—a tool for assessing potential toxicity of pesticide mixtures to freshwater aquatic organisms. *Science of the total environment*, *476*, 144-157.

Noyes, P. D., M. K. McElwee, H. D. Miller, B. W. Clark, L. A. Van Tiem, K. C. Walcott, K. N. Erwin, and E. D. Levin. 2009. The toxicology of climate change: environmental contaminants in a warming world. Environment international, 35(6), 971-986.

NPIC (National Pesticides Information Center). 2003. Carbaryl General Fact Sheet. 5pp. http://npic.orst.edu/factsheets/carbgen.pdf

Ohlberger, J., E. J. Ward, D. E. Schindler, and B. Lewis. 2018. Demographic changes in Chinook salmon across the Northeast Pacific Ocean. Fish and Fisheries 19(3):533-546.

Olesiuk, P. F., M. A. Bigg, and G. M. Ellis. 1990. Life History and Population Dynamics of Resident Killer Whales (*Orcinus orca*) in the Coastal Waters of British Columbia and Washington State. Pages 209-244 in International Whaling Commission, Individual Recognition of Cetaceans: Use of Photo-Identification and Other Techniques to Estimate Population Parameters (Special Issue 12), incorporating the proceedings of the symposium and workshop on individual recognition and the estimation of cetacean population parameters.

Olson, J. K., J. Wood, R. W. Osborne, L. Barrett-Lennard, and S. Larson. 2018. Sightings of southern resident killer whales in the Salish Sea 1976-2014: the importance of a long-term opportunistic dataset. Endangered Species Research 37:105-118.

O'Neill, S. M., G. M. Ylitalo, and J. E. West. 2014. Energy content of Pacific salmon as prey of northern and Southern Resident Killer Whales. Endangered Species Research 25:265–281.

Oruc, E. 2011. Effects of diazinon on antioxidant defense system and lipid peroxidation in the liver of Cyprinus carpio (L.). *Environmental toxicology*, *26*(6), 571-578.

Oziolor, E. M., Howard, W., Lavado, R., and Matson, C. W. 2017. Induced pesticide tolerance results from detoxification pathway priming. *Environmental Pollution*, *224*, 615-621.

Osborne, R. W. 1999. A historical ecology of Salish Sea "resident" killer whales (*Orcinus orca*): With implications for management. Doctoral dissertation. University of Victoria, Victoria, British Columbia. 277p.

Ewing, R. 1999. Diminishing Returns: Salmon Decline and Pesticides. Oregon Pesticides Education Network. 55 p.

Palm Jr, R. C., and Powell, D. B. 2010. Alarm substance recognition and predator avoidance by chinook salmon (Oncorhynchus tschawytscha) following exposure to an organophosphate pesticide. *Environmental Toxicology and Chemistry*, *29*(5), 1113-1122.

Parker, L. M., D. J. Lauren, J. B. Cooke, and D. E. Hinton. 1990. Metabolism of endogenous and xenobi-otic aldehydes by rainbow trout (Oncorhynchus myk- iss) liver fractions. Aquatic Toxicology 18:1-12

Patra, R. W., J. C. Chapman, R. P. Lim, P. C. Gehrke, R. M. Sunderam. 2015. Interactions between water temperature and contaminant toxicity to freshwater fish. Environmental Toxicology and Chemistry 34(8): 1809-1817.

Pauley G. B., B. M. Bortz, and M. F. Shepard. 1986. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest) – steelhead trout. U.S. Fish and Wildlife Service Biological Report 82(11.62). U.S. Army Corps of Engineers, TR EL-82-4.

Pereira, B. V. R., and coauthors. 2019. Cholinesterases characterization of three tropical fish species, and their sensitivity towards specific contaminants. Ecotoxicology and Environmental Safety 173:482-493.

Peterson, J. L., P. C. Jepson, and J. J. Jenkins. 2001. Effect of varying pesticide exposure duration and concentration on the toxicity of carbaryl to two field-collected stream invertebrates, Calineuria californica (Plecoptera: Perlidae) and Cinygma sp. (Emphemeroptera: Heptagaenidae). Environmental Toxicology and Chemistry 20:2215-2223.

Philip, S. Y., S. F. Kew, G. J. van Oldenborgh, F. S. Anslow, S. I. Seneviratne, R. Vautard, D. Coumou, K. L. Ebi, J. Arrighi, R. Singh, M. van Aalst, C. Pereira Marghidan, M. Wehner, W. Yang, S. Li, D. L. Schumacher, M. Hauser, R. Bonnet, L. N. Luu, F. Lehner, N. Gillett, J. Tradowsky, G. A. Vecchi, C. Rodell, R. B. Stull, R. Howard, and F. E. L. Otto. 2021. Rapid attribution analysis of the extraordinary heatwave on the Pacific Coast of the US and Canada. Earth Syst. Dynam. DOI: 10.5194/esd-2021-90.

Phillips, R. 2022. Idaho sockeye returns at Lower Granite Dam are already the second-highest in a decade. IDFG Press Release. Available at: https://idfg.idaho.gov/press/july-sockeye-counts-lower-granite-dam-could-signal-larger-return-recent-years#:~:text=Through%20mid%20July%20(July%2017,the%20coming%20days%20and%20weeks.

Pickering, Q. H., Lazorchak, J. M., and Winks, K. L. 1996. Subchronic sensitivity of one-, four-, and seven-day-old fathead minnow (Pimephales promelas) larvae to five toxicants. *Environmental Toxicology and Chemistry: An International Journal*, *15*(3), 353-359.

Pincetich, C. A. 2004. Metabolic effects of pesticide exposure during embryogenesis in medaka *(Oryzias latipes)* and chinook salmon *(Oncorhynchus tshawytscha)*. University of California, Davis.

PFMC. 2014. Appendix A to the Pacific Coast Salmon Fishery Management Plan, as modified by Amendment 18. Identification and description of essential fish habitat, adverse impacts, and recommended conservation measures for salmon.

Pollesch, N.L., K.M. Flynn, S.M. Kadlec, J.A. Swintek, S. Raimondo, and M. A. Etterson. 2022. Developing integral projection models for ecotoxicology. Ecological Modeling. 464: 109813.

Quinn, T. 2005. The behavior and ecology of Pacific salmon and trout. Seattle: Univ. Washington Press., 378 p.

Reichenberger, S., Bach, M., Skitschank, A., Frede, H.G. 2007. Mitigation strategies to reduce pesticide inputs into ground- and surface water and their effectiveness; A review. Science of the Total Environment 384:1-35.

Relyea, R. A. 2005. The impact of insecticides and herbicides on the biodiversity and productivity of aquatic communities. Ecological Applications 15(2):618-627.

Rodney, S. I., Teed, R. S., and Moore, D. R. 2013. Estimating the toxicity of pesticide mixtures to aquatic organisms: a review. *Human and Ecological Risk Assessment: An International Journal*, *19*(6), 1557-1575.

Rogers JE, Li SW, Felice LJ. 1984. Microbiological transformation of xenobiotics in the aquatic environment. USEPA-600/3-84-043, NTIS PB84-162866

Sabourin, T. D. 1986. A summary of the results of toxicity tests performed by Battelle between March and August in 1986. Battelle Columbus Division, Columbus, OH.

Sabourin, T. D. 1987. Methods for aquatic toxicity tests conducted with acrolein and DEHP as well as the methods and results for acrylonitrile tests. Letter to D. Call, University of Wisconsin-Superior, Superior, WI.

Sandahl, J. F., D.H. Baldwin, J.J. Jenkins, J.J., N.L. Scholz. 2005. Comparative thresholds for acetylcholinesterase inhibition and behavioral impairment in coho salmon exposed to chlorpyrifos. Envirnomental Toxicology and Chemistry 24:136-145.

Sanusi, A., M. Millet, P. Mirabel, and H. Worthman. 2000. Comparison of atmospheric pesticide concentrations at three sampling sites: local, regional and long-range transport. Science of the Total Environment 263:263-277.

Sappington LC, Mayer FL, Dwyer FJ, Buckler DR, Jones JR, Ellersieck MR. 2001. Contaminant sensitivity of threatened and endangered fishes compared to standard species. Environ. Toxicol. Chem. 20:2869-2876.

Scholz, N. L., Truelove, N. K., French, B. L., Berejikian, B. A., Quinn, T. P., Casillas, E., and Collier, T. K. 2000. Diazinon disrupts antipredator and homing behaviors in chinook salmon (Oncorhynchus tshawytscha). *Canadian Journal of Fisheries and Aquatic Sciences*, *57*(9), 1911-1918

Scholz, N. L., Truelove, N. K., Labenia, J. S., Baldwin, D. H., and Collier, T. K. 2006. Dose-additive inhibition of chinook salmon acetylcholinesterase activity by mixtures of organophosphate and carbamate insecticides. *Environmental Toxicology and Chemistry: An International Journal*, *25*(5), 1200-1207.

Schulz, R. 2004. Field studies on exposure, effects, and risk mitigation of aquatic nonpointsource insecticide pollution: A review. Journal of Environmental Quality 33(2):419-448.

Schulz, R., and M. Liess. 1999. A field study of the effects of agriculturally derived insecticide input on stream macroinvertebrate dynamics. Aquatic Toxicology 46(3-4):155-176.

Scott, M. H. 2020. Statistical Modeling of Historical Daily Water Temperatures in the Lower Columbia River. 2020. Dissertations and Theses. Paper 5594.https://doi.org/10.15760/etd.7466

Scott, W. B., and E. J. Crossman. 1973. Freshwater Fishes of Canada (Bulletin 184). Fisheries Research Board of Canada, Ottawa, Canada.

Seguchi, K., and Asaka, S. 1981. Intake and excretion of diazinon in freshwater fishes. *Bulletin of Environmental Contamination and Toxicology*, *27*, 244-249.

Shea, T. B., and E. S. Berry. 1983. Toxicity of carbaryl and 1-naphthol to goldfish (Carassius auratus) and Killifish (Fundulus heteroclitus). Bulletin of Environmental Contamination and Toxicology 31:526-529.

Shelton, A. O., W. H. Satterthwaite, E. J. Ward, B. E. Feist, and B. Burke. 2019. Using hierarchical models to estimate stock-specific and seasonal variation in ocean distribution, survivorship, and aggregate abundance of fall run Chinook salmon. Canadian Journal of Fisheries and Aquatic Sciences 76(1):95-108.

Siegel, J. and L. Crozier. 2019. Impacts of Climate Change on Salmon of the Pacific Northwest: A review of the scientific literature published in 2018. Fish Ecology Division, Northwest Fisheries Science Center, National Marine Fisheries Service, NOAA. December.

Simpson WG. 2018. The entrainment and screening of returning and postspawning adult salmonids at irrigation canals of the Umatilla River, Oregon. Journal of Fish and Wildlife Management 9(1):285-295; e1944-687X. doi:10.3996/072017-JFWM-058

Smith, G. J. 1993. Toxicology and Pesticide Use in relation to Wildlife: Organophosphorus and Carbamate Compounds. U.S. Department of the Interior., Boca Raton.

Snyder-Conn, E. 1997. Acrolein on aquatic ecosystems in Tule National Wildlife Refuge. U.S. Fish and Wildlife Service. 15 pp.

Sparling, D. W., and G. Fellers. 2007. Comparative toxicity of chlorpyrifos, diazinon, malathion and their oxon derivatives to larval Rana boylii. Environmental Pollution **147**:535-539.

Spehar, R.L. 1989. Aquatic toxicity test information on acrolein with fathead minnows *(Pimephales promelas)* and flagfish *(Jordanellajl.oridae).* U.S. EPA, Duluth, MN.

Spence, B., G. Lomnicky, R. Hughes, and R. P. Novitski. 1996. An ecosystem approach to salmonid conservation. TR-4501-96-6057. ManTech Environmental Research Services Corp.: Corvallis, Oregon.

Staley, K. and J. Mueller. 2000. Rainbow Trout (*Oncorhynchus mykiss*). USDA Natural Resources Conservation Service. Fish and Wildlife Habitat Management Leaflet. Volume 13. [on-line] ftp://ftp-fc.sc.egov.usda.gov/WHMI/WEB/pdf/RAINBOW1.pdf

Stephen, C. E., D.I. Mount, D.J. Hansen, J.H. Gentile, G.A. Chapman and W.A. Brungs. 1985. Guidelines for deriving numerical national water quality criteria for the protection of aquatic organisms and their uses. U.S. EPA.

Stewart, J. D., J. W. Durban, H. Fearnbach, L. G. Barrett-Lennard, P. K. Casler, E. J. Ward, D. R. Dapp. 2021. Survival of the fattest: linking body condition to prey availability and survivorship of killer whales. Ecosphere, 12(8), e03660.

Swedberg, D. 1973. Diazinon toxicity to specified fish. *US Environmental Protection Agency, Office of Pesticide Programs registration standard*.

TAC (Technical Advisory Committee). 2008. Biological assessment of incidental impacts on salmon species listed under the Endangered Species Act in the 2008 – 2017 non-Indian and treaty Indian fisheries in the Columbia River basin. U.S. vs. Oregon Technical Advisory Committee, Olympia, Washington.

Thurow, R. 1985. Middle Fork Salmon River fisheries investigations. Job completion report, project F-73-R-6, river and stream investigations. Idaho Department of Fish and Game, Boise.

Thurow, R. 1987. Completion Report Evaluation of the South Fork Salmon River Steelhead Trout Fishery Restoration Program. Performed for U.S. Fish and Wildlife Service, Lower Snake River Fish and Wildlife Compensation Plan Contract No. 14-16-0001-86505. March 1, 1984 – February 28, 1986. 164 pp.

Tierney, K. B., Ross, P. S., and Kennedy, C. J. 2007. Linuron and carbaryl differentially impair baseline amino acid and bile salt olfactory responses in three salmonids. *Toxicology*, *231*(2-3), 175-187.

Tiffan, K. F., and W. P. Connor. 2012. Seasonal Use of Shallow Water Habitat in the Lower Snake River Reservoirs by Juvenile Fall Chinook Salmon. 2010–2011 Final Report of Research to U.S. Army Corps of Engineers Walla Walla District.

Tiffan, K. F., J. M. Erhardt, and S. J. St. John. 2014. Prey availability, consumption, and quality contribute to variation in growth of subyearling Chinook salmon rearing in riverine and reservoir habitats. Transactions of the American Fisheries Society 143:219-229.

Tonina, D., J. A. McKean, D. Isaak, R. M. Benjankar, C. Tang, and Q. Chen. 2022. Climate change shrinks and fragments salmon habitats in a snow dependent region. Geophysical Research Letters, 49, e2022GL098552. https://doi.org/10.1029/2022GL098552

Toumi, H., Burga-Perez, K. F., and Ferard, J. F. 2016. Acute and chronic ecotoxicity of carbaryl with a battery of aquatic bioassays. *Journal of Environmental Science and Health, Part B*, *51*(1), 57-62.

Trites, A. W., and C. P. Donnelly. 2003. The decline of Steller sea lions *Eumetopias jubatus* in Alaska: a review of the nutritional stress hypothesis. Mammal Review 33(1):3-28.

Troiano, A. T., King, K. A., Grue, C. E., Grassley, J. M., and Ekblad, C. J. 2013. Brain acetylcholinesterase activity in shiner perch (Cymatogaster aggregata) and juvenile Chinook salmon (Oncorhynchus tshawytscha) after application of carbaryl to control burrowing shrimp within Willapa Bay, Washington. *Archives of environmental contamination and toxicology*, *65*, 779-789.

Tsuda, T., Kojima, M., Harada, H., Nakajima, A., and Aoki, S. 1997. Acute toxicity, accumulation and excretion of organophosphorous insecticides and their oxidation products in killifish. *Chemosphere*, *35*(5), 939-949.

Turner, L. W. 1982. Acute Toxicity of Selected Chemicals to Fathead Minnow, Water Flea and Mysid Shrimp Under Static and Flow-Through Test Conditions.

Turner, L., and W. E. Erickson. 2003. Acrolein Analysis of Risks from the Aquatic Herbicide Use in Irrigation Supply Canals to Eleven Evolutionarily Significant Units of Pacific Salmon and Steelhead. Page 49 *in* E. F. B. O. o. P. Programs, editor. U.S. EPA, Washington DC.

USBWP (Upper Salmon Basin Watershed Project Technical Team). 2005. Upper Salmon River Recommended Instream Work Window and Fish Periodicity for River Reaches and Tributaries Above the Middle Fork Salmon River Including the Middle Fork Salmon River Drainage. Revised Nov. 30, 2005. Salmon, Idaho.

USDA. 2008. USDA Forest Service Human Health and Ecological Risk Assessment Revised Final Report for Carbaryl. USDA Forest Service Southern Region. Atlanta Georgia. 276 p.

USDA. 2019. Final Human Health and Ecological Risk Assessment for Carbaryl Rangeland Grasshopper and Mormon Cricket Suppression Applications. Page 84 *in* D. o. Agriculture, editor. United States Department of Agriculture Marketing and Regulatory Programs Animal and Plant Health Inspection Service, Riverdale, MD.

USDA. 2021. Land use composition in Idaho. National Agricultural Statistics Service. Accessed at: https://www.nass.usda.gov/Statistics_by_State/Idaho/index.php

USDA. 2023. Cropland Data Layer - Cropland CROS. National Agricultural Statistics Service. Accessed September 2024 at: https://croplandcros.scinet.usda.gov/

USEPA. 1986. U.S. Environmental Protection Agency. Guidelines for the health risk assessment of chemical mixtures. Fed Reg 51:34014-34025.

USEPA. 2003. Toxicological Review of Acrolein In Support of Summary Information on the Integrated Risk Information System (IRIS). US Environmental Protection Agency Washington, DC. 107 pp.

USEPA. 2004. Overview of the Ecological Risk Assessment Process in the Office of Pesticide Programs, U.S. Environmental Protection Agency - Endangered and Threatened Species Effects Determinations.*in* P. a. T. S. Office of Prevention, Office of Pesticide Programs, editor. U.S. Environmental Protection Agency, Washington, D.C.

USEPA. 2005. Aquatic Life Ambient Water Quality Criteria Diazinon. Page 85 *in* O. o. W. O. o. S. T. Washington, editor. U.S. Environmental Protection Agency, Washington DC.

USEPA. 2007. Environmental Fate and Ecological Risk Assessment for the Reregistration of Acrolein. Page 114 *in* P. a. T. S. Office of Prevention, editor. EPA, Washington, DC.

USEPA. 2008a. Diazinon Required Label Changes per NMFS Biological Opinion. EPA-HQ-OPP-2008-0351-0130. Available at https://www.regulations.gov/docket/EPA-HQ-OPP-2008-0351/document

USEPA. 2008b. Environmental Fate and Ecological Risk Assessment for the Reregistration of Acrolein. Page 114 *in* P. a. T. S. Office of Prevention, editor. EPA, Washington, DC.

USEPA. 2009a. Ambient Aquatic Life Water Quality Criteria for Acrolein. Page 49 *in* O. o. Water, editor. U.S. Environmental Protection Agency, Washington, D.C.

USEPA. 2009b. SAP Minutes No. 2009-01. A set of Scientific Issues Being Considered by the Environmental Protection Agency Regarding: Selected Issues Associated with the Risk Assessment Process for Pesticides with Persistent, Bioaccumulative, and Toxic Characteristics. Page 112 *in* OPPT, editor. Arlington, VA.

USEPA. 2010. Registration review - preliminary problem formulation for ecological risk and environmental fate, endangered species, and drinking water assessments for carbaryl in OPP, editor. U.S. Environmental Protection Agency.

USEPA. 2012. Aquatic Life Ambient Water Quality Criteria for Carbaryl. Page 199 pp. *in* O. o. Water, editor. Office of Science and Technology Health and Ecological Criteria Division, U.S. Environmental Protection Agency, Washington, D.C.

USEPA. 2014. Magnacide H Herbicide Application and Safety Manual. EPA Registration number 10707-9. 39 pp.

USEPA. 2016a. Final Pesticide General Permit for Discharges from the Application of Pesticides, USEPA, 2016: https://www.regulations.gov/document/EPA-HQ-OW-2015-0499-0118

USEPA. 2016b. Definition and Procedure for the Determination of the Method Detection Limit, Revision 2.*in* O. o. Water, editor., Washington D.C.

USEPA. 2016c. Diazinon National and State Use and Usage Summary. Office of Chemical Safety and Pollution Prevention. 12 pp.

USEPA. 2017. Diazinon Executive Summary; Biological Evaluation Chapters for Diazinon Endangered Species Act Assessment. U.S. Environmental Protection Agency.

USEPA. 2021a. Columbia and Lower Snake Rivers Temperature Total Maximum Daily Load. U.S. Environmental Protection Agency, Seattle, WA. August 2021. Available at: https://www.epa.gov/system/files/documents/2021-08/tmdl-columbia-snake-temperature-appendix-a.pdf

USEPA. 2021b. Assessment of Impacts to Columbia and Snake River Temperatures using the RBM10 Model Scenario Report: Appendix D to the Columbia and Lower Snake Rivers Temperature Total Maximum Daily Load. U.S. Environmental Protection Agency, Seattle, WA. May 2021. Available at TMDL for Temperature in the Columbia and Lower Snake Rivers | US EPA.

USEPA. 2021c. Columbia River Cold Water Refuges Plan. U.S. Environmental Protection Agency, Seattle, WA. January 2021. Available at https://www.epa.gov/ 38 columbiariver/columbia-river-cold-water-refuges-plan

USEPA. 2021d. Final National Level Listed Species Biological Evaluation for Carbaryl.*in* OPPT, editor. EPA, Washington, DC.

USEPA. 2021e. Memorandum: Carbaryl Draft Ecological Risk Assessment for Registration Review. EPA Office of Chemical Safety and Pollution Prevention. 75 p. https://www.regulations.gov/document/EPA-HQ-OPP-2010-0230-0073

USEPA. 2022a. Balancing Wildlife Protection and Responsible Pesticide Use: How EPA's Pesticide Program Will Meet its Endangered Species Act Obligations. USEPA.

USEPA. 2022b. ESA Workplan Update: Nontarget Species Mitigation for Registration Review and Other FIFRA Actions.*in* HQ-OPP, editor. U.S. Environmental Protection Agency

USEPA. 2023a. EPA Reaches Agreement on Early Mitigation Measures Initiative for an Organophosphate Pesticide. April 27, 2023. Available at https://www.epa.gov/pesticides/epa-reaches-agreement-early-mitigation-measures-initiative-organophosphate-pesticide

USEPA. 2023b. National Management Measures to Control Nonpoint Source Pollution from Agriculture. Polluted Runoff: Nonpoint Source (NPS) Pollution. Accessed August 2024. https://www.epa.gov/nps/national-management-measures-control-nonpoint-source-pollution-agriculture

USEPA. 2024. Biological Evaluation: EPA’s Proposed Approval of Idaho’s Water Quality Standards for Acrolein, Carbaryl, and Diazinon. 184 p.

USEPA. 2024a. Acrolein Proposed Interim Registration Review Decision.*in* O. o. P. Program, editor. EPA HQ, Washington D.C.

USEPA. 2024b. Required Label Changes based on the January 31, 2024, NMFS Biological Opinion on Carbaryl. EPA-HQ-OPP-2010-0230-0140. Available at https://www.regulations.gov/docket/EPA-HQ-OPP-2010-0230/document

USEPA. 2024c. NPDES Program and Permit Quality Review Toolkit. National Pollutant Discharge Elimination System. Accessed August 2024. https://www.epa.gov/npdes/npdes-program-and-permit-quality-review-toolkit

USEPA. 2024d. State Review Framework. Compliance. Accessed August 2024. https://www.epa.gov/compliance/state-review-framework

USEPA. 2024e. Idaho NPDES Program Authorization. NPDES Permits Around the Nation. Accessed August 2024. https://www.epa.gov/npdes-permits/idaho-npdes-program-authorization

USEPA. 2024f. Update to Herbicide Strategy (April 2024). Draft Herbicide Strategy Framework to Reduce Exposure of Federally Listed Endangered and Threatened Species and Designated Critical Habitats from the Use of Conventional Agricultural Herbicides, Nonrulemaking Docket. Available at https://www.regulations.gov/docket/EPA-HQ-OPP-2023-0365/document

USFWS, and NMFS. 1998. Endangered Species Consultation Handbook: Procedures for Conducting Consultation and Conference Activities Under Section of the Endangered Species Act. Page 315 *in* U. S. F. a. W. S. a. N. M. F. Service, editor.

USGS. 2024a. Discrete pesticide results from: 13056500 Henry's Fork near Rexburg, ID. Accessed September 2024 at: https://www.sciencebase.gov/catalog/item/61c08c6ed34ee9cd54ed3281

USGS. 2024b. Discrete pesticide results from: 13092747 Rock Creek at Twin Falls, ID. Accessed September 2024 at: https://www.sciencebase.gov/catalog/item/61c08c77d34ee9cd54ed328b

USGS. 2024c. Discrete pesticide results from: 13154500 Snake River at King Hill, ID. Accessed September 2024 at: https://www.sciencebase.gov/catalog/item/61c08c84d34ee9cd54ed3296

USGS. 2024d. Estimated annual agricultural pesticide use: Pesticide use-maps. Pesticide National Synthesis Project. Accessed November 2024 at: https://water.usgs.gov/nawqa/pnsp/usage/maps/show_map.php?year=2017andmap=DIAZINONandhilo=Handdisp=Diazinon

USGS (U.S. Geological Survey). 2024e. Mineral commodity summaries 2024: U.S. Geological Survey, 212 p., https://doi.org/10.3133/mcs2024

Van Cise, A. M., M. B. Hanson, C. Emmons, D. Olsen, C. O. Matkin, A. H. Wells, and K. M. Parsons. 2024. Spatial and seasonal foraging patterns drive diet differences among north Pacific resident killer whale populations. Royal Society Open Science 11:rsos240445.

Van den Brink, P. J., R. P. A. van Wijngaarden, W. G. H. Lucassen, T. C. M. Brock, and P. Leeuwangh. 1996. Effects of the insecticide Dursban 4E (active ingredient chlorpyrifos) in outdoor experimental ditches: II. Invertebrate community responses and recovery. Environmental Toxicology and Chemistry 15:1143-1153.

Vélez-Espino, L. A., J. K. B. Ford, H. A. Araujo, G. Ellis, C. K. Parken, and K. C. Balcomb. 2014. Comparative demography and viability of northeastern Pacific resident killer whale populations at risk (p.3084). Canadian Technical Report of Fisheries and Aquatic Sciences.

Venditti, D. A., A. Kohler, K. A. Apperson, A. Brimmer, B. Bowersox, C. Bretz, and J. Lockhart. 2008. Idaho Supplementation Studies. Brood Year 2005 Cooperative Report August 1, 2005 – July 31, 2007. Portland, Oregon. Prepared for U.S. Department of Energy, Bonneville Power Administration. IDFG Report Number 08-07.

Venturino, A., C. M. Montagna, and A. M. Pechen De D'Angelo. 2007. Risk assessment of magnacide® h herbicide at Río Colorado irrigation channels (Argentina). Tier 3: Studies on native species. Environmental Toxicology and Chemistry **26**:177.

Viant, M. R., Pincetich, C. A., and Tjeerdema, R. S. (2006). Metabolic effects of dinoseb, diazinon and esfenvalerate in eyed eggs and alevins of Chinook salmon (Oncorhynchus tshawytscha) determined by 1H NMR metabolomics. *Aquatic toxicology*, *77*(4), 359-371.

Vogel, J. R., M. J. Majewski, and P. D. Capel. 2008. Pesticides in rain in four agricultural watersheds in the United States. Journal of Environmental Quality. Journal of Environmental Quality 37:1101-1115.

Waite, D. T., R. Grover, N. D. Westcott, D. G. Irvine, L. A. Kerr, and H. Sommerstad. 1995. Atmospheric deposition of pesticides in a small southern Saskatchewan watershed. Environmental Toxicology and Chemistry **14**:1171 - 1175.

Walker, C. H., H.M. Thompson 1991. Phylogenetic distribution of cholinesterases and realted esterases. Chloinesterase-inhibiting insecticides: Their impact on wildlife and the environment. P. Mineau. New York, Elsevier. 2: 1-17.

Walters, A. W., Damon M. Holzer, James R. Faulkner, Charles D. Warren, Patrick D. Murphy and Michelle M. McClure (2012) Quantifying Cumulative Entrainment Effects for Chinook Salmon in a Heavily Irrigated Watershed, Transactions of the American Fisheries Society, 141:5, 1180-1190, DOI: 10.1080/00028487.2012.679019

Ward, S., A. H. Arthington, and B. J. Pusey. 1995. The effects of a chronic application of chlorpyrifos on the macroinvertebrate fauna in an outdoor artificial stream system - species responses. Ecotoxicology and Environmental Safety 30(1):2-23.

Ward, E. J., E. E. Holmes, and K. C. Balcomb. 2009. Quantifying the effects of prey abundance on killer whale reproduction. Journal of Applied Ecology. 46(3):632–40. https://doi.org/10.1111/j.1365-2664.2009.01647.x.

Ward, E. J., M. J. Ford, R. G. Kope, J. K. B. Ford, L. A. Velez-Espino, C. K. Parken, L. W. LaVoy, M. B. Hanson, and K. C. Balcomb. 2013. Estimating the Impacts of Chinook Salmon Abundance and Prey Removal by Ocean Fishing on Southern Resident Killer Whale Population Dynamics. July 2013. U.S. Dept. Commer., NOAA Tech. Memo., NMFS-NWFSC-123. 85p.

Wasser, S.K., J. I. Lundin, K. Ayres, E. Seely, D. Giles, K. Balcomb, J. Hempelmann, K. Parsons, and R. Booth. 2017. Population growth is limited by nutritional impacts on pregnancy success in endangered Southern Resident killer whales (*Orcinus orca*). PLOS One. 12(6):22. DOI: 10.1371/journal.pone.0179824.

WDFW. 2023. New legislation creates 1000-yard mandatory vessel buffer around endangered Southern Resident killer whales effective January 2025. [Press release]. https://wdfw.wa.gov/newsroom/news-release/new-legislation-creates-1000-yard-mandatory-vessel-buffer-around-endangered-southern-resident-killer

Weitkamp L. 2010. Marine Distributions of Chinook Salmon from the West Coast of North America Determined by Coded Wire Tag Recoveries, Transactions of the American Fisheries Society, 139:1, 147-170, https://doi.org/10.1577/T08-225.1

West, C. J., and P. Larkin. 1987. Evidence for size-selective mortality of juvenile sockeye salmon (Oncorhynchus nerka) in Babine Lake, British Columbia. Canadian Journal of Fisheries and Aquatic Sciences 44(4):712-721.

Williams, A. K., C. R. Sova. 1966. Acetylcholinesterase levels in brains of fishes from polluted waters. Bulletin of Environmental Contamination and Toxicology 1:198-204.

White, K., and Steeger, B. T. 2012. Risks of Diazinon Use to Federally Threatened Delta Smelt (Hypomesus transpacificus) and the Federally Endangered Tidewater Goby (Eucyclogobius newberryi).

WHO. 1998. Diazinon. World Health Organization, Geneva.

Wieben, C. M. 2021. Estimated annual agricultural pesticide use by major crop or crop group for states of the conterminous United States, 1992-2019 (including preliminary estimates for 2018-19): U.S. Geological Survey data release. USGS.

Young, W. P., and M. Busby. 2018. Chinook salmon (*Oncorhynchus tshawytscha*) Spawning Ground Surveys in the South Fork Salmon River and Big Creek; 1996-2016. Nez Perce Tribe, Department of Fisheries Resources Management, Lapwai, Idaho. 61 pp.

Zabel, R. W., and S. Achord. 2004. Relating size of juveniles to survival within and among populations of chinook salmon. Ecology 85:795-806.

Zinkl, J. G., P. J. Shea, et al. 1987. Brain cholinesterase activity of rainbow trout poisoned by carbaryl. Bulletin of Environmental Contamination and Toxicology 38:29-35.