Final Environmental Impact Statement Control of Burrowing Shrimp using Imidacloprid on Commercial Oyster and Clam Beds in Willapa Bay and Grays Harbor, Washington

Water Quality Program
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This report is available on the Department of Ecology's website at:
http://www.ecy.wa.gov/programs/wq/pesticides/imidacloprid/index.html

For more information contact:

Water Quality Program
P.O. Box 47600
Olympia, WA 98504-7600

Phone: 360-407-6600

Washington State Department of Ecology- www.ecy.wa.gov

o Headquarters, Olympia	360-407-6000
o Northwest Regional Office, Bellevue	425-649-7000
o Southwest Regional Office, Olympia	360-407-6300
o Central Regional Office, Yakima	509-575-2490
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Final Environmental Impact Statement (FEIS): Control of Burrowing Shrimp using Imidacloprid on Commercial Oyster and Clam Beds in Willapa Bay and Grays Harbor, Washington

Cover Memo

Environmental Review. Notice of availability of this Final Environmental Impact Statement (FEIS) is being sent to agencies, Tribes, organizations, land owners and lessees, other potentially affected land owners and lessees, and individuals who have expressed an interest in the Willapa-Grays Harbor Oyster Growers Association (WGHOGA) application to the Washington State Department of Ecology (Ecology) for a permit under the National Pollutant Discharge Elimination System (NPDES) to use the insecticide imidacloprid for the control of ghost shrimp (*Neotrypaea californiensis*) and mud shrimp (*Upogebia pugettensis*), collectively referred to as burrowing shrimp. The proposal is to apply imidacloprid on up to 2,000 acres *per year* of commercial shellfish beds[1] within Willapa Bay (up to 1,500 acres *per year*) and Grays Harbor (up to 500 acres *per year*), between the tidal elevations of -2 feet mean lower low water (MLLW) and +4 feet MLLW.

The FEIS, draft NPDES permit, and permit Fact Sheet are available in electronic format on Ecology's website: http://www.ecy.wa.gov/programs/wq/pesticides/imidacloprid

A concurrent 45-day comment period was provided for the Draft EIS and draft permit. Comments were due no later than 5:00 PM on **December 8, 2014**, addressed to:

Derek Rockett, Permit Writer
Washington State Department of Ecology
Water Quality Program
PO Box 47775
Olympia, WA 98504-7775
360-407-6697
e-mail: derek.rockett@ecy.wa.gov

Response to comments submitted within the 45-day comment period (October 24, 2014 through December 8, 2014) are included in the FEIS.

Availability of the Final EIS and Draft Permit. A limited number of printed copies of the FEIS, draft NPDES permit and permit Fact Sheet are available for review at Ecology's Water Quality Program office.

Permits and Approvals Required. State and Federal permits and registrations required for the chemical control of burrowing shrimp on commercial shellfish beds in Willapa Bay and Grays Harbor include: an NPDES Individual Permit/State Waste Discharge Permit, State registration of the imidacloprid products to be used, Federal registration of the imidacloprid products to be used (conditional registration issued by the U.S. Environmental Protection Agency, June 6, 2013), and applicators' licenses to be issued by the

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[1] As used throughout this Environmental Impact Statement in the context of alternatives to implement the proposed action, the term "commercial shellfish beds" refers to tidelands within Willapa Bay and Grays Harbor on which oysters and clams are commercially grown. The requested NPDES permit would not extend to other geographical areas and would not authorize treatment on other species of commercially-grown shellfish (e.g., geoducks or mussels).

State. The FEIS will be used by Ecology and other governmental agencies, along with other relevant considerations and documents, prior to taking action on the WGHOGA application.

The Proposed Action and Alternatives. Commercial shellfish growers have been investigating alternative methods for burrowing shrimp control since the 1950s. These have included mechanical means, alternative shellfish culture methods, a variety of chemical applications, and biological controls, none of which has proven to be as effective, reliable, economical, or more species-specific than carbaryl or imidacloprid applications administered with adaptive management principles. Carbaryl has been used for burrowing shrimp control in Willapa Bay and Grays Harbor since 1963. The FEIS includes a section that describes the other alternative practices in detail, though these are not evaluated in the FEIS since they would not accomplish the primary objective of the proposal; i.e., to control burrowing shrimp on commercial shellfish beds in these two estuaries. At the time of this writing, since there are no known alternatives to chemical applications for this purpose, the FEIS evaluates three alternatives:

- ALTERNATIVE 1: No Action – No Permit for Insecticide Applications.
- ALTERNATIVE 2: Continue Historical Management Practices – Carbaryl Applications with Integrated Pest Management (IPM).
- ALTERNATIVE 3: Imidacloprid Applications with Integrated Pest Management (IPM) – the Preferred Alternative.

Key Environmental Issues. Ecology's NPDES permit decision must comply with the regulations of the Washington State Surface Water Quality Standards. These standards were used to guide the selection of elements of the environment to be addressed in the Imidacloprid EIS: sediments, air quality, surface water, plants, animals, human health, land and shoreline use, recreation, and navigation. The FEIS Table of Contents includes a detailed list of the plant and animal groups for which potential impacts and mitigation measures are evaluated. FEIS Chapter 1 includes a section that lists Areas of Controversy and Uncertainty, and Issues to be Resolved.

Ecology's Water Quality Program appreciates your interest in this proposal. If you would like more information about the burrowing shrimp control proposal and/or the environmental review that has been conducted, please contact Derek Rockett, Permit Writer, his contact information is provided above. Additional information regarding the environmental review process and public involvement opportunities is provided in FEIS Chapter 1, Section 1.3.

Heather R. Bartlett
Heather R. Bartlett
Water Quality Program Manager

Date: 4/9/15

Readers' Guide for this Final EIS

An Environmental Impact Statement (EIS) attempts to strike a balance between the technical information and format required by the State Environmental Policy Act (SEPA), and readability for persons interested in the proposed action who may be unaccustomed to this manner of organizing the document. The Readers' Guide summarizes the content of this Final EIS (FEIS), and suggests locations where information of interest can most readily be found.

Information in this FEIS was drawn from a variety of sources and the citations provided come from research that was performed and ranges from dissertations, to information in scientific journals, to a response to shellfish industry concerns. Citations can be grouped into three categories reflecting various levels of scientific rigor:

1) Peer reviewed and published scientific journal articles.
2) Grey literature, which includes: Agency technical reports, consulting company white papers, websites, and unpublished study results.
3) Anecdotal observations and personal communications.

The **Table of Contents** provides a complete list of the subjects covered in the document. Lists of figures and tables can also be used to locate topics of interest.

For ease of reference while reviewing the FEIS, a **List of Symbols, Acronyms, and Units of Measure** is provided following the Table of Contents to define abbreviations for the numerous agencies, regulations, and scientific terms that occur in the description of the proposed action and impact analysis.

Chapter 1 introduces the purpose for the proposed action, briefly describes the alternatives evaluated, and summarizes the potential impacts of and mitigation measures for each alternative in the context of the elements of the environment evaluated in Chapter 3. Chapter 1 also includes an overview of SEPA procedures and public involvement opportunities during the environmental review process. Near the end of Chapter 1, there is a description of areas of controversy and uncertainty, and issues to be resolved with regard to the proposed use of imidacloprid for burrowing shrimp control on commercial shellfish beds (i.e., areas where oysters and clams are grown) in Willapa Bay and Grays Harbor. Readers are encouraged to review more detailed information in Chapters 2 and 3 on topics summarized in Chapter 1 to gain a more complete, "in-context" understanding of the issues.

Burrowing shrimp control on commercial shellfish beds in Willapa Bay and Grays Harbor, Washington has a long history, described in **Chapter 2**. Numerous alternatives to chemical control have been tried. These are described in detail in Chapter 2. The historical practice of carbaryl applications for burrowing shrimp control is presented as an alternative to the proposed imidacloprid applications, as well as a no action alternative in which there would be no permit for pesticide applications within these two estuaries.

Chapter 3 is the discussion of the environmental information presented in the FEIS. This chapter describes existing conditions for Sediments, Air Quality, Surface Water, Plants, Animals, Human Health, Land Use, Recreation, and Navigation within Willapa Bay and Grays Harbor; evaluates potential impacts to these elements of the environment; and lists mitigation measures for the optional scenarios of the two action alternatives. Existing environmental conditions are described under the heading *Affected Environment*. Following the description of the environmental setting, *Potential Impacts* are described for the three alternatives evaluated in this FEIS. Each impact analysis is followed by a description of proposed and required *Mitigation Measures* that would be implemented to avoid or minimize potentially adverse impacts of pesticide applications for burrowing shrimp control.

Chapter 4, References, provides a comprehensive list of information sources used to prepare the FEIS. Information in this FEIS was drawn from a variety of sources, as described in paragraph two of this Reader's Guide

The Distribution List provided in **Chapter 5** is a list of agencies, Tribes, cities and counties, Port districts, organizations and individuals who have indicated an interest in the proposed action. The list includes persons who spoke at the EIS Scoping meeting, and persons who submitted written comments during the EIS Scoping period. The Distribution List also identifies local area newspapers to whom the Notice of Availability was sent, and local area libraries where printed copies of the document are available for review.

Appendices to the FEIS include Federal conditional registrations that have been issued by the U.S. Environmental Protection Agency for the use of imidacloprid, and species lists for birds, benthic invertebrates and fish that occur within Willapa Bay and Grays Harbor.

Ecology's contact person regarding the proposed issuance of the NPDES individual permit and this Environmental Impact Statement is Derek Rockett, Permit Writer. His address, telephone number, and e-mail address are provided in the Cover Memo that precedes this Reader's Guide. Notice of availability of the FEIS will be sent to all affected agencies, Tribes, organizations, and interested parties.

Fact Sheet

Project Title: **Proposed Use of Imidacloprid for Burrowing Shrimp Control on Commercial Oyster and Clam Beds in Willapa Bay and Grays Harbor, Washington**

Brief Description of the Proposed Action: Two native species of burrowing shrimp (ghost shrimp, *Neotrypaea californiensis* and mud shrimp, *Upogebia pugettensis*) have caused impacts to Pacific Coast commercial clam and oyster production since at least the 1940s by disrupting the structure and composition of the substrate, causing these shellfish to sink and suffocate. Between 1963 and 2013, commercial shellfish growers in Willapa Bay and Grays Harbor, Washington used the N-methyl carbamate insecticide carbaryl to control burrowing shrimp. The Willapa-Grays Harbor Oyster Growers Association (WGHOGA) is now seeking permit approval to use the neonicotinoid insecticide imidacloprid as a replacement for carbaryl for burrowing shrimp control in the aquatic environment of these two estuaries.

Growers use decision criteria to decide whether and when to treat a commercial shellfish bed for burrowing shrimp control. Before applying to Ecology for treatment through an Annual Operations Plan, growers consider factors such as crop cycles, whether the bed can sustain the crop without loss, whether the bed needs to be treated to sustain the crop for the period of time it will occupy this bed, the life stage and population level of burrowing shrimp in the shellfish bed of concern, and other physical and biological conditions at each site. Their assessment correlates directly to shrimp density and the activity of the burrowing shrimp that are present. Not all actively-farmed beds will be treated over the 5-year term of the NPDES permit, and the conditional Federal registrations prohibit any bed from being treated more than once per year.

Purpose and Objectives: WGHOGA has requested issuance of a NPDES permit for the purpose of allowing chemical applications of imidacloprid on up to 2,000 acres *per year* of commercial shellfish beds: approximately up to 1,500 acres *per year* within Willapa Bay, and up to 500 acres *per year* within Grays Harbor. The proposed action covers only these two geographic areas within Washington State, and only commercial shellfish beds on which oysters and clams are grown. It is possible that over the five-year term of the permit, the total acreage to be treated within Willapa Bay could range from 1,500 to 7,500 acres, and within Grays Harbor could range from

500 to 2,500 acres. Growers would apply imidacloprid within the annual acreage limits in each bay based on case-by-case decisions, with the result that they anticipate the upper limits of these ranges would not likely be reached.

Imidacloprid applications would be made using adaptive management principles, as described in an Integrated Pest Management (IPM) Plan to be reviewed by Ecology. The objectives of the proposed action are to:

- Preserve and maintain the viability of shellfish commercially grown in Willapa Bay and Grays Harbor by controlling populations of two species of burrowing shrimp on commercial oyster and clam beds.
- Preserve and restore selected commercial oyster and clam beds in Willapa Bay and Grays Harbor that are at risk of loss due to sediment destabilization caused by burrowing shrimp.

Principal Alternatives:

Commercial shellfish growers have been investigating alternative methods for burrowing shrimp control since the 1950s. These have included mechanical means, alternative shellfish culture methods, various chemical applications, and biological controls, none of which has proven to be as effective, reliable, economical, or more species-specific than carbaryl or imidacloprid applications administered with adaptive management principles.

At the time of this writing, since there are no known alternatives to chemical applications to effectively control burrowing shrimp, this EIS evaluates three alternatives:

ALTERNATIVE 1: No Action – No Permit for Pesticide Applications.

ALTERNATIVE 2: Continue Historical Management Practices – Carbaryl Applications with Integrated Pest Management (IPM).

ALTERNATIVE 3: Imidacloprid Applications with Integrated Pest Management (Preferred Alternative).

The FEIS also includes a section that describes Alternatives Considered and Eliminated from Detailed Evaluation.

Project Proponent:

Willapa-Grays Harbor Oyster Growers Association
PO Box 3
Ocean Park, WA 98640

Schedule for Implementation:	The target date for completion of the EIS and issuance of the NPDES Individual Permit is Spring 2015.
Lead Agency:	Washington State Department of Ecology Water Quality Program 300 Desmond Drive PO Box 47775 Olympia, WA 98504-7775
SEPA Responsible Official:	Heather R. Bartlett, *Program Manager* Water Quality Program
Project Information Contact Person, And Person to Whom Comments are to be Directed:	Derek Rockett, *Permit Writer* 360-407-6697 e-mail: derek.rockett@ecy.wa.gov
Permits and Registrations Required:	The list below identifies State and Federal permits and registrations required for the chemical control of burrowing shrimp on commercial oyster and clam beds in Willapa Bay and Grays Harbor, Washington. Local government requirements may vary for a particular commercial shellfish site or operation.
Washington State Department of Ecology	NPDES Individual Permit/State waste discharge permit and Sediment Impact Zone application
Washington State Department of Agriculture	– State registration of the imidacloprid products Protector 0.5G (granular form) and Protector 2F (flowable form) under the requirements of the Washington Pesticide Control Act (RCW 15.58). Experimental Use Registration issued July 3, 2014 through 2015. – Applicators' licenses for aquatic application of registered pesticides.
U.S. Environmental Protection Agency	Federal registration of imidacloprid products Protector 0.5G (granular form) and Protector 2F (flowable form) under the requirements of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). Conditional FIFRA registrations issued June 6, 2013; see FEIS Appendix A.
Local Government(s):	Shoreline Permit (possible in some locations, though not usually required under local Shoreline Master Programs)
EIS Authors and Principal Contributors:	Hart Crowser, *EIS Prime Consultant* Jeff Barrett, *Principal Scientist* Adrienne Stutes, *Technical Team Project Manager and Co-Author* **Vicki Morris Consulting Services**

Vicki Morris, *EIS Project Manager and Co-Author*

Hart Crowser Technical Team
Adrienne Stutes: *Sediments, Air Quality, and Surface Water Quality*
Diane Hennessey: *Plants*
Jamey Selleck: *Animals, and Threatened and Endangered Species*
Roger McGinnis: *Human Health*

Draft EIS Date of Issue: October 24, 2014

Draft EIS Comment Period (45 days): October 24 – December 8, 2014

Date of Public Meeting: Ecology held a public meeting in the local area on December 2, 2014.

Comments on the Draft EIS Due: 5:00 p.m., December 8, 2014

Availability of Copies of the Draft EIS: Everyone on the Distribution List (Chapter 5) was sent a Notice of Availability of the Draft EIS. A limited number of printed copies of the Draft EIS are available for review at Ecology's Water Quality Program Office, for which the address is provided above. The document is also posted on Ecology's website for review: http://www.ecy.wa.gov/programs/wq/pesticides/imidacloprid

Address Comments to:
Derek Rockett, *Permit Writer*
Washington State Dept of Ecology
Water Quality Program
PO Box 47775
Olympia, WA 98504-7775
e-mail: derek.rockett@ecy.wa.gov

Next Steps in the EIS Process: Following the close of the Draft EIS comment period, Ecology will review and respond to all comments received. Comments and responses will be published in the Final EIS. Everyone on the Draft EIS Distribution List (Chapter 5), and persons who comment on the Draft EIS will receive Notice of Availability of the Final EIS.

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List of Symbols, Acronyms and Units of Measure

>	greater than
<	less than
ADA	Americans with Disabilities Act
AGR	Agriculture (Washington Department of)
a.i./ac	active ingredient per acre
ALS	acetolactate synthesis
AMBS	Area of Marine Biological Significance
AOP	Annual Operations Plan
BMPs	Best Management Practices
CCME	Canadian Council of Ministers of the Environment
cm	centimeter
commercial shellfish beds	commercial oyster and clam beds in Willapa Bay and Grays Harbor, WA
Corps	U.S. Army Corps of Engineers
CNS	central nervous system
CSI	Compliance Services International
CWA	Clean Water Act
DIN	dissolved inorganic nitrogen
DMMU	Dredge Material Management Units
DO	dissolved oxygen
DOC	dissolved organic carbon
DOH	Washington Department of Health
DPS	distinct population segment
ECY/Ecology	Washington State Department of Ecology
EFED	Environmental Fate and Ecological Risk Assessment
EFH	Essential Fish Habitat
EIS	Environmental Impact Statement
ENVIRON	ENVIRON International Corporation
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
EUP	Experimental Use Permit
FFDCA	Federal Food, Drug, and Cosmetic Act
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FLUPSY	floating upwelling systems

FQPA	Food Quality Protection Act
GHCPHSSD	Grays Harbor County Public Health and Social Services Department
GPS	global positioning system
GRAS	Generally-Recognized-As-Safe
IPM	Integrated Pest Management
KCl	potassium chloride
kg	kilogram
KMnO4	potassium permanganate
lbs/a.i./ac	pounds of active ingredient per acre
LC50	lethal concentration
LD50	lethal dose
m	meter
mg	milligram
µg/L	milligrams per liter
MgCl2	magnesium chloride
MHHW	Mean Higher High Water
MLLW	Mean Lower Low Water
MOA	Memorandum of Agreement
MRC	Marine Resources Committee
NAAQS	National Ambient Air Quality Standards
nAChR	nicotinergic acetylcholine receptors
NaCl	sodium chloride
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOAEL	No Observed Adverse Effects Level
NOEL	No Observed Effects Level
NPDES	National Pollutant Discharge Elimination System
NPWRC	Northern Prairie Wildlife Research Center
NWP	Nationwide Permit
OHWL	Ordinary High Water Line
ORP	oxidation reduction potential
PCPHHSD	Pacific County Public Health and Human Services Department
PPE	personal protective equipment
PSAT	Puget Sound Action Team
PSI	Pacific Shellfish Institute

PSU	practical salinity units
PVC	polyvinylchloride
RCW	Revised Code of Washington
RfD	reference dose
SAIC	Science Applications International Corporation
SEPA	Washington State Environmental Policy Act
SIZ	Sediment Impact Zone
SMA	Washington State Shoreline Management Act
SMP	Shoreline Master Program
SMS	Sediment Management Standards
SPD	Shellfish Protection District
SPN	Special Public Notice
TCDD	tetrachlorodibenzo-p-dioxin
TMDL	Total Maximum Daily Load
TOC	total organic carbon
TWQMO	Temporary Water Quality Modification Order
USACE	U.S. Army Corps of Engineers
U.S.C.	U.S. Code
USDI	U.S. Department of the Interior
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WAC	Washington Administrative Code
WDC	Washington State Department of Commerce
WDF	Washington Department of Fisheries
WDFW	Washington State Department of Fish and Wildlife
WDNR	Washington State Department of Natural Resources
WGHOGA	Willapa-Grays Harbor Oyster Growers Association
WLA	waste load allocations
WPS	Worker Protection Standard
WQC	Water Quality Certification
WRA	Wildlife Recreation Area
WSDA	Washington State Department of Agriculture
WSNWCB	Washington State Noxious Weed Control Board
WSU	Washington State University

1.0 Summary

1.1 Introduction and Problem Formulation

Since at least the 1940s, two native species of burrowing shrimp (ghost shrimp, *Neotrypaea californiensis* and mud shrimp, *Upogebia pugettensis*) have caused impacts to Pacific Coast commercial clam and oyster production by disrupting the structure and composition of the substrate, causing these shellfish to sink and suffocate. Until recently, commercial shellfish growers in Willapa Bay and Grays Harbor, Washington, have used the N-methyl carbamate insecticide "carbaryl" to control burrowing shrimp. The Willapa-Grays Harbor Oyster Growers Association (WGHOGA) is now seeking permit approval to use the neonicotinoid insecticide[1] "imidacloprid" as a replacement for carbaryl for burrowing shrimp control in the aquatic environment of these two estuaries. The U.S. Environmental Protection Agency (EPA) issued conditional registrations on June 6, 2013 for the use of liquid (i.e., "flowable") and granular forms of imidacloprid (Protector 2F and Protector 0.5G, respectively) on commercial shellfish beds[2] in Willapa Bay and Grays Harbor. In order for these products to be used in Washington, they also require a Washington State Department of Agriculture (WSDA) registration, a NPDES permit, and Sediment Impact Zone approval from Ecology. The WSDA registration was approved on July 3, 2014, subject to renewal in 2016. Ecology's NPDES permit decision requires environmental review under the Washington State Environmental Policy Act (SEPA). Therefore, the purpose of this Environmental Impact Statement (EIS) is to evaluate the potential impacts of the proposed action and alternatives, and to describe mitigation measures that could avoid or minimize potential adverse effects.

1.2 Purpose and Objectives of the Proposed Action

WGHOGA has requested issuance of a NPDES permit for the purpose of allowing chemical applications of imidacloprid on up to 2,000 acres per year of shellfish beds on which clams and oysters are commercially grown: up to 1,500 acres per year in Willapa Bay, and up to 500 acres per year in Grays Harbor. These applications would be made using adaptive management principles, as described in an Integrated Pest Management (IPM) Plan to be reviewed by Ecology. The objectives of the proposed action are to:

Preserve and maintain the viability of clams and oysters commercially grown in Willapa Bay and Grays Harbor by controlling populations of two species of burrowing shrimp on commercial shellfish beds.

Preserve and restore selected commercial shellfish beds in Willapa Bay and Grays Harbor that are at risk of loss due to sediment destabilization caused by burrowing shrimp.

1.3 SEPA Procedures and Public Involvement

Ecology issued a scoping notice for the Imidacloprid EIS on December 18, 2013. The scoping notice was mailed to government agencies, Tribes, organizations, and interested individuals, and posted on Ecology's

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[1] Neonicotinoids are a class of neuro-active insecticides chemically similar to nicotine. Neonicotinoids were developed in large part because they show reduced toxicity compared to previously used organophosphate and carbamate insecticides. Most neonicotinoids show much lower toxicity in birds and mammals than insects, but some breakdown products are toxic (Lee Chao and Casida 1997, as cited in http://en.wikipedia.org/wiki/Neonicotinoid, September 14, 2014). The neonicotinoid imidacloprid is currently the most widely used insecticide in the world (Yamamoto 1999, as cited in http://en.wikipedia.org/wiki/Neonicotinoid, September 14, 2014).

[2] As used throughout this Environmental Impact Statement in the context of alternatives to implement the proposed action, the term "commercial shellfish beds" refers to tidelands within Willapa Bay and Grays Harbor on which oysters and clams are commercially grown. The requested NPDES permit would not extend to other geographical areas and would not authorize treatment on other species of commercially-grown shellfish (e.g., geoducks or mussels).

website. The notice announced a public comment period on the scope of the EIS between the dates of January 2, 2014, and February 15, 2014, and gave notice of a public meeting to be held for the purpose of receiving comments on the scope of the EIS.

The public meeting was held at the Willapa Harbor Community Center in South Bend, Washington, on February 1, 2014 from 10:00 a.m. to 2:00 p.m. Approximately fifty persons attended. Eleven persons gave recorded testimony at the public meeting.

Written comments on the scope of the EIS were received from the Quinault Nation, two Federal agencies, one State agency, the Board of Pacific County Commissioners, Port of Willapa Harbor, WSU Long Beach Research and Extension Unit, five organizations, six shellfish growers, and approximately twenty-five interested individuals. These comments were reviewed and organized by the EIS Team, and were used to guide the content of Draft EIS preparation. For scoping comments and additional information, you can visit the following website: http://www.ecy.wa.gov/programs/wq/pesticides/imidacloprid.

Ecology issued the Draft EIS for a 45-day public comment period (October 24 – December 8, 2014). These comments were reviewed and responses are included in the Final EIS. Ecology will consider comments received when making the permit decision on the application for a NPDES permit to allow the use of imidacloprid to treat burrowing shrimp on a limited acreage of commercial shellfish beds in Willapa Bay and Grays Harbor. Interested individuals can track the progress of the permit decision on Ecology's website.[3]

1.4 Description of the Proposed Action

WGHOGA has applied to Ecology for issuance of a NPDES Individual Permit to use the neonicotinoid insecticide imidacloprid on up to 2,000 acres *per year* of commercial shellfish beds in two Pacific Coast estuaries: up to 1,500 acres *per year* in Willapa Bay (approximately 3.3 percent of total tideland area exposed at low tide),[4] and up to 500 acres *per year* in Grays Harbor (approximately 1.5 percent of total tideland area exposed at low tide).[5] The proposal covers only these two geographic areas, and the requested permit (if issued) would authorize applications only on commercial shellfish beds where clams and oysters are the primary crop. The term of an NPDES Permit is typically five years. During years two through five of the permit, sprayed tideland acreage may include repeat spraying of some commercial shellfish beds treated in previous years, and some commercial shellfish beds not previously sprayed, depending on shellfish grower plans for their nursery beds, seed beds, and grow-out sites; the efficacy of prior treatments; and the burrowing shrimp population level each year. The application rate, maximum annual acreage, treatment schedule, shrimp presence criteria, Best Management Practices, monitoring requirements, and safety precautions would be specified in the permit.

Growers use an array of information to decide if and when they should treat a commercial shellfish bed. Before applying for treatment, they consider crop cycles, whether the bed can sustain the crop without loss, or whether the bed needs to be treated to sustain the crop for the period of time it will occupy this bed. The assessment correlates directly to shrimp density and the activity of the burrowing shrimp that are

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[3] http://www.ecy.wa.gov/programs/wq/pesticides/imidacloprid

[4] The total area of tide flats exposed on low tide in Willapa Bay is approximately 45,000 acres. Of this acreage, approximately 25,562 acres of tidelands are owned or leased for commercial shellfish aquaculture (NMFS, April 28, 2009), and 9,000 acres are currently farmed for the commercial production of oysters and clams (CSI 2013).

[5] The total area of tide flats exposed on low tide in Grays Harbor is approximately 34,460 acres. Of this acreage, approximately 3,995 acres of tidelands are owned or leased for commercial shellfish aquaculture within Grays Harbor: 3,088 acres in North Bay and 907 acres in South Bay (NMFS, April 28, 2009). Approximately 900 acres of Grays Harbor tidelands are currently farmed for the commercial production of oysters and clams (CSI 2013).

present. If shrimp are causing lots of sediment disturbance, the crop will begin to be lost immediately after planting. With recent high levels of recruitment, growers are also observing that juvenile burrowing shrimp activity can be equally or more damaging to the substrate than the more easily observed adults (personal communications with WGHOGA members, May 28, 2014 and July 30, 2014). If a grower determines that a bed needs to be treated to protect their shellfish crop, they identify the bed in the Annual Operations Plan submitted to Ecology. The bed is then assessed based on the treatment threshold specified in the permit. This threshold is based on the following empirical decision tree that was developed through integrated pest management (B.R. Dumbauld et al. / Aquaculture 261 (2006) 976-992)

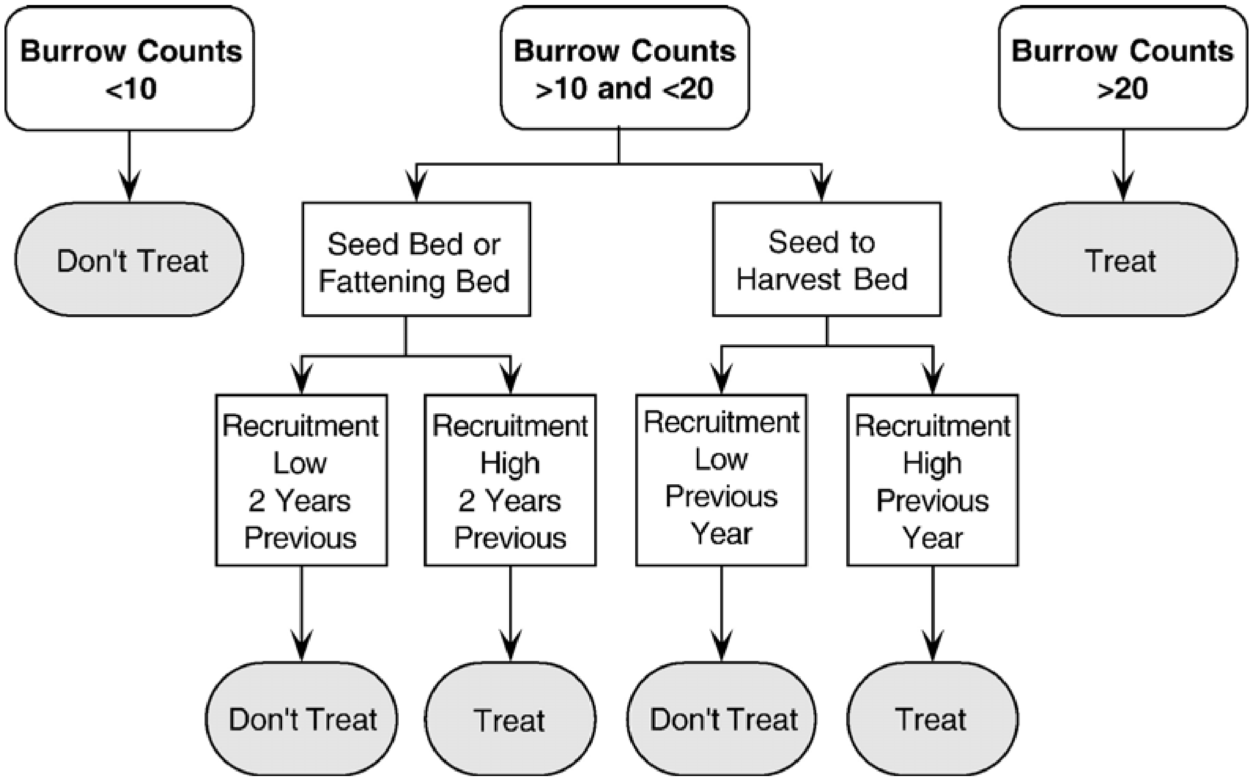

Figure 1.4-1 – Burrow Threshold

The imidacloprid proposal differs from the carbaryl 2006 permit (WA0040975) in total tideland acreage that could be treated each year, and includes treatment of areas primarily grown with commercial clams as well as commercial oysters. Growers report that the 800 acre allowance under the carbaryl permit was not sufficient in years when there was significant recruitment of burrowing shrimp. Some beds that met the carbaryl treatment threshold of ten burrows per square meter went untreated. Growers had to adjust their treatment plans to focus only on beds most in need of treatment. Burrowing shrimp populations are cyclic and are currently beginning to greatly increase in numbers. The purpose for the larger acreage requested under the imidacloprid permit is to address this current trend of high recruitment, the inclusion of areas primarily grown with commercial clams to the tidelands authorized for treatment, and what currently appears to be the reduced effectiveness of imidacloprid compared to carbaryl. Growers anticipate that, at least initially, it may be necessary to treat beds more frequently with imidacloprid than carbaryl to protect the same areas (personal communication with a WGHOGA member, May 28, 2014).[6]

[6] FEIS Section 2.8.2 reports that once a bed has been treated with carbaryl, it typically does not need to be treated again for another 3 to 7 years, depending on the level of shrimp larvae recruitment and lateral movement of adults from neighboring tide flats to the treated bed area. While imidacloprid treatments may be more frequent on some beds, in no case would treatment exceed the once per year restriction under the FIFRA Registration.

There is statutory authority for commercial shellfish beds within Willapa Bay and Grays Harbor to grow oysters, clams, and other commercial shellfish species recognized by the State (see, for example, RCW 79.135.010). Their productivity and commercial appeal results in oysters and Manila clams often being the preferred species for growers,[7] but all of these beds support several species of shellfish at some level (personal communication with WGHOGA member, July 30, 2014). Factors that contribute to a grower's decision about how to effectively use the ground he owns and/or leases include market demand, natural set (recruitment) potential, the cost and availability of seed shellfish, and any substrate augmentation requirements (e.g., addition of oyster shells) needed to support the crop (personal communication with WGHOGA member, July 31, 2014). Some clam beds have either functioned directly as oyster beds in the past, or had oysters as a secondary crop. With low burrowing shrimp recruitment over the past ten years or so, it has been possible to farm some of these beds without shrimp control. However, due to the recent large recruitments of burrowing shrimp in Willapa Bay and Grays Harbor, growers are now seeing high shrimp densities in substrate without distinction by crop. Growers report that the threshold for treatment on areas where clams are primarily or exclusively grown is the same as areas where oysters are grown; i.e., they begin to lose clams at the same shrimp density (adult or juvenile) as that which adversely affects oysters. The effect of liquefied sediments is not crop-specific—both clams and oysters sink and suffocate in these conditions (personal communications with WGHOGA members, May 28, 2014, and July 30, 2014; also see DeFrancesco and Murray 2010). Hard-shelled Manila clams that are cultured in Willapa Bay and Grays Harbor are not as capable of adjusting their position within sediment as soft-shell clams (personal communication with a WGHOGA member, July 31, 2014). Another explanation for the effect of burrowing shrimp activity on clams relates to their feeding methods. Manila clams feed by extending their incurrent siphon to the sediment/water interface and drawing in sea water to filter out phytoplankton. Burrowing shrimp compete for the same food source, churn sediments and excrete waste at the sediment/ water interface, all of which causes clams to use more energy to select and separate-out useable food from unusable organic debris and excretory products. Energy expended for this process results in slower clam growth and lower survival (personal communication with WGHOGA member, July 31, 2014).

Given similar impacts to clams and oysters from burrowing shrimp, the efficacy of chemical treatments to control burrowing shrimp on shellfish beds would be monitored and assessed in the same manner, regardless of shellfish type present (clam and/or oyster), based on juvenile and adult burrowing shrimp density following treatment. For all of these reasons, commercial shellfish growers make no distinction by crop as it relates to burrowing shrimp control.

1.5 Alternatives Considered

Commercial shellfish growers have been investigating alternative methods for burrowing shrimp control since the 1950s. These have included mechanical means, alternative shellfish culture methods, and various chemical applications. None of these approaches has proven to be as effective or practical than chemical application with carbaryl or imidacloprid administered with adaptive management principles[8] Methods that are ineffective at controlling burrowing shrimp would not meet the objectives of the

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7 Clams are generally higher in the intertidal simply because this often tends to be an area where oysters are unable to remain on the substrate due to movement by wind and wave action that pushes them up onto the beach. Some growers utilize small, odd-shaped areas less than an acre or two in size for clam cultivation because these areas are difficult or impossible to access by larger work boats for oyster culture. Clam areas are often selected for easy access by land or skiff since they are harvested by hand; however, none of these areas is exclusively designated for clam cultivation (personal communication with WGHOGA members, July 30 and July 31, 2014).

8 Adaptive management principles include such things as optimum timing for pesticide applications in relation to the life cycle and activity of burrowing shrimp, bed conditions, application timing in relation to tidal conditions, frequency of bed treatment, etc.

proposal, and therefore are by definition under the Washington State Environmental Policy Act (SEPA) not reasonable for analysis in the EIS (WAC 197-11-440[5]). Research into alternative methods of control would continue under the imidacloprid NPDES Individual Permit if the requested permit is issued.

At the time of this writing, since there are no known alternatives to chemical applications to effectively control burrowing shrimp, this EIS evaluates three alternatives:

- ALTERNATIVE 1: No Action – No Permit for Pesticide Applications.
- ALTERNATIVE 2: Continue Historical Management Practices – Carbaryl Applications with Integrated Pest Management (IPM).
- ALTERNATIVE 3: Imidacloprid Applications with Integrated Pest Management (IPM) – the Preferred Alternative.

The potential environmental impacts of each alternative and draft mitigation measures[9] are described in FEIS Chapter 3. Ecology will use the EIS to inform their decision regarding whether to issue the permit, and if so, appropriate mitigation requirements to impose for the proposed insecticide applications.

FEIS Chapter 2 includes a section (2.8.4) that describes other Alternatives Considered and Eliminated from Detailed Evaluation. Experimentation with methods that do not include the use of insecticides has been tried over a period of decades. These have been found to be ineffective, and/or impractical for use on the scale of hundreds (to thousands) of acres of commercial shellfish beds in Willapa Bay and Grays Harbor. Since ineffective or unreasonable alternatives would not achieve the objectives of the proposal, these are not evaluated in FEIS Chapter 3.

1.5.1 Alternative 1, No Action: No Permit for Pesticide Applications

SEPA requires the EIS to evaluate the effects of the No Action Alternative, which is typically defined as maintaining the status quo, or no change from existing conditions. In the case of burrowing shrimp control on commercial shellfish beds in Willapa Bay and Grays Harbor, insecticide applications using carbaryl (trade name Sevin)[10] have been used since 1963. Continuing that practice is evaluated as Alternative 2. For this reason, the EIS evaluates a No Action Alternative in which Ecology would revoke the current NPDES permit for carbaryl applications, and would not issue the requested NPDES Individual Permit for imidacloprid applications.

Under this scenario (Alternative 1), there would be no permit authorizing insecticide applications in Willapa Bay or Grays Harbor for the control of burrowing shrimp. Commercial shellfish growers would only be able to utilize mechanical methods and alternative shellfish culture practices. Therefore, under Alternative 1, most productive clam and oyster grounds would be expected to decline over the next 4 to 6 years. However, some limited areas may continue to produce clams and oysters in size and numbers close to present levels. The economic impacts of a significant decline in the commercial shellfish industry are described in Chapter 2, Section 2.6. Ecosystem changes that would result from a significant increase in burrowing shrimp populations and significant reductions in shellfish (bivalve) populations are evaluated

9 Integrated Pest Management measures and Best Management Practices for the use of imidacloprid will be defined as conditions of the NPDES Individual Permit, if issued. These had not yet been formulated at the time of this writing.

10 The trade name Sevin expired 12/31/13 with the Section 24(C) Special Local Need Label (NovaSource 2012).

under elements of the Affected Environment in FEIS Chapter 3. For more information you can also refer to Chapter 2.8.1.

1.5.2 Alternative 2, Continue Historical Management Practices: Carbaryl with Integrated Pest Management (IPM)

The primary burrowing shrimp management practice used by Willapa Bay and Grays Harbor shellfish growers, between 1963 and 2013, has been chemical treatment with the n-methyl carbamate insecticide carbaryl, applied at a rate of 8 pounds of active ingredient per acre between July 1 and October 31 (Section 2.8.2). Permit conditions strictly control such parameters as the timing, location, quantity, and methods of chemical applications for precise delivery; the substrate condition and density of burrowing shrimp populations that warrants treatment; frequency of application to individual beds; and the anticipated shellfish management use of the bed following treatment.

For the purpose of environmental review in this EIS, it is assumed that a new or modified permit to allow the use of carbaryl for burrowing shrimp control under Alternative 2 would include the same or similar conditions and restrictions to those in the 2006 Carbaryl NPDES Individual Permit. It would be necessary for WGHOGA to renew the registrations for carbaryl. For consistency in comparing the potential environmental effects of Alternative 3, the EIS assumes that areas grown primarily or exclusively with clams as well as oysters could be treated under Alternative 2. If Alternative 2 were selected, these conditions and restrictions could be subject to change. If all approvals for continued use of carbaryl could not be obtained, Alternative 2 would not achieve the objectives of the proposal, and it could not be implemented. For more information refer to 2.8.2.

1.5.3 Alternative 3, Imidacloprid Applications with Integrated Pest Management (Preferred Alternative)

Under Alternative 3, the existing practice of carbaryl applications on commercial oyster grounds in Willapa Bay and Grays Harbor would be discontinued, and a new NPDES Individual Permit would be issued authorizing chemical applications of the neonicotinoid insecticide imidacloprid for burrowing shrimp control on a limited annual acreage of commercial shellfish beds. The NPDES permit would be conditioned to protect State resources. WGHOGA would be required to prepare an Integrated Pest Management (IPM) Plan for the use of imidacloprid, and to submit Annual Operations Plans for proposed treatments for review and approval by Ecology. The conditional Federal registrations for the imidacloprid products Protector 0.5G and Protector 2F limit the application rate to 0.5 (one-half) pound of active ingredient per acre and specify an application period between April 15 and December 15.

Growers have requested larger annual treatment acreage under the imidacloprid permit (2,000 acres) compared to the carbaryl permit (800 acres). It is possible that over the five-year term of the permit, the total acreage to be treated within Willapa Bay could range from 1,500 to 7,500 acres, and in Grays Harbor could range from 500 to 2,500 acres. Growers would apply imidacloprid within the annual acreage limits in each bay (1,500 acres in Willapa Bay and 500 acres in Grays Harbor). Based on factors such as assessments of shrimp density and treatment effectiveness, growers anticipate the upper limits of these ranges would not likely be reached.

Under the imidacloprid permit, growers would continue to experiment with alternative physical, biological, and/or chemical control methods that are as species-specific (to burrowing shrimp) as possible, practical on a commercial scale, economical, reliable, and environmentally responsible. The imidacloprid program and experimental practices would be reviewed by Ecology over the five-year duration of the proposed permit as part of their consideration of future practices for burrowing shrimp control. For more information, refer to Chapter 2.8.

1.5.4 Other Alternatives Considered and Eliminated from Detailed Evaluation

The EIS includes a discussion of other alternatives to control burrowing shrimp that were eliminated from detailed evaluation because they would not meet the objective of adequately controlling such shrimp on commercial shellfish grounds (Section 2.8.4). Much of this discussion was derived from a 2002 WGHOGA Burrowing Shrimp Control Committee Annual Report that included an excerpt from a draft manuscript titled *Alternative Control and Management Techniques for Burrowing Shrimp in Oyster Culture Operations: A Summary and Prioritized Listing* (Harbell and Dewey). The summary list was prepared from two days of presentations and discussions at the conference regarding Alternative Methods for Managing Burrowing Shrimp in Pacific Northwest Estuaries, held March 28–29, 2002 in Long Beach, Washington. It describes alternatives tried or considered for the control of burrowing shrimp to replace chemical control using carbaryl or imidacloprid. Some, but not all of the descriptions in FEIS Chapter 2, Section 2.8.4 include comments regarding efficacy in controlling shrimp, effects on clam and oyster crops present during these treatment options, and other potentially adverse or beneficial effects based on experimentation tried.

Other methods tried since the 2002 list was prepared are also summarized, primarily from *An Updated Plan for Integrated Pest Management of Burrowing Shrimp on Commercial Shellfish Beds* (Booth 2010). The IPM Plan for burrowing shrimp distinguishes pest management strategy from pest management tactics. A *tactic* is an activity created with specific and measurable objectives, whereas a *strategy* is a big picture approach to problem solving that integrates a series of steps/tactics. Different management strategies are characterized in part by the nature of the tactics they employ; e.g., mechanical, shellfish culture, chemical, or biological controls. The goal of alternative management strategies and tactics to manage burrowing shrimp is to achieve efficacy at least sufficient to reduce numbers below the damage threshold of ten burrows per square meter. Section 2.8.4 describes several of the methods tried as alternatives to the use of the insecticides carbaryl or imidacloprid. None of these methods has been shown to effectively control burrowing shrimp in a manner that could reasonably be implemented on the large scale of commercial shellfish beds in Willapa Bay and Grays Harbor.

1.6 Summary of Impacts and Mitigation Measures

The full text of the Affected Environment, Potential Impacts, and Mitigation Measures for the proposed action and alternatives is presented in FEIS Chapter 3. A summary matrix of potential impacts and mitigation measures is provided in Table 1.6-1, following. In some cases, these descriptions are considerably abbreviated from the full discussion in FEIS Chapter 3, and lack explanations of terminology and background information. Summary statements of potential impacts in the table also appear without the context of existing environmental conditions (the Affected Environment discussions in FEIS Chapter 3). For these reasons, readers are encouraged to review the more comprehensive discussion of issues of interest in the FEIS to develop the most accurate understanding of potential impacts and mitigation measures for the proposed action and alternatives.

Table 1.6-1. Summary of environmental impacts and mitigation measures associated with alternatives for burrowing shrimp control in Willapa Bay and Grays Harbor, Washington.

Sediments

No Action Alternative[11]

. Attempts at mechanical control of burrowing shrimp are less effective than chemical treatments and would likely result in a benthic habitat on commercial shellfish beds that is lower in diversity and productivity than that found on shellfish beds with lower densities of shrimp (Ferraro and Cole 2007).
. The activities of burrowing shrimp may influence sediment biogeochemistry by increasing carbon and nitrogen cycling within the sediment-water interface (D'Andrea and DeWitt 2009). This can counter the effects of eutrophication by supplying nutrients necessary for primary and secondary production, and thus decrease the likelihood of the occurrence of hypoxic or anoxic conditions.
. Burrowing shrimp can re-suspend up to 50% of the sediment they occupy, creating a sediment character similar to quicksand (Posey 1985). . Oysters and clams sink and suffocate in softened sediments created by the activity of burrowing shrimp (Dumbauld et al. 2006; DeFrancesco and Murray 2010; and personal communication with WGHOGA members, various dates).

Alternative 2: Carbaryl with IPM

Potential Impacts	***Mitigation Measures***
. Carbaryl would be applied on up to 600 acres/year of commercial shellfish beds in Willapa Bay and up to 200 acres/year of commercial shellfish beds in Grays Harbor during extreme low tide intervals between July 1 and October 31 of each year. These areas would constitute approximately 1.3% *per year* of total tideland acres within Willapa Bay and less than 0.6% *per year* of total tideland acres within Grays Harbor. . Minor (if any) sediment disturbance would occur at the time of treatment with current methods of application: helicopter dispersion of liquid carbaryl, backpack sprayers, or working from all-terrain vehicles using a hand-held nozzle or boom sprayer.	NPDES PERMIT REQUIREMENTS: Permit conditions for the protection of sediment quality comparable to those in WA0040975 would likely include: . Establish a Sediment Impact Zone (SIZ) in accordance with WAC 173-204-415 and -420. . Applicators will be required to follow all insecticide label instructions to prevent spills on unprotected soil. . A Spill Control Plan will be prepared, similar to that described below for Alternative 3.
. Carbaryl is removed from the water column due to sediment adsorption (Sayce 1970). . The compound 1-naphthol decomposes at a pH of 8.2, coincident with the pH of seawater (Lamberton and Claeys 1970). Studies in Willapa Bay indicate that pH is typically 7.3 – 7.6.	Same as above. Carbaryl is removed from the environment through hydrolysis to 1-naphthol, which further degrades to carbon dioxide and water (Karinen et al. 1967).
. Site-specific studies conducted to clarify the persistence of carbaryl in estuarine sediments found that carbaryl and its degradation products were not detectable 16 days after treatment.	Same as above.
Significant Unavoidable Adverse Impacts: Based on currently available information and studies, and requirements to comply with the conditions of all applicable insecticide registrations, permits and regulations (including the Washington State Water Quality Standards and SMS), no significant unavoidable adverse impacts to sediments would be expected with Alternative 2. An administrative extension of the existing carbaryl permit (WA0049075), or a new or modified Ecology NPDES permit to implement Alternative 2, would include sediment monitoring requirements to confirm the effects of carbaryl applications. Adjustments to permit conditions could be made during the five-year term of the permit.	

11 Under the No Action Alternative, there would be no permit application, and thus no mechanism for requiring mitigation measures.

Alternative 3: Imidacloprid with IPM (Preferred Alternative)

Potential Impacts	***Mitigation Measures***
. Imidacloprid would be applied on up to 1,500 acres/year of commercial shellfish beds in Willapa Bay and up to 500 acres/year of commercial shellfish beds in Grays Harbor during several low tide intervals between April 15 and December 15 each year. These areas constitute approximately 3.3% *per year* of total tideland acres within Willapa Bay and approximately 1.5% *per year* of total tideland acres within Grays Harbor. . Minor (if any) sediment disturbance would occur at the time of treatment with methods of application suitable for the chemical formulation (i.e., liquid or granular imidacloprid): helicopter dispersion, scows or shallow-draft boats, all-terrain vehicles equipped with a spray boom, and/or back pack reservoirs with hand-held sprayers.	NPDES PERMIT REQUIREMENTS: The proposed action would require development of a Sediment Impact Zone (SIZ) to comply with the Washington State Water Quality Standards and Sediment Management Standards (SMS). A NPDES permit may only be issued if the proposed use, as conditioned, would comply with all applicable SMS. . The SMS establish sediment quality standards for marine surface sediments, sediment source control standards with which point source discharges must comply, and an anti-degradation policy (WAC 173-204-120, -300 through -350, and -400 through -450). . Sediment quality criteria for marine surface sediments include criteria establishing maximum concentrations of specified chemical pollutants, biological effects criteria, and criteria for benthic abundance (WAC 173-204-320). . Applicators would be required to follow all insecticide label instructions to prevent spills on unprotected soil. . A Spill Control Plan would be prepared to address the prevention, containment, and control of spills or unplanned releases, and will describe the preventative measures and facilities that will avoid, contain, or treat spills of imidacloprid, oil, and other chemicals that may be used, processed or stored at the facility that could be spilled into State waters (if any). The Plan would be reviewed at least annually and updated as needed.
. Imidacloprid has the ability to bind to sediments (Felsot and Ruppert 2002; Grue and Grassley 2013). . Sediment binding rates of imidacloprid are variable and are dependent upon a number of factors including temperature, pH, salinity, alkalinity, redox potential, solar radiation, biological activity, dissolved oxygen, dissolved organic carbon (DOC), and total organic carbon (TOC) (Grue and Grassley 2013).	Same as above.
. Site-specific studies have been conducted to clarify the persistence of imidacloprid in estuarine sediments. Analyses of whole sediment samples indicate that 89% to 98% of the imidacloprid deposited on treatment plots moved off-site. . These studies confirmed that imidacloprid can bind to organic materials in the sediments, but that concentrations of this bound fraction decline between 14 and 27 days after treatment (Grue and Grassley 2013; Hart Crowser 2013).	Same as above.
. The persistence of imidacloprid in sediments will be studied further during 2015 field experiments.	Same as above.

Significant Unavoidable Adverse Impacts: Based on currently available information and studies, and requirements to comply with the conditions of all applicable insecticide registrations, permits and regulations (including the Washington State Water Quality Standards and SMS), no significant unavoidable adverse impacts to sediments would be expected with the proposed action (Alternative 3: imidacloprid applications with IPM). The requested Ecology NPDES permit, if issued, would include sediment monitoring requirements to confirm the effects of

imidacloprid applications. Adjustments to permit conditions could be made during the five-year term of the permit.
Air Quality

No Action Alternative

. There would be gasoline or diesel exhaust emissions to the air associated with the transport and operation of mechanical and shellfish culture equipment if these methods were used to attempt to control burrowing shrimp. . No significant adverse air quality impacts would be expected due to consistent wind circulation within Willapa Bay and Grays Harbor.
. There would be no insecticide applications to commercial shellfish beds under the No Action Alternative, and thus no risk of airborne dispersion.

Alternative 2: Carbaryl with IPM

Potential Impacts	***Mitigation Measures***
. There would be gasoline or diesel exhaust emissions to the air five to ten days per year associated with equipment used to apply carbaryl and attributable to vehicles used for travel to/from application sites. . No significant adverse air quality impacts would be expected due to conditions of wind circulation within Willapa Bay and Grays Harbor.	No mitigation measures would be required for vehicle or vessel exhaust emissions to the air.
. Carbaryl is considered to be non-volatile but slightly toxic by inhalation.	FIFRA REGISTRATION REQUIREMENTS: . It would be the responsibility of the applicator to select appropriate application equipment and treat commercial shellfish beds only during appropriate environmental conditions when wind speed (less than 10 mph), temperature, and tidal elevation would minimize the risk of spray drift, to avoid off-target dispersion. . All handlers of carbaryl would be required to wear a respirator or dust mask.
. Carbaryl applications on commercial shellfish beds would, for the most part, be located well away from public gathering places and should pose little to no risk of exposure to the public or other bystanders.	NPDES PERMIT REQUIREMENTS: WGHOGA would be responsible for implementing public notification requirements comparable to those in WA0040975: . Post public and privately-owned access points with signs prior to treatment. Specific locations would be identified in the carbaryl AOP. . Notify property owners within 200 feet of treatment sites in person, by telephone or by mail at least 24 hours (but not more than ten days) prior to commencement of initial carbaryl application to commercial shellfish beds. Include the name of the insecticide to be used, where it is to be applied, any public health and livestock restrictions, and the name and telephone number of the WGHOGA contact person. . Notify interested parties by telephone, e-mail or fax at least 24 hours prior to carbaryl applications. . Notify the public prior to carbaryl applications through newspaper announcements and signs posted at all reasonable points of public access to proposed treatment areas. . Do not apply carbaryl on commercial shellfish beds during Federal holiday weekends. Ecology would be responsible under WAC 173-204-

	415(2)(e) for identifying and notifying all landowners, adjacent landowners, and lessees affected by the Sediment Impact Zone to implement Alternative 2. This notification would be in addition to the sign postings and electronic notifications regarding application dates and locations for which WGHOGA would be responsible.
. Carbaryl has a mild odor. Most or all applications would be made away from the public and during periods of low wind. For these reasons, it is unlikely that the odor would be detectable to off-site observers.	No mitigation measures would be required for odors associated with the use of carbaryl.
Significant Unavoidable Adverse Impacts: Based on currently available information and studies, and requirements to comply with the conditions of all applicable insecticide registrations, permits and regulations, no significant unavoidable adverse impacts to air quality would be expected with Alternative 2. Carbaryl applications for the control of burrowing shrimp would be implemented in compliance with FIFRA Registration restrictions and NPDES permit conditions that specify appropriate application equipment and spray drift management techniques to avoid or minimize off-target exposures. FIFRA Registration and NPDES permit conditions also include public notification requirements to inform landowners, adjacent landowners, lessees, interested individuals, recreational users and others of proposed application dates and locations so that potential direct exposure could be avoided.	

Alternative 3: Imidacloprid with IPM (Preferred Alternative)

Potential Impacts	***Mitigation Measures***
. The larger number of acres to be treated with imidacloprid in a larger number of application events each year compared to carbaryl applications under Alternative 2 would result in more frequent vehicle and vessel emissions to the air associated with Alternative 3. . No significant adverse impact to air quality would be anticipated due to conditions of wind circulation within Willapa Bay and Grays Harbor.	No mitigation measures would be required for vehicle or vessel exhaust emissions to the air.
. The liquid formulation of imidacloprid (Protector 2F) is considered to be non-volatile, but slightly toxic by inhalation. . The granular formulation of imidacloprid (Protector 0.5G) is also considered to be non-volatile and is relatively non-toxic by inhalation.	FIFRA REGISTRATION REQUIREMENTS: . It would be the responsibility of the applicator to select appropriate application equipment and treat commercial shellfish beds only during appropriate environmental conditions when wind speed, temperature, and tidal elevation would minimize the risk of spray drift, to avoid off-target dispersion. . Average wind speed at the time of application shall not exceed 10 mph. . Persons handling the granular form of imidacloprid (Protector 0.5G) would be required to wear a respirator or dust mask.
. Applications of imidacloprid on commercial shellfish beds should pose little risk of exposure to the public or other bystanders due to lack of proximity to public gathering places.	NPDES PERMIT REQUIREMENTS: . Ecology would be responsible under WAC 173-204-415(2)(e) for identifying and notifying all landowners, adjacent landowners, and lessees affected by the Sediment Impact Zone to implement Alternative 3. This notification would be in addition to the sign postings and electronic notifications regarding application dates and locations for which WGHOGA would be responsible. FIFRA REGISTRATION REQUIREMENTS: WGHOGA would be responsible for implementing the

	following public notification requirements: . Post all public access areas within a one-quarter mile radius of any bed scheduled for treatment with a sign, or with signs at 500-ft intervals at those areas more than 500 feet wide. . Post signs at least 2 days prior to aerial treatment, and maintain these signs in-place for at least 30 days after treatment. . Do not apply imidacloprid on commercial shellfish beds during Federal holiday weekends. ADDITIONAL MITIGATION THROUGH ELEMENTS OF THE WGHOGA PROPOSAL FOR THE USE OF IMIDACLOPRID: . The WGHOGA IPM Coordinator would be responsible for posting, maintaining and removing public notice signs. . Use a website in lieu of newspaper announcements for public notification of specific dates and locations of proposed imidacloprid applications within Willapa Bay and Grays Harbor. The website would include a link for interested persons to request direct notification.
. Both the liquid (Protector 2F) and granular (Protector 0.5G) forms of imidacloprid have only a slight odor, and most or all applications would be made away from the public and during periods of low wind. Therefore, it is unlikely that the odor would be detectable to off-site observers.	No mitigation measures would be required for odors associated with the use of imidacloprid.
Significant Unavoidable Adverse Impacts: Based on currently available information and studies, and requirements to comply with the conditions of all applicable insecticide registrations, permits and regulations, no significant unavoidable adverse impacts to air quality would be expected with the proposed action (Alternative 3: imidacloprid applications with IPM). Imidacloprid applications for the control of burrowing shrimp would be implemented in compliance with FIFRA Registration restrictions and NPDES permit conditions that specify appropriate application equipment and spray drift management techniques to avoid or minimize off-target exposures. FIFRA Registration and NPDES permit conditions also include public notification requirements to inform landowners, adjacent landowners, lessees, interested individuals, recreational users and others of proposed application dates and locations so that potential direct exposure could be avoided.	

Surface Water

No Action Alternative

If mechanical means of burrowing shrimp control were utilized, there would be localized occurrences of turbidity due to sediment destabilization. It is unlikely that any water quality exceedances could occur due to shallow water depth, naturally turbid water, and the fact that Willapa Bay and Grays Harbor are intertidal environments that often go dry.
If alternative shellfish culture methods were used, such as bag culture or long-line culture, potential impacts to surface water quality may include the introduction of anthropogenically-derived waste such as plastics, mesh bags, and ropes that may be dislodged during storm events.
No insecticides would be discharged to Willapa Bay or Grays Harbor under the No Action Alternative for the purpose of burrowing shrimp control.

Alternative 2: Carbaryl with IPM

Potential Impacts	***Mitigation Measures***
. Carbaryl and the degradation byproducts of carbaryl would continue to enter Willapa Bay and Grays Harbor following summer applications on commercial shellfish	NPDES PERMIT REQUIREMENTS: Surface water quality conditions comparable to those in

beds. . The carbaryl application rate authorized by NPDES Permit WA0040975 is 8 pounds of active ingredient per acre. For the purpose of the impact analysis, it has been presumed that this would be the same if a new or modified carbaryl NPDES permit was issued to implement Alternative 2.	WA0040975 would likely include: . Maximum annual acreage limitations for the total area of commercial shellfish beds in Willapa Bay and Grays Harbor that could be treated with carbaryl each year. . Effluent limitations, which under WA0040975 have been 3.0 micrograms per liter (µg/L) for the acute limit, and 0.06 µg/L for the chronic limit. . Discharge monitoring to determine residual concentrations of carbaryl within the application area, and off-site downwind of the spray area. . Monitoring data prepared by a laboratory registered or accredited under the provisions of WAC 173-50. . Preparation of an Annual Discharge Monitoring Report. . Preparation of a Spill Control Plan (SCP). Applicators would be required to comply with all insecticide label instructions for the use of carbaryl to prevent spills on unprotected water. In the event of a spill, applicators would be required to follow spill response procedures outlined in the SCP and NPDES permit.
. Carbaryl applications have historically occurred during extreme low tides in summer months, resulting in five to ten application events per year. . The application period authorized by NPDES Permit WA0040975 is July 1 through October 31. For the purpose of the impact analysis, it has been presumed that this would be the same if a new or modified carbaryl NPDES permit was issued to implement Alternative 2.	Same as above.
If the maximum annual treatment acreage were limited to 800 acres *per year* (600 acres in Willapa Bay and 200 acres in Grays Harbor) as it is under NPDES Permit WA0040975, carbaryl applications would only occur on approximately 1.3% *per year* of total tideland acres within Willapa Bay and less than 0.6% *per year* of total tideland acres within Grays Harbor.	NPDES PERMIT REQUIREMENTS: . Restrict the aerial application of carbaryl so that it would not be applied close to sloughs, channels, or shellfish that are within one year of harvest. . Apply carbaryl only to beds that are uncovered by the outgoing tide. . Maintain buffer zones between the carbaryl treatment area and the nearest shellfish to be harvested within one year: a 200-ft buffer for aerial applications, or a 50-ft buffer for applications made by hand.
. Overall, the rapid hydrolysis of carbaryl in estuarine environments and considerable dilution from successive tides suggests that this insecticide would dissipate from treatment sites, and would have a low potential to cause water quality impacts.	Same as all entries in the Alternative 2 Surface Water: Mitigation Measures column above.
. Studies have shown that carbaryl degrades to 1-naphthol under artificial sunlight with a half-life of five hours. . The compound 1-naphthol has a half-life of less than 1 hour under the same conditions (Armbrust and Crosby 1991).	Same as above.
Significant Unavoidable Adverse Impacts: Based on currently available information and studies, and requirements to comply with the conditions of all applicable insecticide registrations, permits and regulations (including Washington State Water Quality Standards), no significant unavoidable adverse impacts to surface water quality would be expected with Alternative 2. The existing carbaryl permit, or a new or modified Ecology NPDES permit	

to implement Alternative 2, would include conditions that limit the maximum annual tideland acreage for carbaryl applications; specify treatment methods; require buffers from sloughs, channels, and shellfish to be harvested; and require discharge monitoring to evaluate the effects of applications. Adjustments to permit conditions could be made throughout the five-year term of the permit.

Alternative 3: Imidacloprid with IPM (Preferred Alternative)

Potential Impacts	***Mitigation Measures***
. Imidacloprid and the degradation byproducts of imidacloprid would enter Willapa Bay and Grays Harbor following treatment of commercial shellfish beds. . The imidacloprid application rate authorized by the conditional FIFRA Registration for Protector 2F and Protector 0.5G (the liquid and granular forms of imidacloprid, respectively) is 0.5 (one-half) pound of active ingredient per acre.	NPDES PERMIT REQUIREMENTS: . Alternative 3 would require issuance of a NPDES individual permit conditioned to ensure compliance with the Washington State Water Quality Standards and other applicable regulations, including U.S. EPA registration requirements for the use of imidacloprid in the estuarine environment for the purpose of burrowing shrimp control. . Discharge monitoring and data reporting would be required, in a manner similar to WA0040975 requirements for the use of carbaryl for burrowing shrimp control (as described above). . The imidacloprid water quality monitoring plan would take into account the treatment plan proposed, and current information regarding this proposal would be used to condition the permit. . The discharge of imidacloprid authorized by an NPDES permit would be limited to waters of the State of Washington; specifically, to the waters of Willapa Bay and Grays Harbor for the purpose of burrowing shrimp control on commercial shellfish beds. . A Spill Control Plan (SCP) would be required, comparable to the SCP described above for Alternative 2. ADDITIONAL MITIGATION THROUGH ELEMENTS OF THE WGHOGA PROPOSAL FOR THE USE OF IMIDACLOPRID: . Maintain imidacloprid treatment application records using the WSDA "Pesticide Application Record (Version 1)" form (AGR FORM 640-4226 [R/4/07]).
. Imidacloprid is expected to have lower toxicity to burrowing shrimp, and a much smaller amount of active ingredient would be used compared to carbaryl applications; therefore, the more selective approach proposed regarding application times, tides and bed conditions is expected to result in a larger number of application events each year, over smaller areas at a time. . The application period authorized by the conditional FIFRA Registration for the liquid and granular forms of imidacloprid is April 15 through December 15.	Same as above.
. If the maximum annual treatment acreage is 2,000 acres (1,500 acres within Willapa Bay and 500 acres within Grays Harbor) as proposed, imidacloprid applications would occur on approximately 3.3% *per year* of total tideland acres within Willapa Bay and approximately 1.5% *per year* of total tideland acres within Grays Harbor.	FIFRA REGISTRATION REQUIREMENTS: . Restrict imidacloprid treatments so that the pesticide would not be applied on beds where shellfish are within 30 days of harvest. . Make aerial applications of imidacloprid on beds exposed at low tide. Protector 0.5G applications made from a floating platform or boat may be applied to beds

It is possible that the total tideland acreage to be treated over the five-year term of the NPDES permit could range from 1,500 to 7,500 acres within Willapa Bay, and from 500 to 2,500 acres within Grays Harbor. Growers consider it more likely that some commercial shellfish beds would be treated more than once during the five-year term of the permit, with the result that the upper limit of these ranges would not occur.	under water using a calibrated granular applicator. . Maintain buffer zones between the imidacloprid treatment area and the nearest shellfish to be harvested within 30 days: a 100-ft buffer for aerial applications, or a 25-ft buffer for applications made by hand.
Factors such as water chemistry, temperature, adsorption to sediment, water currents, and dilution can all have significant effects on the persistence of imidacloprid (CSI 2013). Field studies have been conducted on ten-acre plots (Hart Crowser 2012). The results of 2014 experimental use studies will be reported in the Final EIS.	Same as all entries in the Alternative 3 Surface Water: Mitigation Measures column above.
. Studies have shown that the half-life of imidacloprid at pH 5 and pH 7 can be greater than one year. (The pH of seawater is more alkaline, tending to range from 7.5 to 8.4). . Laboratory studies of photo-degradation of imidacloprid in water suggest that it has a half-life of approximately 4.2 hours in water and degrades under natural sunlight (CSI 2013). . Further laboratory experiments have shown varied results with a half-life ranging from 14 to 129 days (Spitteller 1993 and Henneböle 1998 as cited in CSI 2013). . Imidacloprid has moderately high solubility in water (Felsot and Ruppert 2002). Imidacloprid that is not degraded by environmental factors would be subject to dilution through tidal flows in the Willapa Bay and Grays Harbor estuaries.	Same as above.
Imidacloprid is expected to have a low potential to cause ecological impacts in non-target areas because it dilutes and moves off treated areas with incoming tides and in drainage channels, and would continue to do so on successive tidal cycles.	FIFRA REGISTRATION REQUIREMENTS: . It is recommended that a properly designed and maintained containment pad be used for mixing and loading imidacloprid into application equipment. . If a containment pad is not used, a minimum distance of 25 feet should be maintained between mixing and loading areas and potential surface to groundwater conduits.
Significant Unavoidable Adverse Impacts: Based on currently available information and studies, and requirements to comply with the conditions of all applicable insecticide registrations, permits and regulations (including Washington State Water Quality Standards), no significant unavoidable adverse impacts to surface water quality would be expected with the proposed action (Alternative 3: imidacloprid applications with IPM). The requested Ecology NPDES permit, if issued, would include conditions that limit the maximum annual tideland acreage for imidacloprid applications; specify treatment methods; require buffers from sloughs, channels, and shellfish to be harvested; and require discharge monitoring to evaluate the effects of applications. Adjustments to permit conditions could be made throughout the five-year term of the permit.	

Plants

No Action Alternative

. Mechanical disturbance of oyster and clam beds for burrowing shrimp control would temporarily affect flora within the treatment areas: microalgae, the upper elevations of eelgrass (both *Z. marina* and *Z. japonica*), and saltmarsh species in their lower elevation locations.

. Since mechanical methods of burrowing shrimp control are less effective than chemical methods of control, untreated areas would be affected by burrowing shrimp over time. . Sediment disturbance caused by burrowing shrimp can inhibit eelgrass growth and density (Dumbauld and Wyllie-Echeverria 2003; Hosack et al. 2006).
. Mechanical methods of burrowing shrimp control (e.g., boats grounding on mudflats, harrowing, raking and other activities) would have localized and temporary effects on marine and salt marsh vegetation. . Damaged plants would be suppressed for a period of time before re-growth; plant seeds may germinate during the same or following season; roots, rhizomes and seeds disrupted in one location may be distributed by the tide to other sites, potentially enhancing dispersion of affected plants.

Alternative 2: Carbaryl with IPM

Potential Impacts	***Mitigation Measures***
. The effect of carbaryl applications on estuarine plants would be localized and temporary. . The degree of carbaryl toxicity to marine vegetation varies considerably (WDF and ECY 1985). Some marine plants and algae are growth-inhibited by carbaryl, while others are not affected. . Marine algae are likely inhibited immediately after spraying until carbaryl concentrations decrease to less than 1.0 ppm (WDF and ECY 1985). . Similarly, planktonic algae would only be affected temporarily.	NPDES PERMIT REQUIREMENTS: . Implementing spray drift management techniques (as described above under Air Quality: Mitigation Measures) would be effective at avoiding potential impacts to off-site non-target plants. Maintaining buffers from sloughs and channels (as described above under Surface Water: Mitigation Measures) would also be effective at avoiding potential impacts to off-site non-target plants. . Maintaining small application areas for short periods of time (as described above under Surface Water: Potential Impacts) would be effective at minimizing potential impacts to plants. . Preparing and implementing a Spill Control Plan (as described above under Surface Water: Mitigation Measures) would also be protective of plants.
Epibenthic algae present on or in sediment may be exposed for longer periods than algae in the water column. Epibenthic algal growth would likely be inhibited at carbaryl concentrations of 1 ppm or greater for up to 16 days, which is the length of time that carbaryl has been determined to persist in sediments.	Same as above.
	Since carbaryl is not accumulated in the food web, no mitigation measures would be required to minimize or avoid this potential.
Significant Unavoidable Adverse Impacts: Based on currently available information and studies, and requirements to comply with the conditions of all applicable insecticide registrations, permits and regulations, no significant unavoidable adverse impacts to estuarine or terrestrial plants would be expected with Alternative 2. FIFRA Registrations specify spray drift management techniques; and a new or modified Ecology NPDES permit to implement Alternative 2 would include conditions that specify treatment methods; require buffers from sloughs and channels; and require discharge monitoring similar to the current permit. Adjustments to permit conditions could be made during the five-year term of a new or modified permit.	

Alternative 3: Imidacloprid with IPM (Preferred Alternative)

Potential Impacts	***Mitigation Measures***
. Limited information is available regarding imidacloprid impacts to marine vegetation. The results of field studies conducted during one season to evaluate uptake in eelgrass tissues showed limited uptake by eelgrass, and imidacloprid was undetectable after 14 days (Grue and Grassley 2013; Hart Crowser 2013). In addition, imidacloprid is an acetylcholinase inhibitor and plants do not have a biochemical pathway involving acetylcholinase. Therefore, it is unlikely that	FIFRA REGISTRATION REQUIREMENTS: . Implementing spray drift management techniques (as described above under Air Quality: Mitigation Measures) would also be effective at avoiding potential impacts to off-site non-target plants. It would be a violation of the FIFRA Registration for the applicator to not follow label directions. . Preparing and implementing a Spill Control Plan (as

imidacloprid would adversely affect eelgrass or other marine vegetation.	described above under Surface Water: Mitigation Measures) would also be protective of plants. ADDITIONAL MITIGATION THROUGH ELEMENTS OF THE WGHOGA PROPOSAL FOR THE USE OF IMIDACLOPRID: . The WGHOGA proposal to avoid aerial (i.e., helicopter) applications of Protector 0.5G or 2F within 200 feet of the Ordinary High Water Line (OHWL) adjacent to shoreline areas would be protective of off-site non-target plants. . WGHOGA would implement measures over time to minimize the frequency and quantity of imidacloprid applications necessary for the effective control of burrowing shrimp.
. Freshwater data indicate that algae are at least three orders of magnitude less sensitive to imidacloprid than many insect and crustacean species (CCME 2007).	Same as above.
Imidacloprid is not known to accumulate in any component of the food web, nor is it transmitted to higher levels in the food chain.	Since imidacloprid is not accumulated in the food web, no mitigation measures would be required to minimize or avoid this potential impact.

Significant Unavoidable Adverse Impacts: Based on currently available information and studies, and requirements to comply with the conditions of all applicable insecticide registrations, permits and regulations, no significant unavoidable adverse impacts to estuarine or terrestrial plants would be expected with the proposed action (Alternative 3: imidacloprid applications with IPM). FIFRA Registrations specify spray drift management techniques; and the requested Ecology NPDES permit, if issued, would include conditions that specify treatment methods; require buffers from sloughs and channels; and require discharge monitoring. Adjustments to permit conditions could be made during the five-year term of the permit.

Animals

No Action Alternative

MARINE ZOOPLANKTON

. Alternative 1 would be unlikely to adversely affect marine zooplankton because, in the absence of insecticide applications for the control of burrowing shrimp, there would be no potential insecticide effect to zooplankton from this source.

BENTHIC INVERTEBRATES (BURROWING SHRIMP, CLAMS AND OYSTERS, DUNGENESS CRAB)

Due to the limited amount of tideland acreage historically treated with carbaryl or proposed for treatment with imidacloprid, the No Action Alternative would be unlikely to have either a significant beneficial or adverse effect on benthic invertebrates, including burrowing shrimp, clams and oysters, and Dungeness crab (as described in FEIS Chapter 2, Section 2.9).

FORAGE FISH AND GROUNDFISH

. The No Action Alternative would be unlikely to have a significant beneficial or adverse effect on forage fish or groundfish in Willapa Bay and Grays Harbor due to the relatively small proportion of tidelands within each estuary that have been or would be treated with a insecticide for the control of burrowing shrimp.

BIRDS

. The No Action Alternative would be unlikely to have a significant beneficial or adverse effect on birds in Willapa Bay or Grays Harbor due to the relatively small proportion of tidelands within each estuary that have been or would be treated with a insecticide for the control of burrowing shrimp.

POLLINATORS

. The No Action Alternative would be unlikely to have either a beneficial or adverse effect on honey bees (or other pollinators) as no insecticides would be sprayed on commercial clam or oyster beds in Willapa Bay or Grays Harbor.
. In addition, potential impacts from this alternative would be limited because honey bees are not attracted to

mudflats, and bumble bees and similar pollinators prefer terrestrial flowering plants that are not found in the bays (Macfarlane and Patten 1997).
MAMMALS . The No Action Alternative would be unlikely to have either a beneficial or adverse effect on mammals in Willapa Bay or Grays Harbor due to the small size of these areas in relation to the total tideland area of Willapa Bay and Grays Harbor.

Alternative 2: Carbaryl with IPM

Potential Impacts	***Mitigation Measures***
MARINE ZOOPLANKTON Carbaryl effects on marine zooplankton have been largely unstudied. Carbaryl may have similar effects to marine zooplankton as it does to adult life history stages of crustaceans and related species.	. Carbaryl would be applied in-water during out-going tides or on the exposed mudflats of commercial shellfish beds when densities of zooplankton would be low due to limited water depth.
BENTHIC INVERTEBRATES (BURROWING SHRIMP, CLAMS AND OYSTERS, DUNGENESS CRAB) . Burrowing shrimp control using carbaryl treatments may indirectly enhance shellfish and eelgrass density and coverage where habitat was no longer limited by burrowing shrimp activity. These conditions may improve the biodiversity of benthic invertebrates on commercial shellfish beds in Willapa Bay and Grays Harbor. . The commensal clam (*Crytomya californica*) is adversely affected by carbaryl treatment (in the form of delayed mortality), because this clam is dependent on burrowing shrimp habitat. . Recent studies have found the use of carbaryl to promote fish and Dungeness crab mortality by way of paralysis and reduced heart rate (NMFS 2009). . Although not studied, it is assumed that carbaryl causes similar mortality in planktonic juvenile life stages of crustaceans and related species. . If the carbaryl application rate and maximum annual treatment acreage were to remain the same under Alternative 2 as it is under NPDES Permit WA0040975 (i.e., 8 pounds of active ingredient per acre on up to 600 acres/year in Willapa Bay and up to 200 acres/year in Grays Harbor), then impacts to fish and Dungeness crab would not be expected to increase over conditions that have occurred since 1963.	NPDES PERMIT REQUIREMENTS: Specific conditions can include, but are not limited to, conditions such as, acreage limitations, seasonal timing, and application methods, similar to the current NPDES permit. . Specific mitigation measures would likely include continuing to limit carbaryl application areas (e.g., total annual treatment acreage), and seasonal timing restrictions, which have encompassed the time period between July 1 and October 31. . Treatment site conditions under WA0040975 limit carbaryl applications to only those commercial oyster beds that are uncovered by an outgoing tide. If Alternative 2 were selected for implementation, WGHOGA has requested that the NPDES permit also authorize carbaryl applications on areas where clams are the predominant crop. . Spray drift management techniques and buffers from sloughs and channels would continue to be required, which would be protective of nearby sensitive crab and fish habitats.
FORAGE FISH AND GROUNDFISH . Improvements to native eelgrass density and coverage could also improve foraging habitat for fish. . Carbaryl affects the nervous system of fish, impacting swimming behavior. Mortality is possible on direct contact (NMFS 2009). While carbaryl dilutes and degrades as it dissipates from treatment sites, in low concentrations it could still increase the susceptibility of some fish to predation.	If the seasonal application of carbaryl were to remain July 1 through October 31, carbaryl exposure would be limited within Willapa Bay and Grays Harbor during forage fish spawning seasons: . Herring spawn from February to March. . Surf smelt spawn from February to September along the coast, but spawning is not documented within the bays. . Sand lance spawn outside of Grays Harbor in December. . Eulachon migrate through Grays Harbor between January and April. Eggs develop within 30 days in

	river, and larvae occasionally unintentionally wash out near the head of the Chehalis River in March or April, preceding the carbaryl application period.
BIRDS . The potential for direct exposure of carbaryl to birds would be limited since application methods would tend to flush birds from the target area (personal communication with Dr. Kim Patten, WSU Pacific County Extension Director). . The overall diversity of prey available for shorebirds (including the red knot) could improve with burrowing shrimp control using carbaryl on the commercial shellfish beds. . *Macoma* clams (a preferred prey organism of red knot) could be affected following burrowing shrimp control using carbaryl. . Waterfowl species such as brant, ducks, and geese could benefit from the expansion of submerged vegetation found in eelgrass and shellfish beds as a result of burrowing shrimp control using carbaryl. These areas would constitute approximately 1.3% *per year* of total tideland acres within Willapa Bay and less than 0.6% *per year* of total tideland acres within Grays Harbor under Alternative 2.	If the seasonal application of carbaryl were to remain July 1 through October 31, carbaryl exposure would be limited during seasonal bird migrations through Willapa Bay and Grays Harbor: . Red knot and other shorebirds, black brant and other waterfowl migrate out of the bays by the end of May. . Mallards are the most common nesting bird, but complete their nesting by late spring.
POLLINATORS . Carbaryl is toxic to bees in direct contact or as a residual on flowering plants (USEPA 2012), and cannot be administered with bees present (NMFS 2009). . There are no flowering plants (other than eelgrass) on commercial shellfish beds as these areas are inundated twice daily by tides. Bees do not pollinate eelgrass. . Carbaryl has historically only been administered on approximately five or ten days each year during the lowest tides in July and August, thereby limiting the risk of pollinator exposure from aerial applications. . The distance between hives seasonally imported to pollinate cranberries would be the same for potential carbaryl application sites under Alternative 2 as that described below for proximity to potential imidacloprid application sites under Alternative 3. . The potential for direct carbaryl exposure to pollinators or their associated plant species would be negligible since honey bees are not attracted to mudflats and bumble bees and similar pollinators prefer terrestrial flowering plants that are not found in the bays (Macfarlane and Patten 1997).	FIFRA REGISTRATION REQUIREMENTS: FIFRA Registration spray drift management techniques would be conditions of the NPDES permit for the use of carbaryl under Alternative 2: . Average wind speed at the time of application shall not exceed 10 mph. . Aerial applications shall not occur during gusty conditions, or during temperature inversions. . Applications shall be made at the lowest possible height that is safe to operate. . Helicopters should be equipped to minimize spray drift by using high flow-rate nozzles, selecting the number and type of nozzles, nozzle orientation, and controlling pressure appropriate for the nozzle type. . No direct treatment on blooming crops or weeds shall occur. NPDES PERMIT REQUIREMENTS: . If the seasonal application of carbaryl were to remain July 1 through October 31, there would be no carbaryl exposure during the peak pollination period adjacent to Willapa Bay and Grays Harbor.
MAMMALS . Carbaryl has similar toxicity issues for mammals as those described above for fish (NMFS 2009). . Harbor seals may be the only marine mammals potentially present in areas near carbaryl applications; however, their preferred haul-out locations do not include shallow tideflats where commercial shellfish	. Conditions described above for Alternative 2: Forage Fish and Groundfish would also be protective of marine and terrestrial mammals. . Carbaryl application methods minimize the risk of exposure to mammals by treating shellfish beds during tidal periods and at tidal elevations where marine mammals are absent.

beds are located.	

Significant Unavoidable Adverse Impacts: Based on currently available information and studies, and requirements to comply with the conditions of all applicable insecticide registrations, permits and regulations (including Washington State Water Quality Standards), no significant unavoidable adverse impacts to marine or terrestrial animals would be expected with Alternative 2. The existing carbaryl permit, or a new or modified Ecology NPDES permit to implement Alternative 2, would include conditions that limit the maximum annual tideland acreage for carbaryl applications; specify treatment methods; require buffers from sloughs, channels, and shellfish to be harvested; and require discharge monitoring to evaluate the effects of insecticide applications. Adjustments to permit conditions could be made during the five-year term of a new or modified permit.

Alternative 3: Imidacloprid with IPM (Preferred Alternative)

Potential Impacts	***Mitigation Measures***
MARINE ZOOPLANKTON The effects of imidacloprid on marine zooplankton species has not been widely studied. Twenty-four hour acute toxicity experiments conducted in laboratory conditions with much higher concentrations of imidacloprid than would generally be found following treatment events on commercial shellfish beds showed high mortality in blue crab megalopae (Osterberg et al. 2012).	. Imidacloprid would be applied in-water during out-going tides or on the exposed mudflats of commercial shellfish beds when densities of zooplankton would be low due to limited water depth. . Imidacloprid breaks down in water and has a low volatilization potential in air, minimizing any potential effects on zooplankton in Willapa Bay or Grays Harbor (Gervais et al. 2010).
BENTHIC INVERTEBRATES (BURROWING SHRIMP, CLAMS AND OYSTERS, DUNGENESS CRAB) . Burrowing shrimp control using imidacloprid treatments could indirectly promote enhanced shellfish and eelgrass density and coverage where habitat was no longer limited by burrowing shrimp activity. . Enhanced shellfish and eelgrass density could improve the biodiversity of benthic invertebrates on commercial shellfish beds in Willapa Bay and Grays Harbor. . Imidacloprid would provide adequate burrowing shrimp control on commercial shellfish beds with reduced environmental side effects compared to Alternative 2. Imidacloprid is overall less toxic than carbaryl. It has lower toxicity effects on most species, and is not toxic to some species for which carbaryl has a toxic effect. Imidacloprid applications at the concentration being proposed (0.5 lb active ingredient per acre) would not cause direct mortality in Dungeness crab, fish, or birds; and would not decrease biodiversity other than to temporarily reduce burrowing shrimp populations within application areas (CSI 2013). . Although there is a potential for imidacloprid to persist in certain sediment types (Grue and Grassley 2013), given the dilution rates, toxic effects to benthic infauna are likely limited. Future studies of bioaccumulation and invertebrate toxicity in organic rich sediments are tentatively planned for summer 2015. . Studies have found that the use of imidacloprid at the proposed level (0.5 lb active ingredient per acre) would not adversely affect polychaete worms or molluscs (bivalves, snails), including oysters and clams (CSI 2013). Other studies have found some limited effects on these organisms (Booth 2012, Hart Crowser 2013).	NPDES PERMIT REQUIREMENTS: . The proposed NPDES permit would be conditioned to protect state resources. Specific conditions can include, but are not limited to, conditions such as, acreage limitations, seasonal timing, and application methods. FIFRA REGISTRATION REQUIREMENTS: . Spray drift management techniques and treatment site requirements specified in the conditional FIFRA Registrations for the liquid and granular forms of imidacloprid would be implemented under Alternative 3. These state that aerial applications must occur on beds exposed at low tide, and granular applications may be applied to beds under water using a calibrated granular applicator, operating from a floating platform or boat. . Application of the granular form of imidacloprid during periods of shallow standing water would limit the potential for crabs to be affected.

. Because the commensal clam lives in shrimp burrows, this species may be adversely affected by decreased shrimp densities in localized areas of direct imidacloprid application. . Imidacloprid is less toxic than carbaryl, causing a temporary paralysis reaction in copepods (small crustaceans) and shrimp, creating an exposure pathway for fish and birds that feed on copepods and shrimp flushed from their burrows. . Imidacloprid could affect Dungeness crabs. They may exhibit a temporary paralysis reaction and therefore become susceptible to predation by gulls (CSI 2013). . Because imidacloprid is less toxic than carbaryl, and the application rate would be considerably less (0.5 pound of active ingredient per acre), potential effects to fish and Dungeness crab would be expected to be less with Alternative 3 than with Alternative 2, even though the maximum annual treatment acreage would be higher (up to 1,500 acres/year in Willapa Bay, and up to 500 acres/year in Grays Harbor).	
FORAGE FISH AND GROUNDFISH . Imidacloprid has very low toxicity to vertebrates (CSI 2013). . Improvements to native eelgrass (*Z. marina*) density and coverage as a result of burrowing shrimp control using imidacloprid treatments could also improve foraging habitat for fish. . It is unlikely that there would be adverse effects to forage fish or groundfish from imidacloprid in water (CSI 2013) due to dilution, adsorption onto sediment, and application during low tide conditions.	FIFRA REGISTRATION REQUIREMENTS: . Aerial dispersal of imidacloprid limited by spray drift management techniques would minimize the potential for exposure to non-target species, and therefore would be unlikely to adversely affect fish populations within Willapa Bay or Grays Harbor.
BIRDS . Concentrations of imidacloprid below 150 mg/kg are generally non-toxic to birds (Gervais et al. 2010), and CSI (2013) found that imidacloprid application was unlikely to adversely affect birds in Willapa Bay or Grays Harbor, based on an application concentration of approximately 3.34 mg/kg.[12] . Improvements to native eelgrass density and coverage as a result of burrowing shrimp control using imidacloprid treatments could also improve foraging habitat and prey diversity for birds, including the red knot, other shorebirds, and waterfowl species. These areas could constitute approximately 3.3% *per year* of total tideland acres within Willapa Bay and approximately 1.5% *per year* of total tideland acres within Grays Harbor. . A red knot preferred prey organism (*Macoma* clams) would benefit from stable sediments following burrowing shrimp control (Buchanan et al. 2012), whereas in the presence of burrowing shrimp, *Macoma*	FIFRA REGISTRATION REQUIREMENTS: . Application of the liquid form of imidacloprid (Protector 2F) disperses quickly, and granular (Protector 0.5G) application dissolves readily in shallow water. In addition, application methods by helicopter and hand-held equipment would tend to flush birds from the target area (personal communication with Dr. Kim Patten, WSU Pacific County Extension Director). . Application events and flushing (i.e., scaring) birds from application sites would be short-term and temporary. . Aerial dispersal of imidacloprid limited by spray drift management techniques would minimize potential exposure to non-target species, and therefore would be unlikely to adversely affect bird populations within Willapa Bay or Grays Harbor. . Application methods and spray drift management techniques required by the conditional FIFRA Registrations would minimize the potential for direct exposure to migratory birds during the imidacloprid

12 Based on an assumption of imidacloprid being present in the top one centimeter of the sediment and a sediment density of 1.5 grams per cubic centimeter (g/cc).

clams occur at a depth that exceeds the bill length of the red knot. . Crustaceans and molluscs do not bioaccumulate imidacloprid in their tissues, thereby minimizing potential exposure to shorebirds that consume these organisms. Mineau (2013) suggests that terrestrial birds can be harmed by ingesting seeds treated with imidacloprid, but does not document studies to describe the level of harm, or what concentration of imidacloprid the seeds contained. . Red knot and other shorebirds that feed in and around shellfish beds could come in contact with low concentrations[13] of the granular form of imidacloprid (Protector 0.5G) immediately following an application. . Birds are unlikely to be present on application sites during imidacloprid treatments due to human activity and machinery operation.	seasonal application period between April 15 and December 15.*Peak abundance of red knot and many shorebirds occurs in April and May, in relation to the imidacloprid application period authorized by the conditional FIFRA Registration: April 15 through December 15.
POLLINATORS . Imidacloprid is less toxic to bees than carbaryl, requiring a higher concentration for toxicity; however, it is still toxic in direct contact or as a residual on flowering plants (USEPA 2013b). . Of the approximately 3,000 hives imported in June each year to pollinate cranberries at the south end of Willapa Bay, a few of these are located approximately 0.5 mile from the nearest commercial shellfish beds. The closest cranberry farm adjacent to Grays Harbor is approximately 1.5 miles from commercial shellfish beds. . The proposed rate of application of imidacloprid (0.5 lb active ingredient per acre) would be below concentrations that would impact honey bees (USEPA 2013b). . The potential for direct exposure to pollinators or their associated plant species would be negligible since honey bees are not attracted to mudflats; bumble bees and similar pollinators prefer terrestrial flowering plants that are not found in the bays (Macfarlane and Patten 1997); and neither are likely to be present over estuarine waters that cover commercial shellfish beds (CSI 2013). . In the professional opinion of the Washington State Department of Agriculture, Special Pesticide Registration Program Coordinator, there is no risk to bees from the application of imidacloprid (either granular or flowable formulation) to tidal flats due to the spray drift management techniques and buffers required by the FIFRA Registrations described in the Mitigation Measures column at right (personal communication with Erik Johansen, March 19, 2014).	FIFRA REGISTRATION REQUIREMENTS: FIFRA Registration spray drift management techniques would become conditions of the NPDES permit for the use of imidacloprid: . Average wind speed at the time of application shall not exceed 10 mph when either Protector 0.5G or 2F is applied by air. Further, aerial applications shall not occur during gusty conditions, or during temperature inversions. Temperature inversions begin to form as the sun sets and often continue into the morning. . Applications of imidacloprid shall be made at the lowest possible height (helicopter, ground or barge) that is safe to operate and that would reduce exposure of the granules to wind. . When applications of Protector 0.5G (the granular formulation) are made crosswind, the applicator must compensate for displacement by adjusting the path of the application equipment upwind. Swath adjustment distance should increase with increasing drift potential. . Helicopters used to apply Protector 2F should be equipped to minimize spray drift. The best drift management strategy and most effective way to reduce drift potential is to apply large droplets that provide sufficient coverage and control. Droplet size can be controlled by using high flow-rate nozzles, selecting the number and type of nozzles, nozzle orientation, and controlling pressure appropriate for the nozzle type. . No direct treatment on blooming crops or weeds shall occur. ADDITIONAL MITIGATION THROUGH ELEMENTS OF THE WGHOGA PROPOSAL FOR THE USE OF IMIDACLOPRID: . The WGHOGA proposal to avoid aerial (i.e., helicopter) applications of Protector 0.5G or 2F within

13 Based on assumptions of imidacloprid present in the top one centimeter of the sediment only, and a sediment density of 1.5 grams per cubic centimeter (g/cc), the concentration of imidacloprid would be approximately 3.34 mg/kg.

	200 feet of the Ordinary High Water Line (OHWL) adjacent to shoreline areas would be protective of pollinators.
MAMMALS . Imidacloprid has very low toxicity to vertebrates (CSI 2013). . Imidacloprid exposure for mammals would be related to direct ingestion. . There is little absorption of imidacloprid through the skin of animals, and concentrations less than 20 mg/kg are metabolized in less than 24 hours. The expected concentration of imidacloprid at the proposed application rate would be approximately 3.34 mg/kg; thus, it is likely to be metabolized within 24 hours. . Harbor seals may be the only marine mammals potentially present in areas near imidacloprid applications, but prefer sandbars and rocky shores for haul-out (Jeffries et al. 2000).	FIFRA REGISTRATION REQUIREMENTS: . Aerial dispersal of imidacloprid limited by spray drift management techniques would minimize the potential for exposure to non-target species, and therefore would be unlikely to adversely affect mammal populations within Willapa Bay or Grays Harbor. . No specific mitigation measures would be required for marine or terrestrial mammals. . Terrestrial mammals are unlikely to be present on shellfish beds during daylight hours when imidacloprid would be applied.
Significant Unavoidable Adverse Impacts: Based on currently available information and studies, and requirements to comply with the conditions of all applicable insecticide registrations, permits and regulations (including Washington State Water Quality Standards), no significant unavoidable adverse impacts to marine or terrestrial animals would be expected with the proposed action (Alternative 3: imidacloprid applications with IPM). The requested Ecology NPDES permit, if issued, would include conditions that limit the maximum annual tideland acreage for imidacloprid applications; specify treatment methods; require buffers from sloughs, channels, and shellfish to be harvested; and require discharge monitoring to evaluate the effects of insecticide applications. Adjustments to permit conditions could be made during the five-year term of the permit.	

Threatened, Endangered and Protected Species

No Action Alternative

SALMONIDS INCLUDING BULL TROUT

. The No Action Alternative would be unlikely to have a significant or adverse effect on salmonids in Willapa Bay or Grays Harbor due to the small size of these areas in relation to the total tideland area of Willapa Bay and Grays Harbor.
. Increased turbidity due to mobilized sediments caused by mechanical control efforts and/or by the burrowing activity of shrimp could locally reduce foraging efficiency for short periods of time, resulting in reduced presence of juvenile salmon in areas using mechanical control methods.

GREEN STURGEON

. The No Action Alternative would be unlikely to have either a beneficial or adverse effect on green sturgeon in Willapa Bay or Grays Harbor due to the relatively small proportion of tidelands within each estuary that have been or would be treated with insecticide for the control of burrowing shrimp.
. The green sturgeon diet may seasonally consist of up to 50% burrowing shrimp (Dumbauld et al. 2008).

MARBLED MURRELET

. The No Action Alternative would be unlikely to have either a beneficial or adverse effect on marbled murrelet, their habitat, or prey availability in Willapa Bay or Grays Harbor.
. Marbled murrelet critical habitat is designated upland from these two bays.

WESTERN SNOWY PLOVER

. The No Action Alternative would be unlikely to have either a beneficial or adverse effect on western snowy plover in Willapa Bay or Grays Harbor. Snowy plover prefer to forage on invertebrates in the wet sand.

STREAKED HORN LARK

. The No Action Alternative would be unlikely to have either a beneficial or adverse effect on streaked horn lark because they do not forage on or near shellfish beds.

. Streaked horned lark critical habitat is centered on nesting beaches along the coast. Nests are established on bare ground, well above MHHW.

Alternative 2: Carbaryl with IPM

Potential Impacts	***Mitigation Measures***
SALMONIDS INCLUDING BULL TROUT . Carbaryl has been documented to cause mortality of juvenile salmon in aquaria studies (NMFS 2009). . The USFWS Biological Opinion for NWP 48 (2009) reported carbaryl effects to bull trout critical habitat in Grays Harbor and foraging habitat in Willapa Bay. . Adult salmonids, including bull trout, use the bays primarily for migration to and from spawning habitat, and would spend varied resident time near carbaryl application sites depending on species.	NPDES PERMIT REQUIREMENTS: . If the seasonal application of carbaryl were to remain July 1 through October 31, carbaryl exposure would be limited within Willapa Bay and Grays Harbor during windows of juvenile salmonid out-migration which ends by July.
GREEN STURGEON . Carbaryl could affect green sturgeon only if applied in direct contact (NMFS 2009). . Carbaryl applications would occur on exposed mudflats or in shallow water during an outgoing tide. Green sturgeon are highly mobile and would not likely be present over commercial shellfish beds under these conditions (CSI 2013). . Sanford (2012) found no adverse effect to green sturgeon as a result of reduced prey availability from the use of carbaryl applications on commercial shellfish beds in Willapa Bay.	No specific mitigation measures would be required for green sturgeon.
MARBLED MURRELET . Carbaryl applications would be unlikely to adversely affect marbled murrelet birds or their critical habitat (USFWS 2009). See description above under the No Action Alternative.	No specific mitigation measures would be required for marbled murrelet.
WESTERN SNOWY PLOVER . Carbaryl applications would be unlikely to adversely affect western snowy plovers or their critical habitat (USFWS 2009). Adverse effects on prey resources would also be unlikely, since snowy plovers are not documented near commercial shellfish beds or during the carbaryl application season.	No specific mitigation measures would be required for western snowy plover.
STREAKED HORN LARK Carbaryl applications would be unlikely to adversely affect streaked horn lark or their nest sites because they do not occur on commercial shellfish beds within Willapa Bay or Grays Harbor.	No specific mitigation measures would be required for streaked horn lark.
Significant Unavoidable Adverse Impacts: With the exception of some salmonid life stages, it is unlikely that these species would be present on treatment sites at the time of carbaryl applications. There is a low probability of adverse effect to birds or large vertebrates. Permit conditions protective of surface water quality would also be protective of salmonids. The existing carbaryl permit, or a new or modified Ecology NPDES Permit to implement Alternative 2, would require discharge monitoring to be conducted to evaluate the effects of insecticide applications. Adjustments to permit conditions could be made throughout the five-year term of a new or modified permit.	

Alternative 3: Imidacloprid with IPM (Preferred Alternative)

Potential Impacts	***Mitigation Measures***
SALMONIDS INCLUDING BULL TROUT . Imidacloprid would be unlikely to adversely affect salmonids or their critical habitat (CSI 2013). . Juvenile salmonids travel through the nearshore habitat during out-migration, feeding on copepods and zooplankton. Since crustaceans and molluscs do not bioaccumulate imidacloprid in their tissues, there would be no expectation of exposure to juvenile salmonids that consume these organisms. . No studies have been found that document the retention of imidacloprid in the tissue of burrowing shrimp. Therefore, no affect to salmonids would be expected if they were to consume some life stage of burrowing shrimp from a treatment site after an imidacloprid application.	. Mitigation measures described above for Alternative 3: Surface Water would be protective of salmonids and their critical habitat within Willapa Bay and Grays Harbor. . Imidacloprid applications would occur during low and out-going tides, when salmon would not be present over commercial shellfish beds. This would limit the potential for salmon exposure during feeding. The granular form of imidacloprid (Protector 0.5G) dissolves before salmon could potentially return to treatment sites.
GREEN STURGEON Imidacloprid has a limited effect on large vertebrates, and only when high concentrations are directly ingested.	Imidacloprid applications would occur in shallow water or on exposed mudflats, when sturgeon are unlikely to be present over commercial shellfish beds. For this reason, no specific mitigation measures would be required for green sturgeon.
MARBLED MURRELET Marbled murrelet critical habitat and foraging habitat do not overlap with areas where imidacloprid applications would occur on commercial shellfish beds in Willapa Bay or Grays Harbor. These birds forage on the outer coast for forage fish, and are not well documented inside the bays. Therefore, imidacloprid would be unlikely to adversely affect marbled murrelet (CSI 2013).	No specific mitigation measures would be required for marbled murrelet.
WESTERN SNOWY PLOVER . Granular-form applications of imidacloprid (Protector 0.5G) on mudflats (commercial shellfish beds) could result in birds' exposure to this chemical through ingestion of the solid form. This period of potential exposure would be interrupted when the mudflats became inundated by the incoming tide. . Liquid-form applications of imidacloprid (Protector 2F) would avoid exposure time for birds (Giddings et al. 2012). . The imidacloprid Risk Assessment (CSI 2013) found imidacloprid toxicity exposure for snowy plover to be "minimal acute," and "low likelihood of indirect effects."	No specific mitigation measures would be required for western snowy plover.
STREAKED HORN LARK Imidacloprid applications under Alternative 3 would be unlikely to adversely affect streaked horn lark or their nest sites because they do not occur on commercial shellfish beds within Willapa Bay or Grays Harbor.	No specific mitigation measures would be required for streaked horn lark.
Significant Unavoidable Adverse Impacts: Based on currently available information and studies, and requirements	

to comply with the conditions of all applicable insecticide registrations, permits and regulations (including Washington State Water Quality Standards), no significant unavoidable adverse impacts to threatened, endangered or protected species would be expected with the proposed action (Alternative 3: imidacloprid applications with IPM). With the exception of some salmonid life stages, it is unlikely that these species would be present on treatment sites at the time of imidacloprid applications. There is a low probability of adverse effect to birds or large vertebrates. Permit conditions protective of surface water quality would also be protective of salmonids. The requested Ecology NPDES Permit, if issued, would require discharge monitoring to be conducted to evaluate the effects of insecticide applications. Adjustments to permit conditions could be made throughout the five-year term of the permit.

Human Health

No Action Alternative

- No human population would be exposed to insecticides in estuarine sediments or water under the No Action Alternative.
- Applicators and shellfish harvesters would have no potential exposures to imidacloprid or carbaryl under the No Action Alternative.

Alternative 2: Carbaryl with IPM

Potential Impacts	***Mitigation Measures***
Continued use of carbaryl would potentially affect insecticide handlers, applicators and commercial shellfish workers.	FIFRA REGISTRATION REQUIREMENTS: To mitigate potential exposure for persons applying carbaryl, applicators, mixers, loaders, and handlers are advised to wear approved PPE, and would be trained in pesticide applications. The following PPE would be required of all imidacloprid applicators and handlers: . Long-sleeved shirt and long pants; . Chemical-resistant gloves (comparable to those listed under Alternative 3 mitigation measures); . Chemical-resistant apron when mixing, loading, or cleaning up spills or equipment; and . Shoes and socks. . Manufacturer's instructions must be followed for cleaning and maintaining PPE. . Helicopter pilots must use an enclosed cockpit in a manner that is consistent with the WPS for Agricultural Pesticides. . A WGHOGA representative shall be present at the treatment site at the time of treatment. WASHINGTON STATE DEPARTMENT OF AGRICULTURE GENERAL PESTICIDE RULES (WAC 16-228-1231[1]): . Applications would be made by a State-licensed applicator with an aquatic endorsement.
. Spray applications of carbaryl have historically occurred on up to 800 acres *per year* of commercial oyster beds in Willapa Bay (600 acres) and Grays Harbor (200 acres) for 50+ years at a rate of 8 lb active ingredient/acre. If Alternative 2 were selected for implementation, it is assumed that applications at this rate and over these acreages would continue under the existing carbaryl NPDES permit, or under a new or modified NPDES permit, and may be authorized on commercial shellfish beds where clams are the	NPDES PERMIT REQUIREMENTS: WGHOGA would be responsible for implementing public notification requirements comparable to those in WA0040975: . Notify property owners within 200 feet of the treatment site in person, by telephone or by mail 24 hours (but not more than ten days) prior to commencement of initial carbaryl application to commercial clam or oyster beds. Include the name of

predominant crop as well as on commercial shellfish beds where oysters are the predominant crop.	the insecticide to be used, where it is to be applied, any public health and livestock restrictions, and the name and telephone number of the WGHOGA contact person. . Notify interested parties by telephone, e-mail or fax at least 24 hours prior to carbaryl applications. . Notify the public prior to carbaryl applications through newspaper announcements and signs posted at all reasonable points of public access to proposed treatment areas. . Do not treat a commercial clam or oyster bed if it contains shellfish within one year of harvest. . Maintain buffer zones between the carbaryl treatment area and the nearest shellfish to be harvested within one year: a 200-ft buffer for aerial applications; or a 50-ft buffer for applications made by hand. . Do not apply carbaryl on commercial shellfish beds during Federal holiday weekends. . It would be the responsibility of the applicator to select appropriate application equipment and treat commercial shellfish beds only during appropriate environmental conditions when wind speed, temperature, and tidal elevation would minimize the risk of spray drift, to avoid off-target dispersion. Ecology would be responsible under WAC 173-204-415(2)(e) for identifying and notifying all landowners, adjacent landowners, and lessees affected by the Sediment Impact Zone to implement Alternative 2. This notification would be in addition to the sign postings and electronic notifications regarding application dates and locations for which WGHOGA would be responsible. FIFRA REGISTRATION REQUIREMENTS: . Implement spray drift management techniques specified for carbaryl applications to avoid off-target dispersion (described above under Air Quality mitigation measures).
. Carbaryl can cause nausea, dizziness, confusion, and at high exposures, respiratory paralysis and death. . However, concentrations of carbaryl required to produce such symptoms in vertebrates, including humans, are much higher than those used to control invertebrates, which are much more sensitive.	Same as above.
Carbaryl is classified as a likely human carcinogen based on laboratory experiments that produced vascular tumors in mice (USEPA 2014).	NPDES PERMIT REQUIREMENTS: . As a dietary precaution for the protection of human health, carbaryl could only be applied on commercial clam and oyster beds where the crop would not be harvested for at least 1 year. This is based on tissue studies designed to determine the length of time it takes carbaryl to break down in oyster tissue.
Significant Unavoidable Adverse Impacts: Based on currently available information and studies, and requirements to comply with all applicable insecticide registrations, permits and regulations (including Washington State Department of Agriculture General Pesticide Rules), no significant unavoidable adverse impacts to human health would be expected with Alternative 2. Applicators and handlers would be required to use appropriate application equipment and wear specified Personal Protective Equipment. Public notification requirements would inform	

landowners, adjacent landowners, lessees, interested individuals, recreational users, and others of proposed application dates and locations so that potential direct exposure could be avoided. As a dietary precaution, avoidance and a waiting period of 1 year is specified between dates of carbaryl application and shellfish harvest for consumption.

Alternative 3: Imidacloprid with IPM (Preferred Alternative)

Potential Impacts	***Mitigation Measures***
Use of imidacloprid would potentially affect only a very small number of people, primarily insecticide handlers and applicators, and to a lesser extent, commercial shellfish workers.	FIFRA REGISTRATION REQUIREMENTS: To mitigate potential exposure for persons applying imidacloprid, applicators, mixers, loaders, and handlers are advised to wear approved Personal Protective Equipment (PPE), and would be trained in pesticide applications. The following PPE would be required of all imidacloprid applicators and handlers: . Long-sleeved shirt and long pants; . Chemical-resistant gloves made of any waterproof material such as barrier laminate, butyl rubber, nitrile rubber, neoprene rubber, natural rubber, polyethylene, polyvinylchloride (PVC) or Viton; . Shoes and socks; . Protective eyewear; and . Dust masks when using Protector 0.5 G, the granular formulation of imidacloprid. . Manufacturer's instructions must be followed for cleaning and maintaining PPE. . Helicopter pilots must use an enclosed cockpit in a manner that is consistent with the WPS for Agricultural Pesticides. WASHINGTON STATE DEPARTMENT OF AGRICULTURE GENERAL PESTICIDE RULES (WAC 16-228-1231[1]): . Applications would be made by a State-licensed applicator with an aquatic endorsement. ADDITIONAL MITIGATION THROUGH ELEMENTS OF THE WGHOGA PROPOSAL FOR THE USE OF IMIDACLOPRID: . A WGHOGA representative would be present at the time of application at each treatment sites scheduled for aerial (i.e., helicopter) applications to provide line-of-sight supervision.
. Under the proposed NPDES permit, imidacloprid applications could occur on up to 2,000 acres *per year* of commercial shellfish beds in Willapa Bay (1,500 acres) and Grays Harbor (500 acres) at a rate of 0.5 lb active ingredient per acre. . To-date, under the carbaryl NPDES permit, imidacloprid has only been used on experimental plots within Willapa Bay since approximately 2002.	NPDES PERMIT REQUIREMENTS: . Ecology would be responsible under WAC 173-204-415(2)(e) for identifying and notifying all landowners, adjacent landowners, and lessees affected by the Sediment Impact Zone to implement Alternative 3. This notification would be in addition to the sign postings and electronic notifications regarding application dates and locations for which WGHOGA would be responsible. FIFRA REGISTRATION REQUIREMENTS: WGHOGA would be responsible for implementing the following public notification requirements: . Notify the public prior to imidacloprid applications

	through signs, website postings, and e-mail to interested parties. . Post public access areas within 0.25 mile and all public boat launches within a 0.25-mile radius of any bed scheduled for treatment with imidacloprid. "WARNING" or "CAUTION" signs shall say *"Imidacloprid will be applied for burrowing shrimp control on [date] on commercial shellfish beds. Do not Fish, Crab or Clam within one-quarter mile of the treated area."* Include the location of the treatment area on the sign. . Post signs at 500-ft intervals, at least 2 days prior to aerial treatments, and maintain signs in-place for at least 30 days after treatment. . Do not treat a commercial clam or oyster bed if it contains shellfish within 30 days of harvest. . Maintain buffer zones between the imidacloprid treatment area and the nearest shellfish to be harvested within 30 days: a 100-ft buffer for aerial applications; or a 25-ft buffer for applications made by hand. . Do not apply imidacloprid on commercial shellfish beds during Federal holiday weekends. . It would be the responsibility of the applicator to select appropriate application equipment and treat commercial shellfish beds only during appropriate environmental conditions when wind speed, temperature, and tidal elevation would minimize the risk of spray drift, to avoid off-target dispersion. . Application equipment specified for the liquid form of imidacloprid (Protector 2F) includes: helicopters equipped with a boom three-quarters as long as the rotor diameter, backpack sprayers, and ground-based vehicles with a boom. . Application equipment specified for the granular form of imidacloprid (Protector 0.5G) includes: conventional granular insecticide applicators ("belly grinders"), helicopters equipped with a boom three-quarters as long as the rotor diameter, and ground-based vehicles equipped with spinners or drop spreaders. ADDITIONAL MITIGATION THROUGH ELEMENTS OF THE WGHOGA PROPOSAL FOR THE USE OF IMIDACLOPRID: . The WGHOGA IPM Coordinator would be responsible for posting, maintaining and removing public notice signs. . Use a website in lieu of newspaper announcements for public notification of specific dates and locations of proposed imidacloprid applications in Willapa Bay and Grays Harbor. The website would include a link for interested persons to request direct notification.
. Imidacloprid is a systemic insecticide of the chemical class of neonicotinoids. . The compound acts on the nervous system of insects, blocking the transmission of nerve signals in the post-synaptic region, resulting in paralysis and death.	Same as above.

. Vertebrate animals, including birds, mammals, fish, and amphibians, and aquatic plants are much less sensitive to imidacloprid than certain aquatic invertebrates (such as burrowing shrimp).	
. Imidacloprid is classified as a "Group E" carcinogen indicating "no evidence of carcinogenicity in humans" (USEPA 1999a, 1999b, and 2003). . Imidacloprid is not considered acutely toxic to humans via dermal or inhalation exposure routes even though it is designated an acute oral toxicant.	FIFRA REGISTRATION REQUIREMENTS: . As a dietary precaution, the conditional FIFRA Registration for imidacloprid specifies that no commercial shellfish bed may be treated with this pesticide if the crop is within 30 days of harvest.

Significant Unavoidable Adverse Impacts: Based on currently available information and studies, and requirements to comply with all applicable insecticide registrations, permits and regulations (including Washington State Department of Agriculture General Pesticide Rules), no significant unavoidable adverse impacts to human health would be expected with the proposed action (Alternative 3: imidacloprid applications with IPM). Applicators and handlers would be required to use appropriate application equipment and wear specified Personal Protective Equipment. Public notification requirements would inform landowners, adjacent landowners, lessees, interested individuals, recreational users and others of proposed application dates and locations so that potential direct exposure could be avoided. As a dietary precaution, avoidance and a waiting period of 30 days is specified between dates of imidacloprid application and shellfish harvest for consumption.

Land Use

No Action Alternative

There would be no direct or indirect impact to upland land uses from the use of mechanical methods of burrowing shrimp control or alternative shellfish culture practices on commercial clam and oyster beds in Willapa Bay and Grays Harbor.

Alternative 2: Carbaryl with IPM

Potential Impacts	***Mitigation Measures***
There would be no direct or indirect impact to upland land uses from the use of carbaryl to treat burrowing shrimp on commercial clam and oyster beds in Willapa Bay and Grays Harbor.	*Spray drift management requirements for carbaryl applications under Alternative 2 would avoid risk of exposure to pollinators seasonally present at cranberry farms in the local area. NPDES PERMIT REQUIREMENTS: . Public notification requirements at public and private shoreline access sites would be the same as those described above for Alternative 2: Human Health.
	FIFRA REGISTRATION REQUIREMENTS: . Average wind speed at the time of application shall not exceed 10 mph. . Aerial applications shall not occur during gusty conditions, or during temperature inversions. . Applications shall be made at the lowest possible height that is safe to operate. . Helicopters should be equipped to minimize spray drift by using high flow-rate nozzles, selecting the number and type of nozzles, nozzle orientation, and controlling pressure appropriate for the nozzle type. . No direct treatment on blooming crops or weeds shall occur.

Significant Unavoidable Adverse Impacts: Based on currently available information and studies, and requirements to comply with all applicable insecticide registrations, permits and regulations, no significant unavoidable adverse impacts to land and shoreline use would be expected as a result of implementing Alternative 2.

Alternative 3: Imidacloprid with IPM (Preferred Alternative)

Potential Impacts	***Mitigation Measures***
There would be no direct or indirect impact to upland land uses from the use of imidacloprid to treat burrowing shrimp on commercial clam and oyster beds in Willapa Bay and Grays Harbor.	FIFRA REGISTRATION REQUIREMENTS: . Public notification requirements at public and private shoreline access sites would be the same as those described above for Alternative 3: Human Health. WGHOGA PROPOSAL FOR THE USE OF IMIDACLOPRID: . Avoid aerial (i.e., helicopter) applications of Protector 0.5G or 2F within 200 feet of the Ordinary High Water Line (OHWL) adjacent to shoreline areas.
Due to the distance between existing cranberry farms and the nearest commercial clam and oyster beds adjacent to Willapa Bay and Grays Harbor, it is expected that drift management requirements for imidacloprid applications would avoid risk of exposure to pollinators present at cranberry farms adjacent to Willapa Bay and Grays Harbor during the approximate period of June 1 through July 5 each year.	FIFRA REGISTRATION REQUIREMENTS: . Average wind speed at the time of application shall not exceed 10 mph when either Protector 0.5G or 2F is applied by air. Further, aerial applications shall not occur during gusty conditions, or during temperature inversions. Temperature inversions begin to form as the sun sets and often continue into the morning. . Applications of imidacloprid shall be made at the lowest possible height (helicopter, ground or barge) that is safe to operate and that would reduce exposure of the granules to wind. . When applications of Protector 0.5G (the granular formulation) are made crosswind, the applicator must compensate for displacement by adjusting the path of the application equipment upwind. Swath adjustment distance should increase with increasing drift potential. . Helicopters used to apply Protector 2F should be equipped to minimize spray drift. The best drift management strategy and most effective way to reduce drift potential is to apply large droplets that provide sufficient coverage and control. Droplet size can be controlled by using high flow-rate nozzles, selecting the number and type of nozzles, nozzle orientation, and controlling pressure appropriate for the nozzle type. . No direct treatment on blooming crops or weeds shall occur.
Significant Unavoidable Adverse Impacts: Based on currently available information and studies, and requirements to comply with all applicable insecticide registrations, permits and regulations, no significant unavoidable adverse impacts to land and shoreline use would be expected as a result of implementing Alternative 3 (the proposed action).	

Recreation

No Action Alternative

. Under the No Action Alternative, persons engaged in recreation in Willapa Bay and Grays Harbor would have no risk of exposure to chemical applications for the purpose of burrowing shrimp control.
. Ongoing attempts at mechanical control of burrowing shrimp, and alternative shellfish culture practices would likely constitute no detectable change from existing conditions to persons using Willapa Bay and Grays Harbor for recreational purposes due to the small size of these areas in relation to the total tideland area of Willapa Bay and Grays Harbor.

Alternative 2: Carbaryl with IPM

Potential Impacts	*Mitigation Measures*
. Carbaryl can overstimulate the nervous system causing nausea, dizziness, and confusion, though such reactions are not likely at the concentrations that would be applied to control burrowing shrimp, which are much more sensitive than vertebrates (including humans). . Carbaryl is classified as a likely human carcinogen; however, there have been no known incidences of human exposure to carbaryl during its 50+ years of use for burrowing shrimp control in Willapa Bay and Grays Harbor.	NPDES PERMIT REQUIREMENTS: . Public notification requirements at public and private shoreline access sites would be the same as those described above for Alternative 2: Human Health. . The WGHOGA Annual Operations Plan (AOP) would identify the location of public access points to Willapa Bay and Grays Harbor where signs would be posted to report the name of the insecticide to be used, where it is to be applied, any public health and livestock restrictions, and the name and phone number of the WGHOGA contact person (likely the IPM Coordinator). . Carbaryl would not be applied to commercial clam or oyster beds during Federal holiday weekends. . NPDES permit conditions would limit the maximum annual treatment area, thereby minimizing the potential for exposure of persons who may use exposed tide flats in these estuaries for recreation.
Significant Unavoidable Adverse Impacts: Based on currently available information and studies, and requirements to comply with all applicable insecticide registrations, permits, regulations, and public notification requirements, no significant unavoidable adverse impacts to recreation would be expected as a result of implementing Alternative 2.	

Alternative 3: Imidacloprid with IPM (Preferred Alternative)

Potential Impacts	*Mitigation Measures*
. Imidacloprid is classified as a "Group E" carcinogen indicating "no evidence of carcinogenicity in humans" (USEPA 199a, 199b, 2003). . There is no indication of possible human health impacts from imidacloprid exposure to the general population engaging in recreational activities (e.g., shellfish gathering, fishing, and swimming) in Willapa Bay or Grays Harbor.	NPDES PERMIT REQUIREMENTS: . Ecology responsibilities for public notification regarding the location of Sediment Impact Zones for the use of imidacloprid would be the same as those described above under Human Health. FIFRA REGISTRATION REQUIREMENTS: . Public notification requirements at public and private shoreline access sites would be the same as those described above for Alternative 3: Human Health. . Imidacloprid would not be applied to commercial clam or oyster beds during Federal holiday weekends. ADDITIONAL MITIGATION THROUGH ELEMENTS OF THE WGHOGA PROPOSAL FOR THE USE OF IMIDACLOPRID: . Use a website in lieu of newspaper announcements for public notification of specific dates and locations of proposed imidacloprid applications in Willapa Bay and Grays Harbor. . Include a link for interested persons to request direct notification regarding proposed treatment dates and locations. The IPM Coordinator would send e-mail notifications to registered interested parties, as needed. . Avoid aerial (i.e., helicopter) applications of Protector 0.5G or 2F within 200 feet of the Ordinary High Water Line (OHWL) adjacent to shoreline areas.

Most commercial shellfish beds are distant from public access areas. The potential for exposure of recreationists to imidacloprid in Willapa Bay and Grays Harbor would be limited by proximity and by the maximum annual treatment area: approximately 1,500 acres within Willapa Bay *per year* (3.3% of total tideland acres exposed at low tide), and approximately 500 acres within Grays Harbor *per year* (1.5 percent of total tideland acres exposed at low tide).	Same as above.
Significant Unavoidable Adverse Impacts: Based on currently available information and studies, and requirements to comply with all applicable insecticide registrations, permits, regulations, and public notification requirements, no significant unavoidable adverse impacts to recreation would be expected as a result of implementing Alternative 3 (the proposed action).	

Navigation

No Action Alternative

There would be no significant impacts to navigation as a result of mechanical methods of burrowing shrimp control or alternative shellfish culture practices on commercial clam and oyster beds in Willapa Bay and Grays Harbor.

Alternative 2: Carbaryl with IPM

Potential Impacts	***Mitigation Measures***
Similar to Alternative 3 discussed below, carbaryl applications under Alternative 2 would require the placement of stakes to identify commercial clam and oyster beds for aerial applications. No stakes or obstructions would be placed in the main navigation channels of either bay.	Public notification requirements at marinas and boat launch sites would be the same as those described above under Alternative 2: Human Health and Recreation.
Significant Unavoidable Adverse Impacts: No significant unavoidable adverse impacts to navigation would be expected as a result of implementing Alternative 2.	

Alternative 3: Imidacloprid with IPM (Preferred Alternative)

Potential Impacts	***Mitigation Measures***
There would be no significant impacts to navigation as a result of imidacloprid treatments for burrowing shrimp control. Commercial shellfish beds are staked for various purposes at various times of the year. Stakes placed to identify beds for aerial applications of imidacloprid would not constitute a new or different obstruction to watercraft that navigate the shallow areas of Willapa Bay or Grays Harbor where these shellfish beds are located. No stakes or obstructions would be placed in the main navigation channels of either bay.	Public notification requirements at marinas and boat launch sites would be the same as those described above under Alternative 3: Human Health and Recreation.
Significant Unavoidable Adverse Impacts: No significant unavoidable adverse impacts to navigation would be expected as a result of implementing Alternative 3 (the proposed action).	

1.7 Areas of Controversy and Uncertainty, and Issues to be Resolved

Areas of Controversy. There is controversy over the use of neonicotinoid insecticides in the environment. Imidacloprid is within this group of insecticides. The majority of data regarding the effects of imidacloprid have been obtained from studies performed in terrestrial agriculture applications, and/or within laboratory settings. Elements of these studies may not be directly transferrable to aquatic organisms in an estuarine environment where tidal exchange occurs four times per day. Studies of imidacloprid and one of its degradation products in these specific estuarine environments have been conducted recently and are ongoing at the time of this writing. Ecology will continue to review the results of these studies and consider their applicability to the proposed use of imidacloprid to treat burrowing shrimp on commercial shellfish beds in Willapa Bay and Grays Harbor.

Beekeepers and others concerned about pollinators (e.g., honey bees, bumble bees, butterflies and moths) have expressed concern about the use of imidacloprid because it is implicated in depleting these populations in terrestrial agricultural applications at various locations in the United States and Europe.

Scoping comments received from local area scientific experts report that pollinators do not use the tideflats, and spray drift management techniques required by the Federal registrations for imidacloprid are sufficiently protective (personal communications received from Ed Darcher, Pacific County *Spartina* Coordinator since 1996, February 6, 2014; and Dr. Kim Patten, WSU Pacific County Extension Director, various dates). There are no flowering plants (other than eelgrass) on commercial shellfish beds as these are inundated twice daily by tides. Of the approximately 3,000 bee hives imported in June each year to pollinate cranberries at the south end of Willapa Bay, a few of these are located approximately 0.5 mile (2,640 feet) from the nearest commercial shellfish beds. The closest cranberry farm in Grays Harbor is approximately 1.5 miles from a commercial shellfish beds. The remaining 98 percent of the colonies are located 6 miles or more from the nearest shellfish beds (see FEIS Chapter 3, Section 3.2.5). The conditional FIFRA Registrations issued for the use of imidacloprid products at the proposed rate of 0.5 lb active ingredient per acre indicate that this would be below concentrations that would impact honey bees (USEPA 2013b). Further, in the professional opinion of the WSDA, Special Pesticide Registration Program Coordinator, there is no risk to bees from the application of imidacloprid (either granular or flowable formulation) to tidal flats. Implementing appropriate spray drift management techniques for the flowable formulation of imidacloprid, or maintaining an adequate buffer between the imidacloprid treatment area and blooming plants (as proposed by WGHOGA) would mitigate potential risk to bees (personal communication with Erik Johansen, March 19, 2014). However, imidacloprid applications on commercial shellfish beds in these estuaries remains a controversial proposal among beekeepers and others concerned about aerial and aquatic drift of imidacloprid applications.

The proposal to control burrowing shrimp is not to eradicate burrowing shrimp in Willapa Bay and Grays Harbor. The proposal is for the control of burrowing shrimp on a limited acreage of commercial shellfish beds that have historically been used and dedicated to growing shellfish in these two estuaries. Not all of the tideland acres owned, leased, or currently farmed for commercial clams and oysters would be treated with imidacloprid over the term of the permit. Burrowing shrimp populations are not uniform across all tidelands. Permit conditions would limit imidacloprid applications to individual treatment sites, not to exceed one application per year.

Areas of Uncertainty and Issues to be Resolved. The Toxicology Review that accompanies the WSDA registration of the granular and liquid forms of imidacloprid (Protector 0.5G and Protector 2F, respectively) identified the following areas of uncertainty based on WSDA's assessment of the preliminary nature of the environmental fate and effects data presented in the studies submitted with the application (Tuttle 2014). WSDA has requested additional data from WGHOGA by 2016 to address these issues with a higher degree of certainty:

The results of multi-year studies (> 2 years) are not yet available to affirm whether imidacloprid and its primary metabolites accumulate in sediments, and if so, the "worst-case" scenario.

Due to the preliminary nature of research data available at the time of this writing, there is uncertainty regarding whether imidacloprid may have potential long-term sediment toxicity effects on benthic and free-swimming invertebrate communities, the species that utilize them as food sources, and the ability of the Willapa Bay and Grays Harbor estuary ecosystems to maintain homeostasis as a whole. Uncertainty has been expressed as to whether the results of experimental trials using imidacloprid on treatment plots up to ten acres in size can be assumed to correlate directly when the spatial extent of the treatment area is increased under the NPDES permit. The WGHOGA application requests permission to treat up to 1,500 acres *per year* of commercial shellfish beds within Willapa Bay, and up to 500 acres *per year* of commercial shellfish beds within Grays Harbor. Studies were being conducted at the time of this writing to help address spraying on commercial shellfish beds larger than ten acres, and multiple beds being treated in close proximity to each other.

There is uncertainty whether the length of the seasonal timing of imidacloprid applications allowed by the FIFRA Registrations for Protector 0.5G and Protector 2F (April 15 through December 15) is needed for efficacy in treating sensitive life cycles of the two target species of burrowing shrimp while at the same time avoiding sensitive life cycles of non-target species.

A well-defined method for determining the treatment threshold to ensure efficacy of the product on the target species of burrowing shrimp (*Neotrypaea californiensis* and *Upogebia pugettensis*) has not yet been formulated from the preliminary research data on imidacloprid.

The WGHOGA Integrated Pest Management (IPM) strategy was in a preliminary stage at the time of this writing, due to the growers' need to continue to experiment with refinements to methods and timing of imidacloprid applications to achieve optimum efficacy with the least undesirable possible side effects (see FEIS Chapter 2, Section 2.8.3).

It is not yet known whether the target species of burrowing shrimp may become resistant to the effects of imidacloprid over time.

On-going studies and monitoring will be performed during the 2014 and 2015 imidacloprid treatment seasons to address these issues with the objective of ensuring that potential impacts to the environment are minimized and short-lived. Sampling and analysis plans, annual operations plans, and/or quality assurance plans will require pre-approval by Ecology and/or WSDA. The studies and monitoring results will be submitted to Ecology, WSDA and EPA for review and decision making regarding the use of imidacloprid after 2015.

Other areas of uncertainty were identified during the EIS scoping process, in subsequent meetings and communications with Ecology, and during preparation of the FEIS. These are listed below.

Research on the effects of burrowing shrimp on commercial shellfish beds has been done where oysters are the primary crop. Field research data are lacking regarding how burrowing shrimp affect clams, and the threshold for damage to clam beds. Growers have provided information that indicates, based on their field observations, there is no biological basis for making a distinction between the effects of burrowing shrimp on tidelands primarily used for the production of commercial clams versus areas primarily used for the production of commercial oysters. The adverse effect is on the substrate, not the crop – both sink and suffocate (DeFrancesco and Murray 2010). Environmental review of the WGHOGA proposal to treat clam beds with imidacloprid is based on the best available information provided on this subject.

Studies on-going at the time of this writing will continue to evaluate the effects of imidacloprid on non-target benthic and epibenthic organisms, to confirm when and whether non-target organisms are unaffected or are able to recover or recolonize application areas after treatment with imidacloprid. Studies will be conducted in areas of different sediment types and/or tidal flushing to further explore these questions.

The effects of imidacloprid on zooplankton species are largely unstudied. While crustaceans (e.g., burrowing shrimp and crabs) are generally more susceptible to indirect effects than worms and mollusks, the potential for direct mortality to planktonic juveniles is unknown. Laboratory studies have shown varied effects of imidacloprid on zooplankton, depending on the conditions present during these studies. Under the proposed action, imidacloprid would be applied on selected commercial shellfish beds under conditions when large numbers of zooplankton would not be present (see FEIS Chapter 3, Section 3.2.5).

Limited information in marine environments is available regarding the possible sub-lethal effects of imidacloprid on non-target aquatic organisms. Ultimately, burrowing shrimp are controlled through sub-lethal effects. Review of future studies will be conducted to further determine the potential long-term sub-lethal effects of imidacloprid on animals in the aquatic environment.

Limited information is available regarding imidacloprid impacts to marine vegetation. The results of field studies conducted during one season to evaluate uptake in eelgrass tissues showed limited uptake by eelgrass, and imidacloprid was undetectable after 14 days. In addition, imidacloprid is an acetylcholinase inhibitor and plants do not have a biochemical pathway involving acetylcholinase. Therefore, it is unlikely that imidacloprid would adversely affect eelgrass or other marine vegetation (see FEIS Chapter 3, Section 3.2.4).

Few studies have been conducted on post-application effects on green sturgeon, such as exposure to imidacloprid in sediment and sediment porewater following an incoming tide when sturgeon may wallow in sediments to eat burrowing shrimp temporarily paralyzed by the treatment. One such study (Frew 2013) shows that green sturgeon do uptake imidacloprid from sediment porewater (see FEIS Chapter 3, Section 3.2.5). However, what is unclear is whether green sturgeon will actually feed on burrowing shrimp present on shellfish beds. It is thought that they do not feed on shellfish beds because the sharp shells hurt their mouths (personal communication with Dr. Kim Patten, WSU Pacific County Extension Director). Observational studies of the presence of green sturgeon pits in shellfish beds was being undertaken at the time of this writing.

Limited field verification data are available at the time of this writing regarding the toxicity and persistence of imidacloprid degradation products. Some laboratory studies have been conducted using marine waters. The results of these studies showed that the imidacloprid degradation products have toxicity levels that are equal to or less than the toxicity of the parent compound (SERA 2005) (see FEIS Chapter 3, Section 3.2.3).

Some field data suggest that the persistence of imidacloprid varies in relation to site characteristics (e.g., longer persistence in sediments with high organic content). This question will be further studied in 2015, during which, data will be collected to determine the persistence of imidacloprid in sediments with higher organic content and in areas with lower tidal flushing.

A limited number of field studies have been conducted in the estuarine environment to confirm off-plot movement of imidacloprid following applications of the flowable and granular forms on commercial shellfish beds. It is not known with certainty whether off-plot movement of imidacloprid and/or its degradation products from treatment sites within some proximity to one another may have an additive effect nearby. On-going studies at the time of this writing are evaluating the off-plot movement of the flowable form of imidacloprid (Protector 2F) applied to commercial shellfish beds.

It is not possible to quantify the total acreage of commercial shellfish beds to be treated with imidacloprid over the five-year term of the NPDES permit. Growers would apply imidacloprid within the annual acreage limits in each bay (up to 1,500 acres *per year* in Willapa Bay and up to 500 acres *per year* in

Grays Harbor) based on case-by-case decisions related to the dynamics of the burrowing shrimp population, and the efficacy of past applications. Individual shellfish beds may be treated once per year at a maximum, though growers estimate that treatment frequency will likely be less often for most beds. Applications to selected areas may occur at intervals as great as three or more years, depending on recovery of burrowing shrimp and the growth rate of burrowing shrimp. While it is possible that the total acreage to be treated within Willapa Bay could range from 1,500 to 7,500 acres, and within Grays Harbor could range from 500 to 2,500 acres over the 5-year term of the permit, growers anticipate that it is more likely the upper limits of these ranges would not be reached.

2.0 Description of the Proposed Action and Alternatives

2.1 Project Proponent

At the request of the Willapa-Grays Harbor Oyster Growers Association (WGHOGA), the Washington State Department of Ecology (Ecology) is evaluating a proposal to develop an Individual Permit under the National Pollutant Discharge Elimination System (NPDES) for the control of two species of burrowing shrimp[1] on commercial shellfish beds[2] in Willapa Bay and Grays Harbor, Washington. Applicators who receive coverage under the Individual Permit must comply with the terms and conditions of the permit.

2.2 Purpose and Objectives of the Proposed Action

WGHOGA has requested issuance of a NPDES permit for the purpose of allowing chemical applications of the neonicotinoid insecticide[3] imidacloprid on up to 2,000 acres *per year* of commercial shellfish beds: up to 1,500 acres in Willapa Bay, and 500 acres in Grays Harbor. The total acreage to be treated within Willapa Bay and Grays Harbor each year would likely vary. It is possible that over the five-year term of the permit, the total acreage to be treated within Willapa Bay could range from 1,500 to 7,500 acres, and in Grays Harbor could range from 500 to 2,500 acres (Refer to section 2.8.3.1).

These applications would be made using adaptive management principles, as described in an Integrated Pest Management (IPM) Plan. The objectives of the proposed action are to:

- Preserve and maintain the viability of clams and oysters commercially grown in Willapa Bay and Grays Harbor by controlling populations of two species of burrowing shrimp on commercial shellfish beds.
- Preserve and restore select tidelands in Willapa Bay and Grays Harbor that are at risk of loss as commercial shellfish beds due to sediment destabilization caused by burrowing shrimp.

2.3 Location

The proposed action would be implemented on commercial shellfish beds in Willapa Bay[4] and Grays Harbor,[5] Washington. These large estuaries are located in Pacific County and Grays Harbor County, respectively, on the Pacific Ocean coast in the southwest corner of the State (see Figure 2.3-1).

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1 The two species of burrowing shrimp to be controlled are the ghost shrimp (*Neotrypaea californiensis*) and mud shrimp (*Upogebia pugettensis*).

2 As used throughout this Environmental Impact Statement in the context of alternatives to implement the proposed action, the term "commercial shellfish beds" refers to tidelands within Willapa Bay and Grays Harbor on which oysters and clams are commercially grown. The requested NPDES permit would not extend to other geographical areas and would not authorize treatment on other species of commercially-grown shellfish (e.g., geoducks or mussels).

3 Neonicotinoids are a class of neuro-active insecticides chemically similar to nicotine. Neonicotinoids were developed in large part because they show reduced toxicity compared to previously used organophosphate and n-methyl carbamate insecticides. Most neonicotinoids show much lower toxicity in birds and mammals than insects, but some breakdown products are toxic (Lee Chao and Casida 1997, as cited in http://en.wikipedia.org/wiki/Neonicotinoid, September 14, 2014). The neonicotinoid imidacloprid is currently the most widely used insecticide in the world (Yamamoto 1999, as cited in http://en.wikipedia.org/wiki/Neonicotinoid, September 14, 2014).

4 Latitude 46.37 through 46.75 and Longitude -124.05 through -123.84.

5 Latitude 46.86 through 47.04 and Longitude -124.16 through -123.84.

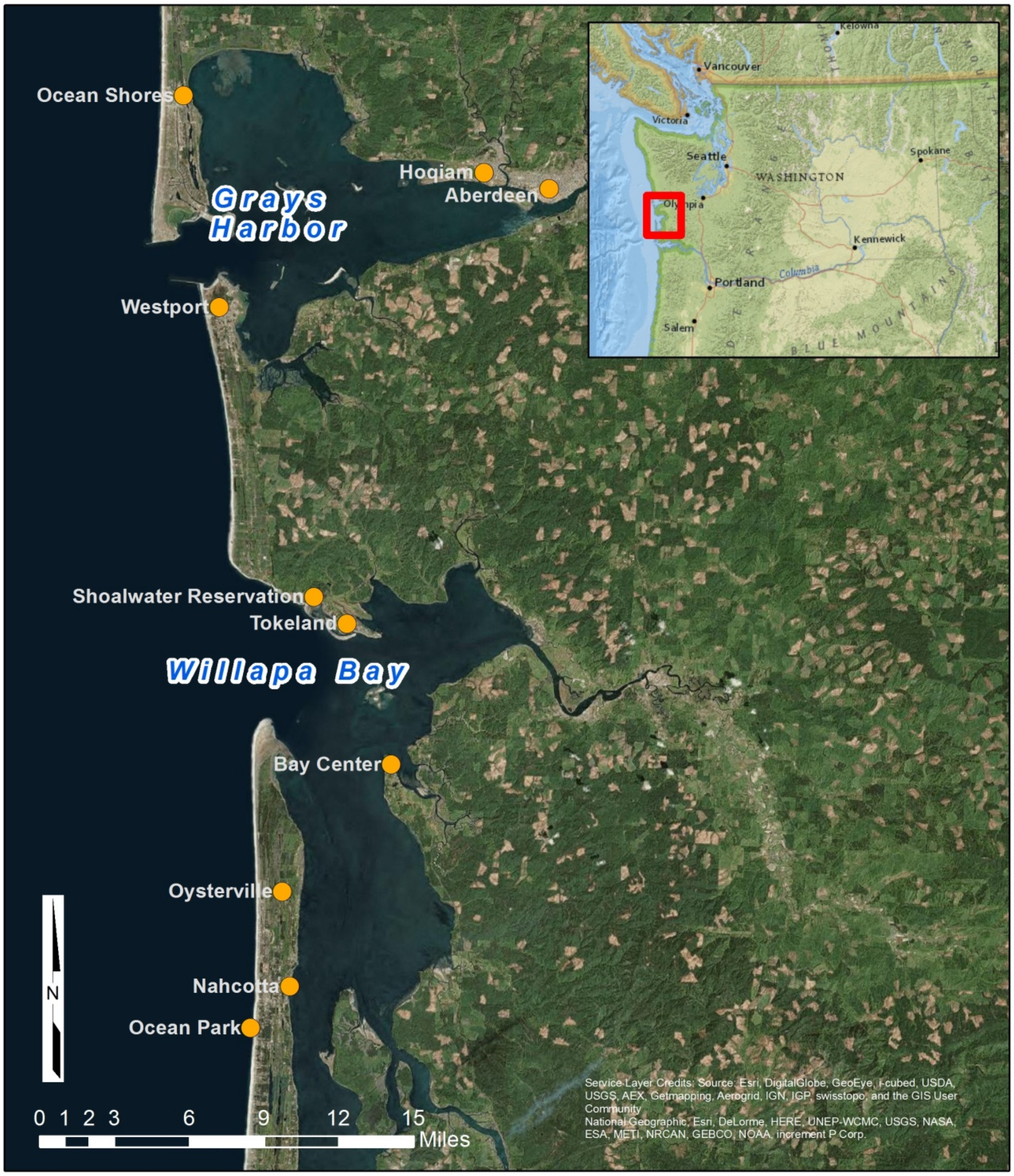

Figure 2.3-1 – Willapa Bay and Grays Harbor Location Map

2.4 History and Background

Willapa Bay and Grays Harbor are highly productive estuaries. Willapa Bay produces approximately 65 percent of the oysters and 13 percent of the clams harvested in Washington State. The combined oyster harvest from Willapa Bay and Grays Harbor constitutes approximately 25 percent of total oyster landings in the United States (see Section 2.6, below). The majority of oysters are raised directly on the substrate from subtidal elevations to about the +3.5-foot mean lower low water (MLLW) elevation level in the intertidal region. There are a total of about 25,622 acres of deeded and classified oyster grounds in Willapa Bay (NMFS, April 28, 2009) (see Figure 2.4-1), of which approximately 9,000 acres are currently farmed (CSI 2013). There are approximately 3,995 acres of tidelands owned or leased for commercial shellfish aquaculture within Grays Harbor: 3,088 acres in North Bay and 907 acres in South Bay (NMFS, April 28, 2009) (see Figure 2.4-2),[6] of which approximately 900 acres are currently farmed for the commercial production of oysters and clams (CSI 2013). In addition, the Washington State Department of Fish and Wildlife (WDFW) manages approximately 10,000 acres of oyster reserve tidelands in Willapa Bay—land originally set aside and State ownership retained to assure that a supply of seed oysters is maintained. The Washington State Department of Natural Resources (WDNR) also leases some additional subtidal and intertidal areas for the cultivation of shellfish in Willapa Bay and Grays Harbor.

Willapa Bay oyster cultivation began before statehood in Washington. Prior to statehood, oysters were cultivated by obtaining native oyster seed from "natural oyster beds" and moving them to other intertidal areas controlled by various growers and companies. At the time of statehood (November 11, 1889), the new constitution claimed all tidelands as State property. The first Legislative session after statehood (1889–1890) allowed those oyster growers who had been transferring shellfish to other intertidal areas the right to purchase these holding and growing areas. These were referred to as the "artificial oyster beds" to distinguish them from the "natural oyster beds" that remained under State ownership. Private ownership of tidelands obtained under this initial Legislative action was transferable (Shotwell 1977).

In 1895, the Washington State Legislature acted to permit the sale of State tidelands to be used exclusively for the planting of oysters. The Bush and Callow Acts permitted deeded ownership of these intertidal areas. These original Acts were modified occasionally by the State Legislature. In 1919, the Acts were changed so that any edible shellfish could be cultivated on the deeded areas, not only oysters.[7] In 1927, a limiting clause was inserted that retained oil, gas and mineral rights for the State on the privately-held tidelands. In 1935, after the successful introduction of the Japanese (Pacific) oyster, the Legislature precluded any additional sale of shellfish culture areas but preserved all of the rights that had been acquired under the original Acts (Shotwell 1977).

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[6] Commercial shellfish beds mapped in the east-central area of Grays Harbor, south and east of the Crossover Channel, are not farmed. These beds are permanently restricted by the Health Department as a result of being within a pollution boundary attributable to upstream inputs (personal communication with WGHOGA member Dave Hollingsworth, June 11, 2014). See FEIS Chapter 3, Section 3.2.3.

[7] The Legislative act to authorize growing any edible shellfish on deeded tidelands is significant to the WGHOGA proposal for the use of imidacloprid for burrowing shrimp control on areas commercially grown for clams as well as on areas commercially grown for oysters.

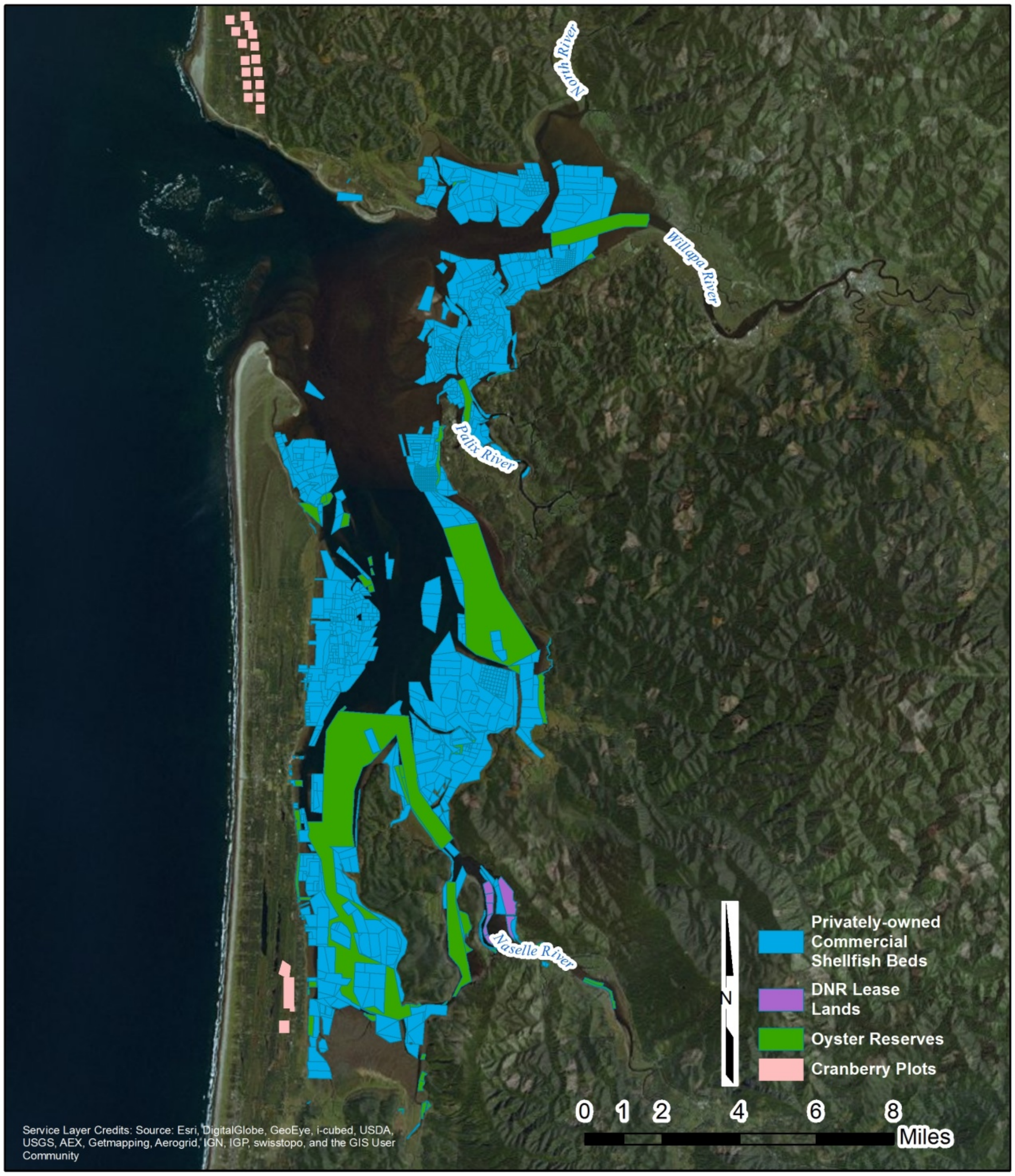

Figure 2.4-1 – Willapa Bay Tidelands

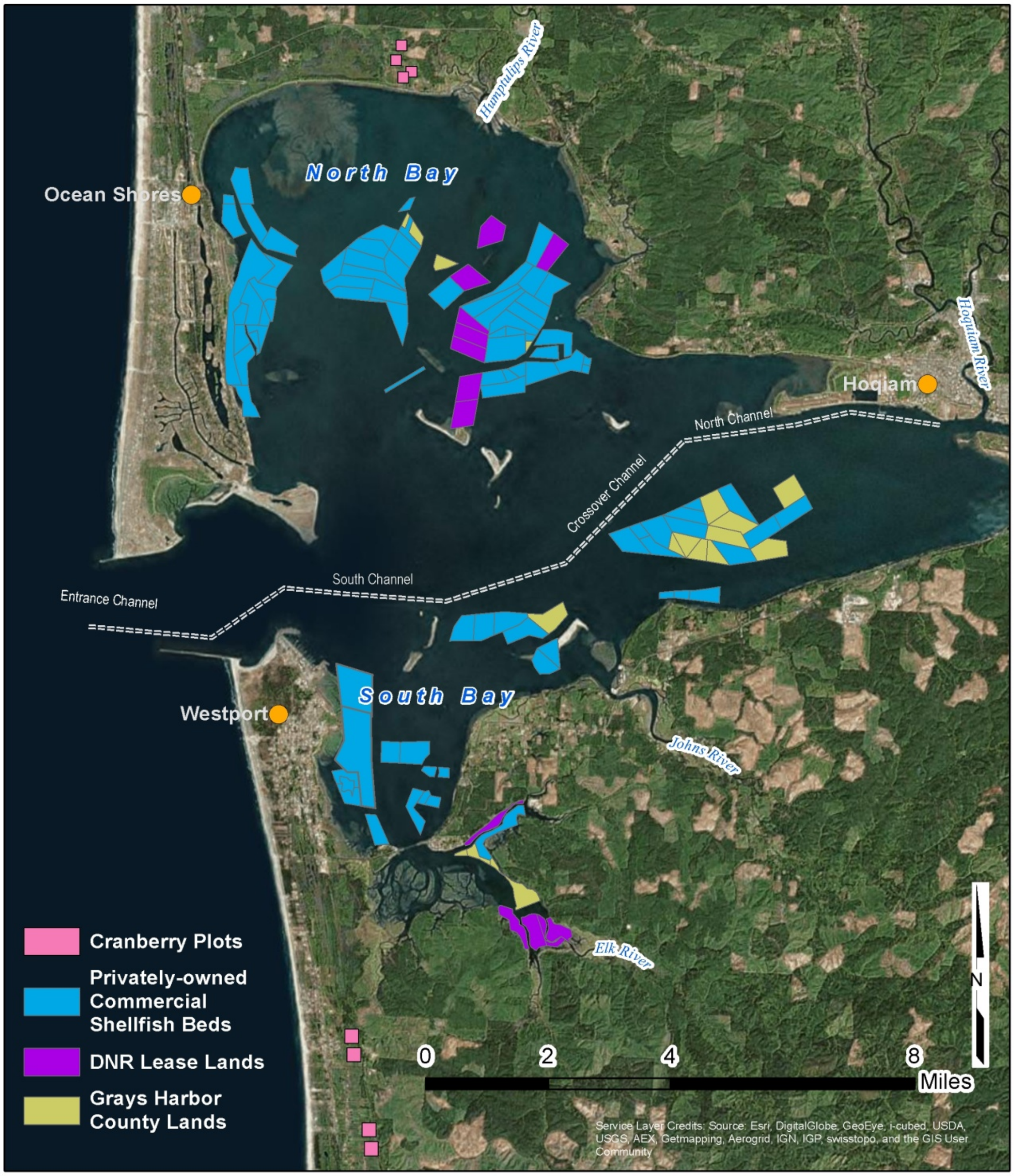

Figure 2.4-2 – Grays Harbor Tidelands

During the period 1910 to 1926, ownership of about 50 percent of the unused deeded land in Willapa Bay reverted to Pacific County through foreclosure for taxes. The oyster industry declined during this period due to the failure of the Eastern oyster that was being transplanted from the East Coast of the United States. Introduction of the Japanese oyster in the late 1920s started what was effectively a new industry for the West Coast. In Willapa Bay, the increase in deeded acreage to current levels (approximately 25,622 acres) was a composite of previously deeded land still in private ownership, oyster land held by Pacific County, and eligible State-owned tideland that had not been purchased prior to this period and was still available from the State (WDC 1986, as cited in WDF/ECY 1992).

After introduction of the Pacific oyster in Willapa Bay, production increased through the 1930s and into the 1940s. From 1940 to 1947, oyster production averaged nearly one million gallons per year in Willapa Bay (two to three times the average annual volume during the 15-year period between 1973 and 1987). A steady decline in oyster production began in the late 1940s and continued into the mid-1970s (Shotwell 1977). Several factors likely influenced this decline, such as the uncertainty and expense of oyster seed supply in the late 1960s and early 1970s. However, the major decline between 1950 and 1965 was in large part due to burrowing shrimp that began a rapid expansion at that time as observed by Willapa Bay and Grays Harbor oyster farmers and WDFW biologists (R. Wilson undated, c. August 1995).

It was recognition of the destructiveness of the two burrowing shrimp species[8] during the 1950s that prompted WDF personnel to begin testing various methods of control. The insecticide carbaryl (for which the trade name was Sevin) was found to have minimal short-term and no long-term effects on the environment, and from 1960 to 1968 was tested quite extensively by WDF biologists working with the oyster growers (R. Wilson undated, c. August 1995).

Carbaryl was, at one time, derived naturally from a Nigerian bean. It is now a man-made chemical. Treated beds begin to soon recover with certain mobile fauna, followed by more sedentary species on a longer timescale (Dumbauld et al. 1997). Carbaryl is site-specific and generally stays on or close to the point of application (R. Wilson 2002); however, studies by Felsot and Ruppert (2002) have also found detectable concentrations of carbaryl up to 150 m (~500 ft) away from the treatment plot one day after treatment. Public and agency concern has increased in recent years, leading to experimental studies both aimed at reducing or eliminating the use of carbaryl, as discussed further below.[9]

Carbaryl works by interfering with the transmission of signals along nerves. Specifically, it inhibits the enzyme acetyl cholinesterase in a manner similar to organophosphates, but the enzyme-inhibitor complex breaks down approximately five times faster. In addition, unlike the phosphorylated enzyme, the carbamylated enzyme does not "age." The aging process prevents enzyme regeneration even when the antidote is administered. Carbaryl is safer toward warm-blooded animals than most organophosphate insecticides (Hastings et al. 2001, as cited in Booth and Wilson 2002). Carbaryl is detoxified and eliminated rapidly in vertebrates (Metcalf 2002 as cited in http://en.wikipedia.org/wiki/carbaryl).

Use of Carbaryl in Washington State. Prior to 1984, treatment was limited to 300 acres within Willapa Bay and 100 acres elsewhere in Washington State, primarily within Grays Harbor. During this period, the spray application rate was 10 pounds per acre (active carbaryl). WDF also permitted one treatment in

8 As noted, two species of thalassinid burrowing shrimp cause problems for oyster growers in Washington State: the ghost shrimp *Neotrypaea californiensis*, and the mud shrimp *Upogebia pugettensis*. Both dig extensive burrows in intertidal sediments, undermining the substrate and causing oysters to sink and die. Unless specifically distinguished in the text, the term "burrowing shrimp" is used to apply to both ghost shrimp and mud shrimp.

9 The regulatory climate related to pesticide registration, the Endangered Species Act, and the Clean Water Act has presented challenges for the continued use of carbaryl.

Puget Sound: 14 acres within Liberty Bay in 1982. After 1984, carbaryl was applied at 5 to 7.5 pounds per acre (WDF and ECY 1992).

Following the El Niño[10] event of 1982–1983, there was a significant increase in burrowing shrimp abundance. As a result, the U.S. Environmental Protection Agency (EPA) and State agencies authorized treatment of up to 600 acres in Willapa Bay and 200 acres elsewhere in Washington. Treatment over seed oysters as well as on bare ground was also authorized. Treatments during the period 1963 through 1989 were restricted to beds meeting the shrimp density and locational requirements specified in the EPA permit, and to the months of July and August with one exception: late June 1988 (WDF and ECY 1992).

The permitted use of carbaryl on up to 800 acres of commercial oyster growing grounds since 1963 has slowed the destructive modification of privately-owned oyster land by burrowing shrimp. Of the original approximately 25,562 acres of recognized oyster growing area in Willapa Bay deeded to private owners by the State, the oyster industry was, in 2012–2013, actively cultivating shellfish on about 9,000 acres (CSI 2013), or approximately 35 percent of that original area. Nearly 12,000 acres or 45 percent of the deeded intertidal shellfish beds now lie fallow but are still considered potentially productive (Shotwell 1977). About 4,000 acres (15 percent) were considered by Shotwell to have never been useable or productive.

The fallow but once productive areas have been rendered unproductive for several reasons, including the adverse effects of burrowing shrimp. Seed beds, grow-out beds, and/or harvest beds can become unusable within a few months or a few years depending upon the shrimp population levels in the shellfish beds, shrimp population levels on abutting beds, and other factors. NPDES Waste Discharge Permit WA 0040975 (2006) established criteria for treating burrowing shrimp populations in commercial shellfish beds that included a requirement for the population density to exceed 10 burrows per square meter. Beds that reach this density level are not suitable for commercial production of shellfish unless they can be treated for shrimp control. Without the ability to treat, all beds would begin to degrade until they reach a point where they cannot be farmed (personal communication with WGHOGA members, February 2014).

At the time of this writing, much of the once-used, deeded commercial shellfish tidelands in Washington State remain heavily populated by burrowing shrimp, which contribute to the soft sandy or muddy substrates that are unsuitable for shellfish production.

Use of Carbaryl in Oregon State. Oyster growers in Tillamook Bay, Oregon, noted in the early 1960s that mud shrimp and ghost shrimp appeared to interfere with oyster cultivation. Beginning in 1964, about 100 tideland acres were treated annually with carbaryl. In early 1982, three oyster growers sought a permit to spray carbaryl on 140 acres. In August 1982, Oregon State granted the permit, which was subsequently appealed (WDF and ECY 1992). The Tillamook Bay industry lost the use of carbaryl to control burrowing shrimp in 1985 due primarily to lack of resources to prepare an impact assessment preceded by an adequate biological inventory, as required by the Oregon Court of Appeals (Balkalian 1985, as cited in WDF and ECY 1992). In 1984, Tillamook Bay produced 30,916 gallons of oysters. Six years later, with no effective tools to control burrowing shrimp, production had dropped 80 percent to 6,149 gallons, and eight years later to 2,911 gallons (USDA NASS Oregon Field Office and Oregon Department of Agriculture 2013). While there were compounding issues in Tillamook Bay related to water quality, burrowing shrimp were considered the dominant factor in the decline between 1984 and 1999 (Booth and Wilson 2002).

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10 The El Niño climate phenomenon is a periodic change in the direction of water currents near the equator that modified upwelling, water temperature, and productivity along the coast of North America.

Comparable Pacific oyster harvest statistics recorded in Oregon for the years 2000 through 2012 range from a low of 4,782 gallons in 2000 to a high of 42, 921 gallons in 2008, and back down to 14,828 gallons in 2012 (USDA NASS Oregon Field Office and Oregon Department of Agriculture 2013). All of these data (and those for prior years 1980 through 1999) are for a limited sector of the commercial oyster industry in Oregon; i.e., shucked oysters only, and for production only on State-leased tidelands. The WGHOGA Project Coordinator conducted telephone interviews with Oregon oyster growers in August 2014 to inquire about possible reasons for the wide range in production increases and declines between 2000 and 2012, specifically inquiring about the effect of burrowing shrimp, burrowing shrimp control measures (or the lack of effective control), and culture techniques. For the most part, Oregon growers report no (or only minor) problems with burrowing shrimp over the past 10 years: populations have remained low and stable, and/or burrowing shrimp only occur in relatively small pockets (not widespread). Oregon growers did not report an effective non-chemical method for controlling burrowing shrimp at the levels that are present in Willapa Bay and Grays Harbor. Some growers use frequent harrowing to keep burrowing shrimp populations suppressed where they occur, but also note that oysters grow faster in their more southerly latitudes compared to Willapa Bay and Grays Harbor. Most Oregon growers interviewed have some portion of their beds that is unusable as a result of past or recent burrowing shrimp populations (personal communication with David Beugli, WGHOGA Project Coordinator, August 20, 2014).

2.5 Description of Shellfish Aquaculture

The description of shellfish aquaculture presented in this Section, and in Subsections 2.5.1 and 2.5.2 below, is derived primarily from the National Marine Fisheries Service (2009) *Endangered Species Act – Section 7 Programmatic Consultation, Biological and Conference Opinion, and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation: Nationwide Permit 48, Washington*. Refinements have been added from the video documentary series *Willapa Bay Oysters* (Cox 2013), and with input from WGHOGA members.

Hatchery and Nursery Operations. Oysters and clams are grown from seed that is caught as wild spat[11] onto "cultch" (mother shell) [12] that is set out expressly for this purpose, or from seed produced in hatchery and nursery operations. Use of wild stock is relatively rare in most parts of the West Coast, but is still practiced extensively in Willapa Bay oyster culture where many areas commercially grown for oysters are established naturally from spawning of the oysters currently cultured in the bay. In Willapa Bay, oyster spawning occurs July through August, with spat settling out two to three weeks after spawning occurs.

Hatchery and nursery operations include algal production for use as feed for shellfish larvae, larval rearing, nursery seed culture, and brood stock maintenance. Hatchery rearing occurs throughout the year in special onshore systems designed to achieve the highest survival rates possible.

Larval culture involves rearing free-swimming bivalve larvae from the time the gametes are spawned by adult shellfish, until the larvae metamorphose and lose their ability to swim. The larvae are raised in tanks filled with filtered, heated seawater that is changed every few days or continuously refreshed. Oyster larvae secrete glue and cement themselves onto hard substrates, preferably clean oyster shell. Whole shells are used to catch multiple larvae for cluster/shucked meat production.

11 "Spat" as used in this document refers to the spawn of oysters, or the larval stage of oysters, particularly when these organisms settle onto a point of attachment and begin to develop a shell.

12 Clam larvae do not require "cultch" (mother shell), but can be set on screens in an up-well or flow-through system.

Nursery seed production is the rearing of larvae from the time they near the settle-out or setting phase, to the time when they are ready for planting. Mature larvae are placed in tanks where they are allowed to settle out onto cultch in mesh bags. When the spat has firmly attached and reaches a suitable size, depending upon the species, time of year, and intended end-use, it is taken to a tideland or floating nursery system in natural marine waters. For areas where "caught shell" will be placed on tidelands known as "seed beds," it may be necessary to treat these tidelands for burrowing shrimp control prior to "caught shell" placement in order to keep these shells from sinking in the substrate.

The majority of oyster culture in Willapa Bay and Grays Harbor uses ground-based methods. The most common cultivation method is to store mesh bags or metal baskets with spat attached to shell in a nursery area where calmer conditions allow the small seed to acclimate and begin the growth cycle. The shell bags are barged to nursery grounds at high tide. The seed bags are off-loaded in the nursery area, onto treated ground or ground with conditions that will be suitable for the planned nursery period. Bags are then stacked in rows on a shell base during the low tide, onto pallets, or onto a PVC rack that will act to support the bags and keep them from sinking into the mud.

The oysters are allowed to grow at the nursery site until large enough for transplanting to a seed bed or grow-out site. At high tide, the bags, tubs, or pallets are picked up and the seed is emptied onto the deck of a boat. The boat or barge moves the seed to a grow-out bed where it is spread over the bed at high tide. At this time, the mesh bags or metal baskets are recovered and opened, spreading the oysters onto the seed grounds. In some locations the oysters are left in-place until harvest. In others, the oysters grow at the seed grounds until they are large enough for transport to a final grow-out location. These oysters are recovered again and moved to a grow-out area where they will put on weight before final harvest (personal communication with WGHOGA members, February 2014).

The methods described above result in clusters of oysters growing together. By contrast, single-set oyster seed is produced by inducing the larvae to set on tiny cultch fragments made from grinding shells and then screening them to obtain uniform fragment sizes. The optimum size is large enough for one larva to settle on it, but small enough so two or more cannot. Once set in this way, single-seed oysters are boosted in size in a nursery system of the grower's preference. The oysters may be raised until harvest in the nursery (for the small half-shell market), or transported to grow-out beds to gain weight before harvest.

Shellfish Bed Characteristics. Productive commercial shellfish ground is dependent on a number of variables, including salinity, temperature, substrate quality, water quality, current flow, and wind exposure. WDFW developed a rating index to classify shellfish ground based on its ability to naturally produce harvestable shellfish. This index is used by WDNR as a tool for the purpose of setting lease rates, but it is also used informally by growers who own their tidelands (personal communication with a WGHOGA member, July 31, 2014). Classifications range from one (1) for ground that recruits natural seed and grows clams and oysters to harvest, to five (5) which is ground that does not naturally recruit or have the realistic ability to grow shellfish to harvest. Several species of shellfish grow on Type 1 ground at the same time. Harvest is aligned with the seed catching events. Type 5 ground is considered buffer ground that the grower can use to catch product that drifts off the area they are farming. General references aligned with the ability of a bed to produce shellfish include natural seed ground; marginal, relay, or grow-out ground (used to store oysters while a fattening bed is prepared to plant them to); fattening or harvest ground. All of these beds can recruit and grow-out clams, or other species of shellfish as well as oysters (personal communication with a WGHOGA member, July 31, 2014).

Supporting Activities. Supporting activities common to all shellfish aquaculture includes vessel operations, work on beaches and tidelands, and onshore facilities. Vessels are used to access the beds. Typical vessels are small, open work boats powered by two- or four-cylinder outboard motors, or inboard motors. Vessels ferry crews and material to and from culture beds. Larger workboats and barges are used for activities like spreading oyster shell or clam substrate used for cultivation, transporting general farm equipment, and harvesting and transporting shellfish.

Crews must walk and work on areas grown with oysters and clams and in immediately adjacent areas to perform almost all activities that occur on the beds. These include bed preparation, inspection and maintenance during grow-out, and harvest. At some sites, tidelands are accessed directly from adjacent upland areas. Workers and equipment sink deeply into the softened sediments of areas with high populations of burrowing shrimp.

Shellfish are transported to a processing facility after harvest from the tidelands. Once received, they may be processed directly or placed in cold dry storage or wet storage until ready for processing.

Shells and shell fragments are the main byproduct of shellfish processing. Whole oyster shell may be reclaimed for use as cultch. Shell may also be crushed for other uses, such as beach modification for shellfish beds, or as substrate in restoration projects.

2.5.1 Oyster Culture Methods

The Pacific oyster (*Crassostrea gigas*) is the predominant species of oyster cultivated in Willapa Bay and Grays Harbor. The native oyster (*Ostrea lurida*), Kumamoto oyster (*Crassostrea sikamea*), Eastern (a.k.a. American) oyster (*Crassostrea virginica*), and European flat oyster (*Ostrea edulis*) are also grown in small numbers.

Different approaches can be taken in bed preparation, seeding, grow-out, and harvesting depending upon the target market, substrate characteristics, predator population, and environmental conditions. For instance, bag, rack-and-bag, and suspended culture methods are typically employed to grow single oysters for the half-shell market. Oysters for the shucked-meat market can be grown in clusters, so the method is determined primarily by environmental conditions such as substrate composition and the presence or absence of certain pests and predators. Suspended cultures, such as long-line and stake culture, are primarily used in areas that are not suitable for bottom culture.

Oyster culture activities are predominantly performed during tides that are low enough to expose the culture bed. These tides occur for a period of several days each lunar month (29 days)—near midnight in December, near noon in June, and at corresponding intermediate times in other months. During these low tides, the workers may typically be on the bed for 3 to 6 hours, depending on tidal elevations.

Oyster Bottom Culture. This method is used to grow oysters directly on the bottom. It has been used for more than a century and is the most widespread form of shellfish cultivation still used at the present time. Beds were selected based on factors such as substrate conditions that would support shellfish throughout their growth cycle, food availability, tidal depth, and wind and wave exposure. Beds are monitored during the grow-out cycle to inspect for pests and predators, debris that may have drifted onto the bed, shifting bed drains that can bury shellfish, and similar effects. Deeded tidelands that are owned by commercial shellfish growers are marked at their corners with wood, PVC pipe or other types of stakes/markers so they can be located at high tide when the beds are covered with water. Other types of markers may be used for defining actual areas to be worked. These are often color-coded so the farmer can locate specific beds for harvesting or bed maintenance activities.

Seed oysters attached to cultch may be hosed off the deck of barges or cast by shovel onto marked beds at an approximately even rate to achieve optimum densities and distribution across the bed. In some cases, farms also rely on natural setting of oyster seed. If the “natural set” method of seeding is used, oyster shells are barged to the site and then spread across the seed bed at high tide when larvae monitoring indicates that the larvae are ready to set (attach) to the shells. If bottom culture is done with grow-out bags (as described below), seed is placed in reusable plastic net bags closed with plastic ties or galvanized metal rings. The bags are placed in the intertidal zone directly on the ground during a low tide. Bags are held in-place using an anchor of some type that is capable of restraining the bags in severe weather conditions.

Oysters may be transplanted from one site to another at some point during grow-out. For example, oysters may be moved from an initial growing area to "fattening" grounds[13] where higher levels of plankton and nutrients are found, allowing the oysters to grow to a market quality. Growers conduct their operations in accordance with applicable transfer permits, regulations, and requirements when transplanting oysters from one area to another.

In areas where the substrate is soft, the oysters sink into the mud. This usually occurs in response to substrate bioturbation caused by ghost shrimp and mud shrimp (collectively known as "burrowing shrimp," described in FEIS Chapter 3, Sections 3.1 and 3.2.5.1). Oysters must stay on the surface to survive. When they sink, they may be periodically drug out with a harrow to pull them up out of the mud. However, if the burrowing shrimp populations have not been controlled, harrowing to lift oysters to the surface would be ineffective, as they would sink again and suffocate due to the soft substrate.

During hand harvest, workers hand-pick oysters into bushel-sized containers at low tide. These may be emptied into large (10- to 30-bushel) containers equipped with ropes and buoys so they can be lifted with a boom crane onto the deck of a barge at high tide. Smaller containers are sometimes placed or dumped on the decks of scows for retrieval at high tide, or they may be manually carried off the tidelands at low tide.

In mechanical harvest, a harvest bag is lowered from a barge or boat by boom crane or hydraulic winch at high tide and pulled along the bottom to scoop up the oysters. Where feasible, the area may be hand-harvested at low tide afterwards to pick up any remaining oysters.

Single oysters cultured loose on the bottom are often hand-harvested into mesh bags or baskets to minimize handling and damage to shells. When single-oyster culture on the bottom is done in hard plastic mesh bags, the bags are simply loaded into a boat or (during low tide) into a wheelbarrow for transport to shore, then transported to processing plants or to market.

Oyster Stake Culture. Beds are prepared for stake culture during low tides by removing debris and pests. This often includes control of burrowing shrimp because high shrimp densities result in stakes leaning or falling over, causing the crop to be lost as it becomes buried. Crop also becomes dislodged from the stakes during grow-out and falls to the bottom. There can be significant losses with this culture method if burrowing shrimp densities are not controlled.

During low tide, short stakes approximately 30 to 36 inches (76 to 91 cm) in length are driven into the ground approximately 2 feet apart to allow good water circulation and easy access during harvest. The stakes are driven to a depth of 15 to 18 inches (38 to 46 cm) to keep them in place.

Stakes may be seeded in hatchery setting tanks before being planted in the beds, or bare stakes may be planted in areas where there is a reliable natural seed set. Bare stakes might be planted during the prior winter to allow barnacles and other organisms to attach to the stakes, increasing the surface area available

[13] Fattening grounds are typically located near the entrance to the harbor, on tidelands most exposed to the flush of ocean currents that enter the bay on each tide cycle.

for setting oyster spat. An alternative method of seeding is to attach from one to several pieces of seeded cultch to each stake.

Stakes are left in-place through a 2- to 4-year growing cycle. Each piece of seeded cultch attached to stakes grows into a cluster of market-sized oysters suspended above the mud and above most pests. In areas where natural spawning occurs, multiple-year classes of oysters grow on the stakes with smaller, younger oysters growing on top of older oysters.

Oysters are selectively harvested by hand during low tides by prying clusters of market-sized oysters from the stakes, or by removing the clusters and stakes and placing them in baskets or buckets. The containers are tagged and either hand-carried off the beach or loaded onto a boat at a higher tide for transport to shore.

The clusters are separated into singles, sorted, culled and rinsed (if destined for the single oyster market) or left as clusters (if intended for the shucked oyster market), and transported to a processing plant. Undersized single oysters from the clusters are transplanted to a special bottom culture bed for grow-out since they cannot reattach to the stakes, and are harvested using bottom culture methods when they reach market size.

Oysters that fall from or are knocked off the stakes are harvested periodically using bottom culture methods. Market-sized drop-offs that have not settled into the mud are harvested along with those pried from stakes, and those that have settled into the mud are periodically picked up and transplanted to firmer ground to improve their condition for harvest at a later time. Bed maintenance takes place during harvest when stakes are repositioned, straightened, or replaced, and the oysters are thinned to relieve overcrowding.

Oyster Long-line Culture. Stakes of metal or PVC pipe are stuck in the ground in rows by hand during low tides. These pipes are typically 30 inches (76 cm) in length and are sunk 15 inches (38 cm) into the sediment. Polypropylene or nylon lines in lengths of approximately 100 feet with seeded oyster cultch attached at approximately one-foot intervals are pulled into place, attached to the stakes, and suspended above the tideland for grow-out. The material and labor costs of long-line culture exceed those of bottom culture, and up to 30 to 50 percent of the oysters typically drop from the lines (personal communication with Coast Seafoods, as cited in Booth 2010).

Oysters grown in this culture method grow in clusters supported by the long-lines, which keep them from sinking into soft substrate and protect them from certain pests and predators. As with stake culture, control of burrowing shrimp is required to prevent stakes from leaning or falling over. Oysters are allowed to grow out over a period of 2 to 3 years. Long-lines are checked periodically during low tides to ensure that they remain secured to the PVC pipe and that the PVC pipe remains in-place.

Long-line cultured oysters may be harvested by hand or by machine. Hand harvest entails cutting oyster clusters off lines by hand at low tide and placing the clusters in harvest tubs equipped with buoys for retrieval at high tide by a vessel equipped with a boom crane or hydraulic hoist. The oysters are then barged to shore. Smaller operations carry the tubs off the beach by hand.

With mechanical harvesting, buoys are attached at intervals along the lines at low tide. On a high tide, the buoys are hooked to a special reel mounted on a vessel that pulls the lines off the stakes and reels them onto the flat deck of the boat. The oyster clusters are then cut from the lines, barged to shore, and transported to processing plants or to market.

In some areas, silt may build up on the substrate of long-line culture beds as a result of wave and wind action. These beds may be leveled manually at the end of a growing cycle, or they may be left fallow to level naturally as a result of wind and wave action. Most residual oysters ("drop-offs") dislodged from the lines during the previous growing cycle are removed from the ground prior to replanting. These actions are performed during low tides. As with any off-bottom culture method, drop-off oysters are a significant portion of the total crop yield. This portion of the crop is lost in areas of high burrowing shrimp, populations, so control is required in order to make this culture method economically viable.

After a harvest, some growers pull all the pipe stakes from the bed, harvest residual drop-off oysters using bottom culture methods, and drag the ground to level it and remove sediment build-up before putting the stakes back in for the next cycle. Other growers leave the stakes in-place from cycle to cycle, depending on conditions in their growing area.

Oyster Suspended Culture. Suspended culture methods include the use of lantern nets, bags, trays, cages or vertical ropes or wires suspended from surface long-lines, or to a lesser extent, from rafts. These methods are used in deeper water so that the structures remain suspended through the tidal cycle. Such areas are not realistically available within Willapa Bay and Grays Harbor due to lack of depth and exposure to severe weather. Thus, suspended culture methods generally are not used in the intertidal areas that are subject to control of burrowing shrimp. However, in the event that this method were used over tidelands, there could be significant oyster loss due to storms, equipment damage, and similar occurrences. In such cases, oysters would be lost if burrowing shrimp densities in the substrate were high enough to bury the drop-off crop.

Surface long-lines are heavy lines suspended by floats or buoys attached at intervals along the lines, anchored in-place at each end. Lantern nets, adopted from Japanese shellfish culture, are stacks of round mesh-covered wire trays enclosed in tough plastic netting. The nets, bags, trays, cages, or vertical ropes or wires are hung from the surface long-lines under the floats or buoys, or from rafts. This method utilizes deeper channel areas, remains visible during all tidal elevations, and must address navigational lane blockage issues.

Single oysters are regularly sorted and graded throughout the growth cycle. Every 3 or 4 months, the trays are pulled up, the stacks are taken apart, oysters are put through a hand- or mechanical-grading process, the trays are restocked, stacks are rebuilt and de-fouled and returned to the water. Oysters grown on vertical lines grow in clusters and require little attention between seeding and harvesting.

A vessel equipped with davits and winches works along the lines, and the trays, nets or bags are detached from the line one by one and lifted onto the boat. The gear is washed down as it is pulled onboard. Oysters are emptied from the gear and placed into tubs, then cleaned and sorted onboard the harvest vessel, on an on-site work raft, or at an off-site processing facility.

Oysters grown using suspended culture may be transplanted to an intertidal bed for 2 to 4 weeks to "harden." Hardening extends the shelf-life of suspended culture oysters by conditioning them to close their shells tightly when out of the water, so they retain water in the shell. Natural wind and wave energy acts to literally harden the shell, making it less prone to chipping, breakage, or mortality during transport. Once hardened, the oysters are re-harvested using bottom culture harvest methods. Alternatively, oysters grown by suspended culture may be hung from docks in shallow water where tidal cycles condition them to close their shells when exposed.

Oyster Rack-and-Bag Culture. Beds are prepared for rack-and-bag culture during low tides by removing debris and pests. The tideland may be marked with stakes for working purposes. During low tides, some operations install lines and PVC pipe or metal stakes on the bed to secure the bags. Alternatively, wood or metal racks may be used to support the bags off the ground. Racks with legs may be placed directly on the bottom, or supports may be driven into the bottom. Bags are typically attached to racks with reusable plastic or wire ties.

Single-set oyster seed is placed in reusable plastic net bags (or “purses”), closed with plastic ties or galvanized metal rings. Oysters grow out in the bags directly on the substrate or on the metal or wooden racks. Some growers attach a float to each bag so that it rotates with each tide. This keeps the shell margin smooth and creates a deeper-bodied oyster that is more attractive for the half-shell market. Rack-and-bag culture operations are checked periodically during low tides to ensure that the bags remain secured to the racks. During harvest, bags are released from supports (if any), loaded onto a boat, or (during low tides) into a wheelbarrow for transport to shore, then transported to processing plants or to market.

All bottom culture and off-bottom culture methods rely on a stable tideland substrate in order to function through the grow-out cycle. Burrowing shrimp may impact oyster crops directly by causing the shellfish to sink in the softened substrate, or indirectly by causing the off-bottom support gear to fail in the unstabilized substrate.

Use of Carbaryl. Shellfish growers in Willapa Bay and Grays Harbor have used the insecticide carbaryl to control burrowing shrimp as part of oyster aquaculture management operations since 1963. These locations are the only U.S. marine tidelands where the use of carbaryl has been permitted. Ecology NPDES Permit No. WA0040975 allows treatment of up to 600 acres annually in Willapa Bay, and up to 200 acres annually in Grays Harbor, at a rate of eight (8) pounds of active ingredient per acre. The permit specifies spraying periods during low tides, July through October. Under the conditions of NPDES Permit No. WA0040975, carbaryl could be applied to areas commercially grown for oysters when burrowing shrimp populations exceed more than 10 shrimp burrows per square meter of tideland.

Carbaryl has been applied as a soluble powder to tidelands at low tides, usually by helicopter. Hand spraying has also been conducted, but to a lesser extent. Helicopters that are used to apply carbaryl are equipped with a 29-foot-long boom with large-orifice nozzles directed downward. The carbaryl solution has been sprayed directly from the nozzles to precisely targeted treatment areas. To minimize potential drift, carbaryl has been applied from a height of 10 to 20 feet above the beds with wind speeds less than 10 miles per hour. To further minimize potential impacts to non-target species and habitat, aerial applications have been prohibited within 200 feet of open water channels or sloughs throughout the tidelands.

2.5.2 Clam Culture Methods

The general description of clam culture provided below is derived from the *Final Environmental Impact Statement: Management of Zostera japonica on Commercial Clam Beds in Willapa Bay, Washington* (Ecology, March 26, 2014). The description of ground culture and bag culture methods is summarized from NMFS (2009), as previously cited.

The Manila clam (*Venerupis philippinarum*) was introduced to the west coast of North America in the 1930s and 1940s. There is speculation as to exactly how the Manila clam was introduced, whether it was in ballast water or in shipments of oyster seed from Japan. The majority of Willapa Bay’s Manila clam production comes from farming on privately-owned or leased tidelands. During the initial years of commercial harvest, the beds were managed to produce a self-sustaining amount of clams. By the 1970s, predator exclusion nets were employed to increase yields. In the 1980s, growers began to occasionally supplement natural sets with hatchery-raised juvenile clams (Dewey 2013). In order to increase natural recruitment and survival of hatchery seed, the substrate is often enhanced with gravel and/or shell (Thompson 1990). This method was initially developed in Willapa Bay in the mid-1970s by WDFW when it used gravel to enhance a recreational harvest area on the west side of Long Island. The substrate provides an optimal recruitment surface as well as protection from predators.

Clam crops are grown on a 3- to 5-year rotation, depending on the substrate and the desired size of mature product. The tidal range at which clams are typically cultivated is approximately +0.5 to +4.0 feet MLLW.[14] Natural recruitment is sometimes supplemented with hatchery seed. Ideally, clams that have reached the proper size are harvested and two to four smaller age-classes will be left in the substrate to grow and mature in subsequent years. The vast majority of clams are harvested by hand using short-handled rakes. Clam culture activities are predominantly performed during tides that are low enough for workers to access the beds on foot.

Clams are collected in plastic mesh bags and allowed to purge (i.e., expel sand and mud from the inner part of the bivalve) before processing/packaging.

Under desired bed conditions, approximately one pound of clams is produced in each square foot of substrate. This is dependent on location within the tidal zone, current flow, food flow, bed drainage characteristics, and other variables. Any disruptions in current flow acts to alter recruitment, feeding, and growth conditions of the clam crop. Bed drainage impacts not only affect crop recruitment, but also the ability to efficiently harvest the crop (Spencer et al. 1991).

Ground Culture. Beds are prepared for ground culture in a number of ways depending on the location. Bed preparation increases the chances of seed recruitment and survival. Preparatory work performed at low tide may include raking debris, adding gravel and/or crushed shell to create more suitable substrate, and sampling salinity and water quality parameters.

When graveling, a method termed “frosting” is used, several light layers are placed over a period of several weeks in order to minimize the burying impact on the benthic and epibenthic habitat. Other bed preparation measures may include laying down netting to protect against predators such as crab and ducks, and marking bed boundaries. Many growers remove the predator netting within a few days of planting clam seed, after the clams have had time to burrow sufficiently into the substrate to avoid most predators, and to minimize the chance that netting will become dislodged and drift away.

Typically, clam seed is planted in the spring and early summer. Most of the clam seed comes from West Coast hatchery and nursery facilities, although natural sets of clams occur in some areas. Clam seed sizes and methods of seeding vary, depending on site-specific factors such as predators and weather conditions. Planting methods include: hand-spreading seed at low tide on bare, exposed substrate; hand-spreading seed on an incoming tide when the water is approximately 4 inches deep; hand-spreading seed on an outgoing tide when the water is approximately 2 to 3 feet deep; or spreading seed at high tide from a boat.

After each growing season, surveys and sampling are typically conducted during low tides to assess seed survival and spreading adequacy, and to estimate harvest yield for the upcoming year. Surveys determine whether additional seeding is required to supplement a natural set or poor hatchery seed survival. The goal is to maintain the optimum sustainable productivity of the growing ground.

Before harvest begins, bed boundaries are typically staked and any remaining predator netting is folded back during low tide. Harvesting crews typically hand-dig clams during low tides, using a clam rake. Market-sized clams are selectively harvested, put in buckets, bagged and tagged, and transported to processing plants. Undersized clams are left in beds for future harvest. Harvested clams are generally left

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[14] Natural oyster seed beds also occur in this tidal range, and oyster hatchery seed can be grown-out within this tidal range (personal communications with WGHOGA members, May 28, 2014 and June 18, 2014).

in net bags in wet storage, either in marine waters or upland tanks filled with seawater, to purge sand for at least 24 hours.

Bag Culture. Prior to setting clam bags on tidelands, debris is removed from the area to be planted and shallow (typically 2- to 4-inch) trenches may be dug during low tide with rakes or hoes to provide a more secure foundation for setting down the clam bags.

Clam seed (typically 5 to 8 millimeters or 0.2 to 0.3 inches in size) is placed in reusable plastic net bags closed with plastic ties or galvanized metal rings. Substrate, consisting of gravel and shell fragments, may be added to the bags. Bags may be placed in shallow trenches during low tide and allowed to "silt-in" (i.e., burrow into the substrate). Bags may be held in place with 4- to 6-inch metal stakes, placed by hand. Bags are monitored during low tides throughout the grow-out cycle to make sure they are properly secured, and turned occasionally to optimize clam growth.

When the clams reach market size, the bags are removed from the growing area. Harvesting occurs when there is 1 to 4 feet of water so that sand and mud that accumulated in the bags during grow-out can be sieved from the bags in-place. Bags are transported to a processing site. Any added substrate may be separated for later reuse.

2.6 Economics

Willapa Bay and Grays Harbor are highly productive estuaries. Willapa Bay produces approximately 65 percent of the oysters and 13 percent of the clams harvested in Washington State[15]. Willapa Bay is the largest producer of farmed oysters in the United States. Combined with Grays Harbor, this area along the southwest Washington coast produces approximately 25 percent of all oysters in the United States. Shellfish aquaculture is the largest private employer in Pacific County and a significant private employer in Grays Harbor County. Oyster cultivation has traditionally been the primary fishery in Willapa Bay. Shellfish aquaculture is one of the major industries in southwest Washington, and has increased in relative importance following declines in the timber and fishing industries.

In 2013, Northern Economics prepared an economic impact assessment of aquaculture in Washington, Oregon, and California for the Pacific Shellfish Institute (PSI) (Northern Economics 2013). This assessment included an input-output analysis modeling tool to measure the economic effects of aquaculture by tracking the flow of money within specified economic regions. The input-output analysis determined that for every dollar spent by shellfish growers, a total of $1.82 worth of economic activity is generated in Washington. In addition, every dollar spent by shellfish growers generates approximately $0.76 in wages, and for every $1 million spent by the industry, nearly 27 jobs are created. Based on these calculations, the PSI study (Northern Economics 2013) estimated that shellfish farmers in Washington spent approximately $101.4 million in the Washington economy in 2010, which in turn generated approximately $184 million. Shellfish farmers generated 1,900 direct jobs and paid $37 million in labor income in 2010, and they generated 810 additional jobs through indirect or induced activity. Further, the PSI study found that shellfish aquaculture in Pacific County in 2010 generated more than $90 million in

15 Production statistics for bivalve aquaculture in Washington and other west coast states are not well documented (DeFrancesco and Murray 2010). Not all methods of culture are included in the statistics, and units of measure are inconsistent among the agencies and organizations that record these data. For example, the Pacific Coast Shellfish Growers Association (PCSGA) reports clam and oyster production in live-weight/in-shell pounds (DeFrancesco and Murray 2010), versus only gallons of shucked meat reported by the U.S. Department of Agriculture, National Agricultural Statistics Service (2013). All statistics reviewed during preparation of this EIS, however, show Washington as the major producer of bivalve commodities in western states that include Oregon, California and Alaska, with Willapa Bay/Grays Harbor as the major producing area among all of these.

total economic output, 1,580 jobs, and more than $45 million in labor income. In Grays Harbor, shellfish aquaculture generated almost $12 million in total economic output, 210 jobs, and almost $6 million in labor income in 2010. Not captured in the PSI study are the economic benefits from shellfish aquaculture in the form of "upstream" jobs created for trucking companies, air freight, wholesalers, retail outlets and restaurants that sell and serve the farmed shellfish (personal communication with PSI Executive Director, June 26, 2014).

As licensed businesses within the State of Washington, shellfish growers pay taxes that generate revenue for State and local governments to fund such services as police protection, fire protection, emergency medical aid, hospitals, libraries, schools, parks, road improvements, and general governmental services. In addition, a portion of the wages paid to shellfish aquaculture employees goes to sales and property taxes that contribute revenues to these same public services. To date, there are no known studies that have quantified tax revenues generated by shellfish aquaculture in Pacific County and Grays Harbor County, but the sums would be substantial given the 2010 total economic output reported above from the Northern Economics (2013) assessment.

Another economic factor aligned with shellfish aquaculture is the ecological services provided by shellfish beds.[16] While still a relatively new area of study, on-going research demonstrates that healthy shellfish beds provide ecological services that result in an economic benefit to the Earth ecosystem as a whole and to the general public. These services include carbon sequestration, nutrient filtration, and similar services that would otherwise require public infrastructure to address. Ecosystem goods and services provided by shellfish include general provisioning services (e.g., food and fiber), regulating services (e.g., water purification, flood control), cultural services, and supporting services (e.g., nutrient cycling). In order to inform policy choices and resource management decisions, researchers apply a number of valuation methodologies to quantify the economic benefits of some these goods and services. For example, ecosystem services may be quantified using the replacement cost method (calculating the cost of providing the service via other means), or by measuring the community's willingness to pay for the service. Using the replacement cost method, the water quality benefit from shellfish in Oakland Bay (Shelton, Washington) has been estimated at between $77,100 and $884,400 annually (Northern Economics 2010). These figures are based on the estimated costs of achieving nitrogen removal equivalent to that provided by harvest of Oakland Bay shellfish, which removes an estimated 11.7 metric tons (MT) of nitrogen per year.[17] Others have estimated the value of nitrogen removal services provided by oysters in Massachusetts estuaries to be $293,993 per year (Rose et al. 2014). Additional goods and services, such as social benefits, are more difficult to value in traditional economic terms.

If burrowing shrimp are not effectively controlled, then commercial shellfish production in Willapa Bay and Grays Harbor will likely be seriously reduced. The *Final Environmental Impact Statement: Use of the Insecticide Sevin to Control Ghost and Mud Shrimp in Oyster Beds of Willapa Bay and Grays Harbor* (WDF and ECY 1985) estimated a worst case scenario of a 70 to 80 percent reduction in oyster production without burrowing shrimp control. Growers currently estimate that they would experience a 60 to 80 percent reduction, and the Washington State University Pacific County Extension Director estimates that the bay-wide loss of clams and oysters in Willapa Bay would be on the order of 80 to 90 percent without pesticide treatments for the control of burrowing shrimp (personal communication with Dr. Kim Patten). These estimates are conservative in relation to the reduced production figures in Oregon

[16] A description of the ecological services provided by burrowing shrimp is included in FEIS Chapter 3, Section 3.1.

[17] It is estimated that a typical oyster bed removes approximately 0.134 MT of nitrogen per acre each year (Higgins et al. 2011).

following the cessation of carbaryl use, where oyster production declined by 90 percent between 1984 and 1999 (USDA NASS Oregon Field Office and Oregon Department of Agriculture 2013).[18]

In recent years, with the substantial increase in the recruitment of burrowing shrimp, growers realize that commercial clam production is equally at risk. A WGHOGA member confirmed that the method of loss (substrate subsidence and bivalve suffocation) is the same for clams as it is for oysters, and that without treatment for burrowing shrimp on areas commercially grown for clams, the clam industry would decline at a rate comparable to that estimated for the oyster industry, or be lost altogether except for some small incidental harvest areas where clams may be a secondary crop to oyster seed (personal communication with a WGHOGA member, May 28, 2014). Additional information on this subject is provided in FEIS Chapter 1, Section 1.4.

2.7 Regulatory Status, Regulatory Control, and Policy Background

2.7.1 Regulatory Requirements for Commercial Shellfish Aquaculture: Federal Clean Water Act

Pursuant to Section 404 of the Clean Water Act (CWA), the U.S. Army Corps of Engineers (Corps) is responsible for administering a regulatory program that requires permits for certain activities in waters of the United States. Under Section 404, the Corps regulates the discharge of dredged or fill material into waters of the U.S. Activities requiring Corps' authorization that are similar in nature and have minimal individual and cumulative environmental impacts may qualify for authorization by a general permit, such as a nationwide permit (NWP). On February 21, 2012, the Corps issued 50 nationwide permits, including NWP 48 that authorizes commercial shellfish aquaculture activities. The Seattle District issued regional conditions for the 2012 NWPs on March 19, 2012 (USACE, Seattle District SPN, 2012).

Under Section 401 of the CWA, an activity involving a discharge into waters of the United States authorized by a Federal permit (such as a Corps NWP) must receive water quality certification (WQC) from the appropriate certifying agency or Tribe. A WQC certifies that the proposed activity meets the State's water quality standards under the State Water Pollution Control Act. The Washington Department of Ecology (Ecology) makes Section 401 certification decisions for activities on non-Tribal trust lands within the State, including Willapa Bay and Grays Harbor where burrowing shrimp control methods with imidacloprid are proposed.

2.7.2 Regulatory Requirements for Commercial Shellfish Aquaculture: Bush and Callow Acts, and Shoreline Management Act

The Bush and Callow Acts were passed in 1895 encouraging and allowing for oyster cultivation on private tidelands in Washington State. DNR records indicate there are presently 25,324 acres of Bush Act Lands in Willapa Bay and 7,054 Bush Act Lands in Grays Harbor. In 1919, the Edible Clam Law was passed allowing for the use of Bush and Callow lands for the cultivation of clams and edible shellfish in addition to oysters. In 2002, the legislature passed HB 2819, allowing for Bush and Callow lands to be used for cultivating clams and edible shellfish in addition to oysters in inter-tidal portions of the property, along with the continued cultivation of shellfish in the sub-tidal portions of the property so long as the species in question was planted prior to December 31, 2001.

[18] Oregon oyster production statistics for 2012 are 50 percent less than production in 1984 (USDA NASS Oregon Field Office and Oregon Department of Agriculture 2013), though for reasons that appear to be unrelated to burrowing shrimp population levels, burrowing shrimp control (or lack thereof), or alternative shellfish culture techniques. See FEIS Section 2.4, above.

The Washington State Shoreline Management Act (SMA), Chapter 90.58 RCW, expresses a preference for uses that are unique to or dependent upon the use of shorelines of the State (RCW 90.58.020). Ecology guidelines for developing Shoreline Master Programs (SMPs) under the SMA recognize aquaculture is a shoreline dependent use and, when consistent with control of pollution and prevention of damage to the environment, is a preferred use of the water area. The SMA guidelines further provide that aquaculture is of Statewide interest and when properly managed can result in long-term over short-term benefit and protect the resources and ecology of the shoreline (WAC 173-26-241[3][b][i][A]). Shellfish beds are recognized as critical saltwater habitats requiring a higher level of protection due to the important ecological functions they provide (WAC 173-26-221[2][c][iii]). The SMA guidelines also state that aquaculture should not be permitted in areas where it would result in a net loss of ecological functions, adversely impact eelgrass and macroalgae, or significantly conflict with navigation and other water-dependent uses, and that aquacultural facilities should be designed and located so as not to spread disease to native aquatic life, establish new non-native species which cause significant ecological impacts, or significantly impact the aesthetic qualities of the shoreline (WAC 173-26-241[3][b][i](C)).

Some local jurisdictions (cities and counties) may require a permit for commercial shellfish aquaculture under the development regulations of their local SMPs. WGHOGA members operate their commercial shellfish farms in compliance with the Pacific County and Grays Harbor County SMPs.

2.7.3 Policy Background for Commercial Shellfish Aquaculture: Federal and State

The National Oceanic and Atmospheric Association (NOAA) launched the National Shellfish Initiative in 2011. The goal of this initiative is "*to increase shellfish aquaculture for commercial and restoration purposes, thereby stimulating coastal economies and improving ecosystem health*." The initiative "*recognizes the broad suite of benefits provided by shellfish aquaculture and aims to increase shellfish production and wild shellfish populations in U.S. coastal and marine waters*." Under this Initiative, NOAA and its partners committed to enhancing shellfish restoration and farming, and to support the authorization of shellfish sanctuaries and increase aquaculture permits and leases.

Washington State launched the Washington Shellfish Initiative in December 2011. The Washington Shellfish Initiative is a convergence of NOAA's "*National Shellfish Initiative and the State's interest in promoting a critical clean water industry*." This initiative "*encompasses the extraordinary value of shellfish resources on the coast" and "[a]s envisioned, the initiative will protect and enhance a resource that is important for jobs, industry, citizens, and tribes*." The Washington State legislature has further expressed a policy preference for shellfish aquaculture in RCW 15.85.010. This statute states, in part:

> *The legislature declares that aquatic farming provides a consistent source of quality food, offers opportunities of new jobs, increased farm income stability, and improves balance of trade. The legislature finds that many areas of the state of Washington are scientifically and biologically suitable for aquaculture development, and therefore the legislature encourages promotion of aquacultural activities, programs, and development with the same status as other agricultural activities, programs, and development within the state. The legislature finds that aquaculture should be considered a branch of the agricultural industry of the state for purposes of any laws that apply to or provide for the advancement, benefit, or protection of the agriculture industry within the state*.

2.7.4 Washington State Regulatory Requirements for Pesticide Applications

Washington State Department of Ecology Requirements for Pesticide Applications. Since 2002, Ecology has regulated aquatic pesticide application under general and individual NPDES/State Waste Discharge permits instead of site-specific administrative orders. An NPDES permit can only be issued if Ecology determines a proposal, as conditioned, will comply with water quality standards established under the Clean Water Act (33 U.S.C. § 1251 et seq.).

There are three primary components to Washington's water quality standards: designated uses, water quality criteria designed to protect those uses, and an anti-degradation policy (Chapter 173-201A WAC; see also 33 U.S.C. § 1313; 40 C.F.R. Part 131, §§ 131.6, 131.10 through .12). Washington has assigned marine waters within the State one or more of the following designated uses: aquatic life uses (designated as extraordinary, excellent, good, or fair); shellfish harvesting; recreational uses (designated as primary or secondary contact); and miscellaneous uses (wildlife habitat, harvesting, commerce and navigation, boating, and aesthetics) (WAC 173-201A-210). Washington has also adopted water quality criteria necessary to support the designated uses (WAC 173-201A-210). A NPDES permit may only be issued if the proposed pesticide discharge, as conditioned, will meet the water quality standards applicable to the receiving waters (33 U.S.C. § 1342[a]; and WAC 173-201A-510[1]). Washington and Federal law also require that a NPDES permit protect the water quality criteria applicable to the most sensitive designated use for each body of water (40 C.F.R. § 131.11[a]; and WAC 173-201A-010[1][c]). Washington's use designations list both Willapa Bay and Grays Harbor as "excellent" for aquatic life uses, for shellfish harvesting, as primary contact for recreational uses, and for all miscellaneous uses (WAC 173-201A-612). A NPDES permit may only be issued to WGHOGA for the use of imidacloprid to control burrowing shrimp if such application, as conditioned and mitigated, will ensure maintenance of the most protective water quality criteria applicable to the most sensitive of these designated uses.

Ecology's review of a NPDES permit application must also ensure that the proposed discharge of imidacloprid would comply with the Washington State Sediment Management Standards (SMS). Washington's SMS establish sediment quality standards for marine surface sediments, sediment source control standards with which point source discharges must comply, and an antidegradation policy (WAC 173-204-120, -300 through -350, and -400 through -450).

The Special Conditions section of Ecology's NPDES Individual Permits include discharge limitations, monitoring requirements, reporting and recordkeeping requirements, preparation of an Annual Operations Plan, compliance schedule, Spill Control Plan, and Best Management Practices to ensure that the regulated action complies with the water quality law and regulations.

Under the proposed Control of Burrowing Shrimp using Imidacloprid on Commercial Oyster and Clam Beds in Willapa Bay and Grays Harbor NPDES Individual Permit (Proposed Permit), Washington State would authorize the use of imidacloprid in Willapa Bay and Grays Harbor for the purpose of controlling burrowing shrimp on commercial shellfish beds for a period of 5 years. The permit decision will be based on available information, including information provided in the Draft and Final EIS.

The NPDES Individual Permit Fact Sheet, a companion document to the Proposed Permit, provides the legal and technical basis for permit issuance (WAC 173-220-060). The Draft Proposed Permit and Fact Sheet are concurrently available for public and agency review with this FEIS, and are incorporated by reference into the EIS. The *Risk Assessment for Use of Imidacloprid to Control Burrowing Shrimp in Shellfish Beds of Willapa Bay and Grays Harbor, WA* (Risk Assessment) prepared by Compliance Services International (June 2013) is also incorporated by reference into this EIS. The Risk Assessment was prepared for WGHOGA to help understand the potential effects of imidacloprid use on the environment.

Washington State Department of Agriculture (WSDA) Requirements for Pesticide Applications. WSDA is the lead agency for the regulation of pesticides in Washington. WSDA registers pesticides for distribution in Washington; licenses pesticide applicators, dealers and consultants; investigates complaints such as pesticide label violations; maintains a registry of pesticide sensitive individuals; and administers a waste pesticide collection program.

WSDA classifies all aquatic pesticides as “restricted use.” Only trained and certified applicators or people under their direct supervision can legally purchase and apply aquatic pesticides in Washington. Most aquatic pesticide treatments occur under joint NPDES and State Waste Discharge permits administered by Ecology.

2.7.5 EPA Statutory Requirements for Pesticides

EPA regulates pesticides under four major statutes:

1. Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) (7 U.S.C. § 136 et seq.).
   FIFRA provides the basis for Federal regulation of the distribution, sale and use of pesticides in the United States. Before registering a new pesticide or new use for a registered pesticide, EPA must first ensure that the pesticide, when used according to label directions, can be used with a reasonable certainty of no harm to human health and without posing unreasonable risk to the environment. WSDA is the lead agency for review if an applicant applies for a state experimental use permit (EUP), Section 24(c) Special Local Needs registration, or a Section 18 emergency exemption in Washington.

2. Federal Food, Drug, and Cosmetic Act (FFDCA) (21 U.S.C. Chapter 9).
   FFDCA authorizes EPA to set tolerances, or maximum legal limits, for pesticide residues in food. Tolerance requirements apply equally to domestically-produced and imported food.

3. Food Quality Protection Act (FQPA) (7 USC §136).
   FQPA fundamentally changed the way that EPA regulates pesticides. Some of the major requirements include stricter safety standards, especially for infants and children, and a complete reassessment of all existing pesticide tolerances. See below for further discussion.

4. Clean Water Act (CWA) (33 U.S.C. 1251 et seq.).

CWA (1972 and later modifications [1977, 1981, and 1987]) established water quality goals for waters of the United States. A 2011 court ruling directed EPA to require NPDES permits for aquatic pesticide applications under the CWA. EPA delegated responsibility for administering the NPDES permit program to the State of Washington based on Chapter 90.48 RCW. This statute defines Ecology’s authority and obligations administering the Wastewater Discharge Permit Program.

EPA requires extensive data as part of its registration review and approval process, requiring more than 120 studies before granting a registration for most pesticides used in food production (e.g., imidacloprid). EPA tiers these study requirements to the intended use and certain properties of the pesticide. The studies provide EPA with information needed to assess risks to human health, domestic animals, wildlife, plants, surface water and groundwater, beneficial insects, and other environmental effects. When new evidence arises to challenge the safety of a registered pesticide, EPA may take action to suspend or cancel its registration and revoke the associated tolerances.

Federal Registrations for imidacloprid (provided in FEIS Appendix A) have already been issued to WGHOGA, one for a granular formulation of the product (No. 88867-1 for Protector 0.5G; USEPA 2013a), and one for a liquid ("flowable") formulation (No. 88867-2 for Protector 2F; USEPA 2013a). The labeling requirements listed on the registrations control when and under what conditions pesticides can be applied, mixed, stored, loaded or used, and specify a 30-day waiting period before shellfish can be harvested. Requirements are also imposed on pesticide container specifications; including rinsing and disposal (see Appendix A).

EPA Ecological Risk Assessments. EPA conducts an Environmental Fate and Ecological Risk Assessment (EFED) for each active ingredient during the pesticide registration process. EPA used the most sensitive toxicity endpoints from surrogate test species to estimate treatment-related direct effects on acute mortality and chronic reproductive, growth, and survival endpoints. In general, categories of acute toxicity ranging from "practically nontoxic" to "very highly toxic" have been established for aquatic organisms based on lethal concentration (LC50) values, terrestrial mammals based on lethal dose (LD50) values, avian species based on LC50 values, and non-target insects based on LD50 values for honey bees.

EPA Human Health Risk Assessments. Federal law requires detailed evaluation of pesticides to protect human health (www.epa.gov/pesticides/factsheets/riskassess.htm). In 1996, Congress made changes to strengthen pesticide laws through the Food Quality Protection Act (FQPA), which require EPA to consider:

- *A new safety standard*: FQPA strengthened the safety standard that pesticides must meet before EPA approves their use. EPA must ensure with a reasonable certainty that no harm will result from the legal uses of the pesticide.
- *Exposure from all sources*: In evaluating a pesticide, EPA must estimate the combined risk from that pesticide from all non-occupational sources such as:
    - Food sources;
    - Drinking water sources; and
    - Residential sources.
- *Cumulative risk*: EPA is required to evaluate pesticides in light of similar toxic effects that different pesticides may share, or a "common mechanism of toxicity." EPA is developing a methodology for this type of assessment.
- *Special sensitivity of children to pesticides*: EPA must ascertain whether there is an increased susceptibility from exposure to the pesticide to infants and children. EPA must build into their risk assessment an additional 10-fold factor of safety to ensure the protection of infants and children, unless it is determined that a lesser margin of safety will be safe for infants and children. The use of the extra 10-fold factor of safety for children is in addition to the traditional 100-fold factor of safety for human health. To further increase protections for infants and children, EPA now requires registrants to conduct acute, sub-chronic, and developmental neurotoxicity studies. EPA also updated the set of test guidelines for development of data on reproductive and developmental effects.

The FQPA requires EPA to set tolerances or grant exemptions for all the ingredients in a pesticide product that is used on food. A tolerance is the maximum amount of pesticide chemical residue that can be in or on a food product or feed commodity. EPA must determine that the levels of the chemical proposed in the tolerance are "safe." Safe means a reasonable certainty of no harm to human health. An exemption from a tolerance is issued when EPA determines that the total quantity of the pesticide chemical in or on the food will present no hazard to public health. Generally, other ingredients in pesticide formulations are not active themselves and are exempt from the need for a tolerance determination so long as they do not present a hazard to public health.

Reduced-Risk Pesticides. The EPA Office of Pesticide Program's Conventional Reduced-Risk/Organophosphate Alternative Program expedites the review and regulatory decision-making process of conventional pesticides that pose less risk to human health and the environment than existing conventional alternatives. Reduced-risk/organophosphate alternative pesticides typically have one or more of the advantages listed in Table 2.7-1 over existing conventional pesticides. The characteristics of imidacloprid as it relates to these potential advantages is indicated in the column at right.

Table 2.7-1. Characteristics of imidacloprid as these relate to the advantages of reduced-risk/organophosphate alternative pesticides.

Potential Advantages of Reduced-Risk/Organophosphate Alternative Pesticides	**Characteristics of Imidacloprid as it Relates to these Potential Advantages**[19]
• Low impact on human health:	
− Very low mammalian toxicity;	Low mammalian toxicity
− Toxicity generally lower than currently-registered higher-risk conventional pesticides	True
− Can displace chemicals that pose potential human health concerns; and	True
− Reduce exposure to pesticide handlers and post-application exposure.	No
• Lower toxicity to non-target organisms (birds, fish, plants):	
− Very low toxicity to birds, honey bees, fish	True for birds and fish
− If toxicity is similar to conventional herbicides, then there is lower exposure potential; and	No
− Potential toxicity/risk is capable of mitigation.	No
• Low potential for groundwater contamination.	No
• Lower use rates or fewer applications than conventional pesticides.	No
• Low pest resistance potential (for example, reduced-risk pesticides may have a new mode of action).	No
• Compatibility with integrated pest management (IPM) practices.	Yes

EPA considers imidacloprid an organophosphate alternative pesticide. The reduced-risk/organophosphate alternative designation applies to only certain uses of a particular pesticide and may not include all labeled uses for that product. In the case of imidacloprid, there is one potential exception: effects to pollinators. The remedy for this potential limitation includes observing buffers and spray restrictions that would be specified in the NPDES Permit, should it be issued.

Endangered Species Act (ESA). Issuance of a NPDES permit by Ecology is not subject to ESA consultation with the National Marine Fisheries Service or the U.S. Fish and Wildlife Service.[20] However, obtaining coverage under an NPDES Individual Permit does not exempt a permit holder from the "take" provisions of the ESA. "Take" means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or attempt to engage in such conduct with respect to a species listed under ESA (16 U.S. C. Section 1532 [19]). Potential impacts to species listed under the ESA are addressed in FEIS Chapter 3, Section 3.2.5.

2.7.6 Memorandum of Agreement (MOA)

[19] Source: Personal communication with Dr. Alan Schreiber, Administrator of the Washington State Commission on Pesticide Registration, July 25, 2014.

[20] *Am. Forest & Paper Association v. EPA*, 137 F.3d 291, 299 (5th Cir. 1998) (EPA may not approve Louisiana's NPDES program on the condition that Louisiana will undertake ESA consultation with the Services); *Oregon Natural Res. Council v. Hallock*, No. 02-1650-CO, 2006 WL 3463432 (D. Or. Nov. 29, 2006) (State of Oregon's issuance of an NPDES permit is not a Federal agency action subject to the ESA's consultation provisions).

Beginning in the early 1990s, the carbaryl-based burrowing shrimp management plan has been subject to increasing regulatory control. In January 2001, a framework to transition the industry toward Integrated Pest Management (IPM) was formalized as a Memorandum of Agreement (MOA) between WGHOGA, the Ecology, and several other State agencies, grower organizations, and interested parties. More recently, and in response to a decision by the Ninth Circuit Court of Appeals, Ecology required oyster producers to apply for a NPDES permit to authorize applications of carbaryl to areas commercially grown for oysters in Willapa Bay and Grays Harbor. Both the MOA and NPDES permit (issued May 22, 2002) specify and prioritize tasks toward IPM development and include a timeline for their execution (Booth and Wilson 2002).

The IPM concept features the use, or integration, of several pest management tools, tactics, and strategies with an overall goal to reduce reliance on conventional broad-spectrum pesticides. Battelle Pacific Northwest Laboratories completed an evaluation in 1997 of the feasibility of using IPM to control burrowing shrimp on areas commercially grown for oysters. The Battelle report concluded that there were a number of areas where there was insufficient information to develop and implement an IPM plan for this purpose. Filling those information gaps was the foundation of the MOA and 2002 NPDES permit (Booth and Wilson 2002).

Three major objectives for the development of an IPM program for burrowing shrimp control include:

1. Determine the relationship between burrowing shrimp density and oyster yield (e.g., the damage/density relationship) to develop both better monitoring techniques and economically-based action thresholds.
2. Evaluate alternatives to carbaryl-based tactics to suppress burrowing shrimp, especially physical methods, or subsurface applications of registration-exempt compounds within a tier of experimental designs that progress from small, tightly-controlled areas through larger *in-situ* systems, to field plot trials.
3. Write and publish an IPM plan for burrowing shrimp and adopt the plan into an Environmental Code of Practice for the West Coast shellfish aquaculture.

Responding to these objectives would continue while using imidacloprid to control burrowing shrimp on areas commercially grown for clams and oysters in Willapa Bay and Grays Harbor. Various mechanical and non-chemical control methods have been tried as methods for controlling burrowing shrimp (see Section 2.8.4 below for detailed descriptions). These methods have either failed to control burrowing shrimp, are too impractical to implement on a commercial scale, or they significantly harm the shellfish crop and/or non-target species. Examples of this include sediment compaction, sediment alteration, and physical barriers (described below in Section 2.8.4). Therefore, IPM studies have shifted to a search for less toxic chemicals that are still effective at controlling burrowing shrimp. Imidacloprid has been identified through years of study and experimentation as a possible substitute for carbaryl.

2.8 The Proposed Action and Alternatives

WGHOGA has requested issuance of a NPDES permit for the purpose of allowing chemical applications of imidacloprid on up to 2,000 acres per year of shellfish beds on which clams and oysters are commercially grown: up to 1,500 acres per year in Willapa Bay, and up to 500 acres per year in Grays Harbor. Ecology's NPDES permit decision requires environmental review under the Washington State Environmental Policy Act (SEPA). Therefore, the purpose of this Environmental Impact Statement (EIS) is to evaluate the potential impacts of the proposed action and alternatives, and to describe mitigation measures that could avoid or minimize potential adverse effects.

Introduction to the Analysis of Alternatives

Ecology listed in the *Determination of Significance and Request for Comments on the Scope of this Environmental Impact Statement* possible alternatives that might be discussed in the EIS (January 2, 2014). As briefly described in Section 2.4 above, commercial shellfish growers have been investigating various alternative mechanical means, shellfish culture methods, and chemical control measures since the 1950s, none of which has proven to be as effective, reliable, economical, or more species-specific than carbaryl[21] applications administered with adaptive management principles (Patten 2002).[22] Methods that are ineffective at controlling burrowing shrimp would not meet the objectives of the proposal, and therefore are by definition not reasonable for analysis in the EIS (see the discussion of the SEPA Rules below). Research into alternative methods of control (including alternatives to imidacloprid applications) would continue under the imidacloprid NPDES Individual Permit if the requested permit is issued.

At the time of this writing, since there are no known alternatives to chemical applications to effectively control burrowing shrimp, this EIS evaluates three alternatives:

- Alternative 1: No Action – No Permit for Pesticide Applications.
- Alternative 2: Continue Historical Management Practices – Carbaryl Applications with Integrated Pest Management (IPM).
- Alternative 3: Imidacloprid Applications with IPM (Preferred Alternative).

The potential environmental impacts of each alternative and recommended mitigation measures[23] are described in FEIS Chapter 3. The information provided will be used by decision makers to assess the alternatives and appropriate mitigation conditions that would be required for the proposed chemical applications.

This FEIS also includes a section (2.8.4) that describes other Alternatives Considered and Eliminated from Detailed Evaluation. Experimentation with methods that do not include the use of pesticides has been tried over a period of decades. These have been found to be ineffective, and/or impractical for use on the scale of hundreds (to thousands) of acres of commercial shellfish beds in Willapa Bay and Grays Harbor. Since ineffective or unreasonable alternatives would not achieve the objectives of the proposal, these are not evaluated in FEIS Chapter 3.

Guidelines for Analysis and Comparison of Alternatives

Washington State Environmental Policy Act (SEPA). The SEPA Rules (Chapter 197-11 WAC) that implement the State Environmental Policy Act (Chapter 43.21C RCW) require an EIS to describe and present the proposal (or preferred alternative, if one exists) and reasonable alternative courses of action. Reasonable alternatives are actions that could feasibly attain or approximate the objectives of the proposal, but at a lower environmental cost or decreased level of environmental degradation. The word “reasonable” is intended to limit the number and range of alternatives, as well as the amount of detailed

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[21] Carbaryl is a carbamate insecticide that has been used for burrowing shrimp control on commercial oyster beds in Willapa Bay and Grays Harbor since 1963.

[22] Adaptive management principles include such things as optimum timing for pesticide applications in relation to the life cycle and activity of burrowing shrimp, bed conditions, application timing in relation to tidal conditions, frequency of bed treatment, etc.

[23] Integrated Pest Management measures and Best Management Practices for the use of imidacloprid will be defined as conditions of the NPDES Individual Permit, if issued. These had not yet been formulated at the time of this writing.

analysis for each alternative. The level of detail is to be tailored to the significance of environmental impacts, and one alternative may be used as a benchmark against which to compare the other alternatives. The EIS may indicate the main reasons for eliminating some alternatives from detailed study.

The SEPA Guidelines also require that the No Action Alternative shall be evaluated and compared to other alternatives (WAC 197-11-440[5][b][ii]). Occasionally, a lead agency may decide that there are no reasonable alternatives to a proposed action, in which case No Action and the Preferred Alternative would be the only alternatives evaluated (2003 SEPA Handbook, Section 3.3.2).

Washington State Surface Water Quality Standards and the Water Pollution Control Act. Washington State surface water quality regulations and standards (Chapter 173-201A WAC) provide authority to Ecology to establish criteria for waters of the State and to regulate various activities. These standards protect public health and maintain the beneficial uses of surface waters, which are defined in the statute to include:

- Recreational activities such as swimming, SCUBA diving, water skiing, boating, fishing, and aesthetic enjoyment;
- Public water supply;
- Stock watering;
- Fish and shellfish rearing, spawning, and harvesting;
- Wildlife habitat; and
- Commerce and navigation.

The potential effects of the proposed action on recreational activities, fish and shellfish, wildlife habitat, and navigation are discussed in FEIS Chapter 3. Public water supply and stock watering would not be affected by the proposed action since the affected environment encompasses the saltwater estuaries of Willapa Bay and Grays Harbor.

Key to the analysis and comparison of alternative methods for the control of burrowing shrimp is the goal to maintain beneficial uses of State waters and protect the environment. Therefore, Ecology will consider each alternative for:

- Economic viability of the shellfish industry
- The extent to which the approach may detract from the beneficial uses of Willapa Bay and/or Grays Harbor;
- Probable adverse environmental impacts;
- Probable adverse human health impacts, particularly for chemical control methods; and
- The effectiveness of the method in controlling burrowing shrimp (*Neotrypaea californiensis* and *Upogebia pugettensis*).

2.8.1 Alternative 1: No Action – No Permit for Pesticide Applications

The Washington State Environmental Policy Act (SEPA) requires the EIS to evaluate the effects of the No Action Alternative, which is typically defined as maintaining the status quo, or no change from existing conditions. In the case of burrowing shrimp control on commercial shellfish beds in Willapa Bay and Grays Harbor, insecticide applications using carbaryl (trade name Sevin brand 4F)[24] were used from 1963 through 2013. Continuing that practice is evaluated below as Alternative 2. Recent changes have placed carbaryl applications in a situation where regulatory action would be required to continue the use of this insecticide (described below under Alternative 2). For this reason, the EIS evaluates a No Action Alternative in which Ecology would revoke the administratively extended permit, and would not issue the proposed NPDES Individual Permit for imidacloprid applications.

Under this scenario (Alternative 1), there would be no permit authorizing insecticide applications in Willapa Bay or Grays Harbor for the control of burrowing shrimp. Commercial shellfish growers would only be able to utilize mechanical methods and alternative shellfish culture practices. Studies performed since the 1950s (such as those described in Section 2.8.4 below) have not yet identified an effective alternative to insecticide applications. Therefore, under Alternative 1, most productive clam and oyster grounds would be expected to decline over the next 4 to 6 years, as evidenced by the Tillamook Bay (Oregon) example described in Section 2.4. Some limited areas may continue to produce clams and oysters in size and numbers close to present levels. However, growers expect that the general trend over the harvest grounds would be a marked decline in productivity, on the order of 60 to 80 percent or more[25] (personal communication with WGHOGA members, November 4, 2013; January 17, 2014; and January 24, 2014). The economic impacts of a decline of this magnitude in commercial shellfish aquaculture are described in Section 2.6. Ecosystem changes that would result from a significant increase in burrowing shrimp populations and significant reductions in shellfish (bivalve) populations are evaluated under elements of the Affected Environment in FEIS Chapter 3.

Most of the studies performed on the effects of burrowing shrimp on commercial shellfish aquaculture have studied effects in areas where oysters are primarily grown. Growers report that the method of loss for clams is the same as it is for oysters (personal communications with WGHOGA members, May 28, 2014, July 30, 2014, and July 31, 2014). A workshop sponsored by the Western Integrated Pest Management Center came to a similar conclusion.[26] The substrate is destroyed by burrowing shrimp that reside beneath the substrate surface where they displace, mix, and re-suspend sediment particles as they feed, transforming the normally hard and sandy tide flat bottom structure to a soft sediment layer. Commercial shellfish bed substrate is altered at a rate aligned with shrimp density; clams and oysters suffocate; and the cultivation investment is lost. Once a bed is lost, it would take years to reclaim it if burrowing shrimp control became available at some future time. Few companies could afford the time and expense of bed reclamation if they were not selling a crop from these tidelands. Without the ability to control burrowing shrimp on areas commercially grown for clams, growers estimate that the clam industry would decline at a rate comparable to that estimated for the oyster industry, or be lost altogether except for some small incidental harvest areas where clams may be a secondary crop to oyster seed (personal communications with a WGHOGA members, May through July 2014). Additional information regarding the WGHOGA proposal to also treat areas where clams are primarily grown is provided in FEIS Chapter 1, Section 1.4.

2.8.2 Alternative 2: Continue Historical Management Practices – Carbaryl Applications with Integrated Pest Management (IPM)

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[24] The FIFRA Section 24(c) Special Local Nedd registration (SLN Reg. No. WA-120013) for the trade name Sevin brand 4F expired on December 31, 2013 (NovaSource 2012).

[25] The Washington State University Pacific County Extension Director estimates that the bay-wide loss of clams and oysters would be on the order of 80 to 90 percent without pesticide treatments for the control of burrowing shrimp (testimony of Dr. Kim Patten at the Imidacloprid EIS Scoping meeting, February 1, 2014).

[26] Burrowing shrimp affect all crops except geoducks grown at deep intertidal or subtidal levels (DeFrancesco and Murray 2010), page 31.

The primary burrowing shrimp management practice used by Willapa Bay and Grays Harbor shellfish growers between 1963 and 2013 has been chemical treatment with the n-methyl carbamate insecticide carbaryl. Development of an Integrated Pest Management (IPM) Plan was required by the *Memorandum of Agreement* (Washington State Department of Ecology et al., January 30, 2001) that accompanied the 2002 NPDES permit. Permit conditions strictly control such parameters as the timing, location, quantity, and methods of chemical applications for precise delivery; the substrate condition and density of burrowing shrimp population that warrants treatment; frequency of application to individual beds; and the anticipated use of the bed following treatment. The IPM approach integrates knowledge of the life history and ecology of both species of burrowing shrimp; their natural predators and competitors; chemical, biological and physical control tactics; cultivation practices; and all other suitable techniques to maintain burrowing shrimp at population densities below economically injurious levels.

Beginning in the 1990s, Ecology authorized the application of carbaryl to commercial shellfish beds in Willapa Bay and Grays Harbor to suppress burrowing shrimp via both a Temporary Water Quality Modification Order (TWQMO) and a FIFRA Section 24(c) Special Local Need registration (SLN Reg. No. WA-900013) issued by the Washington State Department of Agriculture (WSDA). Under these provisions, carbaryl was applied annually on up to 600 acres (1.3 percent of total intertidal acres) in Willapa Bay, and up to 200 acres (approximately 0.6 percent of total intertidal acres) in Grays Harbor,[27] predominantly in the form of liquid spray dispersed on exposed mudflats by helicopter over five to ten days on extreme low tides during July and August of each year. The use of ground-based equipment (such as hand-held sprayers attached to a backpack reservoir, or all-terrain vehicles equipped with a spray boom) is another method used on some of the smaller, more accessible beds. Many of the areas commercially grown for oysters are in remote locations and have terrain that is not suitable for ATVs or use of a backpack sprayer beyond some small areas of one-quarter acre or less in size. Once a bed has been treated with carbaryl, it typically does not need to be treated again for another three to seven years, depending on the level of shrimp larvae recruitment and lateral movement of adults from neighboring tide flats to the treated bed area.

2.8.2.1 Carbaryl NPDES Permits: 2002 and 2006

In January 2001, the MOA entered into by WGHOGA, Ecology and other State agencies had as an objective to transition commercial shellfish aquaculture toward a program to manage burrowing shrimp based on the principles and concepts of integrated pest management (IPM). Also in 2001, in response to a decision by the Ninth Circuit Court of Appeals, Ecology required WGHOGA to apply for a NPDES permit to authorize applications of carbaryl to selected areas commercially grown for oysters in Willapa Bay and Grays Harbor. The NPDES permit was issued May 17, 2002. It included several Special Conditions, such as the submission of detailed records describing the time, location, and shrimp population level (e.g., burrow counts)[28] on oyster beds proposed for carbaryl treatment; plans for experimental use to begin testing an array of alternative pesticides; a plan to monitor the water column for carbaryl at specific timings and locations pertinent to treatment; a spill clean-up plan; and application-related recordkeeping requirements. The carbaryl NPDES permit was reissued in 2006 for a period of 5

[27] Shellfish growers voluntarily reduced the carbaryl treatment area by 10 percent (down to 720 acres) in 2003, by another 10 percent (20 percent total) in 2004, and by an additional 10 percent (30 percent total) to 560 acres since 2005. These actions were taken to comply with a Settlement Agreement entered into by WGHOGA, the Washington Toxics Coalition, and the Ad Hoc Coalition for Willapa Bay. Ecology was not party to this Agreement, and treatment acreage reduction was not a condition of the State-issued NPDES permit.

[28] The carbaryl 2006 NPDES permit (WA0040975) required beds selected for treatment to have a minimum average shrimp density of 10 (ten) shrimp burrows per square meter. Beds selected for treatment by growers are inspected by a designated Burrowing Shrimp Control Coordinator prior to treatment to assure that this minimum criterion is met, as well as to assure adherence to other Best Management Practices (WGHOGA, December 2002).

years, with an administrative extension allowing its continued use. The FIFRA Section 24(c) Special Local Need registration (SLN Reg. No. WA-120013) for the n-methyl carbamate insecticide carbaryl expired on December 31, 2013 (NovaSource 2012). The FIFRA Section 24(c) Special Local Need registration (SLN Reg. No. WA-120013) was voluntarily cancelled by the registrant (NovaSource) on January 15, 2014 (WSDA January 15, 2014).

2.8.2.2 Carbaryl Efficacy

Carbaryl has been very effective at controlling burrowing shrimp. Carbaryl applied at ten pounds per acre from 1963 to 1984 had a 90 to 95 percent efficacy (Feldman et al. 2000; Dumbauld et al. 1997). Concentrations were reduced to 7.5 pounds per acre in 1984, with no decrease in efficacy (Creekman and Hurlburt 1987). Creekman and Hurlburt also found that carbaryl could be applied in lower concentrations in the summer and attain the same degree of efficacy as applying a high concentration in the spring. This appears to be due to carbaryl hydrolysis in warm temperatures. Efficacy studies by Dumbauld et al. (2006) showed that carbaryl achieved 90 percent efficacy in 2000 when applied at a rate of eight pounds per acre.

The efficacy of carbaryl is highly dependent upon exposure time (from pesticide application until the incoming tide covers an area; Dumbauld et al. 1997). Mud shrimp and ghost shrimp are differentially affected by carbaryl, with application rates being more important for mud shrimp and exposure time being more important for ghost shrimp (Dumbauld et al. 1997). This may be due to substrate differences between mud shrimp and ghost shrimp habitat, the difference in burrow design between these two shrimp species, and the behavior of the chemical when it reaches the sediment interface.

2.8.2.3 Carbaryl Effects

Carbaryl is toxic to both burrowing shrimp and other non-target species in the marine environment. It disrupts nerve transmission in invertebrates, likely resulting in respiratory muscle paralysis or reduced heart rate. Carbaryl is considered to be highly toxic to crabs, both by direct contact and through ingestion of shrimp killed by carbaryl. Other arthropod species, such as the amphipod crustacean *Corophium acherusicum*, appear to be highly sensitive to carbaryl (Tagatz et al. 1979). However, studies have found that some benthic invertebrates start to recolonize treated areas reasonably quickly, but full recolonization happens on a longer time scale (Dumbauld et al. 2001, McCauley et al. 1977).

Salmonids can be affected by exposure to carbaryl;[29] however, juvenile salmonids do not typically utilize Willapa Bay and Grays Harbor during the periods when carbaryl has been sprayed (WDF and ECY 1985). In addition, given that carbaryl is applied at extreme low tides, and is then diluted by the incoming high tide, direct salmonid exposure is likely to be limited to diluted water concentrations. For these reasons, it is not likely that salmonids are being affected by the use of carbaryl in Willapa Bay and Grays Harbor. There have been no documented or observed impacts to any fish species since the carbaryl program was initiated in 1963 unless the fish were actually on the bed during treatment at low tide, where overlying shallow water was present. It is possible, however, that some fish may be indirectly affected if their food sources (benthic invertebrates) are reduced in localized areas due to the use of carbaryl (WDF

[29] EPA recently entered into a Stipulated Settlement Agreement with the Northwest Center for Alternatives to Pesticides et al. to impose, for the protection of ESA-listed salmon and steelhead species, certain no-spray buffers from salmon-bearing streams for the use of carbamate insecticides (including carbaryl). Stipulation 3 (page 7) of Case No. 2:10-cv-01919-TSZ, Document 174 provides that buffers do not apply to the use of carbaryl by WGHOGA to treat oyster beds in the estuarine mudflats of Willapa Bay and Grays Harbor, contingent on these applications being made when wind velocity at treatment sites does not exceed 10 mph (Northwest Center for Alternatives to Pesticides, W.D. Wash., August 13, 2014).

and ECY 1985). However, the very small proportion of tidelands treated each year since 2005[30] in Willapa Bay (approximately 420 acres of 45,000 acres total) and Grays Harbor (approximately 140 acres of 34,460 acres total) left vast tideland acreage untreated in each bay where benthic invertebrates (including burrowing shrimp) were unaffected.

The degree of toxicity to other species varies considerably (WDF and ECY 1985). Some marine plants and algae are growth-inhibited by carbaryl, while others are not affected. Marine algae are likely inhibited immediately after spraying, until carbaryl concentrations decrease to less than 1.0 parts per million (ppm) (WDF and ECY 1985). Birds are relatively resistant to the effects of carbaryl, but may be indirectly affected if their food sources decline due to the use of carbaryl. Given the limited acreage sprayed in Willapa Bay and Grays Harbor in any given year (as described above), any such reduction in the bird prey base would also be limited. In addition, studies by Dumbauld et al. (unpublished) indicate that burrowing shrimp are abundant in Willapa Bay, outside of treated commercial shellfish beds.

Carbaryl is not known to be accumulated by any component of the food web, nor is it transmitted to higher levels in the food chains. It rapidly breaks down to a low toxicity "daughter" product (1-naphthol), and ultimately breaks down to carbon dioxide and water (Karinen et al. 1967).

Applications of carbaryl are done at low tide when tidal water is either absent or limited to depressions and channels on the shellfish beds, which limits contact with the water column and non-target species such as fish and birds. However, birds such as gulls are occasionally seen foraging in treated areas, likely eating dead or dying invertebrates on the sediment surface[31] (personal communication with Dr. Kim Patten, WSU Pacific County Extension Director). Carbaryl typically dilutes to concentrations below 3.0 ppb on the first incoming tide (WGHOGA 2011).

2.8.2.4 Administratively Extended, New or Modified Carbaryl Permit

If Alternative 2 were selected, it would be necessary for Ecology to continue the administrative extension of NPDES Permit WA0040975, or to modify and reissue the permit. It would also be necessary for WGHOGA (or another registrant) to apply to the WSDA for a new FIFRA Section 24(c) Special Local Need registration for carbaryl. Continued use of carbaryl would also be subject to other potential approvals.

Many conditions of a new or modified NPDES Permit and Federal registration for carbaryl would likely be the same or similar to the 2006 permit (WA0040975). If the permit for carbaryl applications was modified and reissued, it is likely that WGHOGA would also request coverage for areas commercially grown for clams as well as areas commercially grown for oysters in Willapa Bay and Grays Harbor (see FEIS Chapter 1, Section 1.4). For the purpose of analysis in this Environmental Impact Statement, it is assumed that a new or modified NPDES permit to implement Alternative 2 (carbaryl with IPM) may include the following conditions:

Maximum Annual Acreage:	800 acres (600 acres in Willapa Bay, and 200 acres in Grays Harbor)

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30 WGHOGA reduced the tideland acreage treated in Willapa Bay and Grays Harbor from 800 acres in 2002 to 720 acres in 2003, then to 640 acres in 2004, and to not more than 560 acres in 2005 in accordance with the terms of a Settlement Agreement with the Washington Toxics Coalition and the Ad Hoc Coalition for Willapa Bay (April 28, 2003). The Washington Department of Ecology is not a party to the Settlement Agreement; therefore, the NPDES permit authorizing the use of carbaryl is not bound by the terms of the Settlement Agreement.

31 The effects of carbaryl on birds are discussed under the Potential Impacts of Alternative 2 in FEIS Chapter 3, Section 3.2.5.

Maximum Application Rate:	Eight pounds of active ingredient per acre (a.i./ac)
Application Period:	July 1 through October 31
Burrow Count (shrimp presence criteria):	Exceeds 10 burrows per m^2
Treatment Schedule:	To be specified in an Annual Operations Plan; likely 5 to 10 days per year on the lowest tides in July and August.
Restrictions and Precautions:	• No bed may be treated with carbaryl if it contains oysters within one year of harvest. • Properly stake and flag all ground to be treated to protect adjacent shellfish beds and aquatic areas. • Do not apply carbaryl by helicopter within 200 feet of sloughs, channels or oysters that are within one year of harvest; do not apply by hand sprayer within 50 feet of sloughs, channels, or oysters that are within one year of harvest. • For distribution and use only by applicants approved under a NPDES permit issued by Ecology. • Only certified applicators or persons under the direct supervision of a certified applicator may use or apply carbaryl. • Maintain a restricted-entry interval of 12 hours.
Discharge Limitations:	• Comply with acute and chronic effluent limitations: Acute limit: 3.0 µg/L (subject to short-term modification suspending the acute limit for 48 hr from the time of application. Chronic limit: 0.06 µg/L (subject to short-term modification suspending the chronic limit for 30 days from the time of application). • Limit the discharge of carbaryl authorized by NPDES permit to waters of the State of Washington. There would be no construed authority to discharge carbaryl to tidelands on the Shoalwater Indian Reservation.

The Annual Operations Plan would likely continue to identify the conditions above as well as a Sediment Impact Zone (SIZ), a water quality Sampling and Analysis Plan, a Spill Control Plan, and provisions for experimental use of other treatment methods for the control of burrowing shrimp during the effective period of the NPDES permit.

Best Management Practices for the use of carbaryl may continue to include:

- Complying with all pesticide label instructions.
- Complying with all applicable Federal, State and local laws and ordinances.
- Marking the corners of each commercial shellfish bed scheduled for treatment by aerial application of carbaryl so that the bed would be visible from an altitude of at least 500 feet.

- Having a WGHOGA representative or licensed applicator present at the treatment site at the time of treatment for ground communication with the helicopter pilot.
- Limiting application of carbaryl to one application per commercial shellfish bed per year.
- Applying carbaryl to only commercial shellfish beds that are uncovered by the outgoing tide.
- Adhering to drift management restrictions for aerial and/or ground applications.
- Maintaining complete carbaryl application records on the approved WSDA pesticide application record form (AGR FORM 640-4226 [R/4/07]).

Public notice requirements for carbaryl applications (for which WGHOGA would be responsible) would likely include posting signs at public and privately-owned access points; notifying property owners within 200 feet of treatment sites in person, by telephone, or by mail not less than 24 hours (but not more than ten days) prior to the commencement of carbaryl application; electronic media announcements; and continuing public notifications at a frequency of no less than once per month until carbaryl application was completed for the season. Agency and wildlife refuge 24-hr notifications would likely continue to include Ecology's Non-Point Source Water Quality Specialist, the USFWS Environmental Contaminant Division, Willapa National Wildlife Refuge, Grays Harbor National Wildlife Refuge, and the WDF research scientist in charge.[32]

FIFRA Registration safety precautions for the use of carbaryl would likely continue to include Personal Protective Equipment (PPE) specifications; engineering controls (e.g., requiring pilots to use an enclosed cockpit consistent with WPS for agricultural pesticides); user safety (hand-washing) recommendations; storage and disposal specifications; and first aid instructions.

If all approvals for continued use of carbaryl could not be obtained, Alternative 2 would not achieve the objectives of the proposal, and it could not be implemented. In this case, Alternative 1 would be the only remaining option other than implementation of the Preferred Alternative, and environmental and economic effects would be the same as those described in Chapter 2 sections above and in FEIS Chapter 3 for Alternative 1.

2.8.3 Alternative 3: Imidacloprid Applications with Integrated Pest Management (Preferred Alternative)

Under Alternative 3, the historical practice of carbaryl applications on areas commercially grown for oysters in Willapa Bay and Grays Harbor would be discontinued. Instead, under this alternative, Ecology may issue a five-year NPDES Individual Permit to apply the neonicotinoid insecticide imidacloprid on up to 2,000 acres *per year* of commercial shellfish beds[33] in these bays: up to 1,500 acres *per year* in Willapa

[32] If a new Sediment Impact Zone (SIZ) were defined to implement Alternative 2, Ecology would make a reasonable effort to identify and notify all landowners, adjacent landowners, and lessees potentially affected by the SIZ in accordance with WAC 173-204-415(2)(e). This notification would be in addition to the public notice requirements for chemical applications for which WGHOGA would be responsible.

[33] As used throughout this Environmental Impact Statement in the context of alternatives to implement the proposed action, the term "commercial shellfish beds" refers to tidelands within Willapa Bay and Grays Harbor on which oysters and clams are commercially grown. The requested NPDES permit would not extend to other geographical areas and would not authorize treatment on other species of commercially-grown shellfish (e.g., geoduck or mussels).

Bay (approximately 3.3 percent of total tideland area exposed at low tide),[34] and up to 500 acres *per year* in Grays Harbor (approximately 1.5 percent of total tideland area exposed at low tide).[35] During years two through five of the five-year term of the permit, sprayed acreage may include repeat spraying of some commercial shellfish beds treated in previous years, and commercial shellfish beds not previously sprayed, depending on shellfish grower plans for their seed beds, grow-out sites, and fattening grounds; the efficacy of prior treatments; and the level of burrowing shrimp population each year. The application rate, maximum annual acreage, treatment schedule, shrimp presence criteria, Best Management Practices, monitoring requirements, and safety precautions would be specified in the permit.

The imidacloprid proposal differs from the carbaryl 2006 permit (WA 0040975) in total tideland acreage that could be treated each year, and includes treatment of areas primarily grown with commercial clams as well as areas primarily grown with commercial oysters.[36] Growers report that the 800-acre allowance under the carbaryl permit was not sufficient in years when there was significant recruitment of burrowing shrimp. Some beds that met the treatment threshold of ten burrows per square meter went untreated. Growers had to adjust their treatment plans to focus only on areas primarily grown for oysters and most in need of treatment. Burrowing shrimp populations are cyclic and are currently beginning to greatly increase in numbers. The purpose for the larger acreage requested under the imidacloprid permit is to address this current trend of high recruitment, the inclusion of areas primarily grown with commercial clams to the tidelands authorized for treatment, and what currently appears to be the reduced effectiveness of imidacloprid compared to carbaryl. Growers anticipate that, at least initially, it may be necessary to treat beds more frequently with imidacloprid to protect the same areas (personal communication with a WGHOGA member, May 28, 2014).[37]

Growers seek flexibility through the larger annual treatment area under the imidacloprid permit (2,000 acres) compared to the carbaryl permit (800 acres) in order to evaluate the need for treatment on selected beds. The larger acreage would allow them to defer some treatments to subsequent years with the knowledge that the overall allotment should be sufficient to cover varying annual needs throughout the actively-farmed tidelands. Some portion of the actively-farmed tidelands would likely never be treated, and portions of some beds included in the estimate of actively-farmed tidelands are not useable. For lands that are treated, the treatment timing and frequency will be determined on a site-specific basis depending on shrimp population levels, efficacy of imidacloprid treatments, and physical and biological characteristics of the commercial shellfish beds. In no case would the treatment acreage exceed 1,500 acres *per year* within Willapa Bay or 500 acres *per year* within Grays Harbor.

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[34] The total area of tide flats exposed on low tide in Willapa Bay is approximately 45,000 acres. Of this acreage, approximately 25,562 acres of tidelands are owned or leased for commercial shellfish aquaculture (NMFS, April 28, 2009), and 9,000 acres are currently farmed for the commercial production of oysters and clams (CSI 2013).

[35] The total area of tide flats exposed on low tide in Grays Harbor is approximately 34,460 acres. Of this acreage, approximately 3,995 acres of tidelands are owned or leased for commercial shellfish aquaculture within Grays Harbor: 3,088 acres in North Bay and 907 acres in South Bay (NMFS, April 28, 2009). Approximately 900 acres of Grays Harbor tidelands are currently farmed for the commercial production of oysters and clams (CSI 2013).

[36] There is statutory authority for commercial shellfish beds within Willapa Bay and Grays Harbor to grow oysters, clams, and other commercial shellfish species recognized by the State (see, for example, RCW 79.135.010, and FEIS Section 2.4). Commercial shellfish growers make no distinction by crop as it relates to burrowing shrimp control. The purpose for burrowing shrimp control is to protect the ability of the ground to produce a crop, not the crop itself (personal communications with WGHOGA members, July 30 and July 31, 2014). See FEIS Chapter 1, Section 1.4.

[37] FEIS Section 2.8.2 reports that once a bed has been treated with carbaryl, it typically does not need to be treated again for another 3 to 7 years, depending on the level of shrimp larvae recruitment and lateral movement of adults from neighboring tide flats to the treated bed area. While imidacloprid treatments may be more frequent on some beds, in no case would treatment exceed the once per year restriction under the FIFRA Registration.

Some areas commercially grown with clams have either functioned directly as areas primarily grown for oysters in the past, or have oysters as a secondary crop. With low burrowing shrimp recruitment over the past ten years or so, it has been possible to farm some of these beds without shrimp control. However, due to the large recent recruitments of burrowing shrimp in Willapa Bay and Grays Harbor, growers are now also seeing high shrimp densities in areas primarily cultivated with clams. The threshold for treatment in areas commercially grown with clams is reportedly the same as in areas commercially grown with oysters. Growers report that they begin to lose areas primarily or exclusively grown with clams at the same shrimp density as the threshold within areas where oysters are grown; i.e., at ten adult burrows per square meter (personal communications with WGHOGA members, May 28, 2014, July 30, 2014, and July 31, 2014). This threshold, however, does not address damage done earlier to commercial shellfish beds by juvenile burrowing shrimp (personal communication with a WGHOGA member, July 30, 2014). Efficacy on areas commercially grown with clams would be monitored and assessed the same as areas commercially grown with oysters, based on burrowing shrimp density following treatment. With the flexibility sought by growers under the imidacloprid permit, the assessment of efficacy would include the presence of juvenile as well as adult burrowing shrimp (see Section 2.8.3.3 below).

Growers use an array of information to decide if and when they should treat a commercial shellfish bed. Before applying for treatment, they consider crop cycles, whether the bed can sustain the crop without loss, whether the bed needs to be treated to sustain the crop for the period of time it will occupy a bed, the life stage and population level of burrowing shrimp in the shellfish bed of concern, and other physical and biological conditions at each site. The assessment correlates directly to shrimp density and the activity of the burrowing shrimp that are present. If a few shrimp are causing lots of sediment bioturbation, the crop will begin to be lost immediately after planting. If a grower determines that a bed needs to be treated to protect their crop investment, they identify the bed within the Annual Operations Plan, which would need to be approved by Ecology.

Under the imidacloprid permit, growers would continue to experiment with alternative physical, biological, or chemical control methods that are as species-specific (to burrowing shrimp) as possible, practical on a commercial scale, economical, reliable, and environmentally responsible. The imidacloprid program and experimental practices would be reviewed by Ecology over the five-year duration of the proposed permit (if issued) as part of their consideration of future practices for burrowing shrimp control.

2.8.3.1 Proposed Imidacloprid Applications

Two forms of imidacloprid are proposed for use on burrowing shrimp in commercial shellfish beds: Protector 2F (a "flowable" product), and Protector 0.5G (a granular product). The flowable product would be used in aerial applications by helicopter. These applications would occur on a limited number of days each year during very low tides. The granular application of imidacloprid would be preferred when much or all of the area to be treated retains standing water even at low tide. The granular product sinks through standing water before dissolving and releasing imidacloprid into the water column just above the sediment surface. Protector 2F and Protector 0.5G would only be applied in Willapa Bay and Grays Harbor by those covered under a NPDES permit issued by Ecology, and could only be used on any specific application site once per year. WGHOGA proposes to apply imidacloprid within the tidal range of -2 feet MLLW to +4 feet MLLW.[38]

The total acreage to be treated within Willapa Bay and Grays Harbor each year would likely vary, depending on the dynamics of the burrowing shrimp population (e.g., previous recruitment and the survival and growth rate of burrowing shrimp), and the efficacy of past applications. Individual shellfish

38 Plauché and Carr letter to Greg Zentner, Department of Ecology, November 7, 2013 re: WGHOGA NPDES Application: clarifying information to supplement the July 1, 2013 application.

beds may be treated once per year at a maximum, though treatment frequency may occur less often. Applications to selected areas may occur at intervals as great as three or more years, depending on population levels and the growth rate of burrowing shrimp. It is possible that over the five-year term of the permit, the total acreage to be treated within Willapa Bay could range from 1,500 to 7,500 acres, and in Grays Harbor could range from 500 to 2,500 acres. Growers would apply imidacloprid up to the annual acreage limits in each bay (1,500 acres in Willapa Bay and 500 acres in Grays Harbor) based on case-by-case decisions such as those described above, with the result that they anticipate the upper limit of these ranges would not likely be reached.

Equipment suitable for the chemical formulation (i.e., flowable or granular) may also be used to disperse imidacloprid from scows or shallow-draft boats; all-terrain vehicles equipped with a spray boom; and/or back pack reservoirs with hand-held sprayers. If vessels are used, a barge may accompany a vessel to a treatment site to transport additional supplies and personnel.

Whether with flowable or granular imidacloprid application, the objective is for the chemical to penetrate benthic sediments and thereby reach burrowing shrimp in their burrows. In order to be effective, it is important for the chemical to remain on or near the sediment surface for as long as possible. The activity of burrowing shrimp may cause them to draw in water containing the chemical when the substrate is covered by water. Shrimp feed at or near the sediment surface where they would be exposed to imidacloprid. Laboratory studies have documented that imidacloprid rapidly causes a temporary paralysis in burrowing shrimp, and that this paralysis appears to result in burrow collapse and/or suffocation of the shrimp. Thus, the burrows and feeding habits of burrowing shrimp may make them particularly susceptible to imidacloprid treatments compared to a variety of other epibenthic and infaunal invertebrates (C. Grue, University of Washington, unpublished data).

The objective would be to disperse or spray imidacloprid as evenly as possible over a given area to reach the benthic sediments. Some field trial evidence suggests a differential ability to control burrowing shrimp based on the time of year it is sprayed, either because of differences in the amount of eelgrass coverage (e.g., low in May, high in August), or in the presence of burrowing shrimp juveniles on the beds (i.e., in August through December). Additional field trials were conducted during summer 2014 to further evaluate the efficacy of imidacloprid applications based on time of application. If the results of these studies are available, they will be reported in this Final EIS.

Imidacloprid is expected to have lower toxicity to both burrowing shrimp and non-target organisms. Because a much smaller amount of active ingredient would be used compared to carbaryl applications (both on a per-acre basis and total annual use), growers propose to use a more customized approach to applications. They have identified a need to be more selective regarding application times, tides, and bed conditions (personal communication with WGHOGA members, January 24, 2014, and March 21, 2014). There would be a larger number of application events each year with imidacloprid[39] compared to carbaryl.[40] There will likely be smaller treatment areas during imidacloprid treatment events as individual growers make decisions about how and when to best treat their commercial shellfish beds based on criteria such as the burrowing shrimp life stage, population level, and other physical and biological conditions at each site (described above in Section 2.8.3).

The Integrated Pest Management (IPM) approach for controlling burrowing shrimp with imidacloprid would likely have many similarities to IPM using carbaryl, as defined in the *Memorandum of Agreement*

[39] The imidacloprid treatment period allowed under the FIFRA Registration is April 15 through December 15.

[40] The carbaryl treatment period is July 1 through October 31, with aerial applications occurring on 5 to 10 days during the lowest low tides in July and August.

for Burrowing Shrimp Integrated Pest Management (Washington Department of Ecology et al., January 30, 2001); including but not limited to:

- Prevent pest problems.
- Monitor for the presence of pests and pest damage.
- Establish the density of the pest population that can be tolerated or correlated with a damage level sufficient to warrant treatment of the problem based on health, public safety, economic, or aesthetic thresholds.
- Treat pest problems to reduce populations below those levels established by damage thresholds using strategies that may include biological, shellfish cultural, mechanical, and chemical control methods and thus must consider human health, ecological impact, feasibility, and cost-effectiveness.
- Evaluate the effects and efficacy of pest treatments.

2.8.3.2 FIFRA Registration Restrictions

Conditional Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) Registrations for imidacloprid have been issued to WGHOGA, one for the granular formulation of the product (No. 88867-1 for Protector 0.5G; USEPA 2013a), and one for the flowable formulation (No. 88867-2 for Protector 2F; USEPA 2013a). The labeling requirements listed on the registrations control when and under what conditions these products can be applied, mixed, stored, loaded or used. This section summarizes controls, safety precautions, and mitigation measures that are required by the imidacloprid FIFRA Registrations regardless of additional conditions that would be imposed through Ecology's NPDES permit.

The application period authorized by the FIFRA Registrations is April 15 through December 15. No bed may be treated with imidacloprid if it contains shellfish within 30 days of harvest.

The FIFRA Registrations include several "Application Instructions" that function as Best Management Practices. These include:

- All ground (tidelands) to be treated must be properly staked and flagged to protect adjacent shellfish and water areas. For aerial applications, the corners of each plot must be marked so the plot is visible from an altitude of at least 500 feet.
- A single application of imidacloprid per treated commercial shellfish bed at up to 0.5 pound active ingredient per acre (a.i./ac) is allowed per year.
- The imidacloprid application rate shall not exceed 0.5 pound a.i./ac.
- Aerial applications must be on beds exposed at low tide.
- Applications from a floating platform or boat may be applied to beds under water (at periods other than low tide) using a calibrated granular applicator.
- A 100-foot buffer zone must be maintained between the imidacloprid treatment area and the nearest shellfish to be harvested within 30 days when treatment is by aerial spray; a 25-foot buffer zone is required if treatment is by hand spray if the nearest shellfish bed is to be harvested within 30 days.

- Drift potential is lowest between wind speeds of 3 to 10 mph. Accordingly, the average wind speed at the time of application is not to exceed 10 mph to minimize drift to adjacent shellfish and water areas when applied by air.
- Imidacloprid shall not be applied when winds are greater than 10 mph, during gusty conditions, or during temperature inversions. (Temperature inversions begin to form as the sun sets and often continue into the morning.)
- Applications shall be made at the lowest possible height (by helicopter, ground or barge) that is safe for the operation and that will reduce exposure of the granules to wind.
- When applications of Protector 0.5G (i.e., the granular formulation of imidacloprid) are made crosswind, the applicator must compensate for displacement by adjusting the path of the application equipment upwind. Swath adjustment distance should increase with increasing drift potential.
- Helicopters used to apply either Protector 0.5G or Protector 2F shall be equipped to minimize spray drift. The best drift management strategy and most effective way to reduce drift potential is to apply large droplets that provide sufficient coverage and control. Droplet size can be controlled by using high flow-rate nozzles, selecting the number and type of nozzles, nozzle orientation, and controlling pressure appropriate for the nozzle type.
- Aerial applications shall not be made on Federal holiday weekends.
- Comply with the mixing and loading requirements of the FIFRA Registrations: use of a properly designed and maintained containment pad for mixing and loading of a pesticide into application equipment is recommended. If a containment pad is not used, maintain a minimum distance of 25 feet between mixing and loading areas and potential surface to groundwater conduits.
- All mixers, loaders, applicators, and handlers must comply with the Personal Protective Equipment (PPE) specifications in the FIFRA Registrations: long-sleeved shirt and long pants; shoes plus socks; chemical-resistant gloves; chemical-resistant apron when mixing, loading, or cleaning up spills or equipment; protective eyewear; and a dust mask (when using Protector 0.5G).
- Comply with the user safety recommendations of the FIFRA Registrations: wash hands thoroughly with soap and water before eating, drinking, chewing gum, using tobacco, or using the toilet.
- Comply with the storage and disposal requirements of the FIFRA Registrations.

The public notification requirements (for which WGHOGA would be responsible) specified in the imidacloprid FIFRA Registrations include public access area postings (i.e., signs). At the time of aerial applications, all public access areas within one-quarter mile and all public boat launches within one-quarter mile radius of any bed scheduled for treatment shall be posted. Public access areas shall be posted at 500-foot intervals at those access areas more than 500 feet wide. "WARNING" or "CAUTION" signs shall say *"Imidacloprid will be applied for burrowing shrimp control on [date] on commercial shellfish beds. Do not Fish, Crab, or Clam within one-quarter mile of the treated area."* The location of the treatment area would be included on the sign. Signs shall be posted at least two days prior to aerial treatment and shall remain for at least 30 days after treatment. The Permittee would be responsible for posting, maintaining, and removing these signs. The WGHOGA proposal (described in Section 2.8.3.3 below) includes some additional, more specific notification procedures.[41]

[41] If a Sediment Impact Zone (SIZ) is defined to implement Alternative 3, Ecology would make a reasonable effort to identify and notify all landowners, adjacent landowners, and lessees potentially affected by the SIZ in

2.8.3.3 WGHOGA Proposal for Conditions, Restrictions and Mitigation Measures under the NPDES Permit

The WGHOGA application to Ecology for coverage under an NPDES Individual Permit proposes a maximum annual treatment area of 2,000 acres *per year*: up to 1,500 acres in Willapa Bay and up to 500 acres in Grays Harbor, on commercial shellfish beds.[42]
An Annual Operations Plan (AOP) would be required as a condition of the NPDES Individual Permit. The growers may propose a treatment schedule based on a burrowing shrimp population management approach (i.e., to reduce the shrimp population density below a certain level for a period of time). Because imidacloprid had only been tried on an experimental basis at the time of the NPDES permit application, it is important to WGHOGA to have the flexibility to utilize different treatment times and methods to determine optimum efficacy. These times and methods will be specified in the approved AOP. Information obtained from these efforts may help to define and minimize, over time, the frequency of applications and the amount of imidacloprid to be used. The growers have identified several variations in treatments they may test. Fall treatments would be used to treat burrowing shrimp recruits when they are nearest to the sediment surface; juveniles could be treated in the spring when they are easier to see. Other representative factors that would determine the treatment schedule between April 15 and December 15 would include tidal elevation, sediment type, temperature, and vegetative cover. The AOP could include provisions for exceptions during the treatment period.

As with carbaryl (Alternative 2), Washington State law would require that imidacloprid be used and applied only by certified applicators or persons under the direct supervision of a certified applicator.[43]

The WGHOGA proposal for shrimp presence criteria is to use a conventional pest management approach that involves developing a Risk Profile based on a qualitative scale (e.g., low, medium, high density) for the presence of burrowing shrimp recruits and/or juveniles. WGHOGA proposes to designate an "IPM scout" to conduct a sampling effort at targeted locations around Willapa Bay and the North and South Bays of Grays Harbor, as needed.[44] Shrimp presence would be determined by collecting and sieving sediment samples from commercial shellfish beds, and examining these samples under a microscope to look for shrimp recruits. "Risk alert" areas would be targeted for treatment soon after sampling and during the ensuing treatment season. Growers would work with Ecology over the life of the NPDES Individual Permit to refine the "shrimp risk profile", threshold, for treatment. Because imidacloprid is expected to have lower toxicity to burrowing shrimp, growers want the option to target juveniles before the adult shrimp density reaches the 10 burrows per square meter threshold that was historically used for carbaryl applications. A threshold for treating commercial shellfish beds with high populations of juvenile shrimp has not yet been developed but would be prior to authorizing imidacloprid applications for this purpose.

WGHOGA proposes to modify the carbaryl IPM Plan to address differences for the use of imidacloprid to control burrowing shrimp on commercial shellfish beds in Willapa Bay and Grays Harbor. The IPM Plan would likely continue to include Experimental Use provisions to allow growers to work with alternative

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accordance with WAC 173-204-415(2)(e). This notification would be in addition to the public notice requirements for chemical applications for which WGHOGA would be responsible.

42 Plauché and Carr letter to Greg Zentner, Department of Ecology, November 7, 2013 re: WGHOGA NPDES Application: clarifying information to supplement the July 1, 2013 application.

43 WAC 16-228-1231(1).

44 The efforts of the IPM scout may be needed in different locations of Willapa Bay and Grays Harbor in different years, and may not be needed at all in some years, depending on the recruitment and population level of burrowing shrimp.

physical, biological, or chemical control methods that are as species-specific (to burrowing shrimp) as possible, practical on a commercial scale, economical, reliable, and environmentally responsible.

A preliminary imidacloprid IPM Plan will be submitted to Ecology concurrent with issuance of the final NPDES permit. Growers propose to refine the imidacloprid IPM Plan over time based on what they learn from investigation and evidence gathered each year that applications are made (personal communication with WGHOGA, June 17, 2014).

Best Management Practices proposed by WGHOGA, in addition to those required by the FIFRA Registrations, include but are not limited to:

- Prepare and implement a Spill Control Plan.
- Maintain application records for imidacloprid treatments using the approved WSDA pesticide application record form (AGR FORM 640-4226 [R/4/07]).
- A WGHOGA representative will, at the time of treatment, provide line-of-sight supervision at treatment sites scheduled for aerial (i.e., helicopter) applications of imidacloprid.
- Avoid aerial applications of imidacloprid (e.g., by helicopter) within 200 feet of the Ordinary High Water Line (OHWL) adjacent to shoreline areas.

The WGHOGA proposal includes public notice practices in addition to the public access area sign postings required by the FIFRA Registrations. The growers propose to use a website in lieu of newspaper announcements for public notification regarding specific dates and locations of proposed imidacloprid applications in Willapa Bay and Grays Harbor. The website would include a link for interested persons to request direct notification. The WGHOGA IPM Coordinator would send e-mail notifications to registered interested parties, as needed.[45]

The NPDES permit for imidacloprid will condition the discharge of imidacloprid to waters within Willapa Bay and Grays Harbor only. There would be no construed authority to discharge imidacloprid to tidelands on the Shoalwater Reservation at the north end of Willapa Bay.

2.8.3.4 Imidacloprid Efficacy Trials

As part of the carbaryl IPM program, imidacloprid has been under investigation for use to control burrowing shrimp on areas primarily grown for commercial oysters in Willapa Bay since 1996. Research conducted since 2006 suggests that imidacloprid may be a suitable alternative to carbaryl for this purpose in areas primarily grown for both commercial clams and oysters in Willapa Bay and Grays Harbor. Research efforts to date have focused on refining the efficacy of imidacloprid using different timing, rates, formulations, sediment types and conditions, and application methodologies (WGHOGA 2012), and on the fate, transport, and biological effects of imidacloprid in the environment.

Efficacy trials conducted between 2010 and 2012 suggest that imidacloprid is moderately to highly effective at controlling burrowing shrimp populations in Willapa Bay when it is applied at rates of 0.5 pound (lb) active ingredient per acre (a.i./ac). Results from the 2011 and 2012 experimental trials indicate efficacy rates ranging from 42 to 96 percent burrow reduction at this application rate (Patten 2011 and

[45] Ecology would be responsible under WAC 173-204-415(2)(e) for making a reasonable effort to identify and notify all landowners, adjacent landowners, and lessees potentially affected by the Sediment Impact Zone to implement Alternative 3. This notification would be in addition to the sign postings and electronic notifications regarding application dates and locations for which WGHOGA would be responsible.

2013; Grue and Grassley 2013). Differences in efficacy are due to sediment type (e.g., sandy versus silty) and vegetative cover (primarily eelgrass).

2014 Efficacy Studies. The Willapa-Grays Harbor Oyster Growers Association (WGHOGA) conducted studies in 2014 to evaluate efficacy of imidacloprid in controlling burrowing shrimp under various conditions. Granular and flowable formulations of imidacloprid were applied to commercial shellfish beds under a wide array of variables including; tidal timing, bed habitat characteristics, and application methods. The efficacy sites were chosen based on multiple variables that are believed to affect efficacy. Prior to spraying, pretreatment surveys were conducted to assess shrimp populations during the weeks of May 18, 2014 to June 13, 2014.

Post-treatment effects (change in burrow counts) were assessed starting one day after treatment and will continue when access to beds is possible, dependent upon tides. Grower surveys compared burrow densities pre- and post-treatment within the beds, while WSU compared pre- and post-treatment burrow densities within and immediately adjacent to the treated bed. At the time of this writing, approximately half of the beds had been surveyed for efficacy. The remaining beds are scheduled for surveys during the next appropriate tide series. Percent control is based on the change in burrow density. Factors believed to affect control were also recorded, such as sediment characteristics, seagrass presence, and percent cover. When seagrass was present, percent control varied depending on percent cover of seagrass. Shrimp control ranged from a 41percent to 72 percent reduction in burrow counts in moderate *Zostera marina* cover to 74 percent when *Zostera japonica* was thick. Bare sandy/silty sediment showed the greatest efficacy with percent control ranging from 49 percent to 97 percent. The overall percent control ranged from a 13 percent to 97 percent reduction in burrow counts for all beds surveyed at this time.

Observed Effects on Non-Target Species. During the efficacy studies discussed above, visual surveys of non-target species were made and focused on Dungeness crabs, benthic infauna, and fish. Although these species were not direct subjects of the efficacy studies, observations were made in an attempt to better understand the effects of imidacloprid on non-target species. Surveys one day after imidacloprid treatment demonstrated that Dungeness crabs were either killed or subject to a temporary paralysis at a rate of 0 to 3.8 crabs per acre (Booth et al. 2011; Patten 2013). Affected crabs were subject to predation by birds. During these surveys, fish were not observed to be affected (Booth et al 2011; Patten 2013).[46]

Effects of imidacloprid on benthic infauna indicate that, in most cases, species richness and species diversity of benthic infauna are not adversely affected by imidacloprid over a 14 to 28 day period. (Booth et al. 2011 and 2013). Research also indicates that imidacloprid can move off-site rapidly in surface water and can be detected at least 480 meters (1,575 feet) away from the application site. Imidacloprid was found in seagrass tissue one day after application; however, it degraded rapidly and was undetectable 14 days after application (Grue and Grassley 2013; Hart Crowser 2013). Sediment porewater concentrations of imidacloprid were also examined and researchers found that imidacloprid rapidly dissipated in most samples, but could be detected at least 56 days after application in some samples (Grue and Grassley 2013). Earlier research conducted by Felsot and Ruppert (2002) showed that imidacloprid dissipated rapidly in marine waters, but was detectable in sediments for longer periods of time. The 2012 field research also analyzed for imidacloprid-olefin, a degradation product of imidacloprid. Imidacloprid-olefin was detected in approximately 16 percent of the samples analyzed, in surface water, porewater, and sediments. Concentrations ranged from 0.08 to 3.6 parts per billion (ppb) (Grue and Grassley 2013; Hart Crowser 2013).

A detailed explanation of the results of the 2011 and 2012 field studies is provided below.

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46 The effect of imidacloprid on crabs, birds, fish, and other organisms is described in more detail in FEIS Chapter 3, Section 3.2.5.

2.8.3.5 Field Studies

2011 Field Studies. Experimental trials aimed at determining efficacy, environmental fate and transport, and the biological effects of imidacloprid were performed in 2011. These trials were conducted in Willapa Bay, with the study sites chosen to meet the specific criteria of ownership by a WGHOGA member; adequate densities of burrowing shrimp; adequate distance from previous or planned applications of carbaryl on commercial shellfish beds (>0.5 mile); no previous applications of carbaryl to the tested sites within the past 20 years, if ever (personal communication with Dr. Kim Patten, WSU Pacific County Extension Director, May 29, 2014);[47] accessibility; and desirable characteristics of elevation, vegetation, and substrate that are similar to commercial shellfish beds and that were consistent among the study sites. In addition, treatment and control plots had to be adequately separated to prevent cross contamination (>500 meters). These criteria limited the study sites to two locations within Willapa Bay. The first was located off Rosario Beach on the western side of the Bay Center Peninsula on the eastern shore of the Bay (Bay Center) and the second was located east of the main channel of the Cedar River after it enters the northern part of the bay (Cedar River). At Bay Center, both the granular (Mallet) and flowable (Nuprid) formulations of imidacloprid were used, while at Cedar River only flowable imidacloprid was used (Booth 2014). A total of 51.38 acres of commercial shellfish beds were treated with imidacloprid, 29.54 acres with flowable imidacloprid and 21.84 with granular imidacloprid (Patten 2011). These studies did not have an approved Sampling and Analysis Plan from Ecology.

The Bay Center site contained sandy sediments common to many of the commercial shellfish beds in Willapa Bay and Grays Harbor. The Cedar River site had higher levels of organic matter in the sediments. Results for the two sets of sites were different for some of the factors being analyzed. Where different, they are presented separately in the sections below.

Megafauna Sampling and Analyses. Effects of imidacloprid on epibenthic megafauna (Dungeness crab and fish) were assessed by counting all affected megafauna species on and within 150 feet of the site. Any species exhibiting signs of paralysis or were dead by any cause, directly or indirectly related to treatment (e.g. bird predation of crabs exhibiting paralysis) were considered to be affected. The number of affected Dungeness crab per site ranged from 0 to 19 and the number of affected crab per acre ranged from 0.87 to 3.8 where the treatment site was greater than four acres. There were no affected fish found on the sites following any treatment (Patten 2011).

Efficacy. Efficacy across all sites and treatments ranged from 42 to 96 percent burrow reduction, with highest efficacy on sandy sites with no vegetation and lowest on silty sites and vegetated sites. Studies conducted in 2011 also noted that applications to sites heavily vegetated with eelgrass were problematic due to the lack of site drainage in these areas. These results indicated that eelgrass may impair efficacy by limiting imidacloprid access to shrimp burrows, and by preventing burrow collapse following treatment, thus allowing affected shrimp to recover once paralysis has ceased (Patten 2011).

Sediment Porewater Results. Average imidacloprid concentrations within the sediment porewater ranged from 24 to 154 ppb immediately after treatment. These concentrations decreased to 8 to 20 ppb one day after treatment, and to 0-0.5 ppb at 56 days after treatment.

Epibenthic and Benthic Invertebrate Sampling and Analyses. Epibenthic and benthic invertebrates were sampled at one day before and at 14, 28, and, for Bay Center only, 56 days after treatment. These sampling durations are timed to permit sampling at low tide events following the initial application, and

[47] Treatment sites selected for experimental trials were generally not premium shellfish ground and had not previously been treated with carbaryl.

for 14 days, to allow animals killed by imidacloprid to decompose so that they are not confused with live animals taken at the time of collection. Four on-plot stations were sampled in each treatment plot, with four or five replicate core samples at each station.

In general, the impact of imidacloprid was assessed by comparing each of nine endpoints: absolute abundance, taxonomic richness, and Shannon diversity were calculated separately for each of three primary taxonomic groups: polychaetes, molluscs, and crustaceans. At each post treatment interval (14, 28, and sometimes 56 days after treatment), the value of each of the nine endpoints in the treated plot at each study site (Bay Center or Cedar River) was compared to the same endpoints in the respective control plot.

A consistent problem in the 2011 trials was that the number of invertebrates on the control and treatment plots was not similar to one another at the time of imidacloprid application. This makes interpretation of subsequent differences between treated and control sites more difficult (i.e., are differences due to imidacloprid, or to unequal starting conditions?). The problem was especially evident in Cedar River where some species were as much as 30 times more abundant in the treatment plot than in the control plot at the time of imidacloprid application.

In general, before imidacloprid application, the control and treatment plots at the Bay Center sites were similar for about half of the absolute abundance, taxonomic richness, and diversity metrics for crustaceans, polychaetes, and molluscs. Statistical tests for treatment effects of imidacloprid were more definitive for these measures than for metrics that were not similar before treatment. Regardless, the analysis of all the data from this area consistently failed to find a treatment effect. That is, the invertebrates on the treatment and control sites were similar enough to one another that the data showed no statistical differences after 14 and 28 days, demonstrating there was either no effect, or effect with recovery and recolonization.

Before imidacloprid application, invertebrates on the control and treatment plots at the Cedar River site were statistically different for five of the nine endpoints that were examined. Polychaetes and crustaceans, in particular, were far more abundant on the treatment plot than at the control plot. In part, this was likely due to differences in vegetation levels and tidal elevations between the control and treatment plots. The differences between the plots were great enough to make any interpretation of invertebrate numbers after imidacloprid application difficult. Results of the analyses showed a decrease in abundance for most crustacean and polychaete species on the treatment plot, while a general increase was seen in the control plot. These differences were seen at both 14 and 28 days after treatment. While not conclusive, these results are consistent with an interpretation that imidacloprid reduced the number of polychaetes and crustaceans on the treatment plot, and that the decline lasted for at least 28 days following treatment, at least for some species. However, the data also show that the abundances of some species increased 28 days after treatment. Subtle differences in temperature, tidal elevation, and vegetation accounted for some differences between the treated and control site as well. A treatment effect was not evident for the three endpoints for molluscs (abundance, taxonomic richness, and Shannon diversity), or for richness and diversity in polychaetes or crustaceans.

Given the poor initial match between the treatment and control sites in Cedar River in 2011, and the mixed results with respect to a treatment effect in data from that trial, another study in the Cedar River area is planned for the summer of 2015. This study will again examine whether a treatment effect of imidacloprid application can be detected in invertebrate populations. Because imidacloprid may be more persistent in sediments with higher silt content (Grue and Grassley 2013), a focus of the study will be to look at the interaction between the organic content of the sediment in the treatment site(s) and the persistence of imidacloprid and its potential effects on invertebrates.

2012 Field Studies. Experimental trials aimed at determining efficacy, environmental fate and transport, and the biological effects of imidacloprid were performed in 2012 under an Ecology-approved Sampling and Analysis Plan (Hart Crowser 2012). The scope of these trials was to determine the magnitude, extent and duration of imidacloprid exposure from an application of imidacloprid for the control of burrowing shrimp. This study was also designed to measure one of the degradation products of imidacloprid: imidacloprid-olefin. The specific components of this study included:

- Measurement of pre- and post-application water column concentrations of imidacloprid and imidacloprid-olefin;
- Measurement of whole sediment imidacloprid and imidacloprid-olefin concentrations;
- Measurement of sediment porewater imidacloprid and imidacloprid-olefin concentrations;
- Evaluation of binding of imidacloprid and imidacloprid-olefin to sediments;
- Measurement of imidacloprid and imidacloprid-olefin concentrations in eelgrass tissues;
- Whole sediment characterization (texture, total organic carbon, dissolved organic carbon);
- Evaluation of the efficacy of imidacloprid in controlling burrowing shrimp; and
- Evaluation of the effects of imidacloprid on benthic invertebrate communities.

The 2012 experimental trials were conducted in Willapa Bay and the study sites were selected with specific criteria in mind. Treatment and control sites were located in two areas of Willapa Bay. The first location was between Sandy Point and Ramsey Point in the east side of the bay, below the south fork of the Palix River (Palix). The second location was south of Leadbetter Point and Grassy Island on the north end of the Long Beach peninsula (Leadbetter). Limited sampling also occurred in one small plot near Cedar River. Treatment occurred in August of 2012. Study site criteria included ownership by a WGHOGA member; adequate densities of burrowing shrimp; adequate distance from previous or planned applications of carbaryl on commercial shellfish beds (>0.5 mile); no previous applications of carbaryl within the past 20 years, if ever (personal communication with Dr. Kim Patten, WSU Pacific County Extension Director, May 29, 2014);[48] accessibility; replication of a commercial-scale application; and desirable characteristics of elevation, vegetation, and substrate that are similar to commercial shellfish beds and that were consistent within the study area. In addition, treatment and control plots had to be adequately separated to prevent cross contamination (>500 meters). All treatment and control plots were seven to ten acres in size. Both the granular (Mallet) and flowable (Nuprid) formulations of imidacloprid were used in these trials.[49]

The following screening values were used to determine when levels of imidacloprid in various sample types were high enough to potentially result in environmental consequences:

- Surface water – 3.7 ppb (screening value);
- Sediment – 6.7 ppb (laboratory quantitation limit)
- Sediment porewater – 0.6 ppb (screening value); and
- Eelgrass tissue – 10 ppb (laboratory quantitation limit).

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[48] Treatment sites selected for experimental trials were generally not premium shellfish ground and had not previously been treated with carbaryl.

[49] Mallet and Nuprid used during the experimental trials are the same as the imidacloprid products for which FIFRA Conditional Registrations were issued June 6, 2013: Protector 0.5G and Protector 2F, respectively.

The surface water screening value was derived using EPA guidance (USEPA 1985) on water quality criteria and the sediment porewater screening value is a conservative concentration based upon chronic effects NOEC in 21-day toxicity studies (Ward 1991).

Water Column Sampling and Analyses. Water column samples were collected within each treatment plot, as well as at 60, 120, 240, and 480 meters (m) (197, 394, 787, and 1,575 feet, respectively) from the plot edge on the upstream and downstream side of the plot. Samples were collected as the first advancing tide moved across the treatment area and onto surrounding areas. When drainage channels were present, samples were taken in the drainage channels at distances mentioned above. Some drainage channel samples were collected from water draining from the treated area soon after treatment. Flowable imidacloprid was sprayed on treatment plots that were exposed from an outgoing tide. Granular imidacloprid was applied to treatment plots with 0.5 to 3 feet of water on them during an outgoing tide. Samples were collected prior to and approximately two hours following application of imidacloprid.

Concentrations of imidacloprid were generally highest in drainage channels associated with flowable imidacloprid, with a maximum observed value of 4,200 ppb at 60 m (197 feet), and 120 ppb at 480 m (1,575 feet). Based on the study design, it was expected that the highest concentrations of flowable imidacloprid would be found in the drainage channels. In contrast, granular imidacloprid concentrations were much lower approximately two hours after application. Only 2 of 13 samples were above the quantitation limits and both were below 1.0 ppb.

The results of the water column sampling showed that many offsite locations upslope of the treatment area were found to have at least some concentration of imidacloprid during the first advancing tide that passed over the treated area. Outside of the drainage channels, flowable imidacloprid concentrations reached a maximum of 900 ppb, with concentrations as high as 200 ppb at a distance of 480 m (1,575 feet). Granular imidacloprid concentrations reached 130 ppb at a distance of 60 m (197 feet) and no concentrations above the screening criteria at further distances. The average olefin detection was 1.8 percent of the corresponding imidacloprid measure. Olefin concentrations ranged from 0.08 to 3.6 ppb.

Sediment and Sediment Porewater Sampling and Analyses. Sediment samples were collected for whole sediment and sediment porewater analysis within each treatment plot and from three transects on the high elevation (direction of tidal flow) side of the treatment plot at 60, 120, 240, and 480 m (197, 394, 787, and 1,575 feet, respectively) from the plot edge. When drainage channels were present, samples were taken in the drainage channels at distances mentioned above. One pre-treatment sample was taken. Samples were also collected on days 1, 14, 27, and 56 after application.

The maximum concentration of imidacloprid found in sediment porewater on treatment plots one day post-application was 261 ppb. In general, imidacloprid concentrations were greater on the flowable imidacloprid-treated beds compared to the granular imidacloprid-treated beds. By 14 days post-application, imidacloprid residues in sediments and sediment porewater were reduced by 96.5 percent (maximum 9.1 ppb). Concentrations of imidacloprid within porewater samples collected at high elevation transects off the treatment plots largely followed the pattern of the residues within the water column samples. Analyses have suggested that 0.5 to 2 percent of the imidacloprid observed in the inundation water passing a given position will subsequently be observed in the sediment porewater 1 to 3 days post-application (Grue 2012). Analyses of whole sediment samples indicate 89 to 98 percent of the imidacloprid deposited on the treatment plots had moved off-site in the first 24 hours (see Grue and Grassley 2013 and Hart Crowser 2013 for more details). See Chapter 3 for discussions of potential impacts to non-target plants and animals.

Eelgrass Sampling and Analyses. Eelgrass (*Zostera marina* or *Zostera japonica*) samples were collected within and outside of the treatment plots prior to treatment, and 1, 14, and 28 days post-treatment. Detection of imidacloprid at levels above the laboratory quantitation limit (10 ppb) was found only on the first day post-treatment, with a maximum concentration of 120 ppb. Seven out of 20 eelgrass samples had detectable concentrations of imidacloprid on the first day post-treatment.

Sediment Binding Rates. Whole sediment binding rates of imidacloprid were calculated for 51 samples. A binding rate of 50 percent indicates that half the total imidacloprid is contained within the solid and liquid fractions, but does not indicate that the concentration within the solid and liquid fractions are equal (e.g., the solid fraction may have 20 percent of the imidacloprid while the liquid fraction has 30 percent). Initial bind rates ranged from 17.4 to 39.5 percent at the Palix River and Leadbetter Point treatment plots, while the Cedar River treatment plot had an initial binding rate of 89.8 percent. Approximately 30 to 90 percent of the imidacloprid remaining in the sediment one day after treatment is bound to the sediment, rather than present in the pore water. The proportion of imidacloprid bound to the sediment increased through successive sample collections at 14, 28, and 56 days post-treatment, meaning that there was less imidacloprid present in the porewater. Thus, although imidacloprid levels in sediments declined in both sediment and sediment pore water, the declines occurred more readily in the pore water fraction.

Data on sediment binding of imidacloprid indicate that it binds more readily to sediments that are higher in total organic carbon (TOC) (e.g. at the Cedar River treatment plot), and appears to be more persistent, than in sediments with lower concentrations of TOC (Palix River and Leadbetter Point treatment sites). At the Cedar River site, the concentration of imidacloprid bound to sediment decreased from approximately 28 percent one day after treatment to approximately ten percent 56 days after treatment. At the other two sites with lower TOC, imidacloprid concentrations had declined to less than five percent only 28 days after treatment (Grue and Grassley 2013).

Megafauna Sampling and Analyses. Dungeness crab and fish were counted on the day of application and again 24 hours after treatment. Counts were made at low tide along 3- to 7-m (10- to 23-foot)-wide transects that crossed and extended 50 m (164 feet) on each side of the plots. Species, size, incidence of paralysis, and cause of death were recorded. The average across all sites and treatments was two affected crab per acre. The highest count was 3.4 affected crab per acre. Bird predation of crab impacted by paralysis appeared to be the main cause of crab mortality. However, crushing of crab with the ATV during imidacloprid application was also a significant cause of loss.[50]

Fish mortality ranged from 0 to 0.1 per acre. These results could have been due to chance (e.g., a dead fish drifted into the sample area on the tide, or to fish crushed by the ATV during imidacloprid application). The results do not indicate that imidacloprid application resulted in more than incidental mortality of any fish species.

Birds were observed foraging on and nearby the sites following treatments. No birds exhibiting behaviors consistent with exposure to a pesticide (e.g., confusion, poor balance, paralysis) were observed (Patten 2013). In addition, the tidelands outside the treated area were mapped two weeks post-treatment. The presence of dead commensal clam shells (i.e., clams that live with burrowing shrimp) indicated the pattern and range of significant offsite chemical movement. For the most part, these affected areas were confined to a narrow band around treated plots, with an average 15 percent increase in area beyond what was treated.

[50] There is a certain amount of crab mortality on tidelands that have not been treated with imidacloprid or had ATV traffic. The mortality numbers reported here are the numbers above control sites.

Efficacy. Efficacy across all sites ranged from 65 to 84 percent burrow reduction. Efficacy was reduced at sites with significant eelgrass coverage. Some areas immediately outside the treated areas exhibited some level of burrowing shrimp reduction.

Epibenthic and Benthic Invertebrate Sampling and Analyses. Epibenthic and benthic samples were collected both within and adjacent to the treatment area, using a grid-based sampling approach. Epibenthic and benthic invertebrates were sampled prior to the application of imidacloprid and at 14 and 28 days post-treatment. In general, imidacloprid effects were assessed for nine endpoints (absolute abundance, taxonomic richness, and Shannon diversity for each of three primary taxonomic groups: polychaetes, molluscs, and crustaceans) by comparisons in the treated plots to the same endpoints in the control plots at each post-treatment interval (14, 28, and sometimes 56 days post-treatment).

In general, non-target effects on the epibenthic and benthic invertebrates from imidacloprid were absent to minimal[51] based on the statistical analyses requested by Ecology. Polychaete abundance, richness, or diversity at the treatment sites could not be differentiated from abundance, richness, and diversity at the control site 14 days after treatment (see Hart Crowser 2013 for more details). Molluscs at one treatment site showed post-application declines, which could indicate an effect of imidacloprid; however, other factors may help account for incremental changes in abundance, richness and diversity in this taxon and location, particularly as no declines in mollusc abundance, richness, and diversity were found at the second site. Imidacloprid application did not affect the richness or diversity of crustaceans, but abundance did show a treatment effect. The composite result from the analysis of invertebrate endpoints is that imidacloprid application exhibited limited effects in both space and time. In most comparisons of data from the treatment and control plots, a treatment effect of imidacloprid could not be demonstrated for the invertebrate endpoints being tested, (see Hart Crowser 2013 and Booth 2013 for more details).

Ecology reviewed the results of the 2012 experimental trials and determined that, based on the current review of those studies, “Imidacloprid impacts to benthic and epibenthic communities appear to be minor based on the Sediment Management Standards regulatory framework. The dynamic estuarine environment provides conditions for rapid recolonization of treated plots at this level of treatment. The Sediment Management Standards allow minor impacts within an authorized Sediment Impact Zone (SIZ), provided other conditions are met, including notification and Best Management Practices (BMP) to minimize the extent and duration of the Sediment Impact Zone (WAC 173-204-410)” (Ecology Memo July 30, 2013).

Ecology also stated that “Imidacloprid is likely a better alternative than carbaryl” because imidacloprid has more selective toxicity to burrowing shrimp while non-target species are less affected (Ecology Memo July 30, 2013). Imidacloprid also degrades more rapidly than carbaryl in the water column; therefore, there is a shorter duration of exposure in the water column. Lower application rates result in lower exposure concentrations off-plot that could potentially affect non-target organisms (Ecology Memo July 30, 2013).

2014 Field Studies. 2014 Efficacy Studies are discussed above in 2.8.3.4. Epibenthic and Benthic Invertebrate Sampling and Analyses was done in 2014 under an Ecology approved Sampling and Analysis Plan. The results and analysis of the 2014 benthic invertebrate and persistence studies were finalized after the publication of the Draft EIS. The 2014 study closely followed the methodologies of the previous studies but differed in terms of scale of the treatment areas. Several commentators expressed an interest in reviewing the results from the 2014 studies. We have therefore attached the report and Ecology’s review of the studies in Appendix E.

[51] Minimal effects to epibenthic and benthic invertebrates means that if these organisms are affected by imidacloprid, they recover and recolonize quickly (i.e., within 30 days).

The scale of the treatment areas in the 2014 study are similar in size to many of the expected commercial application areas. Ecology views the results of this data report as consistent with previous studies and has determined that the imidacloprid applications in 2014 do not exceed the Sediment Management Standards. Specifically, the effects of imidacloprid at a commercial scale treatment cannot be discerned from seasonality and site variation or that relative recovery or recolonization is occurring within the 14-day period between the treatment date and the first round of samples.

2.8.3.6 Imidacloprid Effects

The characteristics of imidacloprid and its effects are briefly and concisely described below without overly technical information. This summarized information is based primarily on technical review found in the *Risk Assessment for Use of Imidacloprid to Control Burrowing Shrimp in Shellfish Beds of Willapa Bay and Grays Harbor, WA* (Compliance Services International, June 14, 2013). Additional detailed technical supporting information can be found in that document.

Imidacloprid is moderately to highly effective at controlling burrowing shrimp in marine environments. The efficacy of imidacloprid to control burrowing shrimp varies with substrate type, with better control on sandy substrates versus those with more silt and organic matter (K. Patten, unpublished data). In addition, eelgrass cover appears to interfere with imidacloprid adsorption into sediments (Patten 2013; Grue and Grassley 2013). Laboratory studies of the toxicity of imidacloprid to juvenile and adult ghost shrimp suggest that surface water concentrations high enough to kill the shrimp directly within 96 hours are orders-of-magnitude greater than the magnitude and duration of exposure the shrimp likely receive in the field following experimental applications (C. Grue, University of Washington, unpublished data). Reasons for the observed efficacy in the field are not clear; however, it is thought that immobilization of the shrimp during a period of temporary paralysis following exposure to imidacloprid may result in burrow collapse and/or sufficient degradation in water quality (e.g., dissolved oxygen levels) that the shrimp cannot survive.

Field data from trials in Willapa Bay show that imidacloprid dissipates in surface water and sediment porewater and is usually analytically undetectable within 24 to 48 hours after application in surface water, and up to 28 days in sediment porewater. In addition, imidacloprid is typically undetectable in porewater at distances as far as 480 meters from the application area for time periods greater than 24 hours after application. Imidacloprid can bind to sediment particles leading to a longer residence time (persistence) in some sediments; however, binding rates depend upon many factors, including sediment type, temperature, pH, salinity, alkalinity, redox potential, solar radiation, biological activity, dissolved oxygen, DOC, and TOC (Felsot and Ruppert 2002; Grue and Grassley 2013). See Section 2.8.3.5 and Grue and Grassley (2013) for more details on the persistence of imidacloprid in sediments.

Eight imidacloprid degradation products have been identified as a result of imidacloprid hydrolysis, photolysis, and soil and microbial degradation. Two of these degradation compounds, imidacloprid olefin, and 5-hydroxy imidacloprid were identified by EPA as being of interest due to potential toxicity. One of these degradates, imidacloprid-olefin, was analyzed during 2012 research efforts (Grue & Grassley 2013; Hart Crowser 2013). Of the samples analyzed for imidacloprid-olefin concentrations, less than 20 percent resulted in detectable concentrations of imidacloprid-olefin and these ranged from 0.08 to 3.6 ppb. Imidacloprid-olefin was found in surface water, sediments, and sediment porewater; it was undetectable in eelgrass tissue. Despite numerous attempts, the necessary laboratory standards to test for 5-hydroxy imidacloprid could not be found or synthesized. Subsequent analysis suggests that this degradation product is likely unstable and has a very short half-life in the environment (Hart Crowser 2012).

Although field studies in Willapa Bay demonstrated that imidacloprid can affect non-target invertebrate species, in most instances such effects were limited or statistically undetectable (Patten 2013; Booth 2013; Hart Crowser 2013; see also Section 2.8.3.5 above for a discussion on non-target effects on benthic and epibenthic invertebrates). Other studies have concluded that imidacloprid has low impact effects on non-target species such as fish, Dungeness crabs, some aquatic invertebrates, and seagrasses (Patten 2013; CSI 2013). Studies from Willapa Bay indicate that mortality of Dungeness crabs after exposure to imidacloprid is due to predation during temporary paralysis rather than death from the chemical itself (Patten 2013).

Imidacloprid is notable for the very high concentrations required to produce effects in vertebrates, including humans (CSI 2013). Imidacloprid is not considered acutely toxic to humans via dermal or inhalation exposure routes (Gervais et al. 2010) even though it is designated an acute oral toxicant. There is a slight possibility of human health impacts from imidacloprid exposure to pesticide applicators and, to a much lesser extent, commercial shellfish harvesters and the general population if engaging in recreational activities (e.g., shellfish gathering, fishing, and swimming) during or immediately after treatment of commercial shellfish plots.[52]

Nearshore areas can be accessed by foot at low tide or when incoming tides cover the tide flats with enough water so that boats can be paddled over these shallow areas. Public access points where kayaks, canoes, and other small water craft can be hand-launched for travel around the bay are published by the Willapa Bay Water Trail. Recreational activities are likely to occur close to public boat launches, which are not generally close to commercial shellfish beds.

During treatment, the handlers and applicators of the imidacloprid would face inherent exposure. Recreational swimmers, fishers, and shellfish gatherers would not be present at the treatment sites, and hence would face no exposure. Significant residential exposure[53] is not expected because the proposed use for imidacloprid is purely commercial and to be applied in a commercial setting (CSI 2013).

2.8.4 Alternatives Considered and Eliminated from Detailed Evaluation

Development of effective and sustainable approaches to manage bivalve pests is challenging. There is wide variation in the cultured species, methods of culture, and location. Commercial shellfish beds are accessible only at low tidal intervals that last three to six hours and occur for only five to seven days out of every fourteen. These low tides occur in daylight hours only six months of the year – roughly April through September (DeFrancesco and Murray 2010).

Considerable work has been conducted on potential alternatives to chemical control of burrowing shrimp. The following subsections describe several of these methods tried as alternatives to the use of the insecticides carbaryl or imidacloprid. None of these methods (or dozens of other alternatives tried) has been shown to effectively control burrowing shrimp on commercial shellfish beds in a manner that could reasonably be implemented on the large scale of commercial shellfish grounds in Willapa Bay and Grays Harbor.

The 2002 WGHOGA Burrowing Shrimp Control Committee Annual Report included an excerpt from a draft manuscript titled Alternative Control and Management Techniques for Burrowing Shrimp in Oyster Culture Operations: A Summary and Prioritized Listing (Harbell and Dewey). The summary list was prepared from two days of presentations and discussions at the conference Alternative Methods for Managing Burrowing Shrimp in Pacific Northwest Estuaries held March 28–29, 2002 in Long Beach, Washington. It describes alternatives tried or considered for the control of burrowing shrimp in order to

52 See additional information in FEIS Chapter 3, Sections 3.2.5, 3.2.6, and 3.2.8.

53 Residential exposure refers to exposure to residential neighborhoods and the people and animals located there.

replace chemical control using carbaryl or imidacloprid. Some, but not all of the descriptions below include comments regarding efficacy in controlling shrimp, effects on clam and oyster crops present during these treatment options, and other potentially adverse or beneficial effects based on experimentation tried since these alternatives were identified for consideration. Since the primary objective was to test the efficacy of alternative (i.e., non-chemical) methods of burrowing shrimp control, an effort was not made in many cases to assess other potential effects if the primary objective could not be achieved.

Other methods tried since the 2002 list was prepared are also summarized below, primarily from *An Updated Plan for Integrated Pest Management of Burrowing Shrimp on Commercial Shellfish Beds* (Booth 2010). The IPM Plan for burrowing shrimp distinguishes pest management strategy from pest management tactics. A *tactic* is an activity created with specific and measurable objectives, whereas a *strategy* is a big picture approach to problem solving that incorporates/integrates a series of steps/tactics. Different management strategies are characterized in part by the nature of the tactics they employ; e.g., mechanical measures, shellfish culture practices, chemical, or biological controls. The goal of alternative management strategies and tactics to manage burrowing shrimp is to achieve efficacy at least sufficient to reduce numbers below the damage threshold of 10 burrows per square meter.

2.8.4.1 Mechanical Control Methods

Frequent Mechanical Harvest. Over the past 60 years, it has often been thought or suggested that mechanical harvest of bottom-cultured oysters would perhaps act as a control to reduce or even eliminate expanding populations of burrowing shrimp on specific clam and oyster seed and harvest areas. It was thought that by disturbing the sediment surface layer, juvenile shrimp may be exposed for predation, or that adult burrows may be sealed thereby trapping the adult shrimp. In practice, the growers found that older shrimp that live up to one meter (approximately three feet) deep in bottom sediments are not harmed by this method; they quickly re-establish their burrows after the disturbance ends. Mechanical harvest has shown, on the whole, to be inconclusive as to any effect on burrowing shrimp as it seems to sometimes encourage and at other times to reduce burrowing shrimp abundance. Most times, the widely-used practice of mechanical harvest does not result in any change in shrimp numbers, and has not shown to be reliable as a control method for burrowing shrimp. In addition, any control using this method would be dependent on regular visits to the bed that are not aligned with crop harvest-cycle timing. Implementing a mechanical control activity when the crop is not ready for harvest would cause significant crop damage.

Harrowing, Disking and Shallow Rototilling. In an effort to suppress the effects of burrowing shrimp, shellfish beds are sometimes harrowed prior to planting, or the harvest cycle is shortened. However, the economic impact of these actions has not been measured (DeFrancesco and Murray 2010).

Barge-towed harrows or disks disrupt the top few inches of sediment. Juvenile shrimp that live in this zone can be crushed or lacerated, or forced to the surface where they are subject to greater predation. Sediment disruption of this magnitude can also have undesirable effects on other organisms that live in or on the substrate, including but not limited to commercial shellfish crops.

A test was conducted to determine the ability of a large heavy-duty airboat, originally modified to mow and crush the invasive cordgrass (*Spartina*) to suppress burrowing shrimp by shallow rototilling. At nine days after treatment, burrow density was significantly higher on rototilled ground than on immediately adjacent untreated ground. Rototilling probably exposed burrows that were less apparent in undisturbed substrate. The machine, as constructed, demonstrated a low potential to suppress burrowing shrimp in the trials conducted (Booth 2010). This would also destroy any shellfish crop on the bed and non-target organisms, and damage the substrate layer growers rely on to support the shellfish crop.

Mechanical Compaction. The majority of the research into mechanical control of burrowing shrimp over the past 50 years has focused on mechanical compaction as a control method. Trials were implemented on a large scale pulling weighted rollers, wheels, or sleds across the tide flat to compact sediments and collapse shrimp burrows. These methods have the potential to crush or smother burrowing shrimp, or force them to the surface where they can be harvested for sale as bait or exposed to increased predation.

Sediment compaction as an IPM technique is infeasible on a large scale. It is effective only in the short term, there are problems with implementation (e.g., it is labor-intensive and hard on machinery), and it would destroy commercial shellfish crops (if present). Shellfish farmers would need to be able to drive compaction equipment to the treatment area, which would require that they own upland access. A treatment area could be inaccessible due to adjacent crops; i.e., not all farmers are on the same crop rotation. Beds could be land-locked by commercial shellfish beds owned by other farmers, or completely surrounded by water with no way to drive large equipment to the site. In addition, hardening the substrate would cause it to lose its ability to "hold" the shellfish crop during higher energy weather events. Crops are essentially washed off the beds and lost or buried in these conditions.

A large-wheeled amphibious vehicle (Rolligon)[54] and a tracked-wheel all-terrain vehicle (Argo) were driven over shrimp beds in August 2002 to test whether the pressure exerted on the sediment by the balloon tires or ATV tracks would cause burrowing shrimp to immediately emerge from their burrows and be consumed by gulls following the vehicle (Patten 2002). Based on early data analysis, compaction with a Rolligon reduced shrimp burrow counts by 62 percent on firm sand and 72 percent on soft sand. Compaction with an Argo ATV reduced burrow counts by 81 percent. Gulls and crows were plentiful following compaction treatment, and continued to work the ground for several days in search of surfacing shrimp.[55] The number of burrows remaining, however, was still above ten per square meter (the threshold for treatment with the insecticide carbaryl and a density that impairs successful shellfish cultivation). Compacted beds were checked the following year, and no difference was found in the burrowing shrimp density between compacted beds and uncompacted beds. Burrow numbers increased over time without follow-up treatment. In addition, numerous problems were noted with this method, including equipment failure (getting stuck), change in sediment texture (sediment became too firm for shellfish crops), or topographical alteration (created potential gullies). Additional research and follow-up was done. The follow-up data showed that continued annual compaction would be required to reduce the burrow count of shrimp in sediments treated with this method. It would, however, be prohibitively costly for multiple growers to have Rolligon vehicles custom-manufactured, it would be prohibitively labor-intensive for crews to follow along to push the vehicle onto boards placed under the tires every time it became stuck, and the bed damage caused by this method would damage shellfish crops.

In 2004, a large-scale (three-acre) crushing experiment trial was conducted using a Washington Department of Agriculture Marsh Master II. Three sequential crushing events were conducted in June, July and September. Plots in areas of low, medium, or high initial shrimp density were crushed either once or twice during each event. Burrow density was reduced after the first crushing events across all

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[54] The Rolligon vehicle is a diesel-powered vehicle supported on four balloon tires. It has been used for work on soft tide flats since about the 1970s.

[55] In the experience of another grower who tried the Rolligon method of sediment compaction, some shrimp came to the surface but immediately burrowed back into the sediment. Birds remained some distance from the machines, so consumed few shrimp before they reburied. The exposed shrimp were limited to an area slightly smaller than the width of the wheel or track, and it required several passes over the same area to cause the shrimp to become exposed. Each pass of the machine resulted in a deeper and deeper rut being formed and caused significant bed damage. The machine would become stuck as the rut deepened. Shellfish beds rely on years of accumulation of small shells and other substrate built-up over time to provide a base for the bed. Without this base, shellfish and other species on the bed sink more quickly into the mud or sand, or are otherwise displaced. Using a tracked or wheeled machine acts to destroy this base. This method would crush or bury the shellfish crop.

shrimp densities; however, there were only minor changes in shrimp densities after the next two crushing events. There was little difference at the high density zones between crushing once or twice per event. In the areas of high or medium initial density, burrow density never declined below the threshold of ten burrows per square meter (Booth 2010). For this reason, the efficacy of the method did not meet the objectives for a viable alternative to insecticide applications. Further, this method could not be implemented on an existing shellfish bed without destroying the crop and likely damaging the bed to a point where it would not be useable for a long period of time.

Compaction by Explosion. Sub-surface (benthic) explosions were conducted with a Rodex 4000 (http://www.rodexindustries.com) that utilized a 97 percent oxygen and three percent propane mix, solid state electronic ignition controls and circuitry to create the explosion (Patten 2002). Injections occurred on sandy soil with a high burrow count (more than 70 shrimp burrows per square meter) at low tide. Preparations were made to monitor feasibility and efficacy; however, benthic explosions did not work due to an inability to permeate the substrate with an adequate volume of gas mixture to cause an explosion. The objective of killing burrowing shrimp by concussive explosion was therefore not achieved with this method (Booth 2010).

Triaxial Compaction. Triaxial shear tests consist of applying horizontal and vertical stresses to a cylinder of soil. The feasibility of impeding burrowing by soil densification was evaluated by placing shrimp in cells containing sand with a known extent of compaction and observing whether the shrimp would burrow. Shrimp were able to burrow into cells containing a range of relative density from ten percent (extremely loose) to about 95 percent (extremely dense). Although denser soil discourages burrowing, shrimp were found to burrow either downward or upward in soils with a laboratory level of densification not achievable in the field. It was therefore concluded that soil densification would not prevent shrimp from burrowing (Booth 2010).

The geophysics of tideland sediments was tested using tri-axial compaction. It was found that it is not possible to compact the sediment typical of Willapa Bay enough to kill burrowing shrimp (Hemberry 2008).

2.8.4.2 Physical Control Methods

Physical Barriers. Sediment barriers in the form of geotextiles, plastic or mesh could be used to cover shrimp-laden beds, or vertical barriers could be installed around commercial shellfish beds to prevent lateral migration by burrowing shrimp. Sediment barriers would kill burrowing shrimp directly by smothering, and would prevent new recruits from burrowing into the sediment. However, the smothering effect is not selective, and also kills benthic organisms, macroalgae, eelgrass and the commercial shellfish crop. Fishing gear, anchors, vandalism, or storms can damage sediment barriers. Any tears in the fabric reduces their efficacy. Wave or tidal action limits their use in Willapa Bay, which regularly experiences tidal swings of 8 to 11 feet and strong sustained winds that can generate two to five foot surface waves. This combination of tidal regimes and wave action make anchoring sediment barriers in Willapa Bay difficult and impractical. Past trials on a small scale resulted in these barriers becoming dislodged and lost even when extreme measures were taken to secure them to the bottom.

Sediment Alteration Measures. Several methods of altering bottom sediments have been considered for the control of burrowing shrimp. Some of these methods have been tested; others have not. Since the first priority was to determine efficacy for the intended purpose, other consequences (such as effect on clam and oyster crops, and effect on other benthic organisms) were not investigated.

Clay Injection. A slurry of bentonite clay could be injected into shrimp burrows to smother shrimp or to create an irritation that would cause them to emerge onto the sediment surface where they could be harvested or exposed to greater predation. Alternatively, creating a clay layer in the sediment could interfere with shrimp burrowing activity. This method was found to be ineffective because shrimp clear the clay from their burrows before it has a chance to set up (Harbell and Dewey 2002). The clay layer treatment is costly, of short duration, and particularly ineffective with mud shrimp.

Gravelling or Oyster Shell Pavement. A physical barrier to shrimp burrowing could be created by covering the tide flat surface with a thick layer of shell or gravel. This material would also enhance the habitat for crab predators of juvenile burrowing shrimp, thereby reducing recruitment in the substrate. Studies have shown this to be an effective, though prohibitively costly, approach for suppressing ghost shrimp, and not effective for controlling mud shrimp. It may also affect non-target organisms. This method was eliminated as infeasible due to the high cost of gravel and shells (Booth 2010).

Cementing of Sediment. A surface strengthening technique using Type III Portland cement was tested. At a cement-to-sand ratio of one percent, shrimp burrowing was not altered. At a ratio of three percent, shrimp showed signs of trenching, but the trench depth was not great enough for the shrimp to be completely submerged. Shrimp burrowing was found to be significantly reduced at cement-to-sand ratios of three percent to five percent. Additional hydraulic conductivity testing was planned on treated and untreated samples to assess how the flow of water and nutrients through sediments would be affected (Booth 2010). Ultimately, the alternative of applying cement to large acreages of intertidal sediment was deemed to be both economically and operationally infeasible.

Diking and Damming. Berms could be created on the tide flat to slow the lateral movement of adult shrimp. Ponds or diked areas could be created to hold burrowing shrimp predators on commercial shellfish beds at low tide, or to treat with approved chemicals. Berms may slow the population growth rate for indirect control of burrowing shrimp. However, due to the life history of burrowing shrimp and the dynamic nature of a tidal estuary, berms would not control the recruitment of juvenile shrimp into diked or dammed areas. No studies have evaluated the efficacy of diking or damming methods; however, the cost to construct dikes and dams would be economically impractical on large commercial shellfish beds. Permitting constraints to placing fill on tidelands to construct dikes and dams were not investigated with this alternative as it was determined to be impractical for other reasons, as described.

Water Jets. One grower experimented with a system of high-pressure water jets in 2003 to suppress burrowing shrimp on commercial shellfish beds in Willapa Bay. The purpose of this method was to direct a high-pressure stream of water into the sediment to force burrowing shrimp to the surface where they could be harvested, killed by mechanical means, or subjected to greater predation. A pump of sufficient size to drive a towed water jet sled was purchased. The centrifugal pump was driven by a 200 horsepower diesel engine and had a capacity of about 2,000 gallons per minute. During testing, the pump was able to produce up to 150 pounds per square inch of pressure when attached to the jet sled. The large size and weight of the pump (approximately 10,000 lbs) required a crane for movement from land to the barge. A steel sled was built to carry and support a water manifold fitted with a row of nozzles. Due to the large size of the equipment, many gear deployment problems occurred. The large weight needed to hold the sled down made it hard to tow, turn and maintain a steady tow speed. To remedy deployment and towing problems, a lighter sled was constructed. The new sled was also hard to tow, but the smaller size resulted in better control. Unfortunately, the lighter-weight sled was sometimes lifted from the bed due to the thrust of the water jets. The use of water jets was found to reduce the number of burrowing shrimp, but not below ten burrows per square meter (the threshold for damage to commercial shellfish crops and treatment with pesticide). This method was deemed infeasible due to deployment and operational problems, damage to the substrate layer growers rely on to support the shellfish crop, and crop damage where clams or oysters were present.

Electroshocking. The hypothesis of this method was that an electromagnetic field would cause shrimp to leave their burrows where they could be harvested, killed by mechanical means, or subjected to greater predation. The electromagnetic field may cause direct lethal or sublethal damage to young-of-the-year and adult burrowing shrimp, but also to desirable non-target species that reside in the sediments. Laboratory experiments were conducted in December of 2004 and again in October 2006 to test the effectiveness of using electricity as a means of controlling burrowing shrimp. Electrical current was applied in a seawater aquarium with a Smith-Root Model 1.5 fish barrier pulse generator. Variables controlled included: waveform, voltage, pulse width, and frequency. Shrimp were observed for three responses: change in activity, type of response, and response direction. A change in activity was observed upon initial exposure to electricity with diminishing results with continued trials. It was hoped that application of electricity would cause the shrimp to move out of their burrows. Unfortunately, it was observed that the shrimp in their burrows tended to move away from the electricity, toward the bottom of their burrows. Mortality experiments were also conducted that showed a 100 percent mortality rate when voltage exceeded 85 volts DC and at a time exposure of 120 seconds. The factor preventing the practical use of electricity to control shrimp on a large scale is the long exposure times required. It would be impractical to drag electrodes over the sediment surface at a pace that would provide adequate exposure (Dumbauld and Harlan 2009). Significant negative effects to non-target organisms would also be expected with this method.

High-Pressure Sound. A proposal was developed in 2002 to conduct an experiment with high-pressure sound sources as a direct physical method for the control of burrowing shrimp in the marine environment. The objective of using a modified seismic air gun[56] was to cause physical damage to key organ systems within ghost shrimp and mud shrimp. The unit would be modified to produce a high-intensity sound pulse by cavitation; however, the sound pulse produced by these types of units would be high enough to kill fish within a one to two-meter radius (approximately three to six feet). Also, this method had a higher potential to kill juvenile burrowing shrimp that reside in the upper one to three centimeters of the substrate, and desirable non-target species including commercial shellfish crops, than adult burrowing shrimp that are found at depths up to one meter (approximately three feet). Given potential impacts to non-target species, and the difficulty and expense of setting up the necessary equipment, this experimental concept for the use of high-pressure sound was not tested in the field.

Washington State University experimented with sound wave screening and found that computer-generated sound waves, standardized and varied with an oscilloscope, did not affect burrowing shrimp (personal communication with Dr. Kim Patten, WSU Pacific County Extension Director, February 2014).

Use of Baits. Preliminary field trials were conducted with commercial bait products that could be used in conjunction with traps, or with various poisons. Observations started with several shrimp in an aquarium. The strength of the response varied among the commercial bait products, but rarely did all shrimp move to the source. Shrimp did not move toward the traps in the field baited with the most promising materials from the aquarium trials (Booth 2010).

2.8.4.3 Alternative Culture Systems

Consideration has been given to whether alternatives to on-bottom culture systems may be more compatible with beds with high levels of burrowing shrimp.-[57] Other culture techniques are difficult to

[56] Air guns are used in seismic exploration for oil and natural gas. These units discharge 2,000 pounds per square inch (psi) of air through a solenoid valve to produce low-frequency sound. As typically operated, these units have little direct impact on nearby fish or marine mammals. Units similar to the air gun modified to produce a high intensity sound pulse were in-use on the East Coast to keep eels out of a water intake at the time of the 2002 experiment in Willapa Bay.

[57] One problem with alternative culture systems is that there is a significant and important market for shucked oysters. Given the relatively lower market value of shucked oysters, ground culture, which is particularly sensitive to burrowing shrimp, is the preferred commercial approach.

impractical on a large scale because of the increased labor requirements and materials costs. In areas of burrowing shrimp abundance, it has been found that alternative culture methods still require shrimp treatment, for reasons described below.

Further, off-bottom culture methods raise aesthetic impact concerns. Bottom culture and limited off-bottom culture methods result in a relatively benign impact on the aesthetics of the bay. Transitioning to a predominantly off-bottom culture method throughout Willapa Bay and Grays Harbor would have a dramatic impact on the appearance of these water bodies, and could obstruct navigation, as well.

Long-Line Culture. While long-line culture is a common practice for oysters, it would be necessary to lengthen posts and extend them deeper into the substrate so that posts would not sink or topple in sediments destabilized by burrowing shrimp. However, post sinking and toppling are only two of the ways in which burrowing shrimp impact long-line oyster culture. Other effects include hindering access to the beds (workers and equipment sink deeply into the softened sediments), and loss of approximately 50 percent of the crop that falls from the lines because these oysters sink into the softened sediments and become buried.

Stake Culture. Many growers have also found stake culture to be an ineffective management tactic for controlling burrowing shrimp. Tidal currents and storms dislodge stakes, or stakes sink or tip over in the soft sediment. As with long-lines, oysters that fall off sink and suffocate in heavily populated beds. Stake culture is also impractical on a large scale due to high labor needs and costs (DeFrancesco and Murray 2010). Growers report that stake culture tried in Willapa Bay 35 to 40 years ago resulted in extreme fouling problems (e.g. debris capture) for which cleaning was basically impossible, and “wire and plastic everywhere” (personal communication with WGHOGA members, August 28, 2014).

Bag Culture. Oysters and clams have also been cultured in bags on the beach surface or, in the case of oysters, using a rack-and-bag method. Due to placement of the bags on the tide flats, ground-burrowing shrimp activity causes bags to sink into the sediment. As with long-line culture, fouling can be a problem, resulting in increased labor costs. Success with bag culture depends on placement in areas with low or no burrowing shrimp, thereby limiting available areas for production, or requiring bed treatment for the control of shrimp, similar to ground culture.

2.8.4.4 Alternative Chemical Control Methods

Imidacloprid was identified as the preferred chemical for burrowing shrimp control after many other substances were tried and found to have little or no efficacy in controlling burrowing shrimp. Various compounds were screened in replicated trials in the laboratory and/or in the field by staff in the WSU Long Beach Extension Office.[58] These included traditional insecticides, organic insecticides, generally-recognized-as-safe (GRAS) compounds, and other compounds described below. The rate of application of each compound differed by orders of magnitude.

Traditional Insecticides included Spectrus, Belay (clothianidin), Esteem (pyriproxyfen), Methoprene, Deltaguard (deltamethrin), Brigade (bifenthrin), thiacloprid, acetamiprid, and zeta-cypermethrin.

Organic Insecticides. Plant extracts, essential plant oils or “natural” insecticides included crushed chrysanthemums, naturally-extracted pyrethrums, Pyganic, Pyrenone, mustard seed meal, habanero

[58] Studies of alternative compounds were conducted over many years. Results were included in the WGHOGA Burrowing Shrimp Control Committee Annual Reports. See for example Patten (2002); Patten, Durfey, Raskauskas, and Stern (2005); Patten and Raskauskas (2005); Patten (2006); Patten, Aasen, Durfey, Hilley and Spikewheel Co. (2006); Patten (2007); Patten, Aasen and Versteegen (2007); Patten, Durfey and Liou (2008); and Hemberry 2008.

pepper extract, yucca extract, sabadilla, white pepper, geraniol, citric acid, malic acid, hydrogen peroxide, potassium salts of fatty acids, azadirachtin, vitamin K (Sea Klean), caffeine, clove oil, cinnamon oil, citronella oil, cedar oil, linseed oil, garlic oil, geranium oil, peppermint oil, rosemary oil, thyme oil, neem oil and spearmint oil.

GRAS and Other Compounds. Fertilizer or mineral-based compounds included sulfur, lime, copper, urea, ammonium nitrate, aqua ammonium, ammonium thiosulfate, Kyrocide, ammonium sulfate, magnesium chloride ($MgCl_2$), potassium chloride (KCl), and sodium chloride (NaCl); bleach, potassium permanganate ($KMnO_4$), 2-phenethyl propionate, potassium sorbate, and laurel sulfate.

None of the plant extracts, essential oils, or natural insecticides provided any efficacy for the control of burrowing shrimp. A few of the fertilizer and salt-based products provided marginal control, on the order of 10 to 30 percent. However, efficacy was either too inconsistent to be viable (e.g., with sulfur), or required rates too high to be economically viable (e.g., with KCl or $MgCl_2$). With the exception of the traditional insecticide clothianidin, none of the other insecticides or chemistries showed efficacy. The registrant for clothianidin did not support the proposed use pattern (i.e., applications in an aquatic, estuarine environment for the control of burrowing shrimp).

Delivery Systems for Chemical Control. A major effort was also made to assess new delivery systems for chemical control; specifically, injecting the insecticide below ground, into the substrate where the shrimp live, using shank injection or spike wheel injection. While these methods were successful using traditional chemical control, they did not reduce the rate of insecticide needed for burrowing shrimp control (Booth 2005). Thus, given the extra expense and sediment impacts, they were found to be less favorable than surface application of flowable or granular formulations of imidacloprid.

2.8.4.5 Biological Control Methods

Traditionally, biological controls have been most effective against weeds or insects that are not indigenous to the areas where they are pests. While pathogens or parasites that would adversely affect burrowing shrimp could be introduced to reduce these populations, it would be necessary to exercise care when selecting an exotic (i.e., non-native) predator or parasite because unintended consequences can occur if the introduction switches to an unintended host. Research looking into the success of parasites such as isopods has been explored. While Bopyrid isopods, which are currently found in Willapa Bay and Grays Harbor, have been observed to greatly affect mud shrimp populations (Dumbauld et al. 2010), no pathogens or parasites have been identified that reduce ghost shrimp populations. Ultimately, the culture or introduction of parasites to burrowing shrimp was deemed to be infeasible due to regulatory and scientific concerns.

Biological controls could also consist of the enhancement of predator populations that would consume adult and/or juvenile burrowing shrimp as prey. By virtue of residing in burrows, *Neotrypaea californiensis* and *Upogebia pugettensis* have some innate protection from predators in the water column or on the sediment surface. Still, a number of predators are known to prey on burrowing shrimp, including threespine stickleback, Pacific staghorn sculpins, surf smelt, arrow goby, Pacific herring, chum salmon, shiner surfperch, starry flounder, bay pipefish, bay shrimp, cutthroat trout, white and green sturgeon, Dungeness crab, and yellow shore crab (WDF and ECY 1992; Dr. Stephen Bollens, WSU, and other investigators cited in Booth 2010).

An experiment was conducted in 2007 in an area with observed fish feeding pits located away from commercial shellfish beds. It is believed that the pits are created by sturgeon.[59] Fenced plots were constructed in dense shrimp colonies that excluded sturgeon access. When predators were excluded from the enclosures, an 18 percent increase in shrimp numbers was observed inside the plot while a 15 percent reduction was observed on the outside. Extrapolating these numbers to a larger scale would involve a number of assumptions. Stomach content analysis of commercially-caught sturgeon was also conducted during different times of the year. During the winter months, the majority of sturgeon stomachs were found to be largely empty. When prey items were present in the stomach, it was documented that both green and white sturgeon fed on a diet consisting primarily of benthic prey items and fish; they appear to be opportunists. Both the green and white sturgeon examined fed on burrowing shrimp, which represented a significant portion of their diet, particularly in green sturgeon, in which 40 to 50 percent of the organisms by number and weight were burrowing shrimp (Dumbauld et al. 2008). Unless these large fish could be penned or enclosed[60] in areas where shrimp biocontrol is needed, however, direct shrimp control by sturgeon on aquaculture beds seems unlikely. Sturgeon generally do not feed on shellfish beds. They prefer a sandier, shell-free area for feeding because this substrate is more compatible with their pumping and sucking action to capture burrowing shrimp (personal communication with WGHOGA member, March 7, 2014). Further, due to the seasonality of feeding behaviors and the cost of creating pens around large commercial shellfish beds, this alternative was deemed economically infeasible.

Adult Dungeness and red rock crabs were placed in fenced enclosures in areas with high ghost shrimp burrow counts. Observations in both winter and summer experiments indicated that some predation occurred over a period of 2 to 7 days, reducing burrow counts by 5 to 25 percent; however, final burrow counts remained very high. Although crabs prey on ghost shrimp, the efficacy of this method was considered not significant enough to warrant additional research (Booth 2010).

Experiments were also conducted in large aquariums to determine if an inverse density relationship exists for burrowing shrimp and lugworms (i.e., whether a high density of one is associated with a low density of the other). The authors found little evidence that these two species affected one another's survival. Instead, it was determined that mud flat elevation rather than the presence of lugworms (*Abarenicola pacifica*) determined burrowing shrimp density. Booth (2010) concluded that lugworms likely play a minimal role in shrimp distribution or survival, and therefore their potential to biologically control burrowing shrimp is also minimal.

The potential for indigenous and commercial parasitic nematodes was tested as a biological control agent for burrowing shrimp (Booth 2010). The percent parasitism of burrowing shrimp by indigenous nematodes varied substantially among shrimp species, collection site, and collection date. The indigenous nematode, an undescribed species of *Ascarophis*, infected high percentages of ghost shrimp at some locations, especially females, but did not parasitize mud shrimp. Most *Ascarophis* encysted as third-stage juveniles within the shrimp stomach. Shrimp suspected of being highly parasitized (based on their collection site) did not behave or survive differently compared to shrimp suspected of lower rates of parasitism when observed in small aquariums. It was concluded that both indigenous and commercial formulations of parasitic nematodes have low potential to biologically control burrowing shrimp.

2.9 Comparison of the Environmental Impacts of the Alternatives

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[59] There was a lack of similar feeding pits in oyster aquaculture beds, suspected to be related to the presence of oysters themselves, and perhaps a lower density of other prey including burrowing shrimp in these areas. Some growers reported that they have seen sturgeon stranded on intertidal aquaculture beds at low tide (Booth 2010).

[60] Given that green sturgeon are Federally-listed as threatened, it would be illegal to restrain their movements in pens or enclosures.

Table 1.6-1 in FEIS Chapter 1 presents a comparison of the environmental impacts of the three alternatives for each element of the environment considered in this limited-scope EIS. Readers are encouraged to review more detailed information in FEIS Chapter 3 regarding the impacts summarized there for a more complete, "in-context" understanding of these issues, including citations. The comparative impact analysis of the alternatives is summarized below.

Alternative 1: No Action – No Permit for Pesticide Applications. In general, Alternative 1 (No Action) under which no permit would be issued for pesticide applications for burrowing shrimp control on commercial shellfish beds in Willapa Bay or Grays Harbor, would result in neither significantly beneficial nor significantly adverse ecological impacts to the larger estuary. The reason for this conclusion is the relatively small area of each bay that would be affected by the cessation of chemical treatments.[61] Under any scenario being evaluated in this EIS, the area of effect from the No Action Alternative would range from approximately 1.3 to 3.3 percent *per year* of total tideland areas within Willapa Bay, and from 0.6 to 1.5 percent *per year* of total tideland acreage in Grays Harbor.

The burrowing activities of an increased number of shrimp under the No Action Alternative might have a small-scale beneficial effect in the form of increasing carbon and nitrogen cycling within the sediment-water interface (D'Andrea and DeWitt 2009). This can help supply nutrients necessary for primary and secondary production during periods of low nutrient influx (e.g., El Niño events), and thus decrease the likelihood of the occurrence of hypoxic or anoxic conditions. The No Action Alternative would not significantly benefit threatened or endangered species, as the designated habitat of most listed species that occur in Willapa Bay and Grays Harbor does not include the tideflats of commercial shellfish beds.

Potential small-scale adverse effects to the environment that could result from the No Action Alternative on untreated commercial shellfish beds would likely include an increase in burrowing shrimp populations; sediment destabilization (i.e., conversion to a quick-sand quality) as a result of increased burrowing shrimp activity; reduction in eelgrass growth and density; and reduced biodiversity, which could lead to a reduction in the presence of birds, fish and other species that feed on organisms that inhabit eelgrass communities and on healthy-substrate shellfish beds. To the extent that eelgrass habitat and prey availability were to be reduced in localized areas adversely affected by an increase in burrowing shrimp activity, shelter and food sources could be reduced during the juvenile salmonid out-migration in these limited areas. If growers were to attempt to control burrowing shrimp populations by mechanical means under the No Action Alternative, there could be adverse impacts in the form of temporary increases in turbidity, damage to the benthic community, and damage to and/or displacement of marine and salt marsh vegetation.

The adverse effect of the No Action Alternative to commercial shellfish growers would be larger than the annual treatment acreage. Without effective burrowing shrimp control the number of acres of shellfish culture, and the productivity per acre, are both expected to decline to low levels over time compared to current conditions. The large declines in shellfish aquaculture would have correspondingly large economic impacts on the area given the importance of shellfish culture and processing to the local economy. If burrowing shrimp were not controlled on commercial shellfish beds under the No Action Alternative it would take years to restore the shellfish beds if insecticide treatments became available in the future. Not many companies could afford the investment required to reclaim a shellfish bed over a

[61] The total area of tide flats exposed on low tide in Willapa Bay is approximately 45,000 acres. Of this acreage, up to 600 acres (1.3 percent) per year would be treated with carbaryl under Alternative 2, or up to 1,500 acres (3.3 percent) per year would be treated with imidacloprid under Alternative 3. The total area of tide flats exposed on low tide in Grays Harbor is approximately 34,460 acres. Of this acreage, up to 200 acres (approximately 0.6 percent) per year would be treated with carbaryl under Alternative 2, or up to 500 acres (1.5 percent) per year would be treated with imidacloprid under Alternative 3.

period of years while it was not producing a crop (personal communication with a WGHOGA member, May 28, 2014).

Alternative 2: Carbaryl with IPM. From the perspective of how carbaryl functions in the environment, the beneficial characteristics of carbaryl applications for burrowing shrimp control include: it is removed from the water column (generally within 24 to 48 hours) due to sediment adsorption and by hydrolysis (degradation to 1-naphthol, which further degrades to carbon dioxide and water); carbaryl and its degradation products have been found to be undetectable in sediments 16 days after treatment; no chemical build-up over time would be expected in sediments or in the water column; and carbaryl is not known to be accumulated by any component of the food web, nor is it transmitted to higher levels in the food chain.

The number of carbaryl application events per year would likely be in the range of five to ten days during summer months (though the authorized application period would likely remain July 1 through October 31), on the lowest low tides for maximum commercial shellfish bed exposure.

Carbaryl has potentially more adverse effects in the environment than imidacloprid in the form of fish and Dungeness crab mortality by way of paralysis and reduced heart rate. Carbaryl has been documented to cause mortality of juvenile salmon in aquaria studies.

Carbaryl can cause nausea, dizziness, confusion, and at high exposures, respiratory paralysis and death; however, concentrations of carbaryl required to produce such symptoms in vertebrates, including humans, are much higher than those used to control invertebrates, which are much more sensitive. Carbaryl is classified as a likely human carcinogen based on laboratory experiments that produced vascular tumors in mice; however, non-cancer risks are seen as the primary risk driver for almost all use scenarios. As a dietary precaution, there would be a State-imposed restriction that carbaryl not be applied to commercial shellfish beds within 1 year of harvest.

Alternative 3: Imidacloprid with IPM. From an environmental perspective, the beneficial characteristics of imidacloprid include: a considerably reduced application rate compared to carbaryl (0.5 pound of active ingredient per acre, compared to 8 pounds per acre of carbaryl), and burrowing shrimp control with reduced environmental side effects compared to carbaryl. Imidacloprid is less toxic than carbaryl, though it does cause a temporary paralysis reaction in copepods (small crustaceans) and shrimp, creating an exposure pathway for fish and birds that eat these organisms. Crustaceans and molluscs do not bioaccumulate imidacloprid in their tissues, thereby minimizing potential exposure to shorebirds that consume these organisms. Imidacloprid would be unlikely to adversely affect salmonids or their critical habitat because salmon only travel through the nearshore habitat during out-migration, feeding on copepods and zooplankton that do not bioaccumulate imidacloprid in their tissue. Imidacloprid would be unlikely to adversely affect Dungeness crab, though they may also exhibit a temporary paralysis reaction and therefore become susceptible to predation by gulls and crows for a period of time. In the concentrations proposed for use in Willapa Bay and Grays Harbor, imidacloprid does not cause direct mortality in Dungeness crab, fish, or birds; and it may not decrease biodiversity other than to temporarily reduce burrowing shrimp populations in applied areas.

Imidacloprid is classified as a "Group E" carcinogen indicating no evidence of carcinogenicity in humans. The precautionary waiting period for harvest following imidacloprid treatment on a commercial shellfish bed is 30 days – considerably less than the 1-year waiting period following carbaryl applications.

Compared to carbaryl, there would likely be a larger number of imidacloprid application events each year over a longer authorized application period (April 15 through December 15 each year), as described in FEIS Section 2.8.3.1 above. However, due to the lower toxicity of imidacloprid, and therefore lower effectiveness at controlling burrowing shrimp, a more site-specific approach is proposed for the selection of treatment areas, application times, tides, and bed conditions, resulting in a smaller expected amount of tideland acreage to be treated during each application event. The persistence of imidacloprid in sediments and the water column is affected by factors such as TOC, water chemistry, temperature, adsorption to sediment, water currents, and dilution. The potential for imidacloprid to cause ecological impacts in non-target areas is low because it dilutes with the incoming tide, and would continue to do so on successive tidal cycles.

Environmental Impacts Common to Either Alternative 2 or Alternative 3. Burrowing shrimp control using pesticides under either Alternative 2 (Carbaryl with IPM) or Alternative 3 (Imidacloprid with IPM) would have beneficial environmental effects in the form of preserving the substrate and biodiversity of commercial shellfish beds and promoting native eelgrass density and coverage, thereby improving foraging habitat and prey diversity for birds and fish, and cover for juvenile fish including listed species of salmonids. Depending on the efficacy of imidacloprid treatments, and the rate of recruitment of burrowing shrimp each year, some beds may go multiple years without additional treatment.

The potential for direct exposure of either pesticide to birds would be limited since application techniques by helicopter or hand-held equipment tend to flush birds from the target area (personal communication with Dr. Kim Patten,

Either Alternative 2 or 3 would be unlikely to adversely affect threatened or endangered bird species that use Willapa Bay and Grays Harbor since their critical habitat does not include the tide flats on which commercial shellfish beds occur.

Both carbaryl and imidacloprid are highly toxic to bees that are exposed to direct contact or residues on flowering plants. However, impacts to pollinators are not expected because honey bees are not attracted to mudflats; bumble bees and similar pollinators prefer terrestrial flowering plants that are not found in the bays; pollinators are unlikely to be present over estuarine waters that cover commercial shellfish beds; and these areas are inundated twice daily by tides. Cranberry farms where commercial bee hives are imported for pollination between approximately June 1 and July 5 each year are approximately 0.5 mile from the nearest commercial shellfish beds in Willapa Bay, and approximately 1.5 miles from the nearest commercial shellfish beds in Grays Harbor. Public notice and spray drift management requirements would be implemented under either Alternative 2 or 3 to minimize or avoid the potential for people or sensitive terrestrial species such as pollinators to be exposed to spray applications of either insecticide. In the professional opinion of the Washington State Department of Agriculture, Special Pesticide Registration Program Coordinator, there is no risk to bees from the application of imidacloprid (either granular or flowable formulation) to tidal flats. Implementing appropriate spray drift management techniques for the flowable formulation of imidacloprid, or maintaining an adequate buffer between the imidacloprid treatment area and blooming plants (as proposed by WGHOGA) would mitigate potential risk to bees (personal communication with Erik Johansen, March 19, 2014).

Either carbaryl or imidacloprid could affect large vertebrates (such as green sturgeon, marine mammals, or humans) by direct contact or direct ingestion of treated prey items. Impacts are unlikely both due to low insecticide application rates, and because large vertebrates would not be present on tide flats in shallow water or exposed by an outgoing tide when insecticide applications would be made. Either carbaryl or imidacloprid could potentially affect pesticide handlers, applicators, and to a lesser extent commercial shellfish workers by means of inhalation exposure. Federal regulations and applicable permits require the use of personal protective equipment when working with these insecticides. The majority of commercial shellfish beds are distant from public access areas, and do not tend to attract persons using the bays for recreation.

There would be no new impacts to navigation as a result of either Alternative 2 or Alternative 3. Commercial shellfish beds are staked for various purposes at various times of the year. Stakes placed to identify beds for aerial applications of carbaryl or imidacloprid would not constitute a new or different obstruction to watercraft that navigate the shallow areas of Willapa Bay or Grays Harbor. No stakes or obstructions would be placed in the main navigation channels of either bay.

2.10 Cumulative Impacts and Potential Interactions

2.10.1 Cumulative Impacts

The SEPA Rules specifically define only direct and indirect impacts, as follows: those effects resulting from growth caused by a proposal (direct impacts), and the likelihood that the present proposal will serve as a precedent for future actions (indirect impacts) (WAC 197-11-060[4][d]). In addition to direct and indirect effects, cumulative impacts are those that could result from the combined incremental impacts of multiple actions over time. This analysis considers effects of other past, present, and reasonably foreseeable proposals.

This FEIS considers the following potential effects of other activities with imidacloprid applications on commercial shellfish beds in Willapa Bay:

- Effects of the proposed imidacloprid discharge with the discharge of imazamox to control the non-native eelgrass *Zostera japonica*.
- Effects of the proposed imidacloprid discharge with the existing discharge of imazapyr for *Spartina* control.

Effects of the Proposed Imidacloprid Discharge with the Discharge of Imazamox to Control the Non-native Eelgrass Zostera japonica. Ecology issued a NPDES General Permit (April 2, 2014) for the use of imazamox to control the non-native seagrass Zostera japonica on areas commercially grown for clams in Willapa Bay. Z. japonica is listed as a Class C noxious weed in Washington. There are currently no known studies that address additive or synergistic effects of imidacloprid and imazamox. Imidacloprid and imazamox have completely different toxic modes of action; imidacloprid is a neonicotinoid insecticide that affects neural transmission in animals, and imazamox is an acetolactate synthesis (ALS) inhibitor which acts on a biochemical pathway that occurs in plants but not in animals.

Imazamox is a systemic herbicide that is rapidly absorbed into foliage and moved throughout plants via phloem and xylem tissues. It kills plants by inhibiting the production of certain essential amino acids. It concentrates in the actively growing portions of roots and shoots. Imazamox inhibits plant growth within the first 24 hours after application, though visual symptoms appear about one week after treatment with symptoms evident first on new growth. Susceptible plants develop a yellow appearance or general discoloration and eventually die or suffer severe growth inhibition (Ecology, March 26, 2014).

The half-life of imazamox in the presence of light is 6.8 hours (ENVIRON 2012). The lowest effect level for imazamox is 10 to 40 ppb for a 120-hour static test for algae, diatom and aquatic vegetation, and the no effect level (96-hour exposure) for aquatic invertebrates is 94,000 to 122,000 ppm (ENVIRON 2012). Imazamox dilutes in the leading edge of the water column one order of magnitude every 24 hours (60 ppb to 6 ppb) (ENVIRON 2012). Imazamox discharge in Willapa Bay is limited to April 15 through June 30.

Given that imidacloprid and imazamox affect different groups of organisms (i.e., animals and plants, respectively), there is no reason to expect that they would have synergistic or additive effects. However, until studies are conducted regarding the potential additive or synergistic effects, a cautionary approach of utilizing different treatment periods could be employed to avoid any potential for adverse effects. A 96-hour delay for imidacloprid application after imazamox application could result in a co-exposure scenario: imidacloprid present in the treatment area or in tidewater moving over treated areas could encounter imazamox at approximately 0.006 ppb (i.e., the concentration expected after 96 hours). A value of 0.006 ppb is approximately 4 to 5 orders of magnitude lower than the lowest effect level of imazamox for a 120-hour exposure for aquatic species. Given the extremely low concentrations of imazamox under this scenario, the potential for any chemical synergy or additive effects between imazamox and imidacloprid is effectively eliminated. If future studies demonstrate a lack of additive or synergistic effects through the combined presence of these chemicals in the environment, then maintaining a difference between the treatment periods could be reduced or eliminated.

Effects of the Proposed Imidacloprid Discharge with the Existing Discharge of Imazapyr for Spartina Control. The acreage of *Spartina* in Willapa Bay has been steadily decreasing so that in 2012 only approximately 1.3 acres remain (Washington State Department of Agriculture 2013). It is anticipated that the level of *Spartina* infestation in Willapa Bay will continue to decline with projections for 2013 and 2014 at 0.8 acre and 0.4 acre, respectively. The reported amount of imazapyr[62] discharged for *Spartina* control in Willapa Bay during 2012 was approximately 0.75 pound of active ingredient (data from Aquatic Noxious Weed Management General Permit Reporting). The amount of imazapyr expected to be discharged into Willapa Bay in the future under the Aquatic Noxious Weed Management General Permit should continue to decrease if projections of *Spartina* infestation are correct (Washington State Department of Agriculture 2013).

Similar to imidacloprid, the mode of action for imazapyr is also as an ALS inhibitor (Ecology 2014). It is applied to dewatered plants. Timing of imazapyr treatments generally occur from June 1 through October 31. This would have the potential to result in an overlap of imazapyr discharge and imidacloprid discharge during much of the treatment period. However, this is a very small amount of imazapyr treatment (and chemical release) within a very large estuary, which would tend to limit any potential interaction with imidacloprid applications.

Spartina grows in the intertidal (i.e., along the bay edges). While some areas commercially grown for clams targeted for treatment with imidacloprid may occur in proximity to the remaining small areas of *Spartina*, most of the areas commercially grown for oysters to be treated with imidacloprid are further out in the bay. Thus, any interaction between imazapyr and imidacloprid would likely be in water, where high-volume tidal exchanges would produce significant dilution of both chemicals.

Patten (2002, as cited in Entrix 2003) found that imazapyr diluted beyond detection within approximately 40 hours or less—four to five tidal exchanges after herbicide application. Based on the limited overlap in the timing of discharge and the anticipated use of less than one pound of imazapyr, Ecology does not anticipate that the discharge of imazapyr and imidacloprid concurrently in Willapa Bay will increase the likelihood of non-target impacts to vascular plants such as *Zostera* spp. (ECY 2014).

Effects of Other Shellfish Pests. Other shellfish pests exist in Willapa Bay and Grays Harbor, and in some cases are becoming problematic. These include the oyster drill (*Ceratostoma inornatum*), crab, moon snails (*Euspira lewisii*), starfish, and some polychaetes. Invasive Japanese eelgrass (*Zostera japonica*) is also causing harm to shellfish beds, as described in the *Final EIS for Management of Zostera japonica on*

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[62] Imazapyr is part of the imidazolinone chemical class. Imazapyr is a systemic, non-selective, pre- and post-emergent herbicide used for the control of a broad range of terrestrial and aquatic weeds, and controls plant growth by preventing the synthesis of branched-chain amino acids. Imazapyr is applied either as an acid or as the isopropylamine salt. http://www.ncbi.nlm.nih.gov/pubmed/16023744?dopt=Abstract.

Commercial Clam Beds in Willapa Bay (Ecology, March 26, 2014). The potential additive adverse affects of shellfish pests in Willapa Bay and Grays Harbor is not discussed in this FEIS.

2.10.2 Actions Not Considered as Cumulative Impacts

Potential expansion of permit authority to other aquatic lands (e.g., Puget Sound) and testing of alternative insecticides to treat burrowing shrimp are not being considered in the cumulative impacts analysis. No such proposals have been submitted. Further, Ecology does not know at this time where or whether expansion of future use may be considered or what other chemicals may be researched for the control of burrowing shrimp, making these issues speculative and outside the scope of this proposed action.

2.11 Benefits and Disadvantages of Reserving the Proposed Action for Some Future Time

Opinions vary regarding the benefits and disadvantages of reserving until some future time applications of imidacloprid to control burrowing shrimp on commercial shellfish beds in Willapa Bay and Grays Harbor. For those who are opposed to the use of insecticides in these estuaries, the benefit would be that no additional insecticides would be discharged into Willapa Bay or Grays Harbor. The disadvantage would be that the two species of burrowing shrimp would proliferate unmanaged, with likely unrecoverable damage to commercial shellfish beds and public tidelands, and significant alterations to the bay-wide ecosystem.[63] Even during the 50+ years of the carbaryl control program, methods have often not been enough to protect commercial shellfish beds, causing the industry to shrink over time (testimony of WGHOGA members at the Imidacloprid EIS Scoping meeting, February 1, 2014). Elimination or delay of approval of imidacloprid as a chemical control for burrowing shrimp would therefore be expected to have serious negative effects on shellfish aquaculture in Grays Harbor and Willapa Bay.

There would be both short-term and long-term economic impacts if shellfish aquaculture were to contract significantly or disappear from Pacific County and Grays Harbor County as a result of not controlling burrowing shrimp. Growers would lose their livelihood and way of life, jobs would be lost, and tax revenues generated for public services would significantly decline. Economic impacts would be large and broad-reaching, as described in FEIS Section 2.6.

[63] See the description of the impacts of the No Action Alternative in FEIS Chapter 3.

3.0 Affected Environment, Potential Impacts, and Mitigation Measures

3.1 Biological Background Information

Since at least the 1940s, two indigenous species of burrowing shrimp (Family Callianassidae) have caused impacts to Pacific Coast commercial clam and oyster production by disrupting the structure and composition of the substrate. At that time shellfish growers began to notice that crops were disappearing, but did not understand what was happening. Over a few years it was found that shrimp populations were rapidly expanding into new areas. Hundreds of studies have been conducted over subsequent decades to understand burrowing shrimp and their beneficial and adverse effects in the estuarine environment. No historical baseline conditions were described prior to the beginning of efforts to control burrowing shrimp. What is known is that areas that had supported native oyster populations for thousands of years are now populated with burrowing shrimp. Because native oysters could not have survived in areas of high shrimp population, it seems that these areas may not have been so densely populated with shrimp prior to the 1940s. It is also possible that some loss of native oysters may be due to excess sedimentation caused by human activities and/or overharvest (Sanford 2012).

The morphology and seasonality of the two species of burrowing shrimp differ somewhat; however, their behavior and general ecologies are very similar. Two Environmental Impact Statements (EISs) prepared by the Washington Department of Fisheries and the Washington State Department of Ecology[1] describe characteristics of borrowing shrimp that have reached levels affecting commercial shellfish production in both Willapa Bay and Grays Harbor. Information presented below is summarized from those documents.

Dr. Brett Dumbauld, with the U.S. Department of Agriculture, Agriculture Research Service, has been monitoring burrowing shrimp populations at two long term monitoring locations within dense shrimp beds in Willapa Bay, Washington since the late 1980's and in other coastal estuaries since 2005.

In a recent memo sent on 11/28/2014 his most recent conclusion was that ghost shrimp are recruiting to Willapa Bay and Grays Harbor again after what appeared to be a period of very low or no recruitment and declining adult populations since the mid 1990's. While individual annual recruitment levels are lower than peak recruitment years observed in the mid 1990's in Willapa Bay, it signals that conditions were favorable for ghost shrimp to recruit from 2010 – 2013 and their combined density may be significant. This memo can be found on our web site http://www.ecy.wa.gov/programs/wq/pesticides/imidacloprid/index.html.

Ghost Shrimp Characteristics. Ghost shrimp (*Neotrypaea californiensis*) have a pale pink body with a large, broad abdomen. The first pair of legs have well-developed claws that are slightly dissimilar (females) or very unequal (males). Mature adults range from 2 to 4 inches (51 to 102 millimeters [mm]) in length. The lifespan of ghost shrimp can be up to 13 years (personal communication with Brett Dumbauld, December 8, 2014).

Ghost shrimp are selective deposit feeders and isolate their food particles by sorting, rasping, or sucking food from the surfaces of sediment particles. Benthic microalgae and bacteria are important sources of food for ghost shrimp (Wolff 1983, as cited in WDF and ECY 1992). Although classified as deposit

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1 *Final EIS for Use of the Insecticide Sevin to Control Ghost and Mud Shrimp in Oyster Beds of Willapa Bay and Grays Harbor* (WDF and ECY 1985); and *Supplemental EIS for Use of the Insecticide Carbaryl to Control Ghost and Mud Shrimp in Oyster Beds of Willapa Bay and Grays Harbor* (WDF and ECY 1992).

feeders, a substantial portion of the food of ghost shrimp may come directly from the water column (Bird 1982). Ghost shrimp feed by continually digging in sandy sediments and accumulating detrital particles on appendage hairs. The organic material is ingested when these hairs are cleaned. Since ghost shrimp prefer clean, well-sorted sand rather than muddy substrates, they must process a large amount of sediment (Bird 1982).

Ghost shrimp construct complex, deep burrows (up to 1 meter [m] or approximately 3 feet deep; Dumbauld et al., unpublished), that are more temporary than those of mud shrimp (Suchanek 1985, as cited in WDF and ECY 1992). Excavated sediment and feces are deposited at burrow entrances, forming conspicuous mounds that gradually raise the level of the tidal flat. Oyster growers and biologists have observed that the burrowing habits of ghost shrimp tend to soften a sand flat: the shrimp remove binding particles of silt, clay, and organic material and deposit these particles with excavated sand as unconsolidated sediment on the surface where it is subject to removal by tides and waves.
Ghost shrimp mature at 18 to 24 months, at which time egg-bearing females may be less than 30 mm (1.15 inches) in total length. Female ghost shrimp in the Pacific Northwest can be egg-bearing from April to August (Feldman 2000). The principal breeding period for ghost shrimp in the Pacific Northwest is late spring and early summer, when the water temperature begins to warm. Ghost shrimp can produce broods of planktonic larvae every 6 weeks from March through August (McCrow 1972). Larvae pass through five planktonic zoeal stages, lasting about 6 weeks, in nearshore coastal waters (Johnson and Gonor 1982). Summer high tides carry some larvae into coastal estuaries where they settle on suitable substrate.

Bird (1982, as cited in WDF and ECY 1985) found that female ghost shrimp mature and produce eggs at about 24 months in Oregon estuaries. Growth rates ranged from 15.7 to 22.4 mm (0.6 to 0.85 inch) per year depending on location. The annual rate of recruitment of ghost shrimp to Oregon estuaries was correlated with the density of adult shrimp. Larval recruitment tended to be greatest to areas where there were established adult populations. Juveniles were most abundant in areas with fewer adults present (Bird 1982).

Ghost shrimp create dense beds of up to 400 shrimp per square meter (m^2) (Dumbauld et al., unpublished) in the mid-intertidal zone of many Washington and Oregon sandflats, and are usually not as abundant in the lower intertidal and subtidal (Bird 1982). Current studies of population trends in Willapa Bay and Yaquina Bay, Oregon suggest that ghost shrimp populations have been declining in both bays since the mid-1990s in Willapa Bay, and since 2005 in Yaquina Bay. A decrease of 67 percent was seen in the Palix River area of Willapa Bay between 2006 and 2009 (Dumbauld et al., unpublished). However, more recent data suggests that a large recruitment of shrimp has occurred in the past 3 years: 2011 through 2013 (Dumbauld et al., unpublished, WGHOGA personal communication).

MacGinitie (1934) suggested that colonies of ghost shrimp in California (Elkhorn Slough) are cyclic in abundance. This cycle may take as long as 10 years, depending on factors such as distance from the ocean and presence of other macroinvertebrates. Such cyclic changes were not observed in Oregon estuaries (Bird 1982; Posey 1985a and 1985b); however, they are a feature of other decapod populations (Cheney and Mumford 1986).

Mud Shrimp Characteristics. Mud shrimp (*Upogebia pugettensis*) are usually reported to be smaller than ghost shrimp, at about 50 to 60 mm (approximately 2 to 2.5 inches) in length. However, in Willapa Bay, they are the same size or larger than ghost shrimp (Rudy and Rudy 1983). A mud shrimp is bluish in color with green and orange variants, and their claws are equal in size. Mud shrimp live for approximately 4 to 5 years (Dumbauld et al. 1996).

Mud shrimp build shallow U-shaped or Y-shaped burrows (Suchanek 1985, as cited in WDF and ECY 1992) in the middle to low intertidal zone (Dumbauld et al. 1996). Their burrows are more complex than those of ghost shrimp, and usually have three surface openings (MacGinitie and MacGinitie 1968). As their name indicates, mud shrimp prefer a muddier habitat with sediments that are less well-sorted than those inhabited by ghost shrimp (Bird 1982). There have also been observations of both ghost shrimp and mud shrimp occupying the same areas. Mud shrimp are generally more common, however, farther from the mouths of estuaries (Bird 1982, as cited in WDF and ECY 1992).

Mud shrimp are suspension feeders, feeding on phytoplankton, zooplankton, bacteria and detritus that are suspended in the water column (Posey 1985a). They cycle water through their burrows and remove food particles from this water. Other examples of suspension feeders are the Pacific oyster, clams, bay mussel, barnacles and many polychaetes (Wolff 1983, as cited in WDF and ECY 1992).

Compared to ghost shrimp, mud shrimp significantly increase the organic content of the sediments. The shrimp secrete organic material to cement their burrow walls and deposit undigested organic material as feces at the burrow entrances (Bird 1982).

Mud shrimp are egg-bearing during winter and early spring (October to March) (Bird 1982; and Dumbauld 1988 personal communications, as cited in WDF and ECY 1992). Mud shrimp post-larvae settle to the bottom in spring toearly summer (Personal communication with Dr. Dumbauld, Dec 8, 2014). These young-of-the-year grow to about 0.7 to 1.1 inches (17 to 28 mm) by the following winter. Females grow by about one inch (26 mm) per year and produce eggs when they reach about 2.5 inches (60 mm) in length.

Like ghost shrimp, mud shrimp can also form dense populations (up to 400 shrimp per m^2). Populations of mud shrimp have also declined recently, but the magnitude is not as clear as for ghost shrimp (Dumbauld et al., unpublished). Part of the reason for the decline in mud shrimp populations may be the presence of a parasitic isopod (*Orthione griffenis*) that renders female mud shrimp infertile (Dumbauld et al. 2011; Dumbauld et al., unpublished).

Burrowing, Water Movement, and Water Quality Effects. The rate at which two other species of burrowing shrimp (*Callianassa japonica* and *U. major*) moved water through their burrows was measured by Koike and Mukai (1983) and Mukai and Koike (1984) under simulated, *in-situ* conditions. Estimated flow rates created by burrowing shrimp at 20.5 degrees Centigrade (approximately 69 degrees Fahrenheit) were 0.7 to 1.5 liters per day for ghost shrimp and 0.3 to 0.8 liter per day for mud shrimp. Water volumes of 1.5 to 3.5 liters were cycled through burrows daily by burrowing shrimp in the tropics (Colin et al. 1986). In samples taken 10 centimeters above the bottom, the suspended sediment load of water over areas with high populations of burrowing shrimp was about three times that found over control (i.e., lower shrimp population) areas. Suchanek (1983, as cited in WDF and ECY 1992) measured suspended sediment quantities of up to 2.59 kilograms (kg) per m^2 (18.7 pounds [lbs] per square foot) per day for a shallow-water tropical species. These observations implied that callianassids make a major contribution to total suspended particles in the water column (Colin et al. 1986).

Available evidence suggests that burrowing shrimp act as “ecosystem engineers” by recycling nutrients that might normally be trapped in sediments. Callianassids ingest organic matter and excrete ammonium and phosphorus that is pumped out of their burrows into the water column (WDF and ECY 1992). Work by D’Andrea and DeWitt (2009) suggests that the presence of mud shrimp can affect inorganic nitrogen fluxes across the sediment-water interface and increase benthic respiration rates. Dissolved inorganic nitrogen fluxes can be fifteen times greater in areas where mud shrimp are present. Mud shrimp can, effectively, increase carbon and nitrogen fluxes by 1.9 and 3.7 times, respectively (D'Andrea and DeWitt 2009). Mud shrimp can also alter nutrient porewater concentrations in the sediments.

Interaction of Burrowing Shrimp with Other Mudflat Organisms. Burrowing shrimp are considered ecosystem engineers because of their ability to control and structure the benthic community. Burrowing shrimp greatly modify the substrate, and enhance nutrient and carbon fluxes (D'Andrea and DeWitt 2009; DeWitt et al. 2004; Aller et al. 1983; Webb and Eyre 2004). DeWitt et al. (2004) have estimated that burrowing shrimp have the capacity to bury, remineralize, and recycle higher levels of organic matter than occurs on tide flats without burrowing shrimp or oysters. Burrowing shrimp may act to buffer estuaries from the adverse effects of nutrient enrichment, providing a way of managing nutrients in the environment. There is also a reduced risk of hypoxia and anoxia in sediments inhabited by burrowing shrimp because they are able to rapidly recycle enhanced primary production and detritus from the tide flat surface. DeWitt et al. (2004) suggest that burrowing shrimp provide beneficial ecosystem services by decreasing the effects of eutrophication and supplying dissolved organic nitrogen for primary and secondary productivity within a tide flat food web. These ecosystem benefits may be particularly important in El Niño years when biological productivity decreases due to the lack of upwelling (Stenseth et al. 2002), resulting in lower concentrations of nutrients including dissolved inorganic nitrogen (DIN) (DeWitt et al. 2004). In these circumstances, burrowing shrimp may contribute nitrogen that is important to primary and secondary production. This also becomes important in areas of estuaries with low concentrations of DIN. Burrowing shrimp act to alter local food webs through consumption of phytoplankton and benthic microalgae (Dumbauld et al., unpublished). They also alter habitat structure by displacing seagrasses (Dumbauld and Wyllie-Echeverria 2003). They can also become prey for larger consumers such as crabs, birds, and fish (Dumbauld et al. 2008, Posey 1986).

Bird 1982 and Posey (1985) reported that burrowing shrimp can significantly affect the benthic community in which they live. High densities of ghost shrimp reduce both species composition and abundance of other types of invertebrates in benthic communities. Other studies found burial of invertebrates and general sediment disturbance by burrowing shrimp can substantially affect the composition of infaunal and epifaunal invertebrates in the sediments (Dumbauld et al. 2001; Ferraro and Cole 2007; Posey 1986). Deposit-feeding polychaetes, bivalves, tube-dwelling tanaids and amphipods (e.g., *Corophium* spp.), and other sedentary species were reduced in numbers in areas where dense populations of ghost shrimp were present. Reductions resulted from the frequency of sediment disruption, resuspension of fine particles, and increased soft sediments (Dumbauld et al., unpublished). Mud shrimp cause less sediment disturbance than ghost shrimp and appear to have less effect on other invertebrate organisms.

As noted, burrowing shrimp can make sediments too soft and unstable for clam and oyster survival. It is estimated that burrowing shrimp have eliminated commercial shellfish production on more than 3,000 acres of tide lands in Willapa Bay and Grays Harbor (i.e., approximately 25 percent of the historically-farmed acreage) (Burrowing Shrimp Control Committee 1992). This acreage might be reclaimed if burrowing shrimp could be suppressed to low densities, allowing the return of fine surface sediments and associated microbial, macroinvertebrate, and vegetative communities (Booth and Wilson 2002).

Interactions of Burrowing Shrimp and Eelgrass. The native eelgrass *Zostera marina* is an important part of the tide flat ecosystem in Willapa Bay and Grays Harbor. It contributes to a healthy functioning ecosystem that also includes shellfish beds and mud/sand flats. Eelgrass habitats are highly productive and provide structure and refuge for many species of fish and invertebrates, foraging habitat for migratory waterfowl, and spawning substrate for forage fish like Pacific herring (Dumbauld et al. 2003; Wyllie-Echeverria et al. 2009; Wyllie-Echeverria et al. 2004; Phillips 1984). Eelgrass does this by helping to stabilize the sediment and by reducing current speeds (Wyllie-Echeverria et al. 2009). In Willapa Bay, eelgrass provides habitat for many species of benthic invertebrates. Eelgrass also provides nursery and feeding habitats for juvenile salmon and Dungeness crab (Thom et al. 2003).

Burrowing shrimp act to limit eelgrass presence by disrupting the sediment and making it too soft for eelgrass roots and rhizomes (Dumbauld and Wyllie-Echeverria 2003; Hosack et al. 2006). Dumbauld and Wyllie-Echeverria found a strong increase in eelgrass abundance in areas where carbaryl was experimentally applied to burrowing shrimp. WGHOGA members have observed that the elimination of eelgrass from areas with high levels of burrowing shrimp is somewhat dependent on the shrimp species present (personal communication with a WGHOGA member, June 15, 2014). In addition, the increased turbidity and sedimentation associated with burrowing shrimp also hinder eelgrass growth by decreasing the ability of the plants to photosynthesize (Dumbauld and Wyllie-Echeverria 2003). This is likely elevation-dependent, with increased turbidity affecting the lower depth distribution of eelgrass. Thus, eelgrass present at lower elevations is likely to be affected more than eelgrass present at higher elevations.

Ecology of Oyster-Dominated Communities. A diverse assemblage of plants and animals is associated with oyster beds. These include animals attached to oyster shell, such as red algae, barnacles, and mussels, in addition to animals that live under and around the shell, such as crabs and various fish species. The composition of oyster-dominated communities is a reflection of the diversity of micro-habitats associated with oysters. This contrasts sharply with the more homogeneous habitats of bare mud and sand flats (WDF and ECY 1992), including areas dominated by burrowing shrimp.

Oyster beds provide important ecosystem services such as water filtration, resulting in decreased suspended solids, turbidity, and increased denitrification; habitat for epibenthic invertebrates such as crabs; carbon sequestration; and stabilization of adjacent habitats and the shoreline (Grabowski and Peterson 2007). They provide habitat for other molluscs, polychaetes, and crustaceans (Lenihan et al. 2001, Rothschild et al. 1994), and refuge habitat for juvenile fish and mobile crustaceans (Coen et al. 1999, Grabowski et al. 2005).

Important elements that appear to affect the nature and extent of oyster-dominated communities include physical factors such as the character of the bottom; sedimentation; temperature; biological factors such as food, predators and disease; and other factors such as pollution. Oysters grow well on hard, rocky bottom or on semi-hard mud firm enough to support their weight. Shifting sand and soft mud are usually unsuitable for oysters. A firm bottom of fine gravel, sand, mud or any combination of these three sediment types provides optimum conditions (Quayle 1969). Sedimentation is also an important factor, as rapid settling of suspended material can be highly destructive to an oyster community. Ideal conditions are found when silt does not settle on live oysters (Galtsoff 1964).

Ecology of Clam Communities. As with oyster-dominated communities, clam communities are associated with a large assemblage of plants and animals. These include animals that live under and around the shell, such as crabs and various fish species. Clams are subject to predation by a wide variety of predators such as moon snails, and some crab species (e.g., red rock crab and Dungeness crab; Anderson et al. 1982).

Manila clams (*Venerupis philippinarum*) are generally found on intertidal beaches that are protected from heavy wave action and in gravel substrates with small amounts of mud, sand, and shell (Simenstad and Fresh 1995; Anderson et al. 1982). They are found in the high intertidal zone between +0.5 to +4.0 feet MLLW tidal elevation (personal communication with a WGHOGA member, May 28, 2014). As with oysters, the nature and extent of clams are affected by physical factors such as food, predation, substrate and pollution (Anderson et al. 1982).

Chemical Control of Burrowing Shrimp with Carbaryl. Since 1963, aerial applications of carbaryl on selected commercial oyster beds have effectively suppressed burrowing shrimp. Carbaryl has been applied on tideland acreages of high burrowing shrimp density,[2] as confirmed by ground surveys. Carbaryl has been applied to most commercial beds before oyster placement and one or more times during the 4 to 7 years of oyster development. A helicopter equipped with a spray boom has been the predominant method of application. A limited number of extreme low tides in July or August have been used as the application dates, when migratory salmon are not present and when juvenile crab populations are low. This timeframe also avoids seasonal bird migrations, peak pollination periods, and forage fish spawning periods (see FEIS Section 3.2.5 below for details).

A long-term result of suppressing burrowing shrimp with carbaryl at select locations has been an increase in the diversity of benthic invertebrates, abundance of Dungeness crab, and growth of eelgrass (Doty et al. 1990; Brooks 1995; Dumbauld and Wyllie-Echeverria 1997). Approximately 75 studies focusing on the effects of carbaryl in Willapa Bay demonstrated, in general, that judicious applications of carbaryl were effective and unlikely to result in adverse environmental affects (see Dewitt et al. 1997). For example, while Dungeness crabs are highly susceptible to carbaryl, they recolonized treated oyster beds within two weeks after treatment, and subsequently attained greater densities on treated beds than on comparable untreated beds, as juvenile crab do not normally inhabit grounds heavily populated with burrowing shrimp (Feldman et al. 2000; and Doty et al. 1990). No mammals or endangered species, with the exception of green sturgeon, were present in areas of carbaryl application, and mammals are generally absent during the mid-summer period when carbaryl has been applied. Some birds, primarily gulls, have been seen to feed on dead shrimp shortly after carbaryl application, but no adverse effects on them were observed (DeWitt 1997; WDF and Ecology 1992). N-methyl carbamates do not bioaccumulate in the food chain (WDF and Ecology 1992).

3.2 Elements of the Environment

This section is organized by elements of the environment to be reviewed by the Washington State Department of Ecology (Ecology) when making their permit decision regarding the proposed action to control burrowing shrimp on commercial shellfish beds in Willapa Bay and Grays Harbor using chemical applications of imidacloprid. Existing environmental conditions are described for each of these elements, followed by a description of potential impacts that could result from each of the alternatives being considered. The analysis of the potential impacts of the alternatives is followed by a description of proposed (i.e., voluntary), required, and other recommended mitigation measures that could be implemented to avoid or minimize potential adverse impacts of the proposed action.

Ecology's (Water Quality Program) review of the WGHOGA NPDES permit application must ensure that the proposed discharge of imidacloprid will comply with Washington State Water Quality law and regulations. The permit, if issued, would be conditioned to protect state resources. Before requiring additional mitigation measures through the SEPA process, Ecology is required to consider whether local, State, or Federal requirements and enforcement would adequately mitigate an identified adverse significant impact. The SEPA Rules with regard to imposing mitigation measures are as follows (WAC 197.11.660[1][a through e]):

(1) Any governmental action on public or private proposals that are not exempt may be conditioned or denied under SEPA to mitigate the environmental impact subject to the following limitations:

[2] High burrowing shrimp density is based on the NPDES Permit "rule of thumb" threshold of 10 burrows per m^2.

(a) Mitigation measures or denials shall be based on policies, plans, rules, or regulations formally designated by the agency (or appropriate legislative body, in the case of local government) as a basis for the exercise of substantive authority in effect when the DNS or FEIS is issued.
(b) Mitigation measures shall be related to specific, adverse environmental impacts clearly identified in an environmental document on the proposal and shall be stated in writing by the decision maker. The decision maker shall cite the agency SEPA policy that is the basis of any condition or denial under this chapter (for proposals of applicants). After its decision, each agency shall make available to the public a document that states the decision. The document shall state the mitigation measures, if any, that will be implemented as part of the decision, including any monitoring of environmental impacts. Such a document may be the license itself, or may be combined with other agency documents, or may reference relevant portions of environmental documents.
(c) Mitigation measures shall be reasonable and capable of being accomplished.
(d) Responsibility for implementing mitigation measures may be imposed upon an applicant only to the extent attributable to the identified adverse impacts of its proposal. Voluntary additional mitigation may occur.
(e) Before requiring mitigation measures, agencies shall consider whether local, state, or federal requirements and enforcement would mitigate an identified significant impact.

3.2.1 Sediments

AFFECTED ENVIRONMENT

3.2.1.1 *Willapa Bay*

Willapa Bay encompasses an area of about 260 square kilometers (km^2) (= ± 100 square miles) at mean high water. It is protected from the open ocean by a 30-km (18.6-mile) barrier spit, the North Beach Peninsula, formed from sand transported in by the Columbia River. The bay has a north and south area of embayment with five major rivers. The Palix, Nemah, and Naselle in the south and the North and Willapa Rivers in the north portion. Many other smaller creeks enter along the north, east and south margins (see Figure 2.4-1 in FEIS Chapter 2).

Willapa Bay is dominated by mudflats. The physical structure is shaped by dynamic natural forces including large tidal ranges, strong currents, and heavy runoff (Day et al. 1989, cited in U.S. Department of the Interior [USDI], U.S. Fish and Wildlife Service [USFWS] 1997).

The bay has extensive, gradually sloping, intertidal flats with small, shallow channels connecting to larger, deeper ones that expedite the cyclic flows of tides. The flats in the southern end of the bay have a fine silty substrate accumulated from upland sediments of rivers and streams flowing into the bay. The upper layer of fine sediments may be regularly resuspended by strong currents, wave action, rainfall on exposed mudflats, biological activity on or below the surface (such as that associated with burrowing shrimp), or by human activities (such as boating and aquaculture). Where burrowing shrimp are present in the bay, they influence sediment biogeochemistry and disrupt stratification of surface sediments (D'Andrea and DeWitt 2009). Farther north in the bay where currents are stronger, bare tidal flats collect less silty material and tend to have coarser, sandier bottoms (USDI/USFWS 1997).

In the marine intertidal mudflats of Willapa Bay where imidacloprid applications are proposed to control burrowing shrimp, the pH of sediments and sediment porewater range from 7.3 to 7.6 (Wilson and Partridge 2007, as cited in ENVIRON 2012). In general, Willapa Bay sediments have low organic carbon content (ENVIRON 2012); however, there are some areas within Willapa Bay where the sediments have high organic content.

3.2.1.2 *Grays Harbor*

Grays Harbor is approximately 15 miles long and 12 miles wide at its widest section (see Figure 2.4-2 in FEIS Chapter 2). It has large semi-diurnal tides. Approximately 94 square miles of Grays Harbor is covered at mean higher high water (MHHW), with a tide level of 9.16 feet (USACE 2014). At mean lower low water (MLLW), approximately 38 square miles of Grays Harbor is covered and about 63 percent of the harbor's surface area is mudflats (USACE 2012). More than 80 percent of Grays Harbor is less than 20 feet deep MLLW, and more than 50 percent of the harbor has a depth of approximately 0 feet MLLW (USACE 2011).

Sediment and water input to Grays Harbor is from various rivers, the largest being the Chehalis River at the east end, which accounts for more than 80 percent of the total freshwater in the estuary (USACE 1989). These sediment and water inputs, combined with marine sediment and water inputs from the Pacific Ocean, largely control the overall sediment transport in Grays Harbor (USACE 2014). Grays Harbor is dominated by tidal currents; however, high river flows can control currents in the upper estuary, and the locations of shoals are constantly shifting (USACE 2012).

Commercial shellfish growers in North Bay and South Bay report that most of the sediments on their shellfish beds are composed of muddy sands (personal communication with WGHOGA members). As in Willapa Bay, more sheltered portions of Grays Harbor can be expected to have muddier sediments than areas open to stronger action by tides and waves. Commercial shellfish beds mapped near the Crossover Channel in the east-central portion of Grays Harbor (Figure 2.4.2) are not currently farmed as they are located in a restricted growing area (personal communication with Dave Hollingsworth, WGHOGA member, May 14, 2014).

On June 9, 1989, Ecology listed eight pulp mills as violating water quality standards for the priority pollutant TCDD, a dioxin. At that time, the Weyerhaeuser Paper Company (in Cosmopolis) and ITT Rayonier (in Hoquiam) were discharging to inner Grays Harbor. Their effluent and sludge contained measurable quantities of dioxin. Dioxins are common by-products of a number of human and natural activities, including combustion and incineration, forest fires, chlorine bleaching of pulp and paper, certain types of chemical manufacturing and processing, and other industrial processes. Dioxins are of concern because they are toxic contaminants that last a long time in the environment and can build up in aquatic organisms, becoming more concentrated as they move through the food chain.

Sediment studies were conducted by Ecology (ECY 1999b) to address concerns about the potential for sediment contamination in a number of areas located outside the Chehalis River main channel. These areas were often located adjacent to smaller facilities with known or suspected sediment contamination. The study concluded that chemical concentrations were low in most areas of Grays Harbor; however, localized sites of chemical contamination were found.

Ecology also conducted sediment sampling throughout Grays Harbor in 2002 (ECY 2007). The total organic content (TOC) of sediments in Grays Harbor was found to be less than 1.5 percent. The sediments here were comprised mostly of fine sand, with this fraction comprising 64 percent of the sediment, whereas the silt fraction was approximately 14 percent (ECY 2007).

Maintenance dredging occurs annually in the Grays Harbor Federal navigation channel. The Draft Environmental Assessment for FY 2011 through 2018 maintenance dredging and disposal, and the 2012 sediment sampling and sediment characterization report were reviewed for Grays Harbor sediment quality information. The U.S. Army Corps of Engineers reports few or no sources of chemicals present in sediments to be dredged from the Grays Harbor navigation channel. This conclusion is based on data that show no or low levels of chemicals of concern and no significant toxic responses to biological tests. There are no known hazardous, toxic, or radioactive wastes within the navigation channel maintenance dredge area (Corps of Engineers, Seattle District 2011). Testing results completed in 2012 for 28 dredge material management units (DMMU) found that all sediments were suitable for approved beneficial uses at nearshore and onshore disposal sites (USACE, February 9, 2012).

POTENTIAL IMPACTS

Under Alternative 1 (No Action – No Permit for Pesticide Applications), attempts to remove or manage burrowing shrimp via mechanical and shellfish culture methods may result in a widespread, but temporary increase in turbidity. Although widespread, this increase in turbidity would last for limited durations of time due to tidal cycles. It is unlikely that this increase in turbidity would cause an exceedance of State water quality standards because of the shallow water depth, naturally relatively turbid water, and the intertidal environment that goes dry during low tides.

Mechanical controls of burrowing shrimp are less effective than chemical treatments and would likely result in a benthic habitat that is lower in diversity and productivity than that found in shellfish beds (Ferraro and Cole 2007). Burrowing shrimp construct burrows in the sediment that can be up to 1 m (approximately 3 feet) in depth and may form dense beds of up to 400 individuals per m^2. These activities cause a continuous reworking of the sediment, especially near the surface, often resulting in a very soft, almost fluid sediment environment (Posey 1986). The activities of burrowing shrimp may influence sediment biogeochemistry by increasing carbon and nitrogen cycling within the sediment-water interface (D'Andrea and DeWitt 2009). This can help supply nutrients necessary for primary and secondary production during periods of low nutrient influx (e.g., El Niño events), and thus decrease the likelihood of the occurrence of hypoxic or anoxic conditions. They can re-suspend up to 50 percent of the sediment, causing increases in turbidity and sediments that have a quality similar to quicksand (Posey 1985). This softening of the sediment causes oysters to sink into the substrate and suffocate (Dumbauld et al. 2001) and decreases available habitat for benthic algae and sediment-dwelling invertebrates. The softening of the sediments also causes clams to sink into the substrate and suffocate in a manner similar to that of oysters (DeFrancesco and Murray 2010). Although clams can move, they cannot outpace the bioturbation of burrowing shrimp, leaving them open to increased predation and suffocation (personal communication with a WGHOGA member, June 15, 2014).

Under Alternative 2 (Continue Historical Management Practices – Carbaryl Applications with Integrated Pest Management), carbaryl would be applied to approximately 600 acres of commercial shellfish beds within Willapa Bay, and approximately 200 acres of commercial shellfish beds within Grays Harbor during extreme low tide intervals between July 1 and October 31 of each year (see FEIS Chapter 2, Section 2.8.2). Minor (if any) sediment disturbance would occur at the time of treatment with current methods of application: helicopter dispersion of liquid carbaryl, backpack sprayers, or working from all-terrain vehicles using a hand-held nozzle or boom sprayer. Sediment disruption that occurs during shellfish harvest would continue to occur, as would disruptions concurrent with any mechanical controls implemented through Integrated Pest Management strategies.

Carbaryl is almost insoluble in water (less than 1 percent solubility); however, it is rapidly removed from the water column due to sediment adsorption (Sayce 1970). Carbaryl is removed from the environment through hydrolysis to 1-naphthol, which further undergoes degradation to carbon dioxide and water (Karinen et al. 1967). In seawater, the stability of carbaryl and 1-naphthol is controlled by a number of factors including pH, temperature, alkalinity, sunlight, dilution, and biotic degradation (WDF and ECY

1985). The compound 1-naphthol decomposes rapidly at a pH of 8.2, coincident with the pH of seawater (Lamberton and Claeys 1970).

Site-specific studies have been conducted to clarify the persistence of carbaryl in estuarine sediments. Studies conducted in Yaquina Bay, Oregon (Karinen et al. 1967) and Willapa Bay, Washington (ECY 1999) found that carbaryl was present in sediments at concentrations of 80 to 200 parts per billion (ppb) 42 days after spraying (application rate of 10 lbs/acre), and 105 ppb 60 days after spraying (application rate of 7.51 lbs/acre). Studies have also been conducted in Willapa Bay showing that carbaryl concentrations in mud declined from 1,100 ppb to 600 ppb in four days, and to 100 ppb after eight days, at an application rate of 10 lbs/acre (Sayce 1970). Carbaryl and its degradation products were not detectable 16 days after treatment; therefore, no chemical build-up over time would be expected if a commercial shellfish bed was treated with carbaryl more than once in 5 years (the duration of a NPDES permit).

Under Alternative 3 (Imidacloprid Applications with IPM), imidacloprid would be applied on up to 1,500 acres of commercial shellfish beds *per year* within Willapa Bay, and up to 500 acres of commercial shellfish beds within Grays Harbor *per year* (see FEIS Chapter 2, Section 2.8.3). Integrated Pest Management practices would also be implemented to continue experimenting with alternative physical, biological, or chemical control methods that are as species-specific as possible, economical, reliable, and environmentally responsible. Applications of imidacloprid to shellfish beds would occur on several extreme low tide intervals from April through December each year. Minor (if any) sediment disturbance would occur at the time of treatment with methods of application suitable for the chemical formulation (i.e., "flowable" or granular): helicopter dispersion, scows or shallow-draft boats, all-terrain vehicles equipped with a spray boom, and/or back pack reservoirs with hand-held sprayers. Sediment disruption that occurs during shellfish harvest would continue to occur, as would disruptions concurrent with any mechanical controls implemented through Integrated Pest Management strategies.

Imidacloprid has moderately high solubility in water (Felsot and Ruppert 2002), and has the ability to bind to sediments (Felsot and Ruppert 2002; Grue and Grassley 2013). Sediment binding rates of imidacloprid are variable and are dependent upon a number of factors including temperature, pH, salinity, alkalinity, redox potential, solar radiation, biological activity, dissolved oxygen, dissolved organic carbon (DOC), and total organic carbon (TOC) (Grue and Grassley 2013).

Site-specific studies have been conducted to clarify the persistence of imidacloprid in estuarine sediments. Studies were conducted in Willapa Bay in 2012 (Grue and Grassley 2013; Hart Crowser 2013) to quantify the effects of imidacloprid on whole sediment and sediment porewater. The scope of these trials was to describe the sediment impact zone (SIZ) that could be associated with the commercial use of imidacloprid for the control of burrowing shrimp. A SIZ is the area where the applicable State sediment quality standards of WAC 173-204-320 through 173-204-340 are exceeded due to ongoing permitted or otherwise authorized wastewater, storm water, or nonpoint source discharges (WAC 173-204-200). The 2012 study was also designed to measure one of the degradation products of imidacloprid: imidacloprid-olefin.

The 2012 experimental trials were conducted in Willapa Bay and the study sites were selected with specific criteria in mind. Study site criteria included ownership by a WGHOGA member; adequate densities of burrowing shrimp; adequate distance from previous or planned applications of carbaryl on commercial shellfish beds (>0.5 mile); no previous applications of carbaryl within the past 20 years, if ever (personal communication with Kim Patten, WSU Pacific County Extension Director, May 29, 2014); accessibility; and desirable characteristics of elevation, vegetation, and substrate that are similar to commercial shellfish beds and that were consistent within the study area. In addition, treatment and control plots had to be adequately separated to prevent cross contamination (>500 meters). All treatment and control plots were seven to ten acres in size. Both the granular and flowable formulations of imidacloprid were used in these trials. A screening criterion of 0.6 ppb was used for whole sediment and sediment porewater.

Sediment samples were collected for whole sediment and sediment porewater analysis within each treatment plot and from three transects on the upstream side of the treatment plot at 60, 120, 240, and 480 meters (197, 394, 787, and 1,575 feet) from the plot edge. When drainage channels were present, samples were taken in the drainage channels at the distances mentioned above. One pre-treatment sample was taken. Samples were also collected on days 1, 14, 27, and 56 after application.

The maximum concentration of imidacloprid found in sediment porewater on treatment plots 1 day post-application was 261 ppb. In general, imidacloprid concentrations were greater on the flowable imidacloprid-treated beds compared to the granular imidacloprid-treated beds. By 14 days post-application, imidacloprid residues in sediments and sediment porewater were dramatically reduced (maximum 9.1 ppb). Concentrations of imidacloprid within porewater samples collected at high elevation transects off the treatment plots largely followed the pattern of the residues within the water column samples. Analyses have suggested that 0.5 to 2 percent of the imidacloprid observed in the inundation water passing a given position will subsequently be observed in the sediment porewater 1 to 3 days post-application (Grue 2012). Analyses of whole sediment samples indicate 89 to 98 percent of the imidacloprid deposited on the treatment plots moved off-site. These studies confirmed that imidacloprid can bind to organic materials in the sediments, but that concentrations of this bound fraction decline rapidly between 14 and 27 days after treatment (Grue and Grassley 2013; Hart Crowser 2013).

Imidacloprid persists in the sediment, with lower persistence in sandy sediments than in silty sediments with higher concentrations of organic carbon (personal communication with Kim Patten, WSU Pacific County Extension Director, April 30, 2014; Grue and Grassley 2013). If a NPDES permit is issued for the use of imidacloprid, studies could be required to address the issue of persistence of imidacloprid in sediments with higher concentrations of organic carbon to ensure compliance with applicable regulatory standards.

MITIGATION MEASURES

Prior to issuing a NPDES permit for the discharge of a pesticide to waters of the State, Ecology must determine whether the proposed action will comply with Washington's Water Quality Standards, Sediment Management Standards (SMS), and other applicable laws and regulations. Washington's SMS establish sediment quality standards for marine surface sediments, sediment source control standards with which point source discharges must comply, and an antidegradation policy (WAC 173-204-120, -300 through -350, and –400 through –450). Sediment quality criteria for marine surface sediments include criteria establishing maximum concentrations of specified chemical pollutants, biological effects criteria, and criteria for benthic abundance (WAC 173-204-320). A NPDES permit may only be issued to WGHOGA for the use of imidacloprid if such use, as conditioned, will comply with all applicable Sediment Management Standards.

No sediment mitigation measures would be required for the utilization of mechanical and shellfish culture methods under Alternative 1, unless a violation(s) of the water quality laws and regulations occurred.

Under Alternative 2, mitigation measures included in the new or modified NPDES individual permit for the use of carbaryl would likely be the same or similar to those in Permit No. WA0040975. A Sediment

Impact Zone (SIZ) would be established in accordance with WAC 173-204-415 and WAC 173-204-420. Compliance with the NPDES permit conditions would mitigate significant adverse impacts on sediments.

Applicators would be required to follow all pesticide label instructions to prevent spills on unprotected soil. A Spill Control Plan would be prepared to address the prevention, containment, and control of spills or unplanned releases and would describe the preventative measures and facilities that would avoid, contain, or treat spills of carbaryl. It would also list all oil and chemicals used, processed, or stored at the facility that may be spilled into State waters (if any). The plan would be reviewed at least annually and updated as needed. In the event of a spill, applicators would be required to follow spill response procedures outlined in the NPDES individual permit and the Spill Control Plan. The permit conditions would restrict the aerial application of carbaryl to conditions when the wind speed is 10 miles per hour (mph) or less, and only to shellfish beds that are exposed by the outgoing tide.
Under Alternative 3, the NPDES individual permit for the use of imidacloprid would only be issued if appropriate conditions were imposed to achieve compliance with the Washington State Water Quality Standards and SMS. These conditions would mitigate potential significant adverse impacts on sediments and benthic organisms. The permit would likely require conditions similar to those included in the carbaryl NPDES individual permit to ensure compliance with applicable regulatory standards.

Applicators would be required to follow all pesticide label instructions to prevent spills on unprotected soil. Similar to Alternative 2, a Spill Control Plan would be prepared to implement Alternative 3 that would address the prevention, containment, and control of spills or unplanned releases and would describe the preventative measures and facilities that would avoid, contain, or treat spills of imidacloprid. It would also list all oil and chemicals used, processed, or stored at the facility which may be spilled into State waters (if any). The plan would be reviewed at least annually and updated as needed. In the event of a spill, applicators would be required to follow spill response procedures outlined in the NPDES individual permit and Spill Control Plan. The FIFRA Registrations for imidacloprid restrict aerial applications to conditions when the wind speed is 10 mph or less, and may allow application to beds covered by the outgoing tide (i.e., with a granular form of imidacloprid). These restrictions would help ensure no significant adverse impacts to sediments outside of planned treatment areas.

SIGNIFICANT UNAVOIDABLE ADVERSE IMPACTS

Based on currently available information and studies, and requirements to comply with the conditions of all applicable pesticide registrations, permits and regulations (including the Washington State Water Quality Standards and SMS), no significant unavoidable adverse impacts to sediments would be expected with the proposed action (Alternative 3: imidacloprid applications with IPM), or with Alternative 2 (carbaryl applications with IPM). The requested Ecology NPDES permit, if issued, would include sediment monitoring requirements to confirm the effects of pesticide applications. Adjustments to permit conditions could be made during the 5-year term of the permit.

3.2.2 Air Quality

AFFECTED ENVIRONMENT

The nation's air emissions are regulated by the U.S. Environmental Protection Agency (EPA) under the Clean Air Act, as amended in 1990. EPA established the National Ambient Air Quality Standards (NAAQS) which set the amount of criteria pollutants that can be emitted into the air by stationary sources. The criteria pollutants are carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter, and sulfur dioxide. These standards form a baseline from which to gauge air pollutant emissions across the country in order to gain an understanding of current air quality and to design efforts to improve on it.

The Washington State Clean Air Act (RCW 70.94) also regulates air quality. The act is administered both at the State level (Ecology), and by local clean air agencies at the regional level (e.g., the Olympic Region Clean Air Agency).

Ecology maintains a network of air quality monitoring stations throughout the State. These stations are placed in areas where air quality problems are most likely to occur, usually in or near urban areas or close to large air pollution sources. A limited number of additional stations are located in remote areas to provide an indication of regional background air pollution levels.

Based on monitoring information collected over a period of years, EPA and Ecology designate regions as being attainment or nonattainment areas for regulated air pollutants. Attainment status indicates that air quality in an area meets the Federal, health-based ambient air quality standards; nonattainment status indicates that air quality in an area does not meet those standards. If the measured concentrations in a nonattainment area improve to levels consistently below the Federal standards, Ecology and EPA can reclassify the nonattainment area to a maintenance area. In that case, Ecology and the local clean air agency are required to implement maintenance plans to ensure ongoing emission reductions and continuous compliance with the Federal standards.

3.2.2.1 *Willapa Bay*

There are no major industrial sources of air pollution around the Willapa Bay estuary. The predominant onshore winds and winter storms ensure an almost constant circulation of air from the Pacific Ocean. Temperature inversions that might trap smoke or other pollutants are rare in this area (USDI/USFWS 1997). Willapa Bay meets all NAAQS standards, as well as the more stringent State standards set for total suspended solids and sulfur dioxide.

3.2.2.2 *Grays Harbor*

The ambient air quality in Grays Harbor is generally good with few sources of pollution. Those sources are primarily local automobiles, local fishing vessels, a local pulp mill, and ocean-going commercial cargo vessels. These sources of air pollution are minor compared to the size of the Grays Harbor airshed. To the north and east, logging and lumber mill operations produce air pollution, but this and other air pollution generated in the vicinity is moved out of the area by the prevailing winds from the southwest (Corps of Engineers, Seattle District 2011). Grays Harbor meets all NAAQS standards, as well as the more stringent State standards set for total suspended solids and sulfur dioxide.

POTENTIAL IMPACTS

Under Alternative 1 (No Action – No Permit for Pesticide Applications), there would be gasoline or diesel exhaust emissions to the air associated with the transport and operation of mechanical and shellfish culture equipment if these methods were used to attempt to control burrowing shrimp on commercial shellfish beds within Willapa Bay and Grays Harbor shellfish beds. If manual methods of burrowing shrimp removal were used during harvest, emissions associated with the transport of workers to and from the estuary would be attributable primarily to shellfish culture and harvest rather than to burrowing shrimp control. There may be a small increase in emissions due to mechanical control but this could potentially be offset by reduced emissions from not spraying. Therefore, emissions associated with the No Action Alternative would constitute essentially no change in existing air quality conditions in the area.

Under Alternative 2 (Continue Historical Management Practices – Carbaryl Applications with Integrated Pest Management), gasoline or diesel exhaust emissions to the air would depend on the method of carbaryl application (helicopter, backpack sprayer, or all-terrain vehicles equipped with a single hand nozzle or boom sprayer), and travel to/from application sites. In either case, vehicle exhaust emissions associated with trips to/from shellfish beds for carbaryl applications 5 to 10 days per season would not significantly increase emissions to the air or adversely affect air quality in the Willapa Bay and Grays Harbor areas due to consistent, wind circulation.

Carbaryl has a mild odor and appears white to beige in its liquid suspension. Most or all applications would be made away from the public and during periods of low wind. Therefore, it is unlikely that the odor would be detectable to off-site observers.

Carbaryl is considered to be non-volatile, but slightly toxic by inhalation. There should be little to no inhalation exposure to the applicator during aquatic applications of carbaryl. The pesticide registration requires personal protective gear including a coverall over long-sleeved shirt and long pants, shoes and socks, protective eyewear, respirator or dust mask, chemical-resistant headgear, and chemical-resistant gloves. Carbaryl would be applied on private tidelands that are, for the most part, located well away from public gathering places; therefore, there should be little to no risk of exposure to the public or other bystanders.

Emissions to the air under Alternative 3 (Imidacloprid Applications with IPM) would be slightly higher than with Alternative 2, as there is potential for a larger number of acres to be treated with imidacloprid than with carbaryl. Trips associated with imidacloprid applications would be added to existing trips for shellfish rearing and harvest activities. Boat application of imidacloprid, if approved and used, would also contribute to emissions. Similar to Alternative 2, emissions associated with Alternative 3 would not be expected to impair attainment of air quality standards.

Both the flowable (Protector 2F) and granular (Protector 0.5G) forms of imidacloprid have only a slight odor and most or all applications would be made away from the public and during periods of low wind. Therefore, it is unlikely that the odor would be detectable to off-site observers.

Protector 2F is considered to be non-volatile, but slightly toxic by inhalation. Protector 0.5G is also considered to be non-volatile and is relatively non-toxic by inhalation. There should be little to no inhalation exposure to the applicator during aquatic applications of either formulation. The pesticide label does not require any personal protective gear other than a long-sleeved shirt and long pants, shoes and socks, protective eyewear, dust mask (Protector 0.5G only), and chemical-resistant gloves when applying Protector 0.5G and Protector 2F. Imidacloprid would be applied on private tidelands normally located well away from public gathering locations; therefore, there should be little to no risk of exposure to the public or other bystanders.

MITIGATION MEASURES

No air quality mitigation measures would be required for the utilization of mechanical or shellfish culture methods to control burrowing shrimp under Alternative 1.

Under Alternative 2, it would be the responsibility of the applicator to select appropriate application equipment and treat commercial shellfish beds only during appropriate environmental conditions when wind speed, temperature, and tidal elevation would minimize the risk of spray drift, to avoid off-target dispersion. The Carbaryl NPDES Permit No. WA0040975 states that wind speeds must be less than 10 mph (ECY 2006b); therefore, it is likely that aerial applications would be limited to periods with little or no wind to limit off-site drift. In addition, the carbaryl registration would require the use of a respirator or dust mask by all handlers of carbaryl. It would be a violation of the FIFRA label and the NPDES individual permit for the applicator to not follow label directions.

A new or modified NPDES individual permit used to implement Alternative 2 would specify public notice procedures to be implemented by WGHOGA to limit and prevent human exposure during carbaryl applications. Assuming that public notice procedures would be the same or similar to those in the 2006 carbaryl permit (WA0040975), the Annual Operations Plan would identify locations to be posted with signs at public and privately-owned access points to tidelands where commercial shellfish beds would be treated. In addition, property owners within 200 feet of treatment sites would be notified in person, by telephone, or by mail at least 24 hours (but not more than ten days) prior to commencement of initial carbaryl application to commercial shellfish beds. All notifications would include the name of the pesticide to be used, where it is to be applied, any public health and livestock restrictions, and the name and phone number of the WGHOGA contact person. Notification would continue at a frequency of no less than once per month until carbaryl application was completed for the season. Announcements would be placed in area newspapers and signs would be placed at all reasonable points of public access to proposed treatment areas. Electronic media public service announcements, handbills, mailings to adjacent landowners, or any combination of the above may be used in addition to newspaper and sign notification (ECY 2006b). All notifications will be made in compliance with NPDES permit requirements, and other applicable SMS requirements under WAC 173-204-415(2)(e).[3]

Under Alternative 3, it would be the responsibility of the applicator to select appropriate application equipment and treat commercial shellfish beds only during appropriate environmental conditions when wind speed, temperature, and tidal elevation would minimize the risk of spray drift, to avoid off-target dispersion. The FIFRA Registrations for Protector 0.5G and 2F (No. 88867-1 and 88867-2, the granular and flowable forms of imidacloprid, respectively) state that average wind speed at the time of application is not to exceed 10 mph (USEPA 2013a and USEPA 2013b). In addition, the FIFRA Registration for Protector 0.5G requires the use of a dust mask by all handlers of imidacloprid. It would be a violation of the FIFRA label and the proposed NPDES individual permit for the applicator to not follow label directions.

To help prevent human exposure, the proposed NPDES individual permit required to implement Alternative 3 would require public notification the same as or similar to the measures listed in the FIFRA Registrations for Protector 2F and 0.5G (USEPA 2013a and 2013b). All public access areas within one-quarter mile radius of any bed scheduled for treatment would be posted with a sign, or signs would be posted at 500-foot intervals at those access areas more than 500 feet wide. Signs would be posted at least 2 days prior to aerial treatment and would remain for at least 30 days after treatment (USEPA 2013a and 2013b). In addition, WGHOGA proposes to use a website for public notification of specific dates of proposed imidacloprid applications in Willapa Bay and Grays Harbor. The website would include a link for interested persons to request direct notification regarding proposed treatment dates and locations. The WGHOGA Integrated Pest Management (IPM) Coordinator would send e-mail notification to registered interested parties, as needed.[4]

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3 If a new Sediment Impact Zone (SIZ) were defined to implement Alternative 2, Ecology would make a reasonable effort to identify and notify all landowners, adjacent landowners, and lessees affected by the SIZ in accordance with WAC 173-204-415(2)(e). This notification would be in addition to the public notice requirements for chemical applications for which WGHOGA would be responsible.

4 If a SIZ is defined to implement Alternative 3, Ecology would make a reasonable effort to identify and notify all landowners, adjacent landowners, and lessees affected by the SIZ in accordance with WAC 173-204-415(2)(e). This

SIGNIFICANT UNAVOIDABLE ADVERSE IMPACTS

Based on currently available information and studies, and requirements to comply with the conditions of all applicable pesticide registrations, permits and regulations, no significant unavoidable adverse impacts to air quality would be expected with the proposed action (Alternative 3: imidacloprid applications with IPM) or with Alternative 2 (carbaryl applications with IPM). Pesticide applications for the control of burrowing shrimp would be implemented in compliance with FIFRA Registration restrictions and NPDES permit conditions that specify appropriate application equipment and spray drift management techniques to avoid or minimize off-target exposures. FIFRA Registration and NPDES permit conditions also include public notification requirements to inform landowners, adjacent landowners, lessees, interested individuals, recreational users and others of proposed application dates and locations so that potential direct exposure could be avoided.

3.2.3 Surface Water

AFFECTED ENVIRONMENT

3.2.3.1 Willapa Bay

The Willapa Basin consists of six watersheds: the North, Willapa, Palix, Nemah, Naselle, and Bear Watersheds. The drainage basin is approximately 1,865 km^2 (720 square miles) in area. The main tributaries to Willapa Bay are the North, Willapa, and Naselle Rivers. The Palix River is a minor contributor to the mean daily runoff. Riverine input has a significant influence on circulation and water exchange in Willapa Bay (Jennings et al. 2003 as cited in ENVIRON 2012).

The relatively shallow bay has approximately 45,000 acres exposed at low tide with much of the remaining surface area, except for channels, covered by 1 to 6 feet of water. It consists of three main channels 10 to 20 meters (32.8 to 65.6 feet) deep, surrounded by extensive tidal flats (Banas et al. 2004). The tide is mixed-semidiurnal and tidal levels in the bay vary from 14 to 16 feet (Banas et al. 2004; Banas et al. 2007). The range from mean higher high water to mean lower low water is approximately 11.5 feet (Banas et al. 2007). During a complete tidal cycle, about 45 percent of the water in the bay is exchanged into the Pacific Ocean (NMFS, April 28, 2009). Willapa Bay opens to the Pacific Ocean at its northwestern corner through a broad, shallow pass about 6 miles wide between Cape Shoalwater and Leadbetter Point (see Figure 2.4-1 in FEIS Chapter 2).

River input and ocean water properties are highly correlated with atmospheric conditions on seasonal and event scales (Banas et al. 2007). In the summer, coastal upwelling is driven by southward large-scale winds, bringing cold, salty, nutrient-rich water, and coastal phytoplankton blooms into the estuary (Hickey and Banas 2003; Banas et al. 2007). In general, riverflow and terrestrial inputs of nutrients to Willapa Bay are very low in comparison to tidal circulation, especially in the summer, but rivers may provide some nutrients during the winter and spring (Ruesink et al. 2003). Therefore, Willapa Bay acts more like an unstratified, riverless tidal lagoon than a partially-mixed estuary (Banas et al. 2004).

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notification would be in addition to the public notice requirements for chemical applications for which WGHOGA would be responsible.

Willapa Bay is generally considered to be among the most biologically productive estuaries of the Pacific Coast of the United States. Unpolluted water and good circulation account for this productivity and resulting commercial and recreational benefits (WDF and ECY 1992). Principal water quality parameters are shown in Table 3.2.3-1.

Table 3.2.3-1. Willapa Bay water quality parameters (WDF and ECY 1992).

Feature	**Range of Values**
Temperature	3° C to 20.4° on the Willapa River; 7.2° C to 17.4° C at Toke Point; high of 21.4° C at the WDF Shellfish Laboratory at Nahcotta.
Dissolved Oxygen	Generally above 6 mg/L; occasionally levels of 5 mg/L are recorded in the Willapa River; usual summer levels are 6 to 8 mg/L.
Salinity	Ranges from 7.5 parts per trillion (ppt) on the surface to 25 ppt at 20 feet at the same time and place; salinities near the entrance to the Bay are 30 ppt or more.
Turbidity	2 to 30 JTU in the open bay, with averages of 6.6 JTU on the surface and 8.0 JTU at 20 feet.

Sediment porewater in the Willapa Bay marine intertidal mudflats where imidacloprid would be applied has a pH range from 7.3 to 7.6 (ENVIRON 2012).

The Ruesink Lab describes Willapa Bay as “chemically pristine but biologically transformed.” There are low levels of industrial pollutants, bacterial loads, and nutrient runoff—advantages of a low human population density on the land surrounding the bay combined with high tidal flushing. Sediment runoff from poor logging practices in the early 1900s probably occurred, but the impacts are not well documented. Pesticides used by cranberry farmers have been found in runoff, but have not been traced to the bay (University of Washington, March 19, 2013). The waters of Willapa Bay are generally designated as Category 1[5] by Washington State Surface Water Quality Standards; however, there are multiple locations classified as Category 2, 3, 4A, and 5, indicating low to moderate levels of water quality impairment. The parameters in question are temperature, dissolved oxygen, fecal coliform bacteria, and carbaryl (ECY 2012 303(d) listings).

Two types of pesticides have been used to control pest and weed species in Willapa Bay. The insecticide carbaryl (trade name Sevin brand 4F) has been applied to commercial shellfish beds for the control of burrowing shrimp since 1963. And the herbicides glyphosate (trade names Accord Concentrate, AquaMaster, AquaNeat, Glypro, and Rodeo) and imazapyr have been used to eradicate the invasive species smooth cordgrass *Spartina alterniflora* (University of Washington, March 19, 2013).

The growth and condition of Pacific oysters and estuarine biota in Willapa Bay are partially influenced by the influx of nutrients from upwelling of cold oceanic waters that are well-documented features of the southern Washington Coast (Banas et al. 2004). In the summer, phytoplankton biomass and production in Willapa Bay are high near the mouth and low in the interior. This causes rapid depletion of nutrients and a decline in phytoplankton biomass in the estuary (Banas et al. 2007). Studies have shown that the intertidal benthic grazers in Willapa Bay can account for most of the loss of phytoplankton biomass. It has been

5 Waters that meet State standards for clean waters.

suggested that cultivated Pacific oysters are likely a significant consumer in the phytoplankton budget of the bay (Banas et al. 2007).

Incidences of coastal upwelling are frequent but unpredictable. El Niño events may periodically interfere with this upwelling, reducing the nutrients in the bay, and reducing phytoplankton production as a result. These events are related to extraordinary meteorological changes in equatorial weather involving a significant weakening of the trade winds. This causes the sea water to warm and the sea level to rise over large areas of the Pacific. One manifestation of an El Niño in the northeast Pacific is an extended period of warmer water (+1 to +2° Centigrade) off the coast (Reed 1984 as cited in WDF and ECY 1985). This warmer water inhibits cold water upwelling which limits the amount of nutrients available to nearshore and estuarine biota. It was observed that populations of burrowing shrimp increased in Willapa Bay following the 1982 and 1957–58 El Niño events (WDF and ECY 1985).

3.2.3.2 Grays Harbor

Grays Harbor is a shallow, bar-built estuary, approximately centrally located on the West Coast of Washington, north of Willapa Bay (see Figure 2.3-1 in FEIS Chapter 2). Depths average less than 20 feet, with depths at the entrance reaching a maximum of 80 feet. The navigation channel is dredged annually to a depth of 30 feet. Freshwater inputs to Grays Harbor are attributed to the Chehalis, Hoquiam, Wishkah, Humptulips, Johns, and Elk River systems with a combined drainage basin area of approximately 2,550 square miles. The Chehalis River provides approximately 80 percent of the freshwater input to Grays Harbor (NMFS, April 28, 2009).

The three corners of Grays Harbor are defined by North Bay which receives the waters of the Humptulips River; South Bay into which the Elk and Johns Rivers flow, and East Bay (Aberdeen) into which the Chehalis River flows. At mean higher high water (MHHW), Grays Harbor is approximately 54,708 acres in size (ECY 1983, as cited in WDF and ECY, June 1985). Approximately 34,460 acres are exposed at low tide (NMFS, April 28, 2009).

Grays Harbor differs from Willapa Bay in several important aspects, including geography, water quality, the extent of oyster cultivation, the presence of a larger human population, and the presence of heavy industry. Pacific oyster culture in Grays Harbor is limited to North Bay and South Bay and the immediate vicinity of these bays because water quality is unsuitable for shellfish culture in the eastern area of the harbor. Principal water quality parameters are shown in Table 3.2.3-2.

Table 3.2.3-2. Grays Harbor water quality parameters (ECY 2007a).

Feature	Range of Values
Temperature	10.3 to 18.8° C
Dissolved Oxygen	Generally below 7.3 mg/L
Salinity	Ranges from 26 to 33 practical salinity units (psu)[6], with 20 psu at the mouth of the Chehalis River.

The Grays Harbor estuary is a partially mixed system in which tides dominate over river flows, causing nearly complete mixing of fresh water and salt water. During summer months, the low freshwater inflow and the large estuary volume contribute to poor circulation in the central portion of the bay (ECY 1983, as

[6] Practical salinity units (psu) are approximately equal to parts per thousand (ppt). PSU’s are used in modern oceanography as the recognized, preferred units for salinity measurement.

cited in WDF and ECY, June 1985). Most of Grays Harbor water is clean with little contamination. However, there is some contamination, especially in the lower Chehalis River near Cosmopolis. This area is approximately 16 miles from the commercial shellfish beds in North Bay and South Bay, near the entrance to (west end of) the harbor (see Figure 2.4-2 in FEIS Chapter 2). The waters of Grays Harbor are generally designated as Category 1 by Washington State Surface Water Quality Standards; however, there are two locations classified as Category 2 and one location classified as Category 5. The parameters in question are ammonia-N, temperature, copper (inner harbor), and fecal coliform (Corps of Engineers, Seattle District 2011).

On June 9, 1989, Ecology listed eight pulp mills as violating water quality standards for the priority pollutant TCDD, a dioxin. At that time, the Weyerhaeuser Paper Company (in Cosmopolis) and ITT Rayonier (in Hoquiam) were discharging to inner Grays Harbor. Their effluent and sludge contained measurable quantities of dioxin. Dioxins are common by-products of a number of human and natural activities, including combustion and incineration, forest fires, chlorine bleaching of pulp and paper, certain types of chemical manufacturing and processing, and other industrial processes. Dioxins are of concern because they are toxic contaminants that last a long time in the environment and can build up in aquatic organisms, becoming more concentrated as they move through the food chain. Ecology developed a total maximum daily load (TMDL)[7] for inner Grays Harbor that set a waste load allocation for dioxin discharged into the water body. EPA approved this TMDL in June 1992 (Ecology TMDL projects summary, January 22, 2014).

Grays Harbor has also been listed under Section 303(d) of the Federal Clean Water Act as not meeting water quality standards for fecal coliform bacteria because of inadequate control of point or non-point sources. Fecal coliform is a type of bacteria common in human and animal waste. It can make people sick and cause the closure of shellfish harvesting beds. Bacteria can enter water bodies from untreated or partially treated discharges from wastewater treatment plants, from improperly functioning septic systems, and from livestock, pets and wildlife. Fecal coliform enters Grays Harbor from a variety of dischargers, including the municipal sewage treatment plants in the cities of Aberdeen, Hoquiam, Ocean Shores, and Westport (Ecology TMDL projects summary, January 22, 2014).

Shellfish growers in the outer harbor experience temporary closures at times due to violations of fecal coliform discharge limits in existing point source permits. Limited sampling data also indicate that non-point sources of fecal coliform may be a concern in outer areas of Grays Harbor. Fecal coliform contributions were also traced to the Chehalis River due to stormwater runoff, as well as Grass Creek, Johns River, and the City of Grayland. Non-point contributions, possibly from on-site sewage disposal (OSSD) systems and farm operations, were also found during a shoreline survey conducted by the Washington State Department of Health in 1994 (Ecology TMDL projects summary, January 22, 2014).

Ecology conducted a fecal coliform study in Grays Harbor in 2000, after which it developed a TMDL report in 2001. Waste load allocations (WLA) for fecal coliform bacteria were determined for rivers and creeks that discharge to Grays Harbor, and for the Weyco pulp mill. EPA approved the TMDL with the amended WLA in January 2004 (Ecology TMDL projects summary, January 22, 2014).

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7 TMDL is a calculation of the maximum amount of a pollutant that can be present in a water body segment and still allow attainment of water quality standards, and an allocation of that amount to the point sources of the pollutant. The TMDL takes into account critical conditions such as high and low flows and seasonal variations in water quality. The waste load allocation in a TMDL is implemented through NPDES permits to point source dischargers. There is no Federal regulatory requirement to implement the allocation to non-point sources of the pollutant (EP National Water Quality Assessment Report, http://www.epa.gov/waters/ir/attains_q_and_a.html).

The Washington State Department of Health (DOH), Office of Shellfish and Water Protection, is responsible for providing sanitary control of molluscan shellfish (oysters, clams, and mussels). The program works closely with Tribes, local health jurisdictions, volunteer groups, State and Federal agencies and commercial shellfish growers. A key component of this program is Growing Area Classification. There are two Classified Growing Areas within Grays Harbor County: Grays Harbor (the Bay), and the Pacific Coast (North Beach). Recreational and commercial razor clam harvest protection is vital to the local and State economy (Grays Harbor County, June 2012).

The Grays Harbor Marine Resources Committee (MRC), affiliated with the Washington Sea Grant Program, serves the community by providing technical assistance and educational activities to commercial and sports fishermen, seafood processors and retailers, fish and shellfish growers, coastal planners, marina operators, recreational boaters, teachers, students, and others who use, manage, or simply enjoy the marine resources of the area. The MRC conducts water quality sampling projects in Grays Harbor, the current focus of which is on ocean acidification and harmful algal blooms. A similar MRC has been established for Willapa Bay.

Ocean acidification, generally described as the reduction of pH in marine waters, is the result of increased levels of atmospheric carbon dioxide (CO_2). Increased atmospheric CO_2 results in more CO_2 in ocean waters where it leads to reductions in pH. According to the National Oceanic and Atmospheric Administration (NOAA) Pacific Marine Environmental Laboratory, oceanic pH levels (surface water) have dropped from 8.21 to 8.10 since the industrial revolution. Deeper waters tend to have even lower pH levels, so that when deep water is brought to the surface during coastal upwelling, more significant reductions in pH can result. A reduction in pH constitutes an increase in acidification, which can lead to detrimental impacts to many marine species; specifically, those that rely on calcification to grow shells or body structures, like shellfish. Recent research has identified the larval stage of bivalves as highly vulnerable, because acidic waters can lead to the death of developing larvae (Grays Harbor County MRC). Because this can lead to a reduction in wild or hatchery production of shellfish, commercial shellfish growers buffer the seawater in their hatchery operations to counteract the effect.

During 2009 water quality monitoring at the Westport station, northerly winds created coastal upwelling events that pushed low pH, low dissolved oxygen (DO), and low temperature waters into the Grays Harbor estuary. These values moderated by the time the water reached sampling stations in North Bay and South Bay. From the limited dissolved CO_2 numbers observed in 2009, Grays Harbor had not yet at that time demonstrated corrosive or low pH in commercial shellfish growing areas. Additional sample collections were planned in subsequent years (Grays Harbor County MRC).

The Pacific Shellfish Institute (PSI) conducted water quality sampling in Grays Harbor in 2009 and 2010 for comparison with oyster larval recruitment and spatfall (settling of oyster larvae), open-ocean water quality and upwelling events (PSI, April 2011). Field sampling locations were situated in remote sites in North Bay (at Lone Tree Oyster facility along the Campbell Slough), and in South Bay (at Brady's Oyster facilities on the Elk River channel). YSI water quality sondes (data loggers) were placed near the entrance to the harbor at the U.S. Coast Guard Westport station to monitor incoming and outgoing waters at a 1 m (approximately 3-foot) depth, collecting continuous dissolved oxygen (DO), pH, salinity, temperature, oxidation reduction potential (ORP) and chlorophyll data. YSI data at the Westport station displayed a heavily oceanic influence where pH dropped as temperature decreased and salinity increased during the summers of 2009 and 2010. This was directly attributed to coastal upwelling events spurred by north winds.

Water samples were collected weekly at the North Bay and South Bay sites for bacteria, nutrients, DO and CO_2/pH during peak incoming tides. CO_2/pH data collected at these two Grays Harbor sites in 2010 displayed variations over time. In North Bay, omega aragonite levels[8] closely followed salinity trends: when salinity levels increased (i.e., when saltwater inflow into the bay was stronger), so did omega aragonite levels. When local river discharges of freshwater dropped off near the end of June, salinities and omega aragonite values started to increase at North Grays Harbor. South Grays Harbor displayed similar results but the trends were not as strong (PSI, April 2011).

During both 2009 and 2010, DO data indicated differences between the North Bay and South Bay stations, where South Bay exhibited a stronger oceanic influence. When upwelling events occurred, DO levels dropped noticeably in South Bay but not in North Bay. This trend was also observed in salinity and temperature measurements taken at these sites; salinity was consistently lower and temperature was consistently higher in North Bay. Overall, DO values were never low enough for concern at these locations (PSI, April 2011). This is likely due to the shallow and generally well-mixed water, and strong tidal exchange with the Pacific Ocean.

Increases in nutrient levels above natural levels can result in excessive plant and algae growth, a process called eutrophication. Grays Harbor and Willapa Bay have a low to moderate risk of eutrophication (PSAT 2007, as cited in USFWS, March 24, 2009). This is due, in part, to the high tidal flushing of both estuaries. Nutrient data did not exhibit consistent trends with water quality data or setting success of shellfish larvae during 2009 and 2010, although ammonium, silicate, and nitrate levels did consistently increase with increasing fresh water input to North Bay and South Bay of Grays Harbor (PSI, April 2011).

POTENTIAL IMPACTS

Under Alternative 1 (No Action – No Permit for Pesticide Applications), there would be localized occurrences of turbidity and sediment destabilization if mechanical methods of burrowing shrimp control were utilized It is unlikely that this increase in turbidity would cause an exceedance of State water quality standards because of the shallow water depth, naturally relatively turbid water, and the intertidal environment that goes dry during low tides. If alternative shellfish culture methods were used, such as bag culture or long-line culture, potential impacts to surface water quality may include the introduction of anthropogenically-derived waste such as plastics, mesh bags, wires, stakes, and long lines that may become dislodged during storm events.

Under Alternative 2 (Continue Historical Management Practices – Carbaryl Applications with Integrated Pest Management), carbaryl and the degradation byproducts of carbaryl would continue to enter Willapa Bay and Grays Harbor following summer treatments of commercial shellfish beds. Carbaryl would be expected to dissipate given previous studies showing rapid photolytic degradation,[9] and dilution of carbaryl (WDF and ECY 1992). The major degradation product of carbaryl is 1-naphthol, which does not undergo further hydrolysis[10] (USEPA 2003). Studies have shown that carbaryl degrades rapidly to 1-naphthol under artificial sunlight, with a half-life of five hours. The compound 1-naphthol has a half-life of less than one hour under the same conditions (Armbrust and Crosby 1991).

[8] Omega aragonite values are a means to quantify how likely aragonitic calcium carbonate is to dissolve or precipitate. The lower the omega aragonite value, the harder it is (i.e., the more energy it takes) to form a shell using aragonitic calcium. This is thought to be especially detrimental to oyster larvae which depend more on this type of calcium during their development (Burke Hales, personal communication, as cited in PSI, April 2011). Frequently, when CO_2 values increase, pH values drop and so does omega aragonite. As a rough rule, when omega aragonite values are below 1, oyster larvae have a decreased chance of survival (PSI, April 2011).

[9] Photolysis or phytolytic degradation = chemical breakdown in the presence of sunlight.

[10] Hydrolysis = chemical breakdown through reaction with water.

Research conducted in 1985–1986 followed the incoming tide and measured carbaryl concentrations at the leading edge of the water plume. By sampling this first flush of the sprayed area, it is possible to essentially follow the same water mass through time. Results of these tests found that, once an area is inundated by the tide, carbaryl concentrations appear to persist for only about 20 to 30 minutes (Tufts 1990 in WDF and ECY 1992). A different study found that carbaryl concentrations are detected in water above treated plots 24 to 48 hours after spraying, but were undetectable 30 days after spraying (Moore and Tuft 2011 and 2012). A Federal review found that carbaryl is frequently detected in water up to 4 days after spraying, and can be transported several miles from the application site (USEPA 2003). Carbaryl that is carried off treated beds by the incoming tide can sometimes be found at higher concentrations off the treated plot than on the treated areas (WDF and ECY 1992).

The direction of carbaryl transport would be dependent upon the topography of the plots being sprayed. For example, a bed with a steady gradient will flood from the lowest to highest points, and carbaryl would be transported away from adjacent subtidal channels (WDF and ECY 1992). However, the flooding of a plot also depends upon currents (wind-driven and tidal), and irregular elevations (WDF and ECY 1992). The effects of wind-driven currents on carbaryl transport should be minimal since permit requirements under a new or modified NPDES individual permit would specify that carbaryl could only be sprayed when wind speeds are less than 10 mph, similar to the restrictions in the current permit.

Overall, the rapid hydrolysis of carbaryl in estuarine environments and considerable dilution from successive tides suggests that under Alternative 2 carbaryl would dissipate rapidly from treatment sites (WDF and ECY 1992), and would meet current water quality standards, established in the permit, for acute concentrations of carbaryl within 48 hours after treatment. In addition, any inputs of carbaryl would be limited to a short period each year, and to only small acreages of the total overall area of each estuary: approximately 1.3 percent of total tideland acres within Willapa Bay, and approximately 0.6 percent of total tideland acres in Grays Harbor (see FEIS Chapter 2, Section 2.8.2). Ecology has historically permitted the use of carbaryl under an NPDES permit with conditions to ensure compliance with applicable regulatory standards.

Under Alternative 3 (Imidacloprid Applications with IPM), imidacloprid and the degradation byproducts of imidacloprid would enter Willapa Bay and Grays Harbor following treatments of commercial shellfish beds on approximately 1,500 acres *per year* within Willapa Bay, and approximately 500 acres *per year* within Grays Harbor. These applications could occur between April 15 through December 15 (see FEIS Chapter 2, Section 2.8.3). Hydrolysis, photolysis, sediment, and microbial degradation would be the primary means of imidacloprid breakdown in aquatic environments. Factors such as water chemistry, temperature, adsorption to the sediment, water currents, and dilution can all have significant effects on the persistence of imidacloprid (CSI 2013). Laboratory studies have shown that the half-life of imidacloprid at pH 5 and 7[11] can be greater than one year, while the half-life of imidacloprid at pH 9 is approximately one year (CSI 2013). Other laboratory studies of photodegradation of imidacloprid in freshwater suggest that imidacloprid has a half-life of approximately 4.2 hours in water and quickly degrades under natural sunlight (CSI 2013). Further laboratory experiments have had varied results, with one showing a half-life of 129 days (Spiteller 1993 as cited in CSI 2013) and the other 14 days (Henneböle 1998, cited in CSI 2013). Imidacloprid that is not degraded by environmental factors would be subject to dilution through tidal flows in the estuaries.

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[11] The pH of seawater tends to range from 7.5 to 8.4.

Studies have shown that imidacloprid has eight degradation products as a result of hydrolysis, photolysis, and soil and microbial degradation. These degradation products include: imidacloprid-olefin, 5-hydroxy-imidacloprid, imidacloprid-nitrosimine, imidacloprid-guanidine, imidacloprid-urea, 6-chloronicotinic acid, imidacloprid-guanidine-olefin, and acyclic derivative. The toxicity levels of all the degradation products are equal to or lower than the toxicity of the parent compound (SERA 2005).
Site-specific studies have been conducted to assess the transport and persistence of imidacloprid in surface water. Studies were conducted in Willapa Bay in 2012 (Grue and Grassley 2013; Hart Crowser 2013) to quantify the concentrations of imidacloprid in the water column, sediment, and sediment porewater. The scope of these trials was to describe the SIZ that could be associated with the commercial use of imidacloprid for the control of burrowing shrimp. A SIZ is the area where the applicable State sediment quality standards of WAC 173-204-320 through 173-204-340 are exceeded due to ongoing permitted or otherwise authorized wastewater, storm water, or nonpoint source discharges (WAC 173-204-200). This study was also designed to measure one of the degradation products of imidacloprid: imidacloprid-olefin.

Study sites for the 2012 commercial-scale experimental trials conducted in Willapa Bay were selected with specific criteria in mind. Study site criteria included ownership by a Willapa-Grays Harbor Oyster Growers Association (WGHOGA) member; adequate densities of burrowing shrimp; adequate distance from previous or planned applications of carbaryl on commercial shellfish beds (>0.5 mile); no previous applications of carbaryl within the past 20 years, if ever (personal communication with Dr. Kim Patten, WSU Pacific County Extension Director, May 29, 2014); accessibility; and desirable characteristics of elevation, vegetation, and substrate that are similar to commercial shellfish beds and that were consistent within the study area. In addition, treatment and control plots had to be adequately separated to prevent cross contamination (>500 meters). All treatment and control plots were 7 to 10 acres in size, and treatments on those plots did not show significant environmental impacts. Treatment on a 10 acre plot provides data that can be extrapolated to larger plots. The 2014 experimental use of imidacloprid occurred on larger plots, thus providing additional data on environmental impacts over larger plot sizes. Both the granular (Mallet) and flowable (Nuprid) formulations of imidacloprid were used in these trials. A screening criteria of 3.7 ppb was used to determine when surface water samples indicated a potential for negative biological effects. Flowable imidacloprid was sprayed on treatment plots that were exposed from an outgoing tide. Granular imidacloprid was applied to treatment plots with 0.5 to 3 feet of water on them during an outgoing tide. Samples were collected prior to and approximately 2 hours following application of imidacloprid.

Water column samples were collected within each treatment plot, as well as at 60, 120, 240, and 480 meters (197, 394, 787, and 1,575 feet) from the plot edge on the upstream and downstream side of the plot. When drainage channels were present, samples were taken in the drainage channels at distances mentioned above. Water samples were collected from the leading edge of the incoming tide, in water depths of 10 centimeters or less. This water sampling approach was designed to provide data on the maximum concentration of imidacloprid, off site, before significant dilution from incoming tide waters occurred.

Maximum concentrations of imidacloprid were detected in drainage channels associated with flowable imidacloprid (4,200 ppb at 60 m). These concentrations dissipated to 120 ppb at 480 m. Based on the study design, it was expected that the highest concentrations of flowable imidacloprid would be found in the drainage channels. In contrast, granular imidacloprid concentrations were much lower 2 hours after application. Only 2 of 13 samples were above the quantitation limits and both were below 1.0 ppb.

The results of the water column sampling showed that many off-site locations upstream of the treatment area were found to have at least some concentration of imidacloprid. Outside of the drainage channels, flowable imidacloprid concentrations reached a maximum of 900 ppb, with concentrations as high as 200 ppb still present at a distance of 480 m. However, other samples showed little imidacloprid in surface water off-site of the plots sprayed with flowable imidacloprid. Granular imidacloprid concentrations reached a maximum of 130 ppb at a distance of 60 m and no concentrations above the screening criteria at further distances. The average olefin detection was 1.8 percent of the corresponding imidacloprid measure. Olefin concentrations ranged from 0.08 to 3.6 ppb.

Imidacloprid dissolves readily in surface water and moves off treated areas with incoming tides and in drainage channels. As the data above show, this may allow imidacloprid to impact non-treated areas through surface water conveyance, particularly as tide waters first pass over off-plot areas. However, as tide waters continue to flow onto off-site areas, imidacloprid is expected to dilute significantly and rapidly, a process that would continue through successive tidal cycles. Accordingly, imidacloprid in water is expected to have a low potential to cause ecological impacts in non-target areas.

MITIGATION MEASURES

No surface water mitigation measures would be required for the utilization of mechanical and shellfish culture methods of burrowing shrimp control under Alternative 1.

Alternative 2 could occur under the current administratively extended NPDES Permit or could require issuance of a new or modified NPDES permit, under which mitigation measures and discharge monitoring would be required to ensure compliance with all applicable laws, registrations, and permit conditions. These mitigation measures and monitoring requirements would mitigate potential significant adverse impacts (WAC 197.11.660[e]); additional mitigation would not be required through SEPA. Compliance with applicable laws, including the Clean Water Act and Washington State Water Quality Standards would mitigate potential significant impacts to water quality.

Under Alternative 2, a new or modified NPDES individual permit for the use of carbaryl would likely require similar mitigation measures to those in NPDES Permit No. WA0040975, such as acreage limitations and thresholds. Effluent limitations have been determined for carbaryl, with an acute limit of 3.0 micrograms per liter (μg/L) and a chronic limit of 0.06 μg/L. The discharge of carbaryl authorized by an NPDES permit would be limited to waters of the State of Washington. There would be no construed authority to discharge carbaryl to tidelands on the Shoalwater Indian Reservation.

Discharge monitoring would be required to determine residual concentrations of carbaryl within the application area. Specific sampling and background locations would be associated with the general areas of treatment in a given year. Water samples would be taken within 48 hours after application within the spray site. Further samples would be taken within the spray site approximately 30 days after treatment. In addition, one drift sample would be taken downwind and off-site of the spray area. Surface water samples would be taken as close to the sediment/water interface as possible. Monitoring data would be prepared by a laboratory registered or accredited under the provisions of WAC 173-50. An Annual Discharge Monitoring Report will be required.

Applicators would be required to follow all pesticide label instructions for the use of carbaryl to prevent spills on unprotected water. A Spill Control Plan would be prepared to address the prevention, containment, and control of spills or unplanned releases and would describe the preventative measures and facilities that will prevent, contain, or treat spills of carbaryl. It would also list all oil and chemicals used, processed, or stored at the facility that may be spilled into State waters. The plan would be reviewed at least annually and updated as needed. In the event of a spill, applicators would be required to follow spill response procedures outlined in the NPDES individual permit and the Spill Control Plan. The permit conditions would restrict the aerial application of carbaryl so that it would not be applied close to sloughs, channels, or shellfish that are within one year of harvest. The distance from these areas would be 200 feet for helicopter applications and 50 feet for hand-sprayer applications. Carbaryl would be applied only to beds that are uncovered by an outgoing tide.

Under Alternative 3, a NPDES individual permit for the use of imidacloprid would contain conditions and restrictions to ensure compliance with all applicable laws protecting water quality. The permit would likely require similar mitigation measures to those included in the carbaryl NPDES individual permit (described above). Additional guidance on mitigation measures can be obtained from the EPA registration requirements for the use of imidacloprid. If the proposed NPDES permit is issued by Ecology, it would include appropriate conditions and restrictions to ensure compliance with applicable regulatory standards to address water quality impacts. The discharge of imidacloprid authorized by an NPDES permit would be limited to waters of the State of Washington; specifically, to the waters of Willapa Bay and Grays Harbor for the purpose of burrowing shrimp control on commercial shellfish beds. If issued, this permit would not allow a discharge to tidelands on the Shoalwater Indian Reservation.

Discharge monitoring and data reporting would be required under the NPDES individual permit for the use of imidacloprid (USEPA 2013a and 2013b). The imidacloprid water quality monitoring plan would take into account the treatment plan proposed, and current information regarding this proposal would be used to condition the permit.

Applicators would be required to follow all pesticide label instructions for the use of imidacloprid to prevent spills on unprotected water. A Spill Control Plan would be prepared to address the prevention, containment, and control of spills or unplanned releases and would describe the preventative measures and facilities that would prevent, contain, or treat spills of imidacloprid. It would also list all oil and chemicals used, processed, or stored at the facility that may be spilled into State waters. The plan would be reviewed at least annually and updated as needed. In the event of a spill, applicators would be required to follow spill response procedures outlined in the NPDES individual permit and the Spill Control Plan. The FIFRA Registrations for the flowable and granular formulations of imidacloprid (Protector 2F and Protector 0.5G, respectively) recommend that a properly designed and maintained containment pad be used for mixing and loading imidacloprid into application equipment. If a containment pad is not used, a minimum distance of 25 feet should be maintained between mixing and loading areas and potential surface to groundwater conduits (USEPA 2013a and 2013b).

The NPDES permit conditions would include FIFRA Registration conditions that restrict the aerial application of imidacloprid so that it would not be applied close to slough channels or shellfish that are within 30 days of harvest. A 100-foot buffer zone would be maintained between the imidacloprid treatment area and the nearest shellfish to be harvested within 30 days when treatment was by aerial spray. A 25-foot buffer would be required if treatment was by hand spray if the nearest shellfish bed is to be harvested within 30 days. Aerial applications of imidacloprid must be made to beds exposed at low tide. Protector 0.5G applications made from a floating platform or boat may be applied to beds under water using a calibrated granular applicator (USEPA 2013a and 2013b).

SIGNIFICANT UNAVOIDABLE ADVERSE IMPACTS

Based on currently available information and studies, and requirements to comply with the conditions of all applicable pesticide registrations, permits and regulations (including Washington State Water Quality Standards), no significant unavoidable adverse impacts to surface water quality would be expected with the proposed action (Alternative 3: imidacloprid applications with IPM) or with Alternative 2 (carbaryl applications with IPM). The requested Ecology NPDES permit, if issued, would include conditions that limit the maximum annual tideland acreage for pesticide applications; specify treatment methods; require buffers from sloughs, channels, and shellfish to be harvested; and require discharge monitoring to evaluate the effects of applications. Adjustments to permit conditions could be made during the five-year term of the permit.

3.2.4 Plants

AFFECTED ENVIRONMENT

3.2.4.1 *Willapa Bay*

Plankton (Microalgae). Phytoplankton, also called microalgae, are single-celled organisms that exist in nearly every body of water. There are tens of thousands of different known species around the world. They are responsible for approximately 50 percent of the earth's oxygen production. Marine phytoplankton are the primary food source in the ocean and form the base of the food web for nearly all marine life. Most phytoplankton are harmless. Some, however, at times produce chemical compounds that can be toxic to other life forms in the food web, such as fish, shellfish, marine mammals, and seabirds. Harmful algal blooms (HABs) have increased in frequency, spatial distribution, and magnitude around the world. Harmful algal blooms can cause a wide range of serious health issues in mammals and birds, even death. This is often a result of eating fish or shellfish in which the toxins have bioaccumulated (Grays Harbor County MRC, January 22, 2014).

The phytoplankton community in Willapa Bay is made up of diatoms, dinoflagellates, and microflagellates (Coastal Resources Alliance 2007). These algae are an important source of food for clams, oysters, and zooplankton (WDF and ECY 1992). Diatoms are a particularly important food source for shellfish.

Eelgrass. One of the largest eelgrass meadows in the Pacific Northwest occurs in the protected estuarine waters of Willapa Bay. Hedgpeth and Obrebski (1981, as cited in USDI/USFWS 1997) describe an eelgrass community as "a whole system of growth, catchment of detritus, support of microbial associations, source of oxygen by day and deprivation by night, the mainstay of small Crustacea, and modifier of current and sedimentation patterns and nutrient regimes." Wyllie-Echeverria and Hershman (1994, as cited in USDI/USFWS 1997) listed six major functions of eelgrass from Wood et al. (1969): 1) stabilize bottom sediments; 2) slow and retard current, prompt sedimentation, and inhibit resuspension of organic and inorganic matter; 3) provide shelter and substrate (for other organisms); 4) provide grazing (especially for migratory waterfowl) and detrital food pathways; 5) support high productivity; and 6) cycle nutrients internally. In Willapa Bay, the native *Z. marina* generally occurs in the lower intertidal and subtidal, limited by desiccation stress in the upper elevations and lack of light penetrating the water column due to turbidity at lower elevations (Selleck, et al., 2005).

Another eelgrass species, the non-native eelgrass (*Zostera japonica*), also occurs with *Zostera marina* in Willapa Bay. Characterized as morphologically smaller and faster growing (Ruesink et al. 2010), the non-native *Z. japonica* is generally abundant on the middle to upper intertidal mudflats. It is listed as a Class C noxious weed in Washington State (Washington State Noxious Weed Control Board, January 2013). Some Washington shellfish growers, predominantly those farming in Willapa Bay, report that *Z. japonica* is interfering with shellfish production (particularly Manila clam culture). *Z. japonica* forms dense populations that reduced clam condition (meat weight per clam on tide flats (Tsai 2010). The extensive root and rhizome network as well as the foliage interfere with the cultivation and harvest of shellfish (personal communications with WGHOGA members 2011; and Fisher Bradley and Patten 2011). Ecology has issued a NPDES general permit for the use of chemical applications of imazamox to control the growth and spread of *Z. japonica* on commercial clam beds in Willapa Bay. Refer to the Final

Environmental Impact Statement: Management of *Zostera japonica* on Commercial Clam Beds in Willapa Bay, Washington for more information http://www.ecy.wa.gov/programs/wq/pesticides/eelgrass/docs/03262014ZjFeis.pdf.

Native Saltmarsh Vegetation. Based on 2003 data, 84 square miles of Willapa bay are intertidal and intermittently vegetated with salt marsh species (Coastal Resources Alliance 2007). Native saltmarsh vegetation in what is considered the low marsh (nearest the low-tide line) includes pickleweed (*Salicornia depressa*), jaumea (*Jaumea carnosa*), saltgrass (*Distichlis spicata*), and seaside arrowgrass (*Triglochin maritimum*) (USFWS 2011). Vegetation within high saltmarsh zones include alkali grass (*Pucinella spp.*), tufted hairgrass (*Deschampsia caespitosa*), sandspurry (*Spergularia spp.*), Pacific silverweed (*Potentilla pacifica*), and saltmarsh bulrush (*Scrirpus maritimus*) (Sayce 1993 and Zipperer 1996, as cited in USDI/USFWS 1997, USFWS 2011). There are about 500 acres of native saltmarsh on the Willapa National Refuge (multiple locations within Willapa Bay). Salt marsh vegetation occurs from +1 foot to +12 feet of mean lower low water (MLLW) with more dense vegetation typically starting at +4 feet MLLW and above (Patten et al., 2005).

Spartina Marsh Vegetation. Similar to *Z. japonica*, *Spartina* (cordgrass) may have been introduced to the West Coast as packing material for oyster shipments, *Spartina* coming from the East Coast in the 1890s (Frenkle and Kunze 1984, as cited in USDI/USFWS 1997). *Spartina* may have also been intentionally planted to create a blind for waterfowl hunting, or to help prevent shoreline erosion on State or Federal lands. Historic files located at the Pacific County Historical Society Museum contain a sales brochure in which *Spartina* was advertised for sale for use in creating waterfowl hunting blinds[12]. Typical of Pacific Northwest estuaries, the geologically-young Willapa Bay with its relatively high tidal range has characteristically large expanses of mudflats that are susceptible to *Spartina* invasion. By the mid-1990s, *S. alterniflora* in Willapa Bay reached a level qualifying as the largest *Spartina* infestation in the State of Washington (Washington State 1993, as cited in USDI/USFWS 1997). The rate of spread of *Spartina* is geometric; that is, the quantity of growth each year increases based on the increased amount of *Spartina* from the previous year. In 1945, 4.5 acres of *Spartina* were present; 432 acres in 1982; 2,400 acres in 1990 (Marks 1995, as cited in USDI/USFWS 1997); and 4,700 acres in 1996. Stiller and Denton (1995, as cited in USDI/USFWS 1997) noted that at the expansion rates occurring in the mid-1990s, *Spartina* would, without effective management, occupy most of the intertidal habitat in Willapa Bay within 40 years.[13] As of 2013, eradication efforts had reduced *Spartina* distribution to an approximate combined area of less than a few acres with single plants now spread over a large area of the estuary (Washington State Department of Agriculture 2012).

3.2.4.2 *Grays Harbor*

Grays Harbor has similar marine flora to that described above in Willapa Bay including plankton, eelgrass, and emergent salt marsh species. These flora occur at the same approximate elevations as those described in Willapa Bay.

Plankton (Microalgae). The Draft EIS for the *Grays Harbor Estuary Management Plan* (ECY 1983) reported that the predominant vegetation on Grays Harbor mudflats was epibenthic green and blue-green algae with diatoms dominating the phytoplankton.

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12 Wildlife Nurseries and Game Farm, Oshkosh, Wisconsin brochure: *How to Attract and Hold Game*.

13 The *Spartina* expansion estimate reflects an unmanaged condition. The U.S. Department of the Interior, Fish and Wildlife Service (USFWS) implemented a long-term integrated pest management approach in the late 1990s to eradicate *Spartina alterniflora* on Willapa National Wildlife Refuge and surrounding tidelands in Willapa Bay.

Marine Algae. Macroalgae distribution is limited by availability of stable hard substrate (e.g., logs, roots, boulders, oyster shell) for attachment (ECY 1983). ECY found no attached vegetation in Grays Harbor and epibenthic algal production was low on bare sandflats. The Washington Department of Fisheries and Washington State Department of Ecology (1985) reported the presence of 29 species of marine algae in Grays Harbor in the early 1980s. Among the most abundant and conspicuous algae were three species of green algae (*Enteromorpha* (now *Ulva*) spp.), a brown algae (*Fucus distichus*), and two red algae (*Polysiphonia hendryi* and *Porphyra sanjuanensis*), and a complex of filamentous diatoms. While no comparable information was found for Willapa Bay, marine algae populations in the bay are likely comparable to those described in Grays Harbor.

Eelgrass. The Washington State Department of Fisheries and Washington State Department of Ecology (1985) reported that eelgrass was present throughout the Grays Harbor estuary below Aberdeen in the early 1980s, at tidal elevations between –3 feet and +6 to +7 feet MLLW. There were two species of eelgrass identified at that time: native eelgrass (*Zostera marina*) and European eelgrass (*Z. noltii*, as reported in the Draft EIS for the Grays Harbor Management Plan, ECY 1983). A large area in western North Bay around Oyhut Channel, and another between Point New and Hoquiam was designated an area of marine biological significance (AMBS) for *Z. marina* in the early 1980s (Gardner 1981, as cited in WDF and ECY 1985) (see Figure 2.4-2 in FEIS Chapter 2). It was later recognized that all previously identified *Z. noltii* sightings along the Pacific coast of North America are actually *Z. japonica* (Wyllie-Echeverria and Ackerman 2003). More recently, Fisher Bradley and Patten (2011) list specific locations of the occurrence of the non-native *Z. japonica* in bays and estuaries along the Washington coast, including within Grays Harbor.

The Draft Environmental Assessment for Grays Harbor maintenance dredging and disposal reported that the abundance of eelgrass has been decreasing in recent years. In addition, the movement of shoals results in eelgrass displacement as substrate is alternately created and destroyed (Corps of Engineers, Seattle District 2011).

Tidal Marsh Vegetation. Extensive tidal marsh areas occur from the central portion of the Grays Harbor estuary below Aberdeen throughout North Bay and South Bay. These marsh areas bordered much of the harbor and occupied approximately 4,800 acres in the early 1980s (WDF and ECY 1985). The Grays Harbor National Wildlife Refuge protects approximately 1,500 acres of intertidal mudflats, saltmarsh, and uplands (USACE 2014). The Draft Environmental Assessment for Grays Harbor maintenance dredging and disposal reported that there is some emergent vegetation along the shoreline of the harbor, but much of the shoreline is occupied by commercial enterprises and private homes. Shoreline aquatic vegetation is often removed or damaged by property owners (Corps of Engineers, Seattle District 2011).

POTENTIAL IMPACTS

Under Alternative 1 (No Action − No Permit for Pesticide Applications), only mechanical treatment of burrowing shrimp and alternative shellfish culture methods would occur. Mechanical disturbance of oyster and clam beds would temporarily affect the flora within the treatment areas including the microalgae and the upper elevations of eelgrass (both *Z. japonica* and *Z. marina*), and saltmarsh species in their lower elevation locations. Mechanical methods are not as effective as pesticides at decreasing burrowing shrimp populations, so that untreated areas would be affected by burrowing shrimp over time. Burrowing shrimp disturb the sediment and can inhibit or reduce eelgrass growth and density (Dumbauld and Wyllie-Echeverria 2003; Hosack et al. 2006). One study comparing the density and growth of *Z. japonica* in burrowing shrimp areas treated by carbaryl and those left untreated found a statistically significant drop in density (21 shoots per m^2 in the treated areas versus 14 shoots per m^2 in untreated areas).

Mechanical methods of burrowing shrimp control (e.g., boats grounding on mudflats, harrowing, raking and other activities) would have localized and temporary effects on marine and salt marsh vegetation. For example, fragmentation of roots and rhizomes of seagrasses that occurs with hand-pulling results in re-growth within 1 to 2 years (Ruesink et al. 2012). Harrowing and other forms of mechanical removal of burrowing shrimp disrupt the foliage and tear loose a percentage of root and rhizome structure. The damaged plants are suppressed for a period of time before re-growth, often changing morphology to account for the energetic loss (Ruesink et al. 2012). Plant seeds may germinate during the same or following season. Roots, rhizomes and seeds disrupted in one location can be distributed by the tide to other sites, potentially enhancing dispersion of affected plants. This could be a concern for potentially spreading non-native species. Dumbauld and McCoy (2009) quantified impacts of oyster aquaculture on eelgrass and reported only a minor decline of 0.01 percent or 0.44 hectares based on data from 2005 to 2009.

Salt marsh vegetation would be disturbed and/or damaged to a limited extent during shellfish harvest as a result of workers either walking or driving to shellfish harvesting sites or from boats grounding onto the mudflats. The effects of harvesting on salt marsh would be localized and temporary. Access paths for workers are typically established in set locations to minimize trampling and damaging salt marsh vegetation and if used frequently, could permanently suppress plant growth in these pathways.

Under Alternative 2 (Continue Historical Management Practices – Carbaryl Applications with Integrated Pest Management), the effects of carbaryl applications on estuarine plants would be localized and temporary. The degree of toxicity of carbaryl to marine vegetation varies considerably (WDF and ECY 1985). Some marine plants and algae are growth-inhibited by carbaryl, while others are not affected. Marine algae are likely inhibited immediately after spraying, until carbaryl concentrations decrease to less than 1.0 ppm (WDF and ECY 1985). Cole and Plapp (1974 cited in WDF and ECY 1985) found carbaryl weakly inhibited the growth of *Chlorella* sp. (a single-celled green marine algae) at concentrations of 1 ppm. Christie (1969) found that *Chlorella* growth was continuously inhibited at carbaryl concentration of 6 ppm. Ukeles (1962) found that growth of two of five phytoplankton species was inhibited at 1 ppm of carbaryl, but growth resumed in carbaryl-free water.

Carbaryl is not known to be accumulated by any component of the food web, nor is it transmitted to higher levels in the food chain. It rapidly breaks down in the water column to 1-naphthol, continuing to breakdown to carbon dioxide and water (Karinen et al. 1967). Therefore, planktonic algae would only be affected temporarily.

Epibenthic algae that are present on or in sediment may be exposed for longer periods than algae in the water column. The Sediments section of the FEIS (Chapter 3, Section 3.2.1) describes the residence time of carbaryl in sediment. Studies conducted in Yaquina Bay, Oregon (Karinen et al. 1967) and Willapa Bay, Washington (ECY 1999) found that carbaryl was present in sediments at concentrations of 80 to 200 ppb 42 days after spraying (application rate of 10 lbs/acre) and at 105 ppb, 60 days after spraying (application rate of 7.51 lbs/acre). Studies have also been conducted in Willapa Bay showing the carbaryl concentrations in mud declined from 1,100 ppb to 600 ppb in 4 days, and to 100 ppb after 8 days, at an application rate of 10 lbs/acre (Sayce 1970). Carbaryl and its degradation products were not detectable 16 days after treatment. Epibenthic algae growth would likely be inhibited at carbaryl concentrations of 1 ppm or greater for up to 16 days, which is the length of time that carbaryl has been determined to persist in sediments. (Cole and Plapp 1974 cited in WDF and ECY 1985; Ukeles 1962)

Salt marsh vegetation would be disturbed and/or damaged to a limited extent during shellfish harvest as a result of workers either walking or driving to shellfish harvesting sites or from boats grounding onto the mudflats. The effects of harvesting on salt marsh would be localized and temporary, as described above under Alternative 1.

Under Alternative 3 (Imidacloprid Applications with IPM), the application of imidacloprid may have localized, temporary, and negligible impacts on plants within Willapa Bay and Grays Harbor. Imidacloprid is a systemic insecticide that is taken up from the soil (or sediments) by plants and is present in the foliage of plants. However, this is based on the limited information available regarding imidacloprid impacts to marine vegetation, as discussed below.

While imidacloprid would be applied to areas with high populations of burrowing shrimp on commercial shellfish beds only, research also indicates that imidacloprid can move off-site rapidly in surface water and can be detected at least 480 meters (1,575 feet) away from the application site. Earlier research conducted by Felsot and Ruppert (2002) showed that imidacloprid dissipated rapidly in marine waters, but was detectable in sediments for longer periods of time. Sediment porewater concentrations of imidacloprid were also examined and researchers found that imidacloprid was almost undetectable 56 days after application (Grue and Grassley 2013). Rooted plants such as eelgrass and salt marsh plants could uptake the insecticide in these areas, though field trials described below show limited uptake of imidacloprid in Willapa Bay eelgrass species. Also, if applicators failed to employ effective spray drift management techniques, imidacloprid might stray from the application zone to adjacent aquatic or shoreline plants that are occasionally inundated by tidal waters.

No studies were available to assess the toxicity of imidacloprid to marine algae. Freshwater data indicate that algae are at least three orders of magnitude less sensitive to imidacloprid than many insect and crustacean species (CCME 2007).

Studies of imidacloprid uptake by plants have been restricted to uptake of imidacloprid by eelgrass. Imidacloprid was found in eelgrass tissue one day after application; however, it degraded and was undetectable 14 days after application (Grue and Grassley 2013; Hart Crowser 2013).

Experimental trials aimed at determining efficacy, environmental fate and transport, and the biological effects of imidacloprid on non-target species were performed in 2012 under an Ecology-approved Sampling and Analysis Plan (Hart Crowser 2012). The following screening values and laboratory quantitation limits were used to determine acceptable levels of imidacloprid in various samples: (1) surface water, 3.7 ppb (screening value); (2) sediment, 6.7 ppb (laboratory quantitation limit); (3)sediment porewater, 0.6 ppb (screening value); and (4) eelgrass tissue, 10 ppb (laboratory quantitation limit).

Eelgrass (*Z. marina* or *Z. japonica*) samples were collected within and outside of the treatment plots prior to treatment, and 1, 14, and 28 days post-treatment. Detection of imidacloprid at levels above the laboratory quantitation limit (10 ppb) was found only on the first day post-treatment, with a maximum concentration of 120 ppb. Seven out of 20 eelgrass samples had detectable concentrations of imidacloprid on that first day post-treatment (Grue and Grassley, 2013; Hart Crowser 2013).

Eight imidacloprid degradation products have been identified as products of imidacloprid hydrolysis, photolysis, and soil and microbial degradation. One of these products, imidacloprid-olefin, was analyzed during 2012 research efforts (Grue and Grassley 2013; Hart Crowser 2013). Imidacloprid-olefin was found only in surface water, sediments, and sediment porewater; it was undetectable in eelgrass tissue.

There appears to be limited uptake of imidacloprid by eelgrass. Patten et al. (2011b) reported that eelgrass became established quickly on bare plots treated with 0.4 and 0.5 lb a.i./acre (active ingredient per acre), indicating that eelgrass is capable of rapid growth when burrowing shrimp are reduced. According to Compliance Services International (2013), testing has been conducted on several indicator plant species showing that imidacloprid exhibits low toxicity to terrestrial and freshwater and marine aquatic plants. This is supported by field information indicating limited uptake by eelgrasses on treated shellfish beds. In addition, imidacloprid is an acetylcholinase inhibitor and plants do not have a biochemical pathway involving acetylcholinase, therefore it is unlikely that imidacloprid would affect eelgrass. Based on targeted applications, it is likely that exposure to other estuarine plants would be negligible.

Salt marsh vegetation would be disturbed and/or damaged to a limited extent during shellfish harvest as a result of workers either walking or driving to shellfish harvesting sites or from boats grounding into the mudflats. The effects of harvesting on salt marsh would be localized and temporary, as described above under Alternative 1.

MITIGATION MEASURES

Mitigation measures for plants may be required for mechanical or shellfish culture methods to address potential spread of non-native species while attempting to control burrowing shrimp under the No Action Alternative (Alternative 1).

Mitigation measures for Alternative 2 would include limiting carbaryl application areas and timing restrictions. For the purpose of environmental review, the EIS assumes that current methods for the aerial application of liquid carbaryl under NPDES Permit WA0040975 would likely continue, including limiting these applications to periods of wind less than 10 mph. The carbaryl label describes treatment mitigations to reduce spray drift to avoid potential impacts to off-site, non-target plants. It would be the responsibility of the applicator to select appropriate application equipment and treat only during appropriate environmental conditions (wind speed, temperature, tidal elevation) to avoid off-target dispersion. It would be a violation of the FIFRA Section 24(c) Special Local Need registration and the NPDES individual permit for the applicator to not follow label directions.

A 200-foot buffer would be required around sloughs and channels when carbaryl is applied by helicopter, and a 50-foot buffer would be required if carbaryl applications were to be administered on the ground or by boat.

The 2006 NPDES individual permit (WA0040975) limits carbaryl applications to only 600 acres *per year* in Willapa Bay (1.3 percent of total tideland acres), and only 200 acres *per year* in Grays Harbor (0.6 percent of total tideland acres) during the period July 1 through October 31. However, the area of application has been reduced over time due to a Settlement Agreement between WGHOGA and other parties. The very small proportion of tidelands treated each year since 2005[14] in Willapa Bay (approximately 420 acres of 45,000 acres total) and Grays Harbor (approximately 140 acres of 34,460 acres total) leaves vast tideland acreage untreated in each bay. Also in 2005, carbaryl was administered predominantly in the form of liquid spray dispersed by helicopter over 5 to 10 days on extreme low tides during July and August of each year. If a new or modified NPDES permit were issued for the use of carbaryl under Alternative 2, maintaining small application areas for these short periods would be effective at minimizing potential impacts to plants.

14 WGHOGA reduced the tideland acreage treated in Willapa Bay and Grays Harbor from 800 acres in 2002 to 720 acres in 2003, then to 640 acres in 2004, and to not more than 560 acres in 2005 in accordance with the terms of a Settlement Agreement with the Washington Toxics Coalition and the Ad Hoc Coalition for Willapa Bay (April 28, 2003). The Washington State Department of Ecology is not a party to the Settlement Agreement; therefore, the NPDES permit authorizing the use of carbaryl is not bound by the terms of the Settlement Agreement.

Applicators would be required to follow all pesticide label instructions for the use of carbaryl to prevent spills on unprotected soil and vegetation. A Spill Control Plan would be prepared to address the prevention, containment, and control of spills or unplanned releases and would describe the preventative measures and facilities that would prevent, contain, or treat spills of carbaryl.

Under Alternative 3, WGHOGA proposes to implement measures over time to minimize the frequency and quantity of imidacloprid applications necessary for the effective control of burrowing shrimp. Small concentrations of imidacloprid have been found in eelgrass for limited periods of time (Grue & Grassley 2013; Hart Crowser 2013). Therefore, the number of imidacloprid treatments and the level of concentration applied should be minimized where and when feasible. Imidacloprid could be dispersed by granular formulation or flowable spray, from a helicopter, by boat, or by hand-held equipment. Imidacloprid would be administered off-shore during periods of low wind, and during outgoing tides or over water. Aerial dispersal would be minimized to also limit exposure of imidacloprid to flowering terrestrial plants. It is an element of the WGHOGA proposal for the use of imidacloprid to avoid aerial applications within 200 feet of the Ordinary High Water Line (OHWL).

Similar to Alternative 2, applicators under Alternative 3 would be required to follow all pesticide label instructions for the use of imidacloprid to prevent spills on unprotected soil and vegetation. FIFRA Registration restrictions (USEPA 2013a and 2013b) would restrict the aerial application of imidacloprid to conditions when the wind speed is 10 mph or less, but may allow application to beds covered by an outgoing tide (i.e., with a granular form of imidacloprid). Further, imidacloprid could only be used pursuant to a NPDES permit, which would contain terms and conditions to ensure compliance with all applicable regulatory standards. The permit conditions would mitigate probable significant adverse impacts to plants.

A Spill Control Plan would be prepared to address the prevention, containment, and control of spills or unplanned releases, and would describe the preventative measures and facilities that will prevent, contain, or treat spills of imidacloprid.

The FIFRA Registrations (USEPA 2013a and 2013b) establish a series of application methods and spray drift management techniques that would minimize the risk of exposure of imidacloprid to non-target species. For the granular form of imidacloprid (Protector 0.5G), average wind speed at the time of application would not exceed 10 mph to minimize drift to adjacent shellfish beds and water areas when applied by air. This would minimize the potential for exposure to terrestrial habitats and plants. Applications would also not occur during temperature inversions. Applications would be made at the lowest possible height (helicopter, ground, or barge) that is safe to operate and that would reduce exposure of the granules to wind. When applications of the granular form of imidacloprid (Protector 0.5G) are made crosswind, the applicator would compensate for displacement by adjusting the path of the application equipment upwind. Swath adjustment distance should increase with increasing drift potential. For the flowable form of imidacloprid (Protector 2F), applicators would avoid and minimize spray drift by following detailed instructions on the FIFRA Registration label, including measures to control droplet size, making applications at the lowest possible height (helicopter, ground driven spray boom) that is safe and practical and reduces exposure of droplets to evaporation and wind, applying during appropriate wind speeds and avoiding temperature inversions, and using authorized application methods and equipment.

SIGNIFICANT UNAVOIDABLE ADVERSE IMPACTS

Based on currently available information and studies, and requirements to comply with the conditions of all applicable pesticide registrations, permits and regulations, no significant unavoidable adverse impacts to estuarine or terrestrial plants would be expected with the proposed action (Alternative 3: imidacloprid applications with IPM) or with Alternative 2 (carbaryl applications with IPM). FIFRA Registration specify spray drift management techniques and the requested Ecology NPDES permit, if issued, would include conditions that specify treatment methods; require buffers from sloughs and channels; and require discharge monitoring. Adjustments to permit conditions could be made during the 5-year term of the permit.

3.2.5 Animals

AFFECTED ENVIRONMENT

3.2.5.1 *Willapa Bay*

Willapa Bay and the associated watershed has diverse wildlife resources. Seventeen species of amphibians and reptiles, 51 species of mammals, and more than 200 species of birds (resident and migratory) are known to use Willapa National Wildlife Refuge lands and associated waters (U.S. Fish and Wildlife Service 1991, as cited in USDI/USFWS 1997). The *NEPA Environmental Assessment for Control of Smooth Cordgrass* (Spartina alterniflora) *on Willapa National Wildlife Refuge* (USDI/USFWS 1997) and three other sources were reviewed to obtain descriptions of existing vertebrate and invertebrate animals that use Willapa Bay (WDF and ECY 1992; ENVIRON International Corporation 2012; and Compliance Services International (CSI) 2013).

Zooplankton. Zooplankton, planktonic animals, include the larvae of many benthic organisms, as well as species that are planktonic their entire lives. Dungeness crab (*Cancer magister*) larvae appear in the Willapa Bay zooplankton in the spring; other zooplankton include molluscan larvae (oyster and clam) and copepods (WDF and ECY 1992).

Benthic Invertebrates. Benthic invertebrates in Willapa Bay are limited to epibenthic and infauna species that are tolerant of wide variations in salinity and temperature. The distribution of these species is also dependent upon sediment and substrate type. Several polychaete worm species are common in the mud and silt bottoms of the bay. A wide range of arthropods (shrimp, crabs, amphipods, cumaceans, and mysids) are found throughout intertidal and subtidal soft-sediment habitats. Blue mussels (*Mytilus edulis*) and barnacles are common on solid surfaces such as rocks, piling, and oyster shell. More prominent benthic invertebrate groups are covered in the following sections.

Burrowing Shrimp. Two species of burrowing shrimp are indigenous to Willapa Bay and Grays Harbor: ghost shrimp (*Neotrypaea californiensis*) and mud shrimp (*Upogebia pugettensis*). These shrimp-like crustaceans live in the sediments of these two bays, constructing and maintaining extensive burrow complexes. The general biology, feeding behavior and burrows, reproduction and recruitment, and interaction of burrowing shrimp with other tide flat organisms is described above in FEIS Section 3.1, Biological Background Information.

Ghost shrimp and mud shrimp (collectively referred to as “burrowing shrimp”) are predominantly filter feeders (MacGinitie 1930), competing for phytoplankton and zooplankton resources important to bivalves and other estuarine fauna. Mud shrimp excavate and live inside U-shaped burrows that can range from 10 to 20 inches (250 to 500 mm) deep or more, and can extend up to 3 feet (approximately 1 m) across the mudflat surface, adversely affecting habitat for other benthic organisms (Dumbauld 1994). Ghost shrimp burrow through the sediments constantly to feed, moving large quantities of sediment to the surface (Milne et al. 2002), disrupting the structure of the mudflat substrate by resuspending fine sediments, and fluidizing the sediment surface which causes surface dwelling organisms to sink into the mud (Peterson 1977; Brenchley 1981; Bird 1982; Posey et al. 1991; Dumbauld 1994; and Tamaki 1994).

Burrowing shrimp are gregarious and resilient organisms that can recruit back to areas where they had been completely eliminated (WDF and Ecology 1992; Brooks 1995; Simenstad and Fresh 1995). The detrimental effects of high densities of burrowing shrimp to the rest of the estuarine community have also been demonstrated by the return of higher levels of diversity and key indicator species following the suppression of burrowing shrimp (Dumbauld and Wyllie-Echeverria 1997). For the Pacific oyster, bioturbation associated with burrowing shrimp may interfere with suspension feeding (Rhoads and Young 1970) and surface-deposit feeding (Tamaki 1988), may initiate small-scale emigration of settling larvae (Tamaki 1988), or may bury recent larval recruits (Swinbanks and Luternauer 1987). Burrowing shrimp have also been documented to negatively affect or exclude seagrass communities (Suchanek 1983).

Ecology estimates that there are 15,000 to 20,000 acres of Willapa Bay tidelands dominated by burrowing shrimp (ECY 2006, as cited in CSI 2013).

Clams and Oysters. Commercial shellfish within Willapa Bay include four cultured species and five wild species. Pacific oyster (*Crassostrea gigas*), Kumamoto oyster (*Crassostrea sikamea*), Manila clam (*Ruditapes philippinarum*), and geoduck (*Panopea generosa*) are cultured by shellfish growers. The bay also supports wild stocks of the native Olympia oyster (*Ostrea lurida*), the cockle (*Clinocardium nuttallii*), softshell clam (*Mya arenaria*), native little neck (*Protothaca staminea*), and cherrystone clams (*Mercenaria mercenaria*) (ENVIRON 2012, with input from WGHOGA members).

Approximately 25,562 acres of tidelands are owned or leased for commercial shellfish aquaculture within Willapa Bay (NMFS, April 28, 2009) (see Figure 2.4-1 in FEIS Chapter 2). Of these, approximately 9,000 acres are currently farmed for the commercial production of oysters and clams (CSI 2013).

Oyster culture has traditionally been the principal marine fishery in Willapa Bay. The Willapa Bay wild Dungeness crab fishery is also an important fishery for Pacific County (WDF and ECY 1992).

Dungeness Crab. The Final EIS for Use of the Insecticide Sevin to Control Ghost and Mud Shrimp in Oyster Beds of Willapa Bay and Grays Harbor (WDF and ECY 1985) describes characteristics of the Dungeness crab (Metacarcinus magister) population and fishery along the Washington coast. Information presented below is summarized from that document. Willapa Bay also supports a recreational crab fishery for Dungeness crab and red rock crab (Cancer productus) from December 1 through September 15.

The Washington Dungeness crab fishery is the State's largest crustacean fishery. Landings reported in the early 1980s were around 7.7 million pounds annually (about 80 percent of which occurred along the Washington coast), and in 2011 were around 8.75 million pounds. Only male crabs are harvested. The minimum harvestable size is 6 inches across the back (carapace),[15] which is typically a 4-year old crab. The abundance of crab is highly variable, tending to follow about a 10-year up and down cycle. The life span of a Dungeness crab varies between 8 to 13 years.

Dungeness crab breed offshore in the open ocean. After hatching, larval development takes from 4 to 6 months. Six successive stages (five zoea and one megalopa) occur before the crabs molt into the first juvenile stage. These crabs increase in size with each molt or instar stage. Following the zoeal stages,

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[15] http://wdfw.wa.gov/fishing/shellfish/crab/4 (Willapa Bay) and http://wdfw.wa.gov/fishing/shellfish/crab/5 (Grays Harbor).

many of the megalopae (final planktonic larval stage) are carried inshore by tidal and wind-driven currents and enter estuaries in the spring, from April to June. Many older juveniles (age 1+) and some adult crab also re-enter the estuary. The larval crab settle and begin to function in the life style of an adult crab. Young-of-the-year crab grow rapidly in the estuaries over the following summer and early fall, reaching approximately 30 to 40 mm (approximately 1 to 1.5 inches) in carapace width. During the first two years both sexes grow at similar rates, but after two years the female crabs grow more slowly than the males. Most of these young crab apparently return to the ocean in the late fall to overwinter in warmer ocean waters. Others may stay in the estuaries, buried in the sediment and overwintering in a dormant state (Armstrong et al. 1984, as cited in WDF and ECY 1985).

Population levels of juvenile Dungeness crab within the Willapa Bay and Grays Harbor estuaries vary considerably by season and by year depending upon oceanographic and biologic conditions. There is a 9 to 10-year cycle for Dungeness crab populations (Armstrong et al. 1989), which fluctuate between successful larval recruitment on the outer coast and inside Willapa Bay and Grays Harbor. Studies also show that crab abundance is highly dependent upon substrate type (Armstrong et al. 1984, as cited in WDF and ECY 1985). For example, no young-of-the-year crab were found on bare sand or mud, while the highest abundances were found among oysters, clams, and eelgrass (Dumbauld et al 1993). Armstrong et al. (1984) concluded from this that shell enhances a barren beach making it suitable for juvenile crab. This underscores the significance of littoral habitats as important foraging areas for juvenile and subadult Dungeness crab (Holsman et al. 2006).

Intertidal crab abundance changes dramatically over the course of the summer. Crab density can often range from 600 to 3,000 crabs per hectare (2.47 acres) in sublittoral channels during low tide (Rooper et al. 2002). Only about 2 to 24 percent of these crab are still present in the intertidal area by July, due in part to predation by fish and birds, and in part to movement into deeper water where the crabs can find cover as they grow (WDF and ECY 1985).

Forage Fish. Herring, surf smelt, and sand lance use Willapa Bay and are a source of food for some birds, mammals, and larger fish, including salmon. There is also a small (purse seine) forage fish fishery for anchovy in Willapa Bay (WAC 220-40-030).

Two stocks of Pacific herring (*Clupea pallasii*) reportedly spawn in Willapa Bay and Grays Harbor between mid-January and early April. Herring become ready to spawn over a 2-month period by moving from deep water into shallow nearshore areas. There are large natural variations in herring stock abundance between decades, which is reflected in the area of spawning used annually. Herring deposit transparent, adhesive eggs on intertidal and shallow subtidal *Zostera marina* and marine macroalgae. These eggs typically hatch in 10 to 14 days. Eggs may be deposited anywhere between the upper limits of high tide to a depth of –40 feet, though most spawning takes place between 0 and –10 feet. Herring prefer to spawn at a lower elevation than that preferred by the non-native *Z. japonica* (0 ft to -10 ft) (WDFW 2011).

Documented spawning habitats for Pacific herring occur along the inner shoreline of the North Beach peninsula and the west side of Long Island (Stick and Lindquist 2009). WDFW field reports between 2000 and 2003 documented herring eggs attached to Japanese eelgrass (*Z. japonica*) in Stackpole Harbor along the eastern shore of the North Beach peninsula (WDFW, unpublished data, as cited in ENVIRON 2012). Shellfish growers, however, have not observed the presence of herring spawn attached to *Z. japonica* in Willapa Bay. An Oregon Department of Fish and Wildlife report documented two separate episodes of herring spawn (February and March 2004) on *Z. japonica* in Yaquina Bay. Matteson (2004) observed that *Z. japonica* did not retain herring eggs well. The density of eggs on *Z. japonica* was reduced after one day with no observation of bird predation, causing the author to conclude that the loss was likely due to eggs being washed free from the spawning substrate.

There are no documented areas for surf smelt or sand lance spawning in Willapa Bay, though both species occur in the area.

Groundfish. All Willapa Bay tide flats and shallow channels seaward of the highway river crossings are designated areas for Essential Fish Habitat (EFH) for groundfish (Pacific Fishery Management Council 2005). Juvenile lingcod use Willapa Bay, and flat fish (e.g., starry flounder and English sole) use the bay as a nursery area (Pacific Fishery Management Council 2012, Appendix G). Pacific staghorn sculpin are the dominant groundfish, while other species (e.g., kelp greenling) comprise less than one percent of total catch in the bay (Hosack et al. 2006). NOAA catch records for Willapa Bay show that it is historically not a productive fishery for groundfish.

Green sturgeon and white sturgeon are found in Willapa Bay. Sturgeon feed on smaller fish and benthic invertebrates such as ghost shrimp, amphipods and mollusks. Green sturgeon are discussed below under Threatened, Endangered and Protected Species (Section 3.2.5.3). Willapa Bay also supports a white sturgeon commercial fishery (WAC 220-40-03100J).

Salmonids. There are approximately 745 streams encompassing more than 1,470 linear stream miles in the Willapa watershed (Phinney and Bucknell 1975, as cited in NMFS, April 28, 2009). The major tributaries that support salmon include the South Fork Willapa River, Trap Creek, Mill Creek, Wilson Creek, Fork Creek, and Ellis Creek. Tributaries to Willapa Bay provide spawning grounds for salmon and trout. These fish migrate through Willapa Bay at various times of the year, and use the bay as a nursery area much of the year (WDF and ECY 1992). Anadromous salmonid distribution and utilization within Willapa Bay tributaries is described in detail in ENVIRON (2012; Table 2-4). Species include Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), winter steelhead (*O. mykiss*), and fall chum salmon (*O. keta*). Three hatcheries contribute to the number of salmonids that migrate through Willapa Bay, but none of these contribute to the populations of Federally-listed salmonid species discussed below. The percentage of hatchery-raised fish in the bay was as high as 90 percent in the 1980s (Hiss 1986), but has decreased to 11 percent in recent years as wild stocks have improved.

Bull trout rarely occur in Pacific Coast drainages of Washington. They are found in some of the major rivers in Washington that feed into Puget Sound, and within the Columbia River Basin. There is one documented occurrence of bull trout in the Willapa River (USFWS, March 24, 2009).

Birds. Willapa Bay is an important feeding and resting area for a large variety of birds. The Willapa National Wildlife Refuge was established in 1937 to protect migrating and wintering populations of black brant, other waterfowl, shorebirds, and their respective habitats. Refuge units now total 11,000 acres with a diversity of habitat types represented. Other birding hotspots around Willapa Bay and the North Beach Peninsula include the marshes and tide flats at Bay Center and Tokeland, the Raymond Airport, Loomis Lake, and the rock shoreline of Fort Canby State Park (USFWS 1991). The U.S. Geological Survey, Northern Prairie Wildlife Research Center (NPWRC) bird checklist for the Willapa National Wildlife Refuge and the Columbia River Estuary is provided in Appendix B, along with a matrix of the seasonal and nesting occurrence of grebes, petrels, cormorants, bitterns, herons, waterfowl, osprey, kites, eagles, hawks, plovers, rails, oystercatchers, gulls, terns, seabirds and terrestrial birds within this study area.

Willapa Bay supports three Important Bird Areas (IBA), including one Global IBA (Sand and Gunpowder Islands), and two state-level IBAs (North Willapa Bay, and South Willapa Bay). Important Bird Areas are sites that provide essential habitat for one or more species of birds; sites are ranked as Global, Continental, or State level IBAs, depending on their significance (Audubon Washington, December 8, 2014).

Use of the Willapa Bay estuary by loons, grebes, cormorants, herons, bitterns, ducks, geese, brant, plovers, sandpipers, dunlin and other shorebirds is of special significance, because Willapa Bay is one of ten major wintering and resting areas for waterfowl and shorebirds along the Pacific Flyway. As a major flyway stopover point and staging area, Willapa Bay is of critical importance for fuel replenishment for migrating aquatic birds: they depend on the abundance of mudflat invertebrates, eelgrass, native saltmarsh plants, and associated invertebrates for food. The birds tend to feed mostly in the high intertidal mudflats, which are the first areas available as the tides recede, and the last ones covered by incoming tides (USDI/USFWS 1997). Waterfowl feed primarily on aquatic plants including eelgrass, salt marsh plant seeds, and invertebrates such as amphipods, worms, and insect larvae. Shorebirds probe the mud with elongated bills and extract the small invertebrates that constitute their food. Amphipods are the most important food for dunlin and western sandpipers wintering in western Washington. Caspian terns take a wide variety of fish while feeding over shallow intertidal areas. The wetlands and waterways of Willapa Bay and Grays Harbor may be particularly important to raptors, most of which prey on shorebirds (WDF and ECY 1985).

Red knot is a species of concern in Washington. It occurs in greatest abundance in Willapa Bay during the April–May migration. The overall numbers of waterfowl and shorebirds are lowest in summer, highest in spring and fall, but remain relatively high throughout the winter (USDI/USFWS 1997). Peak migration through Willapa Bay occurs between mid-April and early May. Later migrants are present until the end of May (Slater Museum of Natural History 2011). Red knot feed primarily on bivalves, particularly *Macoma* sp., and similar prey that are smaller than burrowing shrimp (Buchanan et al. 2012).

The distribution of ducks within Willapa Bay was modeled by the National Wildlife Refuge (ENTRIX 2003, as cited in ENVIRON 2012). The hierarchy of distribution according to mid-winter aerial waterfowl surveys was: South Bay (47.1 percent), East Bay (28.6 percent), North Bay (18.8 percent), West Bay (4.2 percent), and Peninsula (1.2 percent). Brant geese (*Branta bernicla*) peak in abundance in Willapa Bay in the spring at approximately 6,900 birds (Moore et al. 2004, as cited in ENVIRON 2012). Aerial surveys conducted by WDFW (2012) found total waterfowl densities from October through January were greatest in North Bay, with South Bay and East Bay varying in density, and West Bay and the North Peninsula consistently having the lowest densities of total birds.

Several protected bird species are associated with the Willapa Bay area (marbled murrelet, western snowy plover, and streaked horned lark). Further information about these species is provided below in Section 3.2.5.3.

Pollinators. Honey bees are not pollinators for submerged aquatic vegetation. Honey bees are protected from pesticide use by State pesticide laws and rules which are enforced by the Pesticide Compliance Program.[16]

Two beekeepers service the cranberry industry between approximately June 1 and July 8 each year by importing approximately 3,000 colonies of short-tongued bumble bees and honey bees (personal communication with Dr. Kim Patten, WSU Pacific County Extension Director). Cranberry farms cover approximately 7 percent of the Willapa Bay watershed (Sanford 2012). Cranberry farms nearest to

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16 http://agr.wa.gov/plantsinsects/Apiary/.

commercial clam and oyster tidelands occur at the south end of Willapa Bay, approximately 0.5 mile (2,640 feet) from the closest shellfish beds.

Bumble bees are ground nesters, with colonies in wooded areas. In the late winter and spring months, the bumble bees are attracted to heathers (*Erica carnea*, *E. x darleyensis*), dewberry, and evergreen huckleberry. After the cranberry season, the bees are found in late summer on birdsfoot trefoil (*Lotus corniculatus*) and bell heather (*E. cinerea*) (Macfarlane and Patten 1997).

The Oregon silverspot butterfly is discussed in the Threatened, Endangered and Protected Species section (3.2.5.3 below).

Mammals. Harbor seals and gray whales have been observed in Willapa Bay. Several isolated sandbar areas within the bay have historically been used as harbor seal haul-out grounds (WDF and ECY 1992). Harbor seals also use channels through the tide flats for swimming and feeding, and haul out on sandy bars or islands throughout the bay to rest. Other marine mammals generally use the deeper, more saline water of the north end of the bay (USDI/USFWS 1997).

Few mammals use the high intertidal mudflats. River otters may venture into channels on the mudflats in search of fish. Raccoons may forage on the tide flats when these areas are exposed at low tide. Small mammals such as shrews, mice, or voles live in native saltmarsh vegetation and may be present in the high intertidal area above regular tidal inundation (USDI/USFWS 1997).

3.2.5.2 *Grays Harbor*

Zooplankton and Benthic Invertebrates. A list of planktonic and benthic invertebrates that were present in Grays Harbor in the late 1980s is provided in Appendix C (reproduced from Appendix E of the WDF and ECY 1985 EIS). Some of these species probably also occur in Willapa Bay. None of the sites from which this species list was compiled were active oyster beds.

More recent benthic work completed in 2005 indicated that the highest abundance and number of invertebrate taxa occurred at subtidal sample stations (–4, –8 and –12 feet MLLW). June samples were dominated by the polychaete *Saccocirrus* sp., while January samples were dominated by Nemerteans (proboscis worms). *Saccocirrus* sp. was not found in the January samples, but Nemerteans were present in June as subdominant species. In both January and June samples, juvenile organisms dominated and a small number of adult organisms were found (SAIC 2005, as cited in Corps of Engineers, Seattle District 2011).

Descriptions provided above in Sections 3.1 and 3.2.5.1 of life history and general characteristics of burrowing shrimp and Dungeness crab are applicable to Grays Harbor as well as to Willapa Bay.

Clams and Oysters. The species diversity and general biology of shellfish in Grays Harbor is similar to that of Willapa Bay, also as described above. Approximately 3,995 acres of tidelands are owned or leased for shellfish aquaculture within Grays Harbor: 3,088 acres in North Bay and 907 acres in South Bay (NMFS, April 28, 2009) (see Figure 2.4-2 in FEIS Chapter 2). Of these, approximately 900 acres are currently farmed for the commercial production of oysters and clams (CSI 2013). There are public clam and oyster beaches in Grays Harbor County at the Westport Boat Basin, Copalis, Mocrocks, and Twin Harbors.

Dungeness Crab. Grays Harbor is an important rearing area for juvenile Dungeness crab; however, only relatively small commercial catches of crab are made in the harbor. The 10-year average of Dungeness crab landings in Grays Harbor between 1975 and 1984 was 42 pounds per year, about 1 percent of the total coastal catch (WDF and ECY 1987). More recent fish survey work in Grays Harbor found that crab assemblages were numerous along the Half Moon Bay shoreline throughout the summer months (R2 Resource Consultants 2005, as cited in Corps of Engineers, Seattle District 2011). There are designated recreational crab fishing areas in Grays Harbor and Westport/Ocean Shores for Dungeness crab and red rock crab.

Forage Fish. Forage Fish species that were present in Grays Harbor in the late 1980s include herring (Pacific herring, Pacific sardine, and American shad); northern anchovy; smelt (surf smelt, longfin smelt, and eulachon); and Pacific sand lance (see Appendix D, reproduced from Appendix E of the WDF and ECY 1985 EIS).
Spawning habitat for herring is documented near the mouth of Grays Harbor, along Damon Point State Park, near the Westport marina, and in the South Bay sloughs south of the State Route 105 bridge. Surf smelt spawning has only been documented on the ocean shore side of Westport, and sand lance spawning has been found in only one small area just east of the Johns River mouth.

Groundfish. All Grays Harbor tide flats and shallow channels are designated areas of Essential Fish Habitat (EFH) for groundfish (Pacific Fishery Management Council 2005). Green sturgeon use the harbor during the early summer for weeks to months each year (Federal Register/Vol. 74, No. 195/October 9, 2009/Rules and Regulations, pp. 52300–52351).

Simenstad and Eggers (1981, as cited in WDF and ECY 1987) conducted a study on juvenile salmonids and flatfish in Grays Harbor in relation to dredging operations. They found that juvenile salmonids and English sole feed over lower intertidal and shallow subtidal areas, which may include Pacific oyster beds. Young salmonids and sole fed mostly on small crustaceans, including harpacticoid copepods, cumaceans, and amphipods.

More recent fish survey work in Grays Harbor indicates that fish assemblages along the Half Moon Bay shoreline are the most diverse and abundant throughout the summer months (R2 Resource Consultants 2005, as cited in Corps of Engineers, Seattle District 2011). From late June through August, juvenile Chinook salmon and juvenile and adult surf smelt were the most numerous and consistent inhabitants of the Bay. Half Moon Bay is a small embayment just inside the south jetty, west of South Bay.

Salmonids. The fishes of Grays Harbor are essentially the same as those described above for Willapa Bay. Pacific salmon, steelhead and cutthroat trout use the estuary for migrations and juvenile rearing. The species composition of fishes in Grays Harbor in the late 1980s is listed in Appendix D (reproduced from Appendix E of the WDF and ECY 1985 EIS). Three hatcheries contribute to the number of salmonids that migrate through Grays Harbor, but none of these contribute to populations of Federally-listed salmonid species discussed in Section 3.2.5.3 below. The percentage of hatchery raised fish in the bay has averaged less than five percent in recent years.

Birds. A variety of birds also use Grays Harbor. Bird species known to use the Grays Harbor estuary are listed in Appendix B (reproduced from Appendix F of the WDF and ECY 1985 EIS). Grays Harbor, like Willapa Bay, is an important wintering area for waterfowl. While waterfowl are least abundant during May, June, and July (Smith and Mudd 1976, as cited in WDF and ECY 1985), total bird populations peak in April and May when more than 1 million other birds stop for rest and food during their northward spring migration. Some nesting and brooding occurs in the dense vegetation of marsh areas. Mallards are the most abundant nesting waterfowl.

A large variety of migrating and wintering shorebirds use estuarine habitats in Grays Harbor. During the spring migration, western sandpiper is the most abundant (Appendix B). Herman and Bulger (1981; cited in WDF and ECY 1985) concluded that Grays Harbor supports more shorebirds during spring migration than any other estuary on the Pacific Coast south of Alaska. Shorebird distribution depends on tide levels. They prefer areas where tide flats are present, such a dredge disposal sites, harbor islands, and Ocasta beach. While these areas account for only three percent of the shoreline of Grays Harbor, 26 percent of all shorebirds were observed in these areas during the spring (Kalinowski et al. 1982, as cited in WDF and ECY 1985).

Seabirds like rhinoceros auklet, common murre, marbled murrelet, pigeon guillemot, and parasitic jaeger typically use deeper water areas of the bay as feeding sites. Other waterbirds observed in the outer bay and deeper waters of both the North and South channels of Grays Harbor included loons, grebes, shearwaters, petrels, and cormorants. Gulls and terns are abundant during the summer months and often nest in the same areas. East Sand, Whitcomb, Rice, and Goose Islands are important nesting colonies, especially for the Caspian tern. The largest identified Caspian tern colonies on the West Coast occur along the lower Columbia River (ECY 1983 as cited in WDF and ECY 1985). Double-breasted cormorants had relatively small nesting colonies on Sand Island and Ned Rock at the time of investigations conducted by sources cited here.

Species observed in the fall, winter, or spring include mallard, pintail, American wigeon, canvasback, Canada goose, red knot, least sandpiper, dunlin, black turnstone, and rhinoceros auklet (Jordan 1981, as cited in WDF and ECY 1985). Goose Island summertime residents include glaucous-winged gull, western gull, and rhinoceros auklet.

The Grays Harbor Estuary was designated a hemispheric reserve by the Western Hemisphere Shorebird Reserve Network as a site of international significance. Grays Harbor also supports six state-level Important Bird Areas (IBAs). Important Bird Areas are sites that provide essential habitat for one or more species of birds; sites are ranked as Global, Continental, or State level IBAs, depending on their significance (Audubon Washington, December 8, 2014).

Pollinators. Honey bees are present in upland and riparian areas along the shoreline of Grays Harbor, and are managed under the same laws and rules as discussed above for honey bees in the vicinity of Willapa Bay. Cranberry farms nearest to Grays Harbor commercial clam and oyster tidelands are north of North Bay, approximately 1.5 miles from the closest shellfish beds. During other seasons, the bees are found on the same flowering species as those described above for the Willapa Bay vicinity.

Mammals. Marine mammals are observed in Grays Harbor throughout the year. Harbor seals are most abundant. They both travel and feed in the estuary (Smith and Mudd 1976, as cited in WDF and ECY 1985). The harbor seal population was estimated to be 500 seals during the winter and 1,400 during the summer (at the time a Draft EIS was prepared for the *Grays Harbor Estuary Management Plan*; ECY 1983). They feed on bottom fish over subtidal and intertidal areas, and occasionally on salmon. Grays Harbor was thought to have the largest breeding colony of harbor seals in Washington and Oregon in 1983. No more recent information was found. The harbor seal pupping season occurs in May, June and July when seals disperse to areas throughout Grays Harbor. Ecology designated five areas in North Bay, six in Central Bay, and one in South Bay as harbor seal haul-out grounds (Gardner 1981 as cited in WDF and ECY 1987). Northern sea lions, harbor porpoises and gray whales have also been occasionally observed in Grays Harbor.

No information was found to describe use of Grays Harbor high intertidal mudflats by mammals. It is assumed that, similar to Willapa Bay, river otters may venture into channels on the mudflats in search of fish, and raccoons may forage on the tide flats when these areas are exposed at low tide.

3.2.5.3 *Threatened, Endangered and Protected Species*

Threatened and endangered species, and species of concern, are those species that have been given special legal and/or protection designations by Federal and State government resource agencies. A species Federally-listed as endangered is one that is in danger of extinction throughout all or a significant portion of its range. A species Federally-listed as threatened is one likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range. A species of concern is one for which status information suggests that the species is not abundant, and for which additional information is sought (ENVIRON 2012). In addition to Federally-listed species, the Washington State Department of Fish and Wildlife maintains a Priority Habitats and Species list.

The *Risk Assessment for Use of Imidacloprid to Control Burrowing Shrimp in Shellfish Beds of Willapa Bay and Grays Harbor* (CSI 2013) found 26 species listed by the U.S. Fish and Wildlife Service within a three-County study area that includes Pacific, Grays Harbor and Wahkiakum Counties. These included seven whale species (blue, finback, humpback, killer, Northern Pacific right, sei, and sperm); Steller sea lion; three species of sea turtle (leatherback, loggerhead, and green); and one plant species (marsh sandwort, *Arenaria paludicola*). These species were all considered to have no risk of affect from the proposed action due to their typical habitats, size, or taxonomy. For this reason, they are not discussed here.

The National Marine Fisheries Service (NMFS) (April 28, 2009) identified three listed species under their jurisdiction for which to consider potential effects (e.g., from the use of pesticides) while preparing the *Endangered Species Act – Section 7 Programmatic Consultation Biological and Conference Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation for Nationwide Permit 48* that covers ongoing shellfish aquaculture operations in Washington State. These include:

Lower Columbia River (LCR) Chinook salmon	*Oncorhynchus tshawytscha*
Columbia River chum salmon	*O. keta*
Green sturgeon	*Acipenser medirostris*

Salmonids. NMFS reports that there are no ESA-listed salmon runs in the Willapa Watershed. Adult Columbia River chum salmon and LCR Chinook salmon dip into Willapa Bay on their migration back to their natal streams (NMFS, April 28, 2009). Although it is likely that juvenile ESA-listed salmonids migrate from their natal areas in the Lower Columbia River and rear for some period of time in Willapa Bay, there are no known investigations or data collected that confirm this occurrence. However, recent findings of juvenile LCR Chinook salmon using north coast and Strait of Juan de Fuca estuaries is strong evidence that they do so (NMFS, April 28, 2009). Juvenile migration of Chinook, coho, and steelhead along the coast occurs between April and July. These species may be present in Willapa Bay during that time (USFWS, 2011).

Similarly, there are no ESA-listed salmon runs in the Grays Harbor Watershed. However, the Columbia River chum salmon and LCR Chinook salmon may migrate from their natal areas and rear and mature for some portion of their life history in Grays Harbor (NMFS, April 28, 2009).

Bull Trout.[17] The coterminous United States population of bull trout was Federally-listed as threatened on November 1, 1999. Bull trout exhibit both resident and migratory life history strategies. Both resident and migratory forms may be found together, and either form may produce offspring exhibiting either resident or migratory behavior (Rieman and McIntyre 1993). Resident bull trout complete their entire life cycle in the tributary (or nearby) streams in which they spawn and rear. Migratory bull trout spawn in tributary streams where juvenile fish rear 1 to 4 years before migrating to either a lake (adfluvial form), river (fluvial form) (Fraley and Shepard 1989; Goetz 1989), or saltwater (anadromous form) to rear as subadults and to live as adults (Goetz 1989; McPhail and Baxter 1996; WDFW et al. 1997).

The conservation needs of bull trout include cold, clean, complex and connected habitat. Cold stream temperatures, clean water quality that is relatively free of sediment and contaminants, complex channel characteristics (including abundant large wood and undercut banks), and large patches of such habitat that are well connected by unobstructed migratory pathways are all needed to promote conservation of bull trout (USFWS, March 24, 2009).

Within the study area, bull trout generally occur in Pacific Coast drainages of Washington, and major rivers in Washington within the Columbia River Basin. There is one documented presence of bull trout in the Willapa River. One bull trout was caught by a WDFW technician one mile downstream of the Willapa/Forks Creek State Salmon Hatchery in 2002 (Berg 2002). It is likely that this bull trout followed migrating salmonids through the entrance of Willapa Bay past Tokeland and up the Willapa River. No other occurrences of bull trout have been recorded in Willapa Bay, although there are no efforts to monitor for them in this system. Based on the infrequent reports of bull trout in Willapa Bay and the Willapa River, it is highly unlikely that there is a spawning population in this watershed, and there is a low likelihood of bull trout being present within the commercial shellfish aquaculture project area (Berg 2002). The closest bull trout core area[18] is the Quinault core area, up the coast more than 50 miles north of Willapa Bay.

Grays Harbor is part of the Lower Chehalis River/Grays Harbor bull trout foraging, migration, and overwintering habitat. Although bull trout have been documented in Grays Harbor and the Chehalis River, the nearest spawning population is likely the Quinault core area (USFWS, March 24, 2009).

Anadromous adult and subadult bull trout utilize nearshore marine waters, including estuaries and shoreline areas. This nearshore environment provides habitat critical to both bull trout and salmon for foraging, refuge (from predation, seasonal high flows, and winter storms), and migration. The entire shoreline of Grays Harbor is designated bull trout critical habitat (USFWS, March 24, 2009, Figure 4.14). For this reason, shellfish aquaculture areas in Grays Harbor overlap bull trout critical habitat. In contrast, there is no designated bull trout critical habitat in Willapa Bay (USFWS, March 24, 2009).

The USFWS requested that the U.S. Army Corps of Engineers undertake a literature review and three-year sampling effort to establish patterns of bull trout use within the area of effect of the annual Grays Harbor navigation channel maintenance dredging and disposal. Fisheries biologists sampled 12 sites in 2001, 2002, 2003, and 2004 (R2 Resource Consultants 2006). Acoustic tags were implanted in the bull trout captured in 2004, so additional data were collected in 2005. The results of the literature review and sampling effort indicated that bull trout are present in the lower Chehalis River beginning in mid-to- late

[17] All sources cited in the description of bull trout are as cited in the U.S. Fish and Wildlife Service Biological Opinion of the Nationwide Permit 48 for the State of Washington (USFWS, March 24, 2009), except as noted.

[18] A core area is defined as a geographic area occupied by one or more local bull trout populations that overlap in their use of rearing, foraging, migratory, and overwintering habitat. Maintenance of viable core areas is considered central to the survival and recovery of bull trout (USFWS, March 24, 2009).

February and continuing through mid-July. The tagged fish appeared to display a preference for the mainstem reach of the Chehalis River between the Elliott Slough Turning Basin and Cow Point Reach. No tagged fish were detected at a fixed receiver station in Half Moon Bay (Corps of Engineers, Seattle District 2011).

Green Sturgeon. The southern Distinct Population Segment (DPS) of green sturgeon likely migrate from their natal area in the Sacramento River and mature for some portion of their life history in Willapa Bay and Grays Harbor. The southern DPS of green sturgeon is Federally-listed as threatened, but is not a State-listed species. Green sturgeon are found along the western coast of the USA, Canada, and Mexico. They are present in Willapa Bay, but do not spawn in Washington waters. According to a NOAA website (cited below), the principal factor in the decline of the green sturgeon on the west coast is reduction of the spawning area to a limited section of the Sacramento River.

> *Willapa Bay, along with the Columbia River and Grays Harbor, is one of the estuaries where green sturgeon concentrate in summer. Generally, green sturgeon are more abundant than white sturgeon here (Emmett et al. 1991). Catches have declined from 3,000–4,000 fish per year in the 1960's to few or none in recent years (WDFW 2002a). Much of this is probably due to reduced size limits and seasonal and area closures.*[19]

Both the Northern and Southern DPS of green sturgeon have designated critical habitat within Willapa Bay and Grays Harbor (Federal Register/Vol. 74, No. 195/October 9, 2009/Rules and Regulations, pp. 52300–52351).

Birds. The U.S. Fish and Wildlife Service identifies two listed bird species under their jurisdiction for which to consider potential effects for projects in Willapa and Grays Harbor:

Marbled murrelet (and their critical habitat)	*Brachyramphus marmoratus*
Western snowy plover (and their critical habitat)	*Charadrius alexandrinus nivosus*

Marbled Murrelet.[20] Marbled murrelet were Federally-listed as threatened in Washington, Oregon, and northern California effective September 28, 1992. The decline of this species has largely been caused by extensive removal of late-successional and old-growth coastal forests that serve as nesting habitat for murrelets. Additional listing factors include high nest-site predation rates and human-induced mortality in the marine environment from gillnets and oil spills.

Murrelets are long-lived seabirds that spend most of their life in the marine environment, with the exception that they use old-growth forests for nesting. Murrelets are usually found within 5 miles from shore, and in water less than 60 meters deep (Ainley et al. 1995; Burger 1995; Strachan et al. 1995; Nelson 1997; Day and Nigro 2000; Raphael et al. 2007). In general, murrelets occur closer to shore in exposed coastal areas and further offshore in protected coastal areas (Nelson 1997). During the non-breeding season, murrelets disperse and can be found farther from shore (Strachan et al. 1995). Little is known about their marine habitat preference outside of the breeding season, but use during the early spring and fall is thought to be similar to that preferred during the breeding season (Nelson 1997). During the winter, there may be a general shift from exposed outer coasts into more protected waters (Nelson 1997). However, in many areas murrelets remain associated with the inland nesting habitat during the

[19] http://www.nmfs.noaa.gov/pr/pdfs/statusreviews/greensturgeon.pdf.
[20] All sources cited in the description of marbled murrelet are as cited in the U.S. Fish and Wildlife Service Biological Opinion of the Nationwide Permit 48 for the State of Washington (USFWS, March 24, 2009).

winter months (Carter and Erickson 1992), and throughout the listed range, murrelets do not appear to disperse long distances, indicating that they are year-around residents (McShane et al. 2004).

Courtship, foraging, loafing, molting and preening occur in marine waters. When murrelets are not foraging or attending a nest, they loaf on the water, appearing to drift with the current or move without direction (Strachan et al. 1995).

Murrelets are wing-propelled pursuit divers that forage both during the day and at night (Carter and Sealy 1986; Gaston and Jones 1998; Kuletz 2005). They usually feed in shallow, nearshore water less than 30 meters (98 feet) deep (Huff et al. 2006), but are thought to be able to dive up to depths of 47 meters (157 feet) (Mathews and Burger 1998). Murrelets typically forage in pairs, but have been observed to forage alone or in groups of three or more (Carter and Sealy 1990b; Strachan et al 1995; Speckman et al. 2003). Juveniles are generally found closer to shore than adults (Beissinger 1995), and forage without the assistance of adults (Strachan et al. 1995). In Alaska, juvenile murrelets were found to congregate in kelp beds, which may provide protection from avian predators (Kuletz and Piatt 1999).

Throughout their range, murrelets are opportunistic feeders and utilize prey of diverse sizes and species. They feed primarily on fish and invertebrates in marine waters, although they have also been detected on rivers and inland lakes (Carter and Sealey 1986). In general, small schooling fish and large pelagic crustaceans are the main prey items. Pacific sand lance, northern anchovy, immature Pacific hearing, capelin, Pacific sardine, juvenile rockfishes, and surf smelt are the most common fish species taken. Squid, euphausiids, mysid shrimp, and large pelagic amphipods are the main invertebrate prey.

The range of the murrelet, defined by breeding and wintering areas, extends from the northern terminus of Bristol Bay, Alaska, to the southern terminus of Monterey Bay in central California. The listed portion of the species' range extends from the Canadian border south to central California. Murrelet abundance and distribution has been significantly reduced in portions of the listed range, and the species has been extirpated from some locations. The areas of greatest concern due to small numbers and fragmented distribution include portions of central California, northwestern Oregon, and southwestern Washington (USFWS 1997).

Limited information is available regarding murrelet use of the marine environment within Grays Harbor and Willapa Bay. WDFW conducts surveys for murrelets in nearshore environments along the coast where the birds forage. Marine observations of murrelets during the nesting season generally correspond to the presence of large blocks of nesting habitat. Studies have found that during the nesting season, murrelets are more numerous along the northern coast of Washington and less abundant along the southern coast. This distribution appears to be associated with the proximity to old growth forest, the distribution of rocky shoreline versus sandy shoreline, and the abundance of kelp and prey items (Carter and Sealy 1990a). Murrelets, therefore, would not be expected to forage regularly in Grays Harbor and Willapa Bay during the nesting season. Observations documented by Speich and Wahl (1995) support this conclusion. They found that murrelets are generally present in Grays Harbor during the fall, winter and spring; they are rarely seen in August and September. The highest numbers occurred generally in the Grays Harbor channel out to the 50-m (approximately 150-foot) depth contour. The USGS bird checklist for the Willapa National Wildlife Refuge reproduced in Appendix B of this FEIS documents the early 1990s presence of marbled murrelet in Willapa Bay as uncommon year-around, though there were observations of murrelets nesting in the area at that time.

Critical habitat was designated for the murrelet to address the objective of stabilizing the population size. The Marbled Murrelet Recovery Plan (USFWS 1997) identified six Conservation Zones throughout the listed range of the species. Willapa Bay and Grays Harbor were within Conservation Zone 2, the Western

Washington Coast Range. In southwest Washington, Conservation Zone 2 extended inland 50 miles from the Pacific Ocean shoreline. Most of the forest lands in the southwestern portion of the State are privately owned. Extensive timber harvest has occurred throughout Zone 2 during the last century, but the greatest loss of suitable nesting habitat is concentrated in the southwest portion of Zone 2 (USFWS 1997). The critical habitat designation was revised in 2011, removing all of Willapa Bay and Grays Harbor in-water areas from critical habitat zones (Federal Register/Vol. 76, No. 193/Wednesday, October 5, 2011/Rules and Regulations, pp. 61599–61621). A parcel inland of Willapa Bay is now managed by the Willapa National Wildlife Refuge, and lands important to marbled murrelet around Grays Harbor are non-Federal (Federal Register/Vol. 71, No. 176 /Tuesday, September 12, 2006/Proposed Rules, pp. 53838–53951).

Western Snowy Plover. The Western snowy plover was listed by the Washington State Department of Fish and Wildlife as a State endangered species in 1981, and was listed as threatened under the Federal Endangered Species Act in 1993. The population has declined from past numbers, but seems to be stabilized at 30-36 birds. In 2013, the number of breeding birds varied from 41-45 birds. (WDFW, 2007-2013) Snowy plovers are year-around residents and nest along Washington coastal beaches from Copalis Spit to the Willapa Bay North Beach peninsula. Breeding season is from late March to early September, and peak breeding time is from mid-May through mid-June. (WDFW, 2007-2013) Early nests have been recorded although the success of these nests is varied. However, breeding success improved as the season progressed. (WDFW 2007-2013) Survey information documents that nesting snowy plovers occur in the vicinity of Willapa Bay on beaches fronting the Pacific Ocean from Grayland to the middle of the North Beach Peninsula. With the exception of Graveyard Spit, which is located at the mouth of Willapa Bay, there are no records of snowy plovers foraging or nesting in the bay or along the eastern shore of the North Beach Peninsula. Although there are a few isolated reports of snowy plovers foraging or sheltering from winter storms on the northern tip of Leadbetter Point, use of the area along the eastern tip of the peninsula is very limited. Snowy plovers also nest and forage along Damon Point, at the mouth of Grays Harbor. Although there are historic records of snowy plovers using the coastal beaches at Westport (south side of Grays Harbor), this area is no longer occupied (USFWS, March 24, 2009).

Snowy plover critical habitat has been designated at Willapa Bay and Grays Harbor. Primary constituent elements are as follows:

1. Sparsely vegetated areas above daily high tides (e.g., sandy beaches, dune systems immediately inland of an active beach face, salt flats, seasonally exposed gravel bars, dredge spoil sites, artificial salt ponds and adjoining levees) that are relatively undisturbed by the presence of humans, pets, vehicles or human-attracted predators;
2. Sparsely vegetated sandy beach, mud flats, gravel bars or artificial salt ponds subject to daily tidal inundation but not currently under water, that support small invertebrates such as crabs, worms, flies, beetles, sand hoppers, clams and ostracods; and
3. Surf- or tide-cast organic debris such as seaweed or driftwood located on open substrates such as those mentioned above (essential to support small invertebrates for food, and to provide shelter from predators and weather for reproduction).

Western snowy plovers forage on invertebrates in the wet sand and amongst surf-cast kelp within the intertidal zone; in dry, sandy areas above the high tide; on salt pans; spoil sites; and along the edges of salt marshes and salt ponds. Little quantitative information is available on food habits. Poor reproductive success, resulting from human disturbance, predation, and inclement weather, combined with permanent or long-term loss of nesting habitat to encroachment of introduced European beachgrass (*Ammophile aranczria*) and urban development, has led to a decline in active nesting colonies, as well as an overall decline in the breeding and wintering population of the western snowy plover along the Pacific coast of the United States (USFWS 2007).

Streaked Horned Lark. The streaked horned lark was listed as threatened in 2013 (Federal Register/Vol. 78, No. 192/Thursday, October 3, 2013/Rules and Regulations, pp. 61452–61503). The horned lark has critical habitat designations in Willapa Bay (Leadbetter Point State Park and on the western shore of Tokeland) and Grays Harbor (Damon Point).

Horned larks nest in April, and will also re-nest in late June or early July. Preferred coastal habitats are areas of extensive bare ground, and larks exhibit a strong natal fidelity to previous nesting sites (Pearson and Hopey 2004 and 2005). Larks forage in terrestrial habitats, in low vegetation, or on bare ground, and are not found in the water.

Oregon Silverspot Butterfly. The Oregon silverspot butterfly was listed as threatened in 1980 (Federal Register/Vol. 45, No. 129/Wednesday, July 2, 1980/Rules and Regulations, pp. 44935–44938). Although no critical habitat was listed in Washington State, the Revised Recovery Plan (2001) lists 30 acres on the North Beach Peninsula, between Loomis Lake and the Pacific Ocean, as managed by WDFW. The butterfly and its caterpillar occupy forest-fringe grassland habitat and salt-spray meadows. The Oregon silverspot butterfly has not been documented in Washington State since 1990. Although there are efforts to reestablish the butterfly as part of the WDFW Recovery Plan (2001), it feeds primarily on the early blue violet flower (*Viola adunca*), which does not grow immediately adjacent to Willapa Bay or Grays Harbor. The silverspot butterfly is not discussed further in this document.

Other Species. Use of Willapa Bay by State-listed species was reported by ENVIRON International Corporation in the Screening-Level Ecological Risk Assessment of the Proposed Use of the Herbicide Imazamox to Control Invasive Japanese Eelgrass (Zostera japonica) in Willapa Bay, Washington (2012) (see Table 3.2.5-1 below). Limited use of the bay by the listed species of salmonids that use the Columbia River system is described above. USFWS information regarding what is known about the occurrence of marbled murrelet, streaked horned lark, and snowy plover in the Willapa Bay area is also reported above. California brown pelicans (analyzed in ENVIRON 2012) were Federally-delisted in 2009, are currently under proposal for delisting in Washington, and only occur in Willapa Bay and Grays Harbor during the summer months. The short-tailed albatross migrate along the outer Washington coast, but are not documented inside Willapa Bay or Grays Harbor (USFWS 2001; Jeffries et al. 2000). Pacific eulachon (Thaleichthys pacificus) are not known to regularly use Willapa Bay, and the bay is not designated as critical habitat for the species. Eulachon are known to spawn in the Chehalis River, but are not long-term residents in the Grays Harbor nearshore during out-migration, and are found only infrequently (USACE 2013). Killer whales are also not documented inside Willapa Bay or Grays Harbor, and are not known to enter the bays during migration along the shore (Wiles 2004).

Table 3.2.5-1. Washington State list of threatened, endangered and candidate species that may occur in Willapa Bay, Pacific County (WDFW 2008 in ENVIRON 2012).

General Taxon		**Species**	**Status**		
			State	Federal	County
Vertebrates	Fish	Green sturgeon	N	T	X
		Eulachon	C	T	X
		Bull trout	C	T	X
		Chinook salmon	C	T	X
		Chum salmon	C	T	X
		Coho salmon	C	T	X

		Steelhead trout	C	T/E	X
Avifauna and Mammals	Marine Birds	Brown Pelican	E	D	X
		Marbled murrelet	T	T	X
		Short-tailed albatross	C	E	X
		Snowy plover	E	T	X
	Marine Mammals	Killer whale	E	E	X
		Northern Steller sea lion	T	T	X

T = Threatened, E = Endangered, C = Candidate for listing, D = Delisted due to recovery, N = Not designated.

POTENTIAL IMPACTS

The proposed action or alternatives would affect only a small percentage of total tideland acreage in Willapa Bay and Grays Harbor (see FEIS Chapter 2, Sections 2.8.2 and 2.8.3), although localized areas dominated by shellfish farms may have a sizeable proportion of the intertidal habitat sprayed with imidacloprid at one time or another over the 5-year duration of the requested NPDES permit. This is not an eradication proposal for burrowing shrimp, but rather a proposal for the control of burrowing shrimp on a limited acreage of commercial shellfish beds in these two bays. The total area of tide flats exposed on low tide in Willapa Bay is approximately 45,000 acres. Of this acreage, approximately 25,562 acres of tidelands are owned or leased for commercial shellfish aquaculture (NMFS, April 28, 2009), and 9,000 acres are currently farmed for the commercial production of oysters and clams (CSI 2013). The total area of tide flats exposed on low tide in Grays Harbor is approximately 34,460 acres. Of this acreage, approximately 3,995 acres of tidelands are owned or leased for commercial shellfish aquaculture within Grays Harbor: 3,088 acres in North Bay and 907 acres in South Bay (NMFS, April 28, 2009). Approximately 900 acres of Grays Harbor tidelands are currently farmed for the commercial production of oysters and clams (CSI 2013). Chemical applications for burrowing shrimp control are proposed on a small percentage of commercial shellfish beds under either Alternative 2 or Alternative 3.

Alternative 1: No Action – No Permit for Pesticide Applications. Under the No Action Alternative, cessation of chemical applications for burrowing shrimp control would affect approximately 600 acres of 45,000 tideland acres within Willapa Bay (1.3 percent of total tideland acres), and approximately 200 acres of 34,460 tideland acres within Grays Harbor (0.6 percent of total tideland acres).

Alternative 2: Continue Historical Management Practices – Carbaryl Applications with Integrated Pest Management. The current administratively extended NPDES Permit or a new or modified NPDES individual permit would be required to implement Alternative 2. It is assumed that a new or modified permit for the use of carbaryl would allow for the use of carbaryl on areas primarily grown for commercial clams as well as areas primarily grown for commercial oysters. It is likely that acreage limitations would remain the same under Alternative 2 as they are under the 2006 NPDES individual permit (WA0040975) and other applicable regulatory requirements, up to 600 acres per year could be treated within Willapa Bay *per year* (1.3 percent of total tideland acres), and up to 200 acres per year could be treated in Grays Harbor *per year* (0.6 percent of total tideland acres).

Alternative 3: Imidacloprid Applications with IPM. Imidacloprid applications on up to 1,500 acres each year within Willapa Bay would affect at most approximately 3.3 percent of total tideland acres within the bay annually. Imidacloprid applications on up to 500 acres within Grays Harbor each year would affect at most approximately 1.5 percent of total tideland acres within the harbor annually (see FEIS Chapter 2, Section2.8.3).

Statements of potential impact below are made in the context of the areas of affect described above.

Zooplankton, and Benthic Invertebrates (Burrowing Shrimp, Clams and Oysters, Dungeness Crab). Alternative 1 would be unlikely to have either a significant beneficial or adverse effect on marine zooplankton. Burrowing shrimp feed primarily on detritus and phytoplankton (Griffen et al. 2004), and filtration rates by burrowing shrimp are comparable to shellfish occupying similar habitats. Mechanical methods have not proven effective at controlling burrowing shrimp and can disturb sediments in which benthic invertebrates live to a greater degree than burrowing shrimp activities. Increased densities of burrowing shrimp could result in decreased biodiversity and increased sedimentation (Dumbauld and Wyllie-Echeverria 1997; Colin et al. 1986). High densities of burrowing shrimp have been associated with lower numbers of Dungeness crab, oysters, and other shellfish due to competitive exclusion and habitat modification caused by the shrimp (Doty et al. 1990; Brooks 1995; Dumbauld and Wyllie-Echeverria 1997).

Shellfish and native eelgrass beds provide important habitats for many species of benthic invertebrates, including Dungeness crabs, polychaete worms, and settling planktonic larvae. A reduction in shellfish, and a reduction in eelgrass densities and coverage would result from sediment disruption caused by the expansion of burrowing shrimp on untreated commercial shellfish beds under Alternative 1. The effect of a reduction in shellfish and native eelgrass habitat function would likely further reduce the diversity of species where burrowing shrimp dominate (Hosack et al. 2006). See Section 3.1 for more details on the interactions between shellfish, burrowing shrimp, and native eelgrass beds.

Continued prescribed use of carbaryl under Alternative 2 would be effective in controlling populations of burrowing shrimp on commercial shellfish beds, while allowing a greater level of biodiversity and habitat complexity than no pesticide treatment within the treated area (Alternative 1). Carbaryl has been used to effectively suppress burrowing shrimp populations since 1963, and has not been known to adversely affect the commercial oyster crop. Molluscs (bivalves, snails) are less susceptible to carbaryl than crustaceans (crabs, shrimp). The commensal clam (*Crytomya californica*) is adversely affected by carbaryl treatment (Dumbauld et al. 2001). Commensal clams are dependent on burrowing shrimp habitat, and displayed delayed mortality after treatment. Burrowing shrimp control indirectly promotes enhanced shellfish and eelgrass density and coverage where habitat is no longer limited by burrowing shrimp activity (Dumbauld and Wyllie-Echeverria 2003). This would improve the biodiversity of benthic invertebrates on commercial clam and oyster beds in Willapa Bay and Grays Harbor. However, recent studies have found the use of carbaryl to promote fish and Dungeness crab mortality, by way of paralysis and reduced heart rate (NMFS 2009). Carbaryl effects on marine zooplankton have been largely unstudied, but the existing application suggests carbaryl may have similar effects to marine zooplankton as it does to adult life history stages of crustaceans and related species. Cyclical recruitment events for Dungeness crab in Grays Harbor have not been correlated to environmental factors (Armstrong et al. 1989). Since 2004, the tideland acreage of carbaryl application has been gradually reduced in Willapa Bay and Grays Harbor[21]. If the commercial shellfish bed acreage authorized for carbaryl applications under Alternative 2 were to remain the same as the acreage authorized under NPDES Permit No.

[21] WGHOGA reduced the tideland acreage treated in Willapa Bay and Grays Harbor from 800 acres in 2002 to 720 acres in 2003, then to 640 acres in 2004, and to not more than 560 acres in 2005 in accordance with the terms of a Settlement Agreement with the Washington Toxics Coalition and the Ad Hoc Coalition for Willapa Bay (April 28, 2003). The Washington State Department of Ecology is not a party to the Settlement Agreement; therefore, the NPDES permit authorizing the use of carbaryl is not bound by the terms of the Settlement Agreement.

WA0040975 (i.e., up to 600 acres per year in Willapa Bay and up to 200 acres per year in Grays Harbor), then no increased effect or impact to fish or Dungeness crab would be anticipated.

Alternative 3 (Imidacloprid Applications with Integrated Pest Management) would provide adequate burrowing shrimp control on commercial shellfish beds with potentially reduced environmental side effects, compared to carbaryl. Imidacloprid would be unlikely to adversely affect polychaete worms or molluscs (bivalves, snails), including oysters and clams (Hart Crowser 2013; Grue and Grassley 2013; CSI 2013). A potential exception is imidacloprid effects in sediments high in organic matter. The limited information available for such sediments suggests adverse effects to polychaete worms and crustaceans (see FEIS Chapter 2, Section 2.8.3.5). A study of imidacloprid effects in high organic soils is expected during the summer of 2015. Results from this trial may result in adjustments to permit conditions during the five-year term of the permit.

The commensal clam lives in shrimp burrows, and may be adversely affected by decreased shrimp densities. Any effect would be highly localized to the areas of direct imidacloprid application, and should not affect the overall commensal clam population in Willapa Bay or Grays Harbor due to high densities of burrowing shrimp elsewhere. Imidacloprid is less toxic than carbaryl (Gervais et al. 2010), causing a temporary paralysis reaction in crustaceans, including shrimp. The paralysis creates an exposure pathway for fish and birds that predate on flushed shrimp. Imidacloprid can cause a temporary paralysis (paralysis) reaction in Dungeness crab and they may become susceptible to predation by gulls (CSI 2013).

The effect of imidacloprid on marine zooplankton species is largely unstudied. While crustaceans are generally more susceptible to indirect effects than worms and molluscs, as described above, the potential for adverse effects to planktonic juveniles is unknown. Twenty-four hour acute toxicity experiments were conducted using blue crab megalopae and juveniles under laboratory conditions (Osterberg et al. 2012), with higher concentrations of imidacloprid than would generally be found following proposed treatment events. The authors of the laboratory experiments found that blue crab megalopae did not molt as readily when exposed to imidacloprid, and mortality was high (Osterberg et al. 2012). Sanchez-Bayo and Goka (2006) analyzed the effect of imidacloprid on freshwater zooplankton crustaceans, and found varied effects depending on light levels and concentrations. However, all of these experiments were conducted under laboratory conditions and did not account for dilution and dispersion of imidacloprid that would occur in Willapa Bay and Grays Harbor. Sanchez-Bayo and Goka (2006) acknowledge that their findings are not a reliable predictor for field use. Imidacloprid would be applied on selected commercial shellfish beds in-water during out-going tides or on exposed mudflats, when densities of zooplankton would be low due to limited water depth. Imidacloprid breaks down rapidly in water and has a low volatilization potential in air, minimizing potential adverse effects on zooplankton in Willapa Bay or Grays Harbor (Gervais et al. 2010).

Forage Fish and Groundfish. Herring, smelt, sand lance, and anchovy feed on phytoplankton and zooplankton in Willapa Bay and Grays Harbor. Juvenile lingcod and flatfish feed in the shallow water near shellfish beds. Alternative 1 (No Action – No Permit for Pesticide Applications) would be unlikely to have a significant beneficial or adverse effect on forage fish or groundfish in the bays. Habitat complexity and biodiversity may be reduced as described above within the treated areas, resulting in decreased foraging opportunities for fish. However, these areas would be small in relation to total tideland acreage in Willapa Bay or Grays Harbor (as described above in the introductory paragraphs to the Animals: Potential Impacts section).

Carbaryl (Alternative 2) affects the nervous system of fish, impacting swimming behavior. The effects are localized, causing mortality on direct contact (NMFS 2009). While carbaryl dilutes and degrades as it dissipates from treatment sites, in low concentrations it could still increase the susceptibility of some fish to predation.

Burrowing shrimp control indirectly promotes native eelgrass (*Z. marina*) density and coverage, and therefore could indirectly improve foraging habitat for fish under either Alternative 2 or Alternative 3.

It is unlikely that there would be adverse effects to forage fish or groundfish from imidacloprid in water (Alternative 3) (CSI 2013) due to dilution and adsorption onto sediment.

Birds. Marbled murrelet, Western snowy plover, and streaked horned lark are individually discussed below in the Threatened, Endangered, and Protected Species section. Alternative 1 (No Action – No Permit for Pesticide Applications) would be unlikely to have a significant beneficial or adverse effect on birds in Willapa Bay or Grays Harbor due to the small percentage of total tideland acreage that has historically been treated for burrowing shrimp control (as described above in the introductory paragraphs to the Animals: Potential Impacts section). Eelgrass provides an important foraging habitat for many species of birds. Under Alternative 1, a reduction in native eelgrass density and coverage could result from sediment disruption caused by an increased number of burrowing shrimp on untreated commercial shellfish beds. This may affect bird foraging habitat on these tidelands; however, these areas would be small in relation to total tideland acreage in Willapa Bay and Grays Harbor. Disrupted habitats would affect the prey availability of crustaceans and molluscs on which shorebirds feed in the sediment, resulting in reduced bird presence in untreated areas. Species of interest include the red knot, sandpipers, and plovers. Waterfowl that feed on submerged vegetation would also be affected by reduced foraging habitat from mechanical harvest. These species include mallards, brant, ducks, and geese.

Carbaryl (Alternative 2) would be unlikely to adversely affect bird species. The potential for direct exposure would be limited since application techniques by helicopter and hand-held equipment tend to flush birds from the target area. Secondary poisoning by ingestion of contaminated prey has been documented for other pesticides (NMFS 2009), but carbaryl in contaminated invertebrates is actively metabolized, and studies on fish do not suggest a significant transfer of the pesticide beyond environmental exposure. Studies on pelican and shorebirds found the maximum concentration of carbaryl in burrowing shrimp to be 15 mg/kg (USFWS 2009), and field experiments found that the birds did not feed exclusively on contaminated prey, reducing their exposure below a significant level. Burrowing shrimp control using carbaryl would improve forage habitat and prey diversity for birds. Shorebirds such as the red knot feed on an assortment of crustaceans and molluscs. While carbaryl may affect, but would be unlikely to adversely affect crustaceans, overall diversity of prey availability would improve as a result of burrowing shrimp control. Red knot feed on *Macoma* clams in particular, which benefit from stable sediments after burrowing shrimp control (Buchanan et al. 2012). Red knot do not feed on commensal clams associated with burrowing shrimp because their bill limits foraging depth. Waterfowl species such as brant, ducks, and geese could also benefit from the expansion of submerged vegetation found in eelgrass and shellfish beds as a result of burrowing shrimp control. Burrowing shrimp control areas under Alternative 2 would be limited to 1.3 percent *per year* of total tideland acres within Willapa Bay, and less than 0.6 percent *per year* of total tideland areas within Grays Harbor.

Concentrations of imidacloprid (Alternative 3) below 150 milligrams per kilogram (mg/kg) are generally non-toxic to most birds (Gervais et al. 2010), with a low of 15 mg/kg direct application found toxic to the gray partridge (Mineau and Palmer 2013). Similarly, CSI (2013) found imidacloprid application was unlikely to adversely affect birds in Willapa Bay or Grays Harbor based on an application concentration of approximately 3.34 mg/kg[22]. The flowable form of imidacloprid disperses in water, and granular application dissolves in shallow water. Although crustaceans and molluscs uptake imidacloprid during exposure (Frew 2013), they do not bioaccumulate imidacloprid in their tissues, minimizing potential exposure to foraging shorebirds. Red knot and other shorebirds that feed in and around shellfish beds could come in contact with low concentrations of granular imidacloprid immediately following an application. Peak abundance for red knot and many shorebirds occurs in April and May.

Pollinators. Pesticide exposure to honey bees is the primary concern for pollinators in Willapa Bay and Grays Harbor. Alternative 1 (No Action – No Permit for Pesticide Applications) would be unlikely to have a significant beneficial or adverse effect on honey bees in the Willapa Bay or Grays Harbor area due to the small percentage of total tideland acreage that has historically been treated for burrowing shrimp control (as described above in the introductory paragraphs to the Animals: Potential Impacts section).

Carbaryl (Alternative 2) is highly toxic to bees that are exposed to direct contact or residues on flowering plants (USEPA 2012), and cannot be applied with bees present (NMFS 2009). There are no flowering plants (other than eelgrass) on commercial shellfish beds as these are inundated twice daily by tides. Of the approximately 3,000 hives imported in June each year to pollinate cranberries at the south end of Willapa Bay, a few of these are located approximately 0.5 mile from the nearest commercial shellfish beds. The closest cranberry farm in Grays Harbor is approximately 1.5 miles from commercial shellfish beds. The remaining 98 percent of the colonies are located 6 miles or more from the nearest shellfish beds (personal communication with Kim Patten, WSU Pacific County Extension Director). If the conditions of a new or modified carbaryl NPDES individual permit were the same as the 2006 permit (WA0040975), carbaryl would only be administered on approximately 5 to 10 days during the lowest tides in July and August each year, thereby limiting the risk of pollinator exposure from aerial applications.

Imidacloprid (Alternative 3) is highly toxic to bees that are exposed to direct contact or residues on flowering plants, and cannot be applied with bees present . Honey bees in lab tests exhibited behavioral responses in short direct exposure doses greater than 12 μg/kg, and cumulative effects on mortality after 10 days of continued exposure (Gervais et al. 2010). Another pathway for imidacloprid fatal exposure to bees is through uptake by targeted plants (Cresswell 2011). In the proposed application of imidacloprid on commercial shellfish beds in estuarine tidelands, this pathway would not exist. Eelgrass is the only flowering plant near the targeted area, and bees do not pollinate eelgrass. The potential for direct exposure to pollinators or their associated plant species would be negligible since honey bees are not attracted to mudflats, bumblebees and similar pollinators prefer terrestrial flowering plants that are not found in the bays (Macfarlane and Patten 1997), and neither are likely to be present over estuarine waters that cover commercial shellfish beds (CSI 2013).

Mammals. Alternative 1 (No Action – No Permit for Pesticide Applications) would be unlikely to have a significant beneficial or adverse effect on mammals in Willapa Bay or Grays Harbor. These areas would be small in relation to the total tideland area of Willapa Bay and Grays Harbor (as described above in the introductory paragraphs to the Animals: Potential Impacts section).

Carbaryl (Alternative 2) has similar toxicity issues for mammals as those described above for fish (NMFS 2009). Carbaryl application methods implemented since 2001 significantly minimize the exposure of carbaryl to mammals in Willapa Bay and Grays Harbor by treating shellfish beds during tidal periods and at tidal elevations where marine mammals are absent. If it is assumed that limitations on carbaryl use

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[22] Based on an assumption of imidacloprid being present in the top one centimeter of the sediment and a sediment density of 1.5 grams per cubic centimeter (g/cc).

would be the same (or similar) with a new or modified NPDES permit to implement Alternative 2 as they are under the 2006 NPDES individual permit and other applicable restrictions, then there would be limited potential for adverse effects to mammals under this alternative.

Imidacloprid (Alternative 3) exposure to mammals would be related to direct ingestion. There is little opportunity for the absorption of imidacloprid through the skin of animals, and concentrations less than 20 mg/kg are metabolized in less than 24 hours. The proposed imidacloprid application rate would produce a concentration of 3.34 mg/kg[23] Imidacloprid would be unlikely to adversely affect mammals under the proposed use on commercial shellfish beds. Terrestrial mammals are unlikely to be present on shellfish beds during daylight hours when imidacloprid would be applied. Harbor seals may be the only marine mammals potentially present in areas near imidacloprid applications, but prefer sandbars and rocky shores for haul-out (Jeffries et al. 2000).

Threatened, Endangered and Protected Species.

Salmonids including Bull Trout. Alternative 1 (No Action – No Permit for Pesticide Applications) would be unlikely to have a significant beneficial or adverse effect on salmonids in Willapa Bay or Grays Harbor due to the small percentage of total tideland acreage that has historically been treated for burrowing shrimp control (as described above in the introductory paragraphs to the Animals: Potential Impacts section). Indirect effects would include reduced eelgrass habitat and prey availability in limited areas during juvenile out-migration, as a result of increased burrowing shrimp densities on commercial shellfish beds. Increased turbidity due to mobilized sediments caused by mechanical control efforts and/or by the burrowing activity of shrimp could locally reduce foraging efficiency for short periods of time, resulting in reduced presence of juvenile salmon in untreated areas.

Carbaryl (Alternative 2) has been documented to cause mortality of juvenile salmon in aquaria studies (NMFS 2009). The USFWS Biological Opinion for Nationwide Permit 48 (2009) also found reported effects to bull trout critical habitat in Grays Harbor and foraging habitat in Willapa Bay. Salmonids, including bull trout, use the bays primarily for migration to and from spawning habitat, as adults and juveniles respectively, and would spend varied residence times near carbaryl application sites depending on species. Juvenile salmonids spend more residence time in the bay than adults, and swim relatively closer to shore; however, the area for carbaryl application would be small in relation to the total tideland area of Willapa Bay and Grays Harbor (as described above).

Imidacloprid (Alternative 3) would be unlikely to adversely affect adult salmonids, bull trout, or their critical habitat (CSI 2013). Juvenile salmonids travel through the nearshore habitat during out-migration, feeding on copepods and zooplankton. There would be a possible short-term paralysis effect on crustacean zooplankton during imidacloprid application in localized areas of Willapa Bay and Grays Harbor, but the area for imidacloprid application would be small in relation to the total tideland area of Willapa Bay and Grays Harbor (see the introductory paragraphs to the Animals: Potential Impacts section, above). Imidacloprid does not bioaccumulate in invertebrates, and uptake through contaminated prey would be no greater than environmental exposure.

Green Sturgeon. Alternative 1 (No Action – No Permit for Pesticide Applications) would be unlikely to have a significant beneficial or adverse effect on green sturgeon in Willapa Bay or Grays Harbor. The green sturgeon diet may seasonally consist of up to 50 percent burrowing shrimp (Dumbauld et al. 2008).

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[23] Based on an assumption of imidacloprid being present in the top one centimeter of the sediment and a sediment density of 1.5 grams per cubic centimeter (g/cc).

Alternative 1 may indirectly affect prey availability by allowing for increased abundance of burrowing shrimp on untreated commercial shellfish beds; however, the effects would be highly localized relative to the full extent of the two bays.

Carbaryl (Alternative 2) could affect green sturgeon only if applied in direct contact (NMFS 2009). Carbaryl application would occur on exposed mudflats during an outgoing tide. Green sturgeon are highly mobile and would not likely be present over commercial shellfish beds under these conditions (CSI 2013). Although green sturgeon are known to opportunistically feed on burrowing shrimp on mudflats, it is unclear whether they actively feed in shellfish beds due to the sharp quality of the shells present (personal communication with Dr. Kim Patten, WSU Pacific County Extension Director, August 7, 2104). Observational studies of the presence of green sturgeon pits in shellfish beds were being undertaken at the time of this writing. Sanford (2012) found no adverse effect to green sturgeon as a result of reduced prey availability from the use of carbaryl applications on commercial shellfish beds in Willapa Bay.

Imidacloprid (Alternative 3) has a limited effect on large vertebrates, and only when high concentrations are ingested directly. Imidacloprid applications would occur in shallow water or on exposed mudflats, when sturgeon are unlikely to be present over commercial shellfish beds. Although green sturgeon are known to opportunistically feed on burrowing shrimp on imidacloprid-treated mudflats, it is unclear whether they actively feed on shellfish beds due to the sharp quality of the shells present (personal communication with Dr. Kim Patten, WSU Pacific County Extension Director, August 7, 2104). Observational studies of the presence of green sturgeon pits in shellfish beds were being undertaken at the time of this writing. If available, the results will be discussed in the Final EIS. Further, Alternative 3 would be unlikely to adversely affect green sturgeon foraging habitat due to the limited area where imidacloprid would be applied relative to the size of Willapa Bay and Grays Harbor (as described above in the introductory paragraphs to the Animals: Potential Impacts section).

Marbled Murrelet. Alternative 1 (No Action – No Permit for Pesticide Applications) would be unlikely to have a significant beneficial or adverse effect on marbled murrelet, their habitat, or prey availability in Willapa Bay or Grays Harbor. Marbled murrelet critical habitat is designated upland from Willapa Bay and Grays Harbor.

The USFWS Biological Opinion for Nationwide Permit 48 (2009) determined that carbaryl application would be unlikely to adversely affect marbled murrelet birds or critical habitat. These birds forage on the outer coast for forage fish, and are not well documented inside the bays. For these reasons, Alternative 2 would be unlikely to adversely affect marbled murrelet.

Similarly, marbled murrelet critical habitat and foraging habitat do not overlap with areas where imidacloprid applications (Alternative 3) would occur on commercial shellfish beds in Willapa Bay or Grays Harbor; therefore, it would be unlikely to adversely affect marbled murrelet (CSI 2013).

Western Snowy Plover. Alternative 1 (No Action – No Permit for Pesticide Applications) would be unlikely to have a significant beneficial or adverse effect on snowy plover in Willapa Bay or Grays Harbor. Snowy plover prefer to forage on invertebrates in the wet sand.

The USFWS Biological Opinion for Nationwide Permit 48 (2009) determined that carbaryl application (Alternative 2) would be unlikely to adversely affect snowy plover birds or critical habitat. Adverse effects on prey resources would also be unlikely since snowy plovers are not documented near commercial clam or oyster beds or during the carbaryl application season.

Granular-form applications of imidacloprid (Alternative 3) on commercial shellfish beds (mudflats) could result in an opportunity for birds to be exposed to this chemical through ingestion of the solid form, but direct exposure would be limited since application techniques flush birds from the site, and imidacloprid dissolves readily in water. This limited period of potential exposure would be interrupted when the mudflats became inundated by the incoming tide. CSI (2013) found imidacloprid toxicity exposure for snowy plover to have a low likelihood of indirect effects, and concluded that it would be unlikely to have adverse effects. "Flowable"-form applications of imidacloprid would avoid exposure time for birds (Giddings et al. 2012).

Streaked Horned Lark. Streaked horned lark critical habitat is centered on nesting beaches along the coast. Nests are established on bare ground, well above MHHW, and the birds do not forage on or near shellfish beds. Therefore, Alternative 1 (No Action – No Permit for Pesticide Applications) would be unlikely to have either a significant beneficial or adverse effect on horned lark. Application of carbaryl (Alternative 2), or application of imidacloprid (Alternative 3) would be unlikely to adversely affect streaked horned lark or their nest sites because they do not occur on commercial shellfish beds within Willapa Bay or Grays Harbor.

MITIGATION MEASURES

Regulatory pathways for imposing mitigation measures under the No Action Alternative would be limited to local, State and Federal permits that regulate commercial shellfish aquaculture. There would be no NPDES permit issued by Ecology for Alternative 1.

Mitigation measures for Alternative 2 would be imposed under the current administratively extended NPDES Permit or pursuant to a new or modified NPDES permit as necessary to ensure compliance with all applicable State regulations and NPDES approval criteria, including Washington State Water Quality Standards that protect water quality, fish and wildlife. Compliance with these laws would avoid and minimize significant adverse impacts to animals. Specific mitigation measures would likely include limiting carbaryl application areas and seasonal timing restrictions as described in FEIS Chapter 2, Section 2.8.2. Treatment site conditions under the 2006 carbaryl NPDES Permit (WA0040975) have historically limited carbaryl applications to only those commercial oyster beds that are uncovered by an outgoing tide. Current methods for the aerial application of flowable carbaryl would likely continue to be limited to periods of wind less than 10 mph to avoid spray drift and therefore exposure to nearby sensitive fish and crab habitats (NMFS 2009). The majority of Dungeness crab and salmon mortality was documented as occurring from exposure during direct application. Animals trapped in shallow pools during low tide received direct contact with concentrated carbaryl. To limit exposure to these species, the same or similar restrictions to those in the 2006 NPDES Permit would likely continue in a new or modified carbaryl permit to implement Alternative 2. It is likely that a 200-foot buffer would continue to be required around sloughs and channels for carbaryl applications by helicopter, with a 50-foot buffer for carbaryl applications administered on the ground or by boat.

The carbaryl application rate is limited by the amended EPA Interim Registration Eligibility Decision to 8 pounds per acre. If the seasonal application of carbaryl were to remain July 1 through October 31, carbaryl exposure would be minimized during windows of juvenile salmonid out-migration, seasonal bird migrations, peak pollination periods, and forage fish spawning periods. Juvenile salmonid migration ends in July. Red knot and other shorebirds, black brant and other waterfowl migrate out of the bays by the end of May. Mallards are the most common nesting bird, but complete their nesting by late spring.

Mitigation measures for the use of imidacloprid (Alternative 3) would be imposed pursuant to a new NPDES permit as necessary to ensure compliance with all applicable NPDES approval criteria, including

Washington State Water Quality Standards that protect water quality, fish and wildlife. Compliance with these laws would avoid and minimize significant adverse impacts to animals. Specific mitigation measures would likely require imidacloprid to be administered on commercial shellfish beds in a manner consistent with the spray drift management techniques and treatment site requirements specified in the FIFRA Registrations for the flowable and granular formulations of imidacloprid. These state that aerial applications must occur on beds exposed at low tide, and granular applications may be applied to beds under water using a calibrated granular applicator, operating from a floating platform or boat. Aerial dispersal would be limited by spray drift management measures to minimize exposure of imidacloprid to non-target terrestrial species or flowering terrestrial plants, and therefore would be unlikely to adversely affect local honey bee, bumble bee, butterfly, fish, mammal, or bird populations. It is unlikely that there would be adverse effects outside of the targeted habitat of burrowing shrimp due to photolysis of imidacloprid in the marine environment and dilution on successive tidal cycles (CSI 2013). Although there is a potential for imidacloprid to persist in certain sediment types (Grue and Grassley 2013), it is unlikely to be bioavailable to benthic infauna. Imidacloprid does move off-plot during the first tidal cycle after treatment; however, subsequent tidal cycles should further dilute the imidacloprid to undetectable levels, and the rapid photolysis of imidacloprid in water would effectively reduce the potential exposure to zooplankton species as well.

To avoid and minimize potential exposure to bees, the spray drift management requirements indicated in the FIFRA Registrations for the granular and flowable formulations of imidacloprid (Protector 0.5G and Protector 2F, respectively) would be employed (USEPA 2013a and 2013b). Imidacloprid would be applied either to exposed mudflats at low tide or to shallow water covering shellfish beds during an out-going tide. Drift management techniques include, among other things, a controlled nozzle applicator used during low wind speeds, and an established buffer area between the treatment area and blooming plants. Additional spray drift management requirements described below.

With regard to Alternative 3, the WSDA Special Pesticide Registration Program Coordinator has stated that, in his professional opinion, there is no risk to bees from the application of imidacloprid (either granular or flowable formulation) to tidal flats. Implementing appropriate spray drift management techniques for the flowable formulation of imidacloprid, or maintaining an adequate buffer between the imidacloprid treatment area and blooming plants, would mitigate potential risk to bees (personal communication with Erik Johansen, March 19, 2014).

The FIFRA Registrations limit the application of imidacloprid to the period between April 15 and December 15. This application window would limit exposure to herring and sand lance during their peak spawning periods, and would avoid the late winter migration of birds. Application of imidacloprid between April 15 and July 15 would overlap with the window of juvenile salmon out-migration, and with spring and fall bird migrations; however, application methods would minimize the potential for direct exposure to juvenile salmonids and migrating birds, and studies discussed above have determined that it is unlikely there would be adverse effects to these species. The effects of imidacloprid on Dungeness crab are temporary, and only from direct contact. Application of the granular formulation of imidacloprid during periods of shallow standing water would limit the potential for crabs to be affected. Because imidacloprid currently appears to be less effective than carbaryl at controlling burrowing shrimp densities, repeated applications over a larger treatment area within Willapa Bay and Grays Harbor is proposed; however, only a single application of imidacloprid of up to 0.5 pound of active ingredient per acre *per year* would be allowed on any commercial shellfish bed selected for treatment (USEPA 2013a and

2013b). The proposed treatment area is 2,000 acres *per year*: up to 1,500 acres *per year* within Willapa Bay, and up to 500 acres *per year* within Grays Harbor[24].

Imidacloprid would not be applied to any areas with shellfish to be harvested within 30 days of treatment (FIFRA Registrations 88867-1 and 88867-2; USEPA 2013a and 2013b). In addition, a 100-foot buffer zone would be maintained between the treatment are and the nearest shellfish to be harvested within 30 days when treatment is by aerial spray, and a 25-foot buffer zone would be maintained when treatment is by hand spray. All shellfish beds to be treated would be properly staked and flagged to protect adjacent shellfish and water areas. For aerial applications, the corners of each plot would be marked so the plot would be visible from an altitude of at least 500 feet. During aerial applications, all public access areas within one-quarter mile and all public boat launches within one-quarter (1/4)-mile radius of any bed scheduled for treatment would be posted with signage indicating imidacloprid will be applied for burrowing shrimp control and notifying the public not to fish, crab, or clam within one-quarter mile of the treated area. These signs will be posted at least two days prior to aerial treatment and will remain posted for at least 30 days after treatment.

The FIFRA Registrations for the flowable and granular formulations of imidacloprid (USEPA 2013a and 2013b) establish a series of application methods for spray drift management that would minimize the risk of exposure to non-target species. For the granular form of imidacloprid (Protector 0.5G), average wind speed at the time of application would not exceed 10 mph to minimize drift to adjacent shellfish and water areas when applied by air. This would reduce the likelihood of exposure for birds, terrestrial habitats, and bees. Applications would also not occur during temperature inversions. Applications would be made at the lowest possible height (helicopter, ground, or barge) that is safe to operate and reduce exposure of the granules to wind. When applications are made crosswind, the applicant would compensate for displacement by adjusting the path of the application equipment upwind. Swath adjustment distance should increase with increasing drift potential. For the flowable form of imidacloprid (Protector 2F), applicators would avoid and minimize spray drift by following detailed instructions in the FIFRA Registration, including measures to control droplet size, making applications at the lowest possible height (helicopter; ground-driven spray boom) that is safe and practical and reduces exposure of droplets to evaporation and wind, applying during appropriate wind speeds and avoiding temperature inversions, and using authorized application methods and equipment.

SIGNIFICANT UNAVOIDABLE ADVERSE IMPACTS

Based on currently available information and studies, and requirements to comply with the conditions of all applicable pesticide registrations and regulations (including Washington State Water Quality Standards), no significant unavoidable adverse impacts to marine or terrestrial animals; or threatened, endangered or protected species would be expected with the proposed action (Alternative 3: imidacloprid applications with IPM), or with Alternative 2 (carbaryl applications with IPM). With the exception of some salmonid life stages, it is unlikely that these species would be present on treatment sites at the time of pesticide applications. There is a low probability of adverse effects to birds or large vertebrates. Permit conditions and mitigation measures protective of surface water quality would also be protective of salmonids. The Ecology NPDES permit, if issued, would include conditions that limit the maximum annual tideland acreage for pesticide applications; specify treatment methods; require buffers from sloughs, channels, and shellfish to be harvested; and require discharge monitoring to evaluate the effects

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[24] Plauché and Carr letter to Greg Zentner, Department of Ecology, November 7, 2013 re: WGHOGA NPDES Application: clarifying information to supplement the July 1, 2013 application.

of pesticide applications. Adjustments to permit conditions could be made throughout the five-year term of the permit.

3.2.6 Human Health

AFFECTED ENVIRONMENT

3.2.6.1 *Willapa Bay*

The Pacific County Board of County Commissioners serves as the local board of health for the area that includes Willapa Bay, with responsibility for all matters pertaining to the preservation of the life and health of people within its jurisdiction.

The Pacific County Public Health and Human Services Department (PCPHHSD) collects, analyzes, and reports information related to the overall health status of the County. The Department uses data from a variety of sources to prepare and disseminate reports that describe general health status, behavioral health, youth health, and risk factors, access to health care and a number of other topics. Individuals, agencies, and organizations use PCPHHSD data to identify community needs, develop and plan programs, prepare grant requests, and measure program effectiveness. The South County office of PCPHHSD is located in Long Beach, Washington (Pacific County Health and Human Services Department 2013).

Hospitals and clinics in Pacific County that serve the Willapa Bay area include the Ocean Beach Hospital at 174 First Avenue N. in Ilwaco, the Ocean Beach Medical Clinic at 176 First Avenue N. in Ilwaco, the North Beach Family Health Center north of Long Beach, the Naselle Medical Clinic at 21 N. Valley Road in Naselle, and the Willapa Harbor Hospital (a critical access hospital) at 800 Alder Street in South Bend. Both the Ocean Beach Hospital and Willapa Harbor Hospitals have helipads that are available 24 hours per day, weather permitting. Hospital services include emergency care, general surgery, laboratory, nuclear medicine, radiology, cardiac rehabilitation, oncology, orthopedic surgery, and nutrition.[25]

3.2.6.2 *Grays Harbor*

Grays Harbor County Public Health and Social Services Department (GHCPHSSD) is located at 2109 Sumner Avenue in Aberdeen. Services provided by GHCPHSSD include implementing a community health improvement plan; clinic services; a medical reserve corps; health education and prevention; maintaining community health data; mental health and chemical dependency counseling; a Healthy Communities workgroup; and support for mothers, children, and pregnant and parenting teens.[26]

Grays Harbor Community Hospital has three campuses in Aberdeen serving County residents and visitors: the Main Campus (West) at 915 Anderson Drive; the East Campus at 1006 North H Street, and the Education Building at 2302 W. 6th Street.[27]

As described in Subsection 3.2.3.2 above, there are two Shellfish Protection Districts (SPDs) in Grays Harbor: the Bay and the Pacific Coast (North Beach). Water quality is monitored in these areas, with an emphasis on detecting fecal coliform levels for the protection of public health and to ensure the continued viability of shellfish beds. Seasonal concerns have been noted on razor clam beds (Grays Harbor County,

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25 http://www.oceanbeachhospital.com
26 http://www.healthygh.org
27 http://www.ghchwa.org

June 2012). Stakeholders include, but are not limited to, State agencies (the Department of Health, Department of Ecology, Department of Fish and Wildlife, Department of Natural Resources, and Washington State Parks), the Quinault Indian Nation, the City of Ocean Shores, area property owners, and beach users in general. Grays Harbor County monitors freshwater sources near impaired marine sampling stations, as these have the potential to carry polluted runoff onto clam beds.

POTENTIAL IMPACTS

The proposed action or alternatives would likely have no effect on human health or potentially affect only a very small number of people (primarily pesticide handlers and applicators) in Willapa Bay and Grays Harbor.

No population would be exposed to imidacloprid in estuarine sediments or water under Alternative 1 (No Action – No Permit for Pesticide Applications). It is illegal to use imidacloprid formulations on sediments in Willapa Bay and Grays Harbor without Ecology approval and no parties have been granted such license except on limited acreage for experimental use and research. Therefore, there would be no exposure under the No Action Alternative to pesticides that might result in health impacts to shellfish workers or the general population engaging in recreational activities such as, shellfish gathering, fishing, or swimming.

Continued use of carbaryl under Alternative 2 would potentially affect only a very small number of people (primarily pesticide handlers and applicators, and to a much lesser extent, commercial shellfish workers). Carbaryl has been used to control burrowing shrimp in Willapa Bay and Grays Harbor from 1963 through 2013 under a FIFRA Section 24 (c) Special Local Need registration issued by the Washington State Department of Agriculture (WSDA).

Historical use of carbaryl to control burrowing shrimp included spreader application in July and August at the lowest tides to exposed beds, and by helicopter with boom sprayers (ECY 2006). Application rates were 8 lbs active ingredient/acre on up to 800 acres/year in Willapa Bay and Grays Harbor (up to 600 acres in Willapa Bay, and up to 200 acres in Grays Harbor). It is assumed that these applications would continue under the current administratively extended NPDES Permit or a new or modified carbaryl NPDES permit to implement Alternative 2, and may be authorized on commercial shellfish beds primarily grown with clams as well as oysters (see FEIS Chapter 2, Section 2.8.2).

Carbaryl is a reversible inhibitor of the neurotransmitter acetylcholinesterase. A member of the n-methyl carbamate class of pesticides, carbaryl can cause cholinesterase inhibition in humans; that is, it can overstimulate the nervous system causing nausea, dizziness, confusion, and at high exposures, respiratory paralysis, and death. Concentrations of carbaryl required to produce symptoms in vertebrates, including humans, are much higher than those used to control invertebrates, which are much more sensitive. Carbaryl is classified as a likely human carcinogen based on laboratory experiments that produced vascular tumors in mice. However, non-cancer risks are seen as the primary risk driver for almost all use scenarios (USEPA 2014). EPA has derived a chronic reference dose (RfD) for carbaryl of 0.06 mg/kg per day. This value is based on a "no observed adverse effects level" (NOAEL) of 5.7 mg/kg per day in rats with an uncertainty factor of 100 applied. Acute occupational exposure of humans (i.e., pesticide handlers and applicators) to carbaryl has been observed to cause cholinesterase inhibition (which impairs central nervous system (CNS) function), resulting in nausea, vomiting, bronchoconstriction, blurred vision, convulsions, coma, and respiratory failure.

The 2006 NPDES Permit that authorizes use of carbaryl (WA0040975) requires a minimum 1-year waiting period between the date of application to commercial oyster beds and harvest of oysters for consumption from these beds. This 1-year waiting period encompasses the length of time it takes carbaryl to break down in oyster tissue and become undetectable.

Similar to Alternative 2, there would be a risk of exposure under Alternative 3 to a small number of people who would handle and apply imidacloprid. Up to 2,000 acres would be treated *per year*: up to 1,500 acres in Willapa Bay and up to 500 acres *per year* within Grays Harbor on commercial clam and oyster beds (see FEIS Chapter 2, Section 2.8.3). Imidacloprid is a systemic insecticide of the chemical class of chloronicotinyls-neonicotinoids; specifically, it is a chloronicotinyl nitroguanidine. The compound acts on the nicotinergic acetylcholine receptors (nAChR) in the nervous system of insects, blocking the transmission of nervous signals in the post-synaptic region, resulting in paralysis and death. Mammals, fish, amphibians, and aquatic plants are much less sensitive to imidacloprid than certain aquatic invertebrates. Imidacloprid is not considered acutely toxic to humans via dermal or inhalation exposure routes even though it is designated an acute oral toxicant.

Health effects attributed to three cases of accidental worker exposure to imidacloprid in California between 1995 and 2001 included eye irritation, blurred vision, tearing, and pain in the eyes. In 115 other probable or possible exposures to mixtures of imidacloprid and other pesticides, the most common clinical effects included: rash, breathing difficulty, headache, eye tearing, nausea, itching, dizziness, increased salivation, vomiting, numbness, and dry mouth (Cal EPA 2006). Three case reports of unsuccessful suicide attempts described signs of toxicity included drowsiness, dizziness, vomiting, disorientation, and fever (Wu et al. 2001, Shadnia 2007, Deepu et al. 2007). In two of the cases, the authors concluded that ingredients in the formulated product other than imidacloprid likely accounted for the observed symptoms. The only fatality that has been reported involved a 69-year old woman who ingested a formulation containing 9.6 percent imidacloprid in N-methylpyrrolidine, an organic solvent (Huang et al. 2006).

Table 3.2.6-1 summarizes some of the toxicity endpoints used to evaluate potential health risks to humans as determined by EPA-approved toxicity testing during the imidacloprid registration process.

Table 3.2.6-1. Summary of acute toxicity studies for imidacloprid.

Study	Organism	NOAEL (mg/kg)	LOAEL (mg/kg)	Toxicity Category	Reference
Oral	Rat	50	100	II	Bowman 1989a
Oral	Rat	50	200	II	Bowman 1991a
Oral	Rat	200	300	II	Bowman 1991b
Oral	Mouse	10	71	II	Bowman 1989a
Inhalation	Rat	1220	2577	IV	Pauluhn 1988a
Dermal	Rat	> 5000	-	IV	Kroetlinger 1989
Dermal	Rabbit	None	-	IV	Pauluhn 1998b
Eye irritation	Rabbit	None	-	IV	Pauluhn 1998c
Dermal sensitization	Guinea pig	None	-	IV	Otha 1988

EPA has derived a RfD for imidacloprid of 0.057 mg/kg per day. This value is based on a NOAEL of 5.7 mg/kg per day in rats with an uncertainty factor of 100 applied. EPA developed an acute RfD of 0.14 mg/kg per day based on the "lowest observed adverse effects level" (LOAEL) of 42 mg/kg per day in rats and an uncertainty factor of 300. For a human weighing 70 kilograms (about 155 pounds), exposure to 8.8 milligrams and 21.7 milligrams adjusted for the uncertainty factor in extrapolating between rats and humans would be required for the NOAEL and LOAEL, respectively. During chemical applications, imidacloprid handlers and applicators would face inherent exposure. Chemical applications would be small-scale activities that occur on privately-owned or leased tidelands designated for commercial shellfish aquaculture. These areas are normally located well away from public gathering areas. People do not tend to walk on the commercial shellfish beds as most are remote and are private farm lands. Therefore, recreational swimmers, fishers, and shellfish gathers are unlikely to be present at the treatment sites, and potential exposure to the public would be from more distant locations. Following application, commercial workers such as oyster harvesters may experience dermal exposure though, based on field studies, imidacloprid is not persistent in water or on the shellfish beds. Thus, there is a slight possibility of human health impacts from imidacloprid exposure to pesticide applicators and, to a much lesser extent, commercial shellfish workers, but not to the general population engaging in recreational activities (e.g., shellfish gathering, fishing, swimming). Imidacloprid is classified as a "Group E" carcinogen indicating "no evidence of carcinogenicity in humans" (USEPA 1999a, 1999b, and 2003).

Two forms of imidacloprid are proposed to be applied to affected tidelands–Protector 0.5G (a granular formulation) and Protector 2F (a flowable formulation). Aerial and ground applications would be used with the flowable form of imidacloprid, and the granular form would be applied by the air, ground, and/or boat. Imidacloprid use and application rates are anticipated to be a single yearly application[28] of 0.5 pound of active ingredient per acre, so there are unlikely to be on-going cumulative or chronic exposures. In addition, there is a 30-day waiting period between treating with imidacloprid and harvesting shellfish. This waiting period is based on the length of time it takes imidacloprid to become undetectable in shellfish tissue.

MITIGATION MEASURES

No mitigation measures for human health effects would be required under the No Action Alternative (Alternative 1).

If a new or modified NPDES individual permit were issued for continued use of carbaryl under Alternative 2, the following mitigation measures for protection of human health would likely be instituted. These mitigations measures are based on the FIFRA Section 3 registration and FIFRA Section 24 (c) Special Local Need registration labels for carbaryl and are based on Federal and State laws that require various measures to be implemented to protect human health. These measures would mitigate potential significant adverse impacts.

- Applications would be made by a State-licensed applicator with an aquatic endorsement, as required by WAC 16-228-1231(1) and no person would be allowed on or within 200 feet of the treatment site during aerial spraying.
- Property owners within 200 feet of the treatment site would be notified in person, by telephone, or by mail 24 hours (but not more than 10 days) prior to commencement of initial carbaryl application to commercial clam or oyster beds. All notifications would include the name of the pesticide to be used, where it is to be applied, any public health and livestock restrictions, and the name and telephone number of the WGHOGA contact person. All notifications will be made in compliance with NPDES permit requirements, and other applicable SMS requirements under WAC 173-204-415(2)(e).[29]

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[28] Individual shellfish beds may be treated once per year at a maximum, though treatment frequency would likely be less often. Applications to selected areas may occur at intervals as great as 3 or more years, depending on re-population levels and the growth rate of burrowing shrimp.

[29] If a Sediment Impact Zone (SIZ) is defined to implement Alternative 2, Ecology would make a reasonable effort to identify and notify all landowners, adjacent landowners, and lessees affected by the SIZ in accordance with

- Interested parties would be notified by telephone, e-mail or fax at least 24 hours prior to carbaryl applications.
- The public would be notified prior to carbaryl applications through newspaper announcements and signs posted at all reasonable points of public access to proposed treatment areas.
- No bed would be treated with carbaryl if it contains shellfish within one year of harvest.
- Buffer zones would be maintained between the carbaryl treatment area and the nearest shellfish to be harvested within one year when treatment is by aerial spray (a 200-foot buffer for aerial applications, or a 50-foot buffer for applications made by hand).
- Carbaryl would not be applied to commercial shellfish beds during Federal holiday weekends.

To mitigate potential exposure for persons applying carbaryl, applicators, mixers, loaders, and handlers would be advised to wear approved Personal Protective Equipment (PPE), and would be trained in pesticide applications. The following PPE would be required of all carbaryl applicators and handlers, as required by the FIFRA labels (i.e., required pursuant to Federal law) and would mitigate potential significant impacts:

- Long-sleeved shirt and long pants;
- Chemical-resistant gloves made of any waterproof material such as barrier laminate, butyl rubber, nitrile rubber, neoprene rubber, natural rubber, polyethylene, polyvinylchloride (PVC) or Viton;
- Chemical resistant apron when mixing, loading, or cleaning up spills or equipment; and
- Shoes and socks.

Manufacturer’s instructions must be followed for cleaning/maintaining PPE. If instructions for washables do not exist, detergent and hot water would be used. PPE should be kept and washed separately from other laundry.

Helicopter pilots must use an enclosed cockpit in a manner that is consistent with the worker protection standards (WPS) for Agricultural Pesticides.

Helicopters would be equipped with Accuflow nozzles. Treatment sites would be marked so as to be visible to the naked eye from an elevation of 500 feet. The helicopters would also be equipped with agricultural-grade application global positioning systems (GPS) and precise shapefiles for all polygons destined for treatment with carbaryl. No aerial application of carbaryl would occur if the wind velocity at the treatment site exceeds 10 mph. Past applications of carbaryl have been very accurate (personal communication with WGHGOA members); therefore, future applications are also expected to have limited off-site drift. It would be the responsibility of the applicator to select appropriate application equipment and to treat commercial shellfish beds only during appropriate environmental conditions when wind speed, temperature, and tidal elevation would minimize the risk of spray drift, to avoid off-target dispersion. A WGHOGA representative would be present at application sites at the time of treatment.

While no mitigation for potential impacts to human health with implementation of Alternative 3 are indicated by the results of testing imidacloprid, Federal and State laws require various measures to be implemented to protect human health. These measures would mitigate potential significant adverse

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WAC 173-204-415(2)(e). This notification would be in addition to the public notice requirements for chemical applications for which WGHOGA would be responsible.

impacts. The following conditions imposed by the imidacloprid FIFRA Registrations (USEPA 2013a and 2013b) would be protective of human health:

- The public would be notified prior to imidacloprid applications through signs, website postings, and e-mail to interested parties.
- All public access areas within one-quarter mile and all public boat launches within one-quarter mile radius of any bed scheduled for treatment with imidacloprid would be posted. Public access areas would be posted at 500-foot intervals at those access areas more than 500 feet wide.
- Signs would be posted at least 2 days prior to aerial treatment and will remain for at least 30 days after treatment. Signs shall say "Imidacloprid will be applied for burrowing shrimp control on [date] on commercial shellfish beds. Do not Fish, Crab or Clam within one-quarter mile of the treated area." The location of the treatment area would be included on the sign. The WGHOGA IPM Coordinator would be responsible for posting, maintaining, and removing these signs.[30]
- WGHOGA proposes to use a website for public notification of specific dates of proposed imidacloprid applications in Willapa Bay and Grays Harbor. The website would include a link for interested persons to request direct notification regarding proposed treatment dates and locations. The WGHOGA IPM Coordinator would send e-mail notifications to registered interested parties, as needed.
- No bed would be treated with imidacloprid if it contains shellfish within 30 days of harvest.
- A 100-foot buffer zone would be maintained between the imidacloprid treatment area and the nearest shellfish to be harvested within 30 days, when treatment is by aerial spray; a 25-foot buffer zone will be required if treatment is by hand spray when the nearest shellfish bed is to be harvested within 30 days.
- Imidacloprid would not be applied during Federal holiday weekends.

Washington State law requires that imidacloprid be used and applied only by certified applicators or persons under the direct supervision of a certified applicator.[31]

To mitigate potential exposure for persons applying imidacloprid, applicators would be required to wear approved Personal Protective Equipment (PPE), and would be trained in pesticide applications. The following PPE would be required of all imidacloprid applicators and handlers, as required by the FIFRA labels (i.e., required pursuant to Federal law) and would mitigate potential significant impacts:

- Long-sleeved shirt and long pants;
- Chemical-resistant gloves made of any waterproof material such as barrier laminate, butyl rubber, nitrile rubber, neoprene rubber, natural rubber, polyethylene, polyvinylchloride (PVC) or Viton;
- Shoes and socks;
- Protective eyewear; and

[30] If a Sediment Impact Zone (SIZ) is defined to implement Alternative 3, Ecology would make a reasonable effort to identify and notify all landowners, adjacent landowners, and lessees affected by the SIZ in accordance with WAC 173-204-415(2)(e). This notification would be in addition to the public notice requirements for chemical applications for which WGHOGA would be responsible.

[31] WAC 16-228-1231(1).

- Dust mask when using Protector 0.5G, the granular formulation of imidacloprid.

Manufacturer's instructions must be followed for cleaning/maintaining PPE. If instructions for washables do not exist, detergent and hot water would be used. PPE should be kept and washed separately from other laundry.

Helicopter pilots must use an enclosed cockpit in a manner that is consistent with the WPS for Agricultural Pesticides.

Helicopters would be equipped with Accuflow nozzles. Imidacloprid treatment sites would be marked so as to be visible to the naked eye from an elevation of 500 feet. The helicopters would also be equipped with agricultural-grade application GPS and precise shapefiles for all polygons destined for treatment. Helicopters would use a hopper and a crew of "hopper loaders." Boats would also need to use a hopper, hopper loaders, and possibly a barge to hold additional chemical, equipment and personnel. Because previous carbaryl applications have been very accurate, it is also expected that imidacloprid applications would have limited off-site drift.

It would be the responsibility of the applicator to select appropriate application equipment and to treat commercial shellfish beds only during appropriate environmental conditions when wind speed, temperature, and tidal elevation would minimize the risk of spray drift, to avoid off-target dispersion. Application equipment specified in the FIFRA Registration for the flowable formulation of imidacloprid (Protector 2F) includes: helicopters equipped with a boom three-quarters as long as the rotor diameter, backpack sprayers, and ground-based vehicles with a boom. Application equipment specified in the FIFRA Registration for the granular formulation of imidacloprid (Protector 0.5G) includes: conventional granular pesticide applicators ("belly grinders"), helicopters equipped with a boom three-quarters as long as the rotor diameter, and ground-based vehicles equipped with spinners or drop spreaders.

The FIFRA Registrations for Protector 0.5G and Protector 2F include the following spray drift management requirements (USEPA 2013a and 2013b):

Helicopters used to apply Protector 2F should be equipped to minimize spray drift. The best drift management strategy and most effective way to reduce drift potential is to apply large droplets that provide sufficient coverage and control. Droplet size can be controlled by using high flow-rate nozzles, selecting the number and type of nozzles, nozzle orientation, and controlling pressure appropriate for the nozzle type

Drift potential is lowest between wind speeds of 3 to 10 mph. Average wind speed at the time of application shall not exceed 10 mph to minimize drift to adjacent shellfish and water areas when either Protector 0.5G or 2F is applied by air.

Protector 0.5G or Protector 2F shall not be applied when winds are greater than 10 mph, during gusty conditions, or during temperature inversions. Temperature inversions begin to form as the sun sets and often continue into the morning.

Applications shall be made at the lowest possible height (helicopter, ground, or barge) that is safe to operate and reduces exposure of the granules to wind.

When applications of Protector 0.5G are made crosswind, the applicator must compensate for displacement by adjusting the path of the application equipment upwind. Swath adjustment distance should increase with increasing drift potential.

The WGHOGA proposal for the use of imidacloprid includes having a WGHOGA representative present at the time of application on treatment sites scheduled for aerial (i.e., helicopter) applications to provide line-of-sight supervision.

SIGNIFICANT UNAVOIDABLE ADVERSE IMPACTS

Based on currently available information and studies, and requirements to comply with all applicable pesticide registrations and regulations (including Washington State Department of Agriculture General Pesticide Rules), no significant unavoidable adverse impacts to human health would be expected with the proposed action (Alternative 3: imidacloprid applications with IPM), or with Alternative 2 (carbaryl applications with IPM). Applicators and handlers would be required to use appropriate application equipment and wear specified Personal Protective Equipment. Public notification requirements would inform landowners, adjacent landowners, lessees, interested individuals, recreational users and others of proposed application dates and locations so that potential direct exposure could be avoided. As a dietary precaution, avoidance and waiting periods are specified between dates of pesticide application and shellfish harvest for consumption.

3.2.7 Land Use

AFFECTED ENVIRONMENT

3.2.7.1 *Willapa Bay*

Land use patterns in rural Pacific County are largely dominated by private forestland dedicated to commercial timber production. Private homes are generally located on large lots, scattered along major highways and secondary County roads.

Communities on the North Beach Peninsula (west side of Willapa Bay) include Long Beach, Ilwaco, Seaview, Nahcotta, Ocean Park, and Oysterville (see Figure 3.2.7-1). The City of Long Beach at the south end of the peninsula encompasses a total area of 1.26 square miles. Tourism is the main industry, with approximately 450,000 to 500,000 visitors to the peninsula on an annual basis (Long Beach Peninsula Visitors Bureau 2010, as cited in USFWS 2011). The predominant focus of tourist activities is along the west (ocean) side of the peninsula.

The small unincorporated town of Oysterville is located on the Willapa Bay side of the North Beach Peninsula. It was listed on the National Register of Historic Places in 1976 as a National Historic District, encompassing about 80 acres. The historic and current mariculture industry (production and harvest of oysters, clams, and crabs) has sustained the economy of this community for more than a century. The high quality of the annual harvest is due to the overall water quality of Willapa Bay. Willapa Bay oysters are shipped to restaurants all over the world (USFWS 2011).

Residential and other land uses along the Willapa Bay (east) side of the North Beach Peninsula border Sandridge Road. While Pacific County classifies Sandridge Road a major collector, it is a two-lane asphalt road with a speed limit of 45 mph. Properties adjacent to Sandridge Road have a predominantly rural residential character, with single-family homes on large lots near the road and/or overlooking the bay to the east. Agricultural land uses are readily visible in the form of cranberry farms, cattle grazing, and a horse arena (USFWS 2011).

Cranberry farms at the south end of Willapa Bay are approximately 0.5 mile (2,640 feet) from the nearest tidelands on which commercial clam and shellfish beds are located.[32]

Figure 3.2.7-1 – Willapa Bay Communities

32 Approximate distance as measured on Google Earth.

3.2.7.2 *Grays Harbor*

The area surrounding Grays Harbor is sparsely populated except for Westport, Aberdeen, Hoquiam, and Cosmopolis (see Figure 3.2.7-2). With the exception of Westport, these communities are located at the east end of the bay, adjacent to the confluence of the Chehalis and Hoquiam Rivers with Grays Harbor. The majority of undeveloped land/resource production is located along the north and south margins of Grays Harbor. Timber and fishing industries are large components of the local economy. Businesses along the western side of the harbor (in the vicinity of Westport) include fishing, shellfish harvesting, seafood processing, tourism and, more recently, ship and boat building (USACE 2014). The urban areas of Aberdeen, Hoquiam, and Cosmopolis are 10 or more nautical miles east of North Bay and South Bay where commercial shellfish beds are located.

Most of the land surrounding Grays Harbor is forested in native vegetation that has undergone repeated and extensive timber harvest over the past 150 years. Land surrounding the harbor is sparsely populated with the exception of the cities of Aberdeen, Hoquiam, Cosmopolis, Ocean Shores and Westport. Due to the zoning of intertidal areas, there are some industrial/commercial and resource production land uses waterward of the shoreline and within the harbor. The majority of these uses include shellfish/oyster farming, and cranberry harvesting on lands along the southern shoreline of the harbor (USACE 2014). Cranberry farms nearest to commercial clam and oyster beds are north of North Bay, approximately 1.5 miles from the nearest tidelands.[33]

Residential use occurs along all sides of Grays Harbor, particularly concentrated in and around municipal and industrial areas. In some locations, industrial land use exists directly adjacent to residential use. This occurred during early shoreline development of the harbor for commerce, resulting in manufacturing uses and housing being developed concurrently. Residential use is also clustered on the western peninsulas of the harbor in and around Westport and Ocean Shores. These communities have predominantly flat shorelines and promontories with ocean and harbor views that are popular vacation and retirement spots (USACE 2014).

[33] Approximate distance as measured on Google Earth.

Figure 3.2.7-2 – Grays Harbor Communities

POTENTIAL IMPACTS

There would be no direct or indirect impact to upland land uses from the No Action Alternative or either of the two action alternatives.

Due to the distance between existing cranberry farms and the nearest commercial shellfish beds adjacent to Willapa Bay and Grays Harbor, it is expected that spray drift management requirements for the use of carbaryl or imidacloprid under Alternative 2 or Alternative 3 would avoid risk of exposure to pollinators present at these farms during the approximate period of June 1 through July 5 each year.

MITIGATION MEASURES

No mitigation measures for impacts to land use would be required with the No Action Alternative (Alternative 1).

If Alternative 2 or Alternative 3 were selected for implementation, public notification requirements at public and private shoreline access sites would be the same as those described above under mitigation measures for Human Health (FEIS Section 3.2.6), or below under mitigation measures for Recreation (FEIS Section 3.2.8).

Federal and State regulations contain measures to mitigate potential significant impacts to land and shoreline use. The FIFRA Registrations for the use of either carbaryl with IPM techniques (Alternative 2) or imidacloprid with IPM techniques (Alternative 3) include precautions and spray drift management practices for the use of either of these insecticides on commercial clam or oyster tidelands. Primarily, no direct treatment on terrestrial blooming crops or weeds would occur. This would avoid the potential for impacts to pollinators.

With regard to Alternative 3, the WSDA Special Pesticide Registration Program Coordinator has stated that, in his professional opinion, there is no risk to bees from the application of imidacloprid (either the granular or flowable formulation) to tidal flats. Implementing appropriate spray drift management techniques for the flowable formulation of imidacloprid, or maintaining an adequate buffer between the imidacloprid treatment area and blooming plants would mitigate potential risk to bees (personal communication with Erik Johansen, March 19, 2014).

The FIFRA Registrations for the granular and flowable formulations of imidacloprid (Protector 0.5G and Protector 2F, respectively) include the following spray drift management requirements (USEPA 2013a and 2013b):

- Drift potential is lowest between wind speeds of 3 to 10 mph. Average wind speed at the time of application shall not exceed 10 mph to minimize drift to adjacent shellfish and water areas when either Protector 0.5G or 2F is applied by air. Further, aerial applications shall not occur during gusty conditions, or during temperature inversions. Temperature inversions begin to form as the sun sets and often continue into the morning.
- Applications of imidacloprid shall be made at the lowest possible height (helicopter, ground, or barge) that is safe to operate and that would reduce exposure of the granules to wind.
- When applications of Protector 0.5G (the granular formulation) are made crosswind, the applicator must compensate for displacement by adjusting the path of the application equipment upwind. Swath adjustment distance should increase with increasing drift potential.

- Helicopters used to apply Protector 2F (the flowable formulation) should be equipped to minimize spray drift. The best drift management strategy and most effective way to reduce drift potential is to apply large droplets that provide sufficient coverage and control. Droplet size can be controlled by using high flow-rate nozzles, selecting the number and type of nozzles, nozzle orientation, and controlling pressure appropriate for the nozzle type.

In addition to spray drift management practices, it is an element of the WGHOGA proposal for the use of imidacloprid (Alternative 3) to avoid aerial (i.e., helicopter) applications of Protector 0.5G or 2F within 200 feet of the OHWL adjacent to shoreline areas.

SIGNIFICANT UNAVOIDABLE ADVERSE IMPACTS

Based on currently available information and studies, and requirements to comply with the conditions of all applicable pesticide registrations and regulations, no significant unavoidable adverse impacts to land and shoreline use would be expected as a result of implementing either Alternative 3 (the proposed action), or Alternative 2.

3.2.8 Recreation

AFFECTED ENVIRONMENT

Ecology will review the WGHOGA application for NPDES permit coverage for the use of imidacloprid to control burrowing shrimp on commercial clam and oyster beds in Willapa Bay and Grays Harbor for potential effects on beneficial uses of surface waters, which include recreational activities such as swimming, SCUBA diving, water skiing, boating, fishing and aesthetic enjoyment. Washington State surface water quality regulations and standards (RCW 90.48; Chapter 173-201A WAC) authorize Ecology to establish criteria for waters of the State and to regulate impacts to water quality.

3.2.8.1 *Willapa Bay*

Willapa Bay, the rivers that flow into the bay, and surrounding hills offer a variety of outdoor recreation activities. Traditional hunting, fishing and shellfish gathering opportunities attract both local residents and visitors. Activities include elk, deer, and waterfowl hunting; razor clam digging; freshwater and saltwater fishing, including sturgeon and salmon fishing. Willapa Bay has been recognized for its ecotourism opportunities with bird watching, kayaking, and water trails. The 180 square mile estuary contains abundant wildlife, forests, and historic sites. Willapa Bay is a place that naturalists, boaters and historians enjoy as a year-around destination (Port of Willapa Harbor 2013).

The Willapa National Wildlife Refuge encompasses four separate areas within Willapa Bay: the southern units (Lewis, Porter Point, and Riekkola); and the Long Island, Leadbetter Point, and Cape Shoalwater units (see Figure 3.2.8-1). The Refuge allows camping on Long Island, a popular kayaking destination, which has five primitive campgrounds and hiking trails. Because of shallow water depths, large tidal ranges, swift currents, frequent high winds, and changeable weather patterns in the bay, recreational boating opportunities are limited. Paddling (kayaking, canoeing) mostly occurs in shallow waters near shorelines. While there are some opportunities to fish deeper channel waters for Dungeness crab and white sturgeon, these activities normally occur closer to a few public boat launch sites. Salmon fishing opportunities occur in the Willapa River at the north end of Willapa Bay. Recreational clamming within the bay is limited to public lands. Waterfowl hunting and wildlife viewing are primarily land-based and occur along the dike and saltmarsh areas of the Refuge's southern units and tidal flats adjacent to the Leadbetter Point unit (U.S. Department of the Interior, U.S. Fish and Wildlife Service 1997).

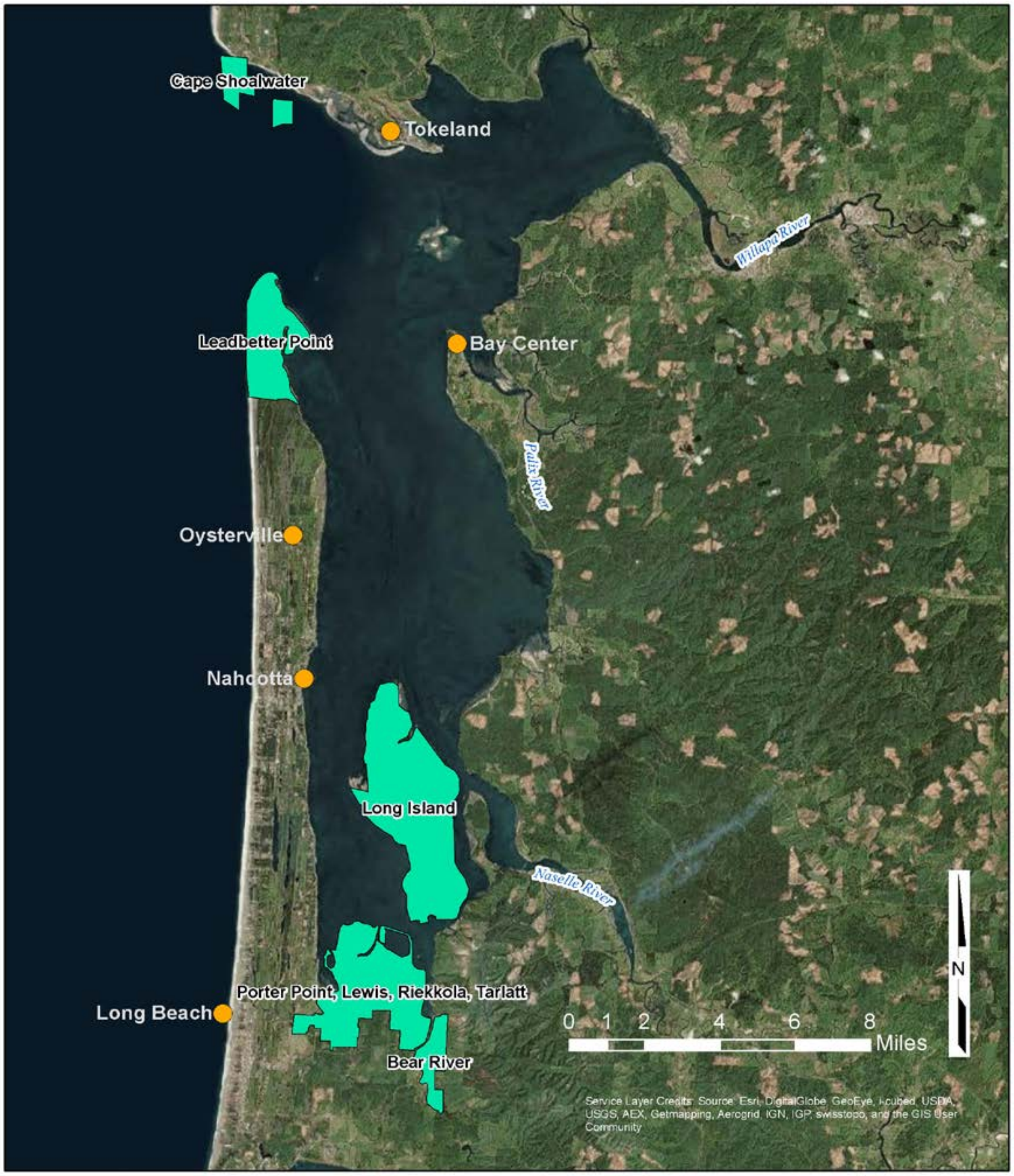

Figure 3.2.8-1 – Willapa Bay National Wildlife Refuge Units

The Willapa Bay Water Trail stretches around the bay with connections to the shoreline, providing views of sandy beaches, dune grasslands, coastal pine forests, and wildlife (Port of Willapa Harbor 2013). The Water Trail provides information on public bay access points where kayaks, canoes, and other small water craft can be hand-launched for travel around the bay. Near shore areas can be accessed when incoming tides cover the tide flats with enough water so that boats can be paddled over these shallow areas. Hand-launch boat access to the Willapa Bay Water Trail is available at the following locations (see Figure 3.2.8-2), with amenities as described by the Washington Water Trails Association (2014). Most amenities are for day-use only, though there are a few existing and planned primitive campsites.

Figure 3.2.8-2 – Willapa Bay Public Boat Launch Locations

Swimming is not a significant attraction for visitors to Willapa Bay. Saltwater temperatures rarely rise above 55 degrees even during the summertime (Washington State Parks and Recreation Commission, June 2005). The large tidal ranges, swift currents, frequent high winds, and changeable weather patterns in the bay are also deterrents to open-water swimming. These characteristics of the bay, and shallow water depths over mudflats may also be reasons why SCUBA diving and water skiing are not identified among recreational activities in Willapa Bay.

3.2.8.2 *Grays Harbor*

Grays Harbor recreational areas include State and local parks and designated wildlife areas. Most of these occur in the western half of the harbor within and near the north (Ocean Shores) and south (Westport) peninsulas. Recreational activities include fishing, bird watching, wildlife viewing, hiking and boating (USACE 2014), clamming and crabbing (Corps of Engineers, Seattle District 2011). Recreational fishermen are present during annual salmon runs, and people dig for clams in season during low tides. Swimming, SCUBA diving, and water skiing are not identified among the recreational activities identified for Grays Harbor, likely for reasons similar to those described above for Willapa Bay.

State and local shoreline parks in the vicinity of North Bay and South Bay where commercial shellfish beds are located include the following (USACE 2014) (see Figure 3.2.8-3):

- Damon Point State Park is a 61-acre day-use park located at the southeastern tip of the Ocean Shores peninsula. The park includes a one-mile walkable strip of land within a one-mile long, 0.5-mile wide stretch of land jutting out into the ocean. Activities include bird watching, wildlife viewing, hiking, picnicking, fishing, clamming, crabbing, rock collecting, and beachcombing.
- Bottle Beach State Park is a 75-acre day-use park with 6,000 feet of shoreline on the east shore of South Bay in the community of Ocosta. Activities include bird/wildlife viewing, and a walking trail.

Figure 3.2.8-3 – Grays Harbor State and Local Shoreline Parks and Designated Wildlife Areas

Designated wildlife areas in Grays Harbor near North Bay and South Bay include (see Figure 3.2.8-3):

- Oyhut Wildlife Recreation Area.
- Ocean Shores Bay Wildlife Area.
- Olympic-Willapa Hills Wildlife Area.
- The 1,500-acre Johns River Wildlife Area, Johns River Unit.
- Bowerman Basin near Hoquiam (USACE 2014).

The City of Westport, located on the east side of the tip of the southern peninsula at the entrance to Grays Harbor, is advertised as "the salmon fishing capital of the world." Salmon fishing charter boats operate out of the West Port Marina, Washington's largest fish landing port (USACE 2014).

Saltwater boat launch facilities in the vicinity of North Bay and South Bay include the following (http://www.ghonline.com/boatlaunches) (see Figure 3.2.8-4):

- Ocean Shores Marina.
- Johns River Wildlife Recreation Area (WRA), managed by the Washington State Department of Fish and Wildlife (WDFW).
- Westport Marina is located just inside the entrance to Grays Harbor.

There are other popular recreational activities in the Grays Harbor area such as, recreational clam digging and crabbing. Wave riding/surfing, is another popular activity at locations on the ocean side of the entrance to Grays Harbor.

Figure 3.2.8-4 – Grays Harbor Saltwater Public Boat Launch Locations

POTENTIAL IMPACTS

Under Alternative 1 (No Action – No Permit for Pesticide Applications), persons engaged in recreation in Willapa Bay or Grays Harbor would have no risk of exposure to chemical applications for the purpose of burrowing shrimp control. Ongoing attempts at mechanical control, and alternative shellfish culture practices would likely constitute no detectable change from existing conditions to persons using Willapa Bay and Grays Harbor for recreational purposes.

Carbaryl can overstimulate the nervous system causing nausea, dizziness, and confusion, though not likely at the concentrations that would be applied to control burrowing shrimp, which are much more sensitive than vertebrates (including humans). Carbaryl is classified as a likely human carcinogen based on laboratory studies in which mice developed vascular tumors. However, non-cancer risks are seen as the primary risk driver for almost all use scenarios (USEPA 2014). In addition, there have been no known incidences of human exposure to carbaryl during its 50+ years of use for burrowing shrimp control in Willapa Bay and Grays Harbor. If the conditions for using carbaryl on commercial shellfish beds were to remain the same under Alternative 2 as they are under the 2006 NPDES individual permit (WA0040975) and other applicable regulatory requirements, up to 600 acres per year could be treated in Willapa Bay (1.3 percent of total tideland acres), and up to 200 acres per year could be treated in Grays Harbor (0.6 percent of total tideland acres) (see FEIS Chapter 2, Section 2.8.2). These small areas of application each year would significantly minimize the potential for exposure of persons who may use exposed tide flats for recreation in Willapa Bay or Grays Harbor.

Under Alternative 3, imidacloprid applications on up to 1,500 acres *per year* in Willapa Bay would affect at most approximately 3.3 percent of total tideland acres within the bay *per year* (see FEIS Chapter 2, Section 2.8.3). Imidacloprid applications on up to 500 acres in Grays Harbor *per year* would affect at most approximately 1.5 percent of total tideland acres within the harbor *per year* (see FEIS Chapter 2, Section 2.8.2). These small areas of application each year would minimize the potential for exposure of persons using exposed tide flats for recreation in Willapa Bay or Grays Harbor. Further, as described above in FEIS Section 3.2.6 (Human Health), based on the relatively low acute toxicity and short half-life of imidacloprid in sediment and surface water, there is a very low likelihood of possible human health impacts from imidacloprid exposure to the general population engaging in recreational activities (e.g., shellfish gathering, fishing, swimming) under Alternative 3. Imidacloprid is classified as a “Group E” carcinogen indicating “no evidence of carcinogenicity in humans” (USEPA 1999a, 1999b, 2003).

MITIGATION MEASURES

No mitigation measures for recreation would be required for the No Action Alternative.

If Alternative 2 were selected for implementation, and if a new or modified NPDES individual permit for the use of carbaryl was issued by Ecology with conditions similar to the current 2006 permit (WA0040975), it is assumed for the purpose of environmental review that public notification requirements would be the same or similar to those in the 2006 permit (described here). Those conditions, along with the requirements of a FIFRA registration, would mitigate potential significant adverse impacts. The Annual Operations Plan (AOP) would identify the location of public access points to Willapa Bay and Grays Harbor where signs would be posted to report the name of the pesticide to be used, where it is to be applied, any public health and livestock restrictions, and the name and phone number of the WGHOGA contact person (likely the IPM Coordinator). If carbaryl applications were proposed within 200 feet of any public access location to the water, a sign would be posted at each location 24 hours (but not more than 10 days) prior to commencement of carbaryl applications. Signs would remain posted until carbaryl applications were completed for the season. Carbaryl applications typically occur on 5 to 10 days per year, during the lowest tides in July and August.

If Alternative 3 (the preferred alternative) were selected, Federal and State regulations would mitigate potential significant adverse impacts. The FIFRA Registrations would require public access points within a one-quarter-mile (1,320-foot) radius of any commercial shellfish bed scheduled for aerial applications of either Protector 0.5G or Protector 2F to be posted with a "WARNING" OR "CAUTION" sign that states "*Imidacloprid will be applied for burrowing shrimp control on [date] on commercial shellfish beds. Do not fish, crab or clam within one-quarter mile of the treated area*." The location of the treatment area would be included on the sign. If the public access area at any of these locations is more than 500 feet wide, additional signs would be posted at 500-foot intervals. Signs would be posted at least 2 days prior to aerial treatment and would remain for at least 30 days after treatment at locations within a one-quarter mile radius of any commercial clam or oyster bed scheduled for aerial application of imidacloprid (USEPA 2013a and 2013b). The WGHOGA IPM Coordinator would be responsible for posting, maintaining and removing these signs.

Under Alternative 3, WGHOGA proposes to also use a website in lieu of newspaper announcements for public notification of specific dates of proposed imidacloprid applications in Willapa Bay and Grays Harbor. The website would include a link for interested persons to request direct notification regarding proposed treatment dates and locations. The WGHOGA IPM Coordinator would send e-mail notifications to registered interested parties, as needed.

Further, it is an element of the WGHOGA proposal for the use of imidacloprid (Alternative 3) to avoid aerial (i.e., helicopter) applications of Protector 0.5G or 2F within 200 feet of OHWL adjacent to shoreline areas.

SIGNIFICANT UNAVOIDABLE ADVERSE IMPACTS

Based on currently available information and studies, and requirements to comply with the conditions of all applicable pesticide registrations, regulations, and public notification requirements, no significant unavoidable adverse impacts to recreation would be expected as a result of implementing either Alternative 3 (the proposed action), or Alternative 2.

3.2.9 Navigation

AFFECTED ENVIRONMENT

3.2.9.1 *Willapa Bay*

Willapa Bay has a well-established system of U.S. aids to navigation, including entrance lights, channel lights, lighted buoys, day-beacons on pilings and dolphins, jetty lights, range lights, yellow can and red nun buoys (U.S. Coast Guard 2013). The main east-west entrance channel is at the very north end of the bay, passing by North Cove and Toke Point and providing access to the Willapa River and South Bend. The main north-south channel through the central portion of the bay is Nahcotta Channel. Expansive mudflats and shallow subtidal areas border the Nachotta Channel and Stanley Channel to the southeast. The majority of these mudflats and those from Toke Point eastward are owned by commercial shellfish growers (see Figure 2.4-1 in Chapter 2).

There are public boat launch sites at the following locations around Willapa Bay (see Figure 3.2.8-2 above):

- Tokeland Marina.
- WDFW Smith Creek ramp at the mouth of Smith Creek and the North River.
- South Bend ramp on the west end of the community of South Bend.
- Port of Willapa Moorage.
- Bay Center Ramp at the mouth of the Palix River.
- WDFW Bay Center ramp.
- Willapa National Wildlife Refuge Headquarters Ramp.
- Nahcotta Marina boat basin (Port of Peninsula).
- Leadbetter Point State Park.

3.2.9.2 *Grays Harbor*

Similar to Willapa Bay, Grays Harbor has a well-established system of U.S. aids to navigation, including entrance lights, channel lights, lighted buoys, day-beacons on pilings and dolphins, jetty lights, range lights, can and nun buoys (U.S. Coast Guard 2011). There is a lookout tower and horn on the south jetty, and a U.S. Coast guard station in Westport.

East-west access through the harbor is provided in a regulated navigation channel that is dredged by the U.S. Army Corps of Engineers each year to maintain adequate depth for cargo vessels to reach the east end of the harbor. The navigation channel dimensions range from 900 feet wide and 46 feet deep (MLLW) at the Bar Channel to 200–300 feet wide and 32 feet deep (MLLW) in South Aberdeen (Corps of Engineers, Seattle District 2011). The main entrance to the harbor is in the South Channel, which traverses to the Cross-Over Channel (between the Outer Harbor and Inner Harbor) in approximately the middle of the bay, and then to the North Channel for vessels to access the four Port of Grays Harbor marine terminals in Hoquiam and Aberdeen. The marine terminal berthing depth at these four locations is -41 feet MLLW. Commercial shellfish beds in South Bay are 3 or more nautical miles south of the South Channel. In North Bay, commercial shellfish beds are 5 or more nautical miles north of the South Channel (see Figure 2.4-2 in Chapter 2).

Each round trip through the navigation channel to a terminal is a “vessel call.” Vessel calls at the Port of Grays Harbor have increased significantly in recent years from 22 calls in 2002 to 82 calls in 2012. Between 2007 and 2012, barge calls ranged from 15 to 41 calls. Barge cargoes are dominated by shipments of logs and wood chips. Terminal 1 in Aberdeen is a bulk liquid loading facility that stores and conveys products such as biodiesel, ethanol, U.S. crude oil, jet fuel, gasoline, diesel, vegetable oil, and feedstock (Imperium Renewables 2013 as cited in USACE 2014). Terminal 2 in Aberdeen is a multi-type bulk loading facility with enclosed conveyers that transport products from silos. The current proposal for use of Terminal 3 in Hoquiam is a bulk liquids rail logistics facility, to handle primarily crude oil or light oil. Terminal 4 in Aberdeen is the Port of Grays Harbor main general cargo terminal (USACE 2014).

There are public saltwater boat launch sites at the following locations in the vicinity of North Bay and South Bay where commercial shellfish beds are located (see Figure 3.2.8-4 above):

- Ocean Shores Marina.
- Johns River Wildlife Recreation Area.
- Westport Marina.

POTENTIAL IMPACTS

There would be no significant impacts to navigation as a result of the No Action Alternative (No Action – No Permit for Pesticide Applications), Alternative 2 (Continue Historical Management Practices: Carbaryl Applications with Integrated Pest Management), or Alternative 3 (Imidacloprid Applications with IPM). The tidelands where commercial shellfish beds are located are staked for various purposes at various times of the year. For this reason, stakes placed to identify beds for aerial applications of carbaryl or imidacloprid under Alternative 2 or 3 would not constitute a new or different obstruction to watercraft that navigate the shallow areas of Willapa Bay or Grays Harbor where these shellfish beds are located. There would be no stakes or obstructions placed in the main navigation channels of either bay.

MITIGATION MEASURES

No mitigation measures for impacts to navigation would be required with the No Action Alternative.

If Alternative 2 or Alternative 3 were selected for implementation, public notification requirements at marinas and boat launch sites would be the same as those described above under mitigation measures for Recreation (FEIS Section 3.2.8). These measures would mitigate potential significant adverse impacts.

SIGNIFICANT UNAVOIDABLE ADVERSE IMPACTS

No significant unavoidable adverse impacts to navigation would be expected as a result of implementing Alternative 3 (the proposed action), or Alternative 2.

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5.0 Distribution List

WASHINGTON STATE DEPARTMENT OF ECOLOGY

Sally Toteff, Southwest Region Director
Heather R. Bartlett, Water Quality Program Manager
Rich Doenges, Water Quality Program Section Manager
Derek Rockett, Water Quality Program Permit Writer
Deborah Cornett, Water Quality Program
Barry Rogowski, Toxics Control Program Section Manager
Jason Landskron, Toxics Control Program
SEPA Center

OTHER STATE DEPARTMENTS

Office of the Washington State Attorney General: Gordon Karg, AAG

Washington State Department of Agriculture
Erik Johansen
Ted Maxwell
Kelly McLain
George Tuttle

Washington State Department of Fish and Wildlife
Joseph Buchanan
Randy Carman
Brock Hoenes
Lester Holcolm
Bruce Kauffman
Amy Spoon
WDFW SEPA Desk: Lisa Wood

Washington State Department of Natural Resources
Jeff Gaeckle
WDNR SEPA Desk: Rochelle Knust

Washington State Commission on Pesticide Registration
Alan Schreiber, Administrator

CITIES AND COUNTIES

City of Aberdeen
Mayor Simpson
Lisa Scott, Community Development

City of Hoquiam
Mayor Durney
Brian Shay, City Administrator
Franklin Daniels

City of Long Beach: Gene Miles, City Administrator

City of Montesano
Mike Wincewicz, Community Development, Planning, Facilities, and Parks

City of Ocean Shores
Crystal Dingler, Mayor
Alicia, Bridges City Planner

City of Raymond
Robert Jungar, Mayor

City of South Bend
Julie Struck, Mayor
Kirk Church

City of Westport
Mayor Bruce
Mark Davis, Building Official

Grayland Water Department
Patty Cole

Grays Harbor County
L. Gray
Jeff Nelson, Grays Harbor Environmental Health
Grays Harbor Board of County Commissioners

Pacific County
Tim Crose
Pacific County Board of County Commissioners

Chambers of Commerce and Economic Development Councils

Grays Harbor Chamber of Commerce: D. Garson
North Cove Chamber of Commerce: Mary Grimes
Ocean Park Chamber of Commerce: Karen Boardman, Office Manager
Pacific County Economic Development Council: Paul Philpot
Willapa Harbor Chamber of Commerce: Michelle Layman

PORT DISTRICTS

Port of Grays Harbor: Leonard Barnes
Port of Peninsula: Mary DeLong
Port of Willapa Harbor: Rebecca Chaffee

TRIBES

Quinault Tribal Council
Fawn Sharp, President
Scott Mazzone, Marine Fish and Shellfish Biologist
Mark Mobbs
Joe Schumacker, Department of Fisheries
Dave Bingaman, Department of Natural Resources

Shoalwater Bay Tribal Council
Gary Burns, Department of Natural Resources

Center for Salish Community Strategies
Barbara Dykes
Tim Erlichman

FEDERAL AGENCIES AND ELECTED OFFICIALS

U.S. Coast Guard: Tim Westcott, Private Aids to Navigation Manager, 13th Coast Guard District, Prevention Division, Waterways Management Branch, Seattle
U.S. Department of Agriculture: Brett Dumbauld
U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service: Kim Kratz, Assistant Regional Administrator, Oregon-Washington Coastal Area Office, Portland, OR
U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service: Laura Hoberecht, Aquaculture Coordinator, West Coast Region, Seattle, WA
U.S. Environmental Protection Agency: Jennifer Urbanski
U.S. Environmental Protection Agency: Joseph Decant
U.S. Environmental Protection Agency: Karen Burgess
U.S. Fish and Wildlife Service: Ken Berg, Manager, Washington Fish and Wildlife Office, Lacey, WA
Office of Senator Maria Cantwell
Dena Horton

APPLICANT AND APPLICANT'S LEGAL COUNSEL

Willapa-Grays Harbor Oyster Growers Association (WGHOGA)
EXECUTIVE BOARD:
Don Gillies, President

Ken Wiegardt, Vice President
Brian Sheldon, Secretary
Mark Ballo, Brady's Oyster, Inc.
Leonard Bennett, R&B Oyster Co.
Warren Cowell, Willapa Bay Shellfish
Bill Dewey, Taylor Shellfish
Dan Driscoll, Oysterville Sea Farms
Eric Hall, Taylor Shellfish
John Heckes, Heckes Clams, Inc.
Dave Hollingsworth, Markham Oyster, Inc.
Nick Jambor, Jambor Oyster, LLC
Tim Morris, Coast Seafoods
David Nisbet, Nisbet Oyster Co., Inc.
Phil Olsen, Olsen & Son Oyster Co.
Eric Petit, Willapa Fish and Oyster Co.
Dick Sheldon, Willapa Resources
Bill Taylor, Taylor Shellfish
Dobby Wiegardt
Richard Wilson, Bay Center Mariculture Co.

Jesse DeNike, Plauché and Carr

CONSULTANTS

Jeff Barrett, Hart Crowser
Adrienne Stutes, Hart Crowser
Vicki Morris, Vicki Morris Consulting Services

INTERESTED ORGANIZATIONS

Coalition to Protect Puget Sound Habitat: Laura Hendricks
Coalition to Protect Puget Sound Habitat: Landye Bennett Blumstein
Friends of Grays Harbor: Arthur Grunbaum
Grays Harbor Audubon Society: Arnold Martin
Grays Harbor National Wildlife Refuge: Sheila McCartan
Independent Shellfish Growers of Washington
Olympic Coast National Marine Sanctuary: Carol Bernthal
Pacific Coast Shellfish Growers Association (PCSGA): Margaret Barrett
Pacific Shellfish Institute: Steven Booth, Bobbi Hudson
Sierra Club: Laura Hendricks
Surfrider Association: Jody Kennedy
The Nature Conservancy: Bill Robinson

Washington Coastal Marine Advisory Council (WCMAC):
Greig Arnold, Makah Tribe Representative
J.T. Austin, Governor's Office Representative

Miles Batchelder, Washington Coast Sustainable Salmon Partnership Representative
Dale Beasley, Commercial Fishing Representative
Chad Bowechop, Makah Tribe Representative
Mark Cedergreen, Recreational Fishing Representative
Charlie Costanzo, Shipping Representative
Michele Culver, Washington State Department of Fish & Wildlife Representative
Garrett Dalan, Grays Harbor MRC Representative
Penelope Dalton, Washington Sea Grant Representative
Casey Dennehy, Recreation Representative
Carol Ervest, Wahkiakum MRC Representative
Rod Fleck, North Pacific MRC Representative
Dave Fluharty, Educational Institution Representative
Lonnie Foster, Quileute Tribe Representative
Rich Grunbaum, Conservation Representative
Mark Horton, Ports Representative
Doug Kess, Pacific MRC Representative
Randy Kline, Washington State Parks Representative
Katie Krueger, Quileute Tribe Alternate Representative
Rich Osborne, Science Representative
Mark Plackett, Citizen Representative
Michal Rechner, Washington State Department of Natural Resources Representative
Steven Sewell, Washington State Department of Commerce Representative
Brian Sheldon, Shellfish Industry Representative
Russ Svec, Makah Tribe Representative
Ray Toste, Commercial Fishing Representative
Jeff Ward, Coastal Energy Representative
Alla Weinstein, Energy Industry Representative

Washington Toxics Coalition: Erika Schreder
Willapa National Wildlife Refuge
WSU Long Beach Extension Office: Kim Patten, Pacific County Extension Director
Xerces Society: Aimee Code, Pesticide Program Coordinator

INTERESTED INDIVIDUALS

The Aggie	
Atkins, Gail	
Barkhurst, Christine	
Barkhurst, Ross	
Bova, Cindy	
Branch, Harry	
Brock, Meghan	
Bruton, Peggy	
Cohen, Fritzi	
Coverdale, Mike	
Darcher, Ed	

Emrick, Mark	
Erickson, Jordan	
Garoutte, Denise	
Hartung, Zena	
Holz, Tom	
Johannes, Jerry	
Johnson, Gary	
Kalich, Gary	
Krebs, Nathan	
Lambert, Michael	
Manike, Roy	
Mansfield, Kris	
Potter, Ross	
Rasmussen, Pat	
Roloff, Rich	
Rondeau, Gary	
Rotmark, L.	
Stallard, Cindi	
Wahl, Lisa	
Walker, Dorothy	
Warnberg, Larry	
Weber, Joy	
Weber, Sally	
Wilson, Steve and Vicki, Arcadia Point Seafood	

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Chemical Safety and Pollution Prevention
Registration Division (7505C)
1200 Pennsylvania Ave., N.W.
Washington, D.C. 20460

NOTICE OF PESTICIDE:
_X_ Registration
___ Reregistration

(under FIFRA, as amended)

EPA Reg. Number: 88867-1

Date of Issuance: JUN 0 6 2013

Term of Issuance: Conditional

Name of Pesticide Product: Protector 0.5G

Name and Address of Registrant (include ZIP Code):

Willapa-Grays Harbor Oyster Growers Association
P.O. Box 3, Ocean Park, WA 98640

Note: Changes in labeling differing in substance from that accepted in connection with this registration must be submitted to and accepted by the Registration Division prior to use of the label in commerce. In any correspondence on this product always refer to the above EPA registration number.

On the basis of information furnished by the registrant, the above named pesticide is hereby registered under the Federal Insecticide, Fungicide and Rodenticide Act.

Registration is in no way to be construed as an endorsement or recommendation of this product by the Agency. In order to protect health and the environment, the Administrator, on his motion, may at any time suspend or cancel the registration of a pesticide in accordance with the Act. The acceptance of any name in connection with the registration of a product under this Act is not to be construed as giving the registrant a right to exclusive use of the name or to its use if it has been covered by others.

This product is conditionally registered in accordance with FIFRA section 3(c)(7)(a). You must:

1. Submit and/or cite all data required for registration/registration review of your product when the Agency requires all registrants of similar products to submit such data.

2. Submit or cite any data which have previously been required for imidacloprid.

3. Make the following label change before you release the product for shipment:

- Revise the EPA Registration Number to read, "EPA Reg. No 88867-1."

Signature of Approving Official:

John Hebert, Product Manager 07
Insecticide-Rodenticide Branch, Registration Division (7505P)

Date: JUN 0 6 2013

EPA Form 8570-6

4. Note that monitoring data reporting is required under the National Pollutant Discharge Elimination System (NPDES) permit. We request that you submit this information to the Registration Division, Office of Pesticide Programs, as well.

5. Submit one copy of the revised final printed label for the record before you release the product for shipment.

If these conditions are not complied with, the registration will be subject to cancellation in accordance with FIFRA section 6(e). Your release for shipment of the product constitutes acceptance of these conditions. A stamped copy of the label is enclosed for your records. Please also note that the CSF currently on file for this product is the basic CSF, dated 2/21/12.

If you have any questions, please contact Dr. Jennifer Urbanski at 703-347-0156 or urbanski.jennifer@epa.gov.

John Hebert
Product Manager 07
Insecticide-Rodenticide Branch
Registration Division (7505P)

Enclosure

Draft Label

ACCEPTED
JUN 0 6 2013
Under the Federal Insecticide, Fungicide, and Rodenticide Act, as amended, for the pesticide registered under:
EPA. Reg. No: 88867-1

GROUP 4A INSECTICIDE

PROTECTOR 0.5G

FOR USE ONLY IN WILLAPA BAY/ GRAYS HARBOR, WASHINGTON, TO CONTROL BURROWING SHRIMP IN COMMERCIAL SHELLFISH BEDS

ACTIVE INGREDIENT:
Imidacloprid: 1-[(6-Chloro-3-pyridiny) methyl]-N-nitro-2-imidazolidinimine.........................0.5%
OTHER INGREDIENTS:..99.5%
TOTAL:..100.0%

KEEP OUT OF REACH OF CHILDREN
CAUTION-CAUCION

Si usted no entiende la etiqueta, busque a alguien para que se la explique a usted en detaile.
(If you do not understand the label, find someone to explain it to you in detail.)

EPA Reg. No.

EPA Establishment No.

FIRST AID

If in eyes:	• Hold eye open and rise slowly and gently with water for 15-20 minutes, then continue rinsing eye. • Call a poison control center or doctor for treatment advice

Have the product container or label with you when calling poison control center or doctor or going for treatment. You may also 1-800-222-1222 for emergency medical treatment information.

NOTE TO PHYSICIAN

No specific antidote is available. Treat the patient symptomatically

PRECAUTIONARY STATEMENTS
HAZARDS TO HUMANS AND DOMESTIC ANIMALS

CAUTION: Causes moderate eye irritation. Avoid contact with eyes or clothing. Wash thoroughly with soap and water after handling and before eating, drinking, chewing gum or using tobacco.

PERSONAL PROTECTIVE EQUIPMENT (PPE)

Applicators and other handlers must wear:

- Long-sleeved shirt and long pants
- Chemical-resistant gloves made of any waterproof material such as barrier laminate, butyl rubber, nitrile rubber, neoprene rubber, natural rubber, polyethylene, polyvinylchloride (PVC) or viton
- Shoes and socks
- Protective eyewear
- Dust mask

Follow manufacturer's instructions for cleaning/maintaining PPE. If instructions for washables do not exist, use detergent and hot water. Keep and wash PPE separately from other laundry.

ENGINEERING CONTROLS STATEMENTS

When handlers use closed systems, enclosed cabs, or aircraft in a manner that meets the requirements listed in the Worker Protection Standard (WPS) for agricultural pesticides [40 CFR 170.240 (d)(4-6)], the handler PPE requirements may be reduced or modified as specified in the WPS.

USER SAFETY RECOMMENDATIONS

Users Must:

- Wash hands before eating, drinking, chewing gum, using tobacco or using the toilet.
- Remove clothing immediately if pesticide gets inside. Then wash thoroughly and put on clean clothing.
- Remove PPE immediately after handling this product. Wash the outside of gloves before removing.

ENVIRONMENTAL HAZARDS

Do not contaminate water when disposing of equipment wash waters. This product is toxic to wildlife and highly toxic to aquatic invertebrates.

DIRECTIONS FOR USE

It is a violation of the Federal law to use this product in a manner inconsistent with its labeling. A copy of this label must be in the possession of the user at the time the product is applied.

READ THIS LABEL: Read the entire label and follow all use directions and precautions.
For use only to control burrowing shrimp in intertidal commercial shellfish beds [of Washington State's Willapa Bay and Grays Harbor]

MIXING INSTRUCTIONS:

Do NOT formulate this product into other end-use products.

APPLICATION INSTRUCTIONS:

To control burrowing shrimp in intertidal commercial shellfish beds [of Washington State's Willapa Bay and Grays Harbor], apply at a maximum rate of 0.5 lb a.i. imidacloprid/acre per year.
Apply this product uniformly over the area being treated using drop-type or rotary–type spreaders. Do not use spreaders that would apply the material in narrow, concentrated bands. All spreader equipment must be calibrated at the time of application to achieve desired application rate.

Use one of the following properly calibrated application equipment:

- Conventional granular pesticide applicators ("belly grinders").
- Helicopters equipped with boom ¾ as long as rotor diameter.
- Ground based vehicles equipped with spinners or drop spreaders.

RESTRICTIONS:

- Do not harvest shellfish within 30 days after treatment.
- All ground must be properly staked and flagged to protect adjacent shellfish and water areas. For aerial applications, the corners of each plot must be marked so the plot is visible from an altitude of at least 500ft.
- A single application of imidacloprid at up to 0.5 ai per acre per year is allowed.
- No adjuvants or surfactants are allowed with the use of this product.
- Aerial applications must be on beds exposed at low tide. Applications from a floating platform or boat may be applied to beds under water using a calibrated granular applicator.
- All applications must occur between April 15 and December 15.
- A 100-foot buffer zone must be maintained between the treatment area and the nearest shellfish to be harvested within 30 days when treatment is by aerial spray; a 25 foot buffer zone is required if treatment is by hand spray if nearest shellfish bed is to be harvested within 30 days.
- Do not apply aerially during Federal holiday weekends.
  During aerial applications, all public access areas within one-quarter (1/4) mile and all public boat launches within quarter (1/4) mile radius of any bed scheduled for treatment shall be posted. Public access areas shall be posted at 500 feet intervals at those access areas more than 500 feet wide. Signs shall be a minimum of 8 ½ x 11 inches in size, and be made of a durable weather-resistant, white material. The sign will say "Imidacloprid will be applied for burrowing shrimp control on [date] on commercial shell fish beds. Do not Fish, Crab or Clam within one-quarter mile of the treated area." The location of the treated area will be included on the sign.

The sign will include lettering shall be in bold black type with the word "WARNING" or "CAUTION" at least one-fourth (1/4) of an inch high. Signs shall be posted so they are secure from the normal effects of weather and water currents, but cause no damage to private property. Signs shall be posted at least 2 days prior to treatment and shall remain for at least 30 days after treatment.

DRIFT MANAGEMENT:

The interaction of many equipment and weather related factors determine the potential for product drift. Average wind speed at the time of application is not to exceed 10 mph to minimize drift to adjacent shellfish and water areas when applied by air. Drift potential increases at wind speeds of less than 3 mph (due to inversion potential) or more than 10 mph. However, many factors including height of granular spreader above the tideflat and equipment specifications determine drift potential at any given wind speed. Do NOT apply when winds are greater than 10 mph or during temperature inversions. Make applications at the lowest possible height (helicopter, ground or barge) that is safe to operate and reduces exposure of the granules to wind. When applications are made crosswind, the swath will be displaced downwind. Therefore, on the up and downwind edges of the treatment area, the applicator must compensate for this displacement by adjusting the path of the application equipment upwind. Swath adjustment distance should increase with increasing drift potential.

Mixing and Loading Requirements

The use of a properly designed and maintained containment pad for mixing and loading of any pesticide into application equipment is recommended. If containment pad is not used, maintain a minimum distance of 25 feet between mixing and loading areas and potential surface to groundwater conduits such as field sumps, uncased well heads, sinkholes, or field drains.

STORAGE AND DISPOSAL

Do not contaminate water, food, or feed by storage or disposal.

Pesticide Disposal: Wastes resulting from the use of this product may be disposed of on site or at an approved wasted disposal facility.

Pesticide Storage: Store in a cool, dry place an in such a manner as to prevent cross contamination with other pesticides, fertilizers, food, and feed. Store in original container and out of the reach of children, preferably in a locked storage area.

Handle and open container in a manner as to prevent spillage. If material is spilled for any reason or cause, carefully contain any spilled material to prevent non-target contamination. Do not walk through spilled material and dispose of as directed for pesticides above. Refer to Precautionary Statements on label for hazards associated with handle of this material. In spill or leak incidents, keep unauthorized people away. For chemical spill, leak, fire, or exposure, you may contact CHEMTREC at 800-424-9300.

Container Disposal: Non-Refillable: Do not reuse or refill this container. Completely empty bag into application equipment. Dispose of empty bag in a sanitary landfill, by incineration, or if allowed by state and local authorities, by burning. If burned, stay out of smoke.

This product is registered by the Willapa-Grays Harbor Oyster Growers Association, P.O. Box 3, Ocean Park, WA 98640

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Chemical Safety and Pollution Prevention
Registration Division (7505C)
1200 Pennsylvania Ave., N.W.
Washington, D.C. 20460

EPA Reg. Number:	Date of Issuance:
88867-2	JUN 06 2013

NOTICE OF PESTICIDE:
_X_ Registration
__ Reregistration
(under FIFRA, as amended)

Term of Issuance:
Conditional

Name of Pesticide Product:
Protector 2F

Name and Address of Registrant (include ZIP Code):

Willapa-Grays Harbor Oyster Growers Association
P.O. Box 3, Ocean Park, WA 98640

Note: Changes in labeling differing in substance from that accepted in connection with this registration must be submitted to and accepted by the Registration Division prior to use of the label in commerce. In any correspondence on this product always refer to the above EPA registration number.

On the basis of information furnished by the registrant, the above named pesticide is hereby registered under the Federal Insecticide, Fungicide and Rodenticide Act.

Registration is in no way to be construed as an endorsement or recommendation of this product by the Agency. In order to protect health and the environment, the Administrator, on his motion, may at any time suspend or cancel the registration of a pesticide in accordance with the Act. The acceptance of any name in connection with the registration of a product under this Act is not to be construed as giving the registrant a right to exclusive use of the name or to its use if it has been covered by others.

This product is conditionally registered in accordance with FIFRA section 3(c)(7)(a). You must:

1. Submit and/or cite all data required for registration/registration review of your product when the Agency requires all registrants of similar products to submit such data.

2. Submit or cite any data which have previously been required for imidacloprid.

3. Make the following label change before you release the product for shipment:
- Revise the EPA Registration Number to read, "EPA Reg. No 88867-2."

Signature of Approving Official:

John Hebert, Product Manager 07
Insecticide-Rodenticide Branch, Registration Division (7505P)

Date:
JUN 06 2013

EPA Form 8570-6

4. Note that monitoring data reporting is required under the National Pollutant Discharge Elimination System (NPDES) permit. We request that you submit this information to the Registration Division, Office of Pesticide Programs, as well.

5. Submit one copy of the revised final printed label for the record before you release the product for shipment.

If these conditions are not complied with, the registration will be subject to cancellation in accordance with FIFRA section 6(e). Your release for shipment of the product constitutes acceptance of these conditions. A stamped copy of the label is enclosed for your records. Please also note that the CSF currently on file for this product is the basic CSF, dated 2/21/12.

If you have any questions, please contact Dr. Jennifer Urbanski at 703-347-0156 or urbanski.jennifer@epa.gov.

John Hebert
Product Manager 07
Insecticide-Rodenticide Branch
Registration Division (7505P)

Enclosure

Draft Label

GROUP 4A INSECTICIDE

PROTECTOR 2F

FOR USE ONLY IN WILLAPA BAY/ GRAYS HARBOR, WASHINGTON, TO CONTROL BURROWING SHRIMP IN COMMERCIAL SHELLFISH BEDS

ACTIVE INGREDIENT:
Imidacloprid: 1-[(6-Chloro-3-pyridiny)methyl]-N-nitro-2-imidazolidinimine........................ 21.4%
OTHER INGREDIENTS:.. 78.6%
TOTAL:...100.0%

Contains 2 pounds of imidacloprid per gallon.

KEEP OUT OF REACH OF CHILDREN
CAUTION-CAUCION

Si usted no entiende la etiqueta, busque a alguien para que se la explique a usted en detaile.
(If you do not understand the label, find someone to explain it to you in detail.)

EPA Reg. No.

EPA Establishment No.

SHAKE WELL BEFORE USING

ACCEPTED
JUN 0 6 2013
Under the Federal Insecticide, Fungicide, and Rodenticide Act, as amended, for the pesticide registered under:
EPA. Reg. No: 88867-2

FIRST AID

If swallowed:	• Call a poison control center or doctor immediately for treatment advice. • Have person sip a glass of water if able to swallow. • Do not induce vomiting unless told to do so by the poison control center or doctor. • Do not give anything by mouth to an unconscious person.
If inhaled	• Move person to fresh air • If person is not breathing, call 911 or an ambulance, then give artificial respiration, preferably by mouth-to-mouth, if possible
If on skin or clothing:	• Take off contaminated clothing. • Rinse skin immediately with plenty of water for 15-20 minutes. • Call a poison control center or doctor for treatment advice.

Have the product container or label with you when calling a poison control center or doctor or going for treatment. You may also contact 1-800-222-1222 for emergency medical treatment information

NOTE TO PHYSICIAN

No specific antidote is available. Treat the patient symptomatically.

PRECAUTIONARY STATEMENTS
HAZARDS TO HUMANS AND DOMESTIC ANIMALS
CAUTION

Harmful if swallowed. Harmful if inhaled. Harmful if absorbed through skin. Avoid contact with skin, eyes, or clothing. Avoid breathing spray mist

PERSONAL PROTECTIVE EQUIPMENT (PPE)

Applicators and other handlers must wear:

- Long-sleeved shirt and long pants
- Chemical-resistant gloves made of any waterproof material such as barrier laminate, butyl rubber, nitrile rubber, neoprene rubber, natural rubber, polyethylene, polyvinylchloride (PVC) or viton
- Shoes and socks
- Protective eyewear

Follow Manufacturer's instructions for cleaning/maintaining PPE. If instructions for washables do not exist, use detergent and hot water. Keep and wash PPE separately from other laundry.

ENGINEERING CONTROLS STATEMENTS

When handlers use closed systems, enclosed cabs, or aircraft in a manner that meets the requirements listed in the Worker Protection Standard (WPS) for agricultural pesticides [40 CFR 170.240 (d)(4-6)], the handler PPE requirements may be reduced or modified as specified in the WPS.

USER SAFETY RECOMMENDATIONS

Users Must:

- Wash hands before eating, drinking, chewing gum, using tobacco or using the toilet.
- Remove clothing immediately if pesticide gets inside. Wash contaminated area thoroughly and put on clean clothing.
- Remove PPE immediately after handling this product. Wash the outside of gloves before removing.

ENVIRONMENTAL HAZARDS

Do not contaminate water when disposing of equipment washwaters. This product is highly toxic to bees exposed to direct treatment or residues on blooming crops and weeds. Do not allow this product to drift to blooming crops or weeds are visiting the treatment area. This product is toxic to wildlife and highly toxic to aquatic invertebrates.

DIRECTIONS FOR USE

It is a violation of the Federal law to use this product in a manner inconsistent with its labeling. A copy of this label must be in the possession of the user at the time the product is applied.

READ THIS LABEL: Read the entire label and follow all use directions and precautions.
For use only to control burrowing shrimp in intertidal commercial shellfish beds of Washington State's Willapa Bay and Grays Harbor.

MIXING INSTRUCTIONS:

To prepare the application mixture, add a portion of the required amount of water to the spray tank, begin agitation, and add the Protector 2F. Complete filling tank with the balance of water needed. Be sure to maintain agitation during both mixing and application.

Do NOT formulate this product into other end-use products.

APPLICATION INSTRUCTIONS:

To control burrowing shrimp in intertidal commercial shellfish beds [of Washington State's Willapa Bay and Grays Harbor], apply at a maximum rate of 0.5 lb a.i.imidacloprid /acre per year using the following properly calibrated application equipment:

- Helicopters equipped with boom ¾ as long as rotor diameter equipped with Accuflo or similar nozzles
- Backpack sprayer.
- Ground based vehicle with boom.

RESTRICTIONS:

- Do not harvest shellfish within thirty days after treatment.
- All ground must be properly staked and flagged to protect adjacent shellfish and water areas. For aerial applications, the corners of each plot must be marked so the plot is visible from an altitude of at least 500ft.
- Aerial applications must be on beds exposed at low tide.
- A single application of imidacloprid per year is allowed.
- No adjuvants or surfactants are allowed with the use of this product.
- All applications must occur between April 15 and December 15.
- A 100-foot buffer zone must be maintained between the treatment area and the nearest shellfish to be harvested when treatment is by aerial spray; a 25 foot buffer zone is required if treatment is by hand spray.
- Do not apply aerially during Federal holiday weekends.
  During aerial applications, all public access areas within one-quarter (1/4) mile and all public boat launches within a quarter (1/4) mile radius of any bed scheduled for treatment shall be posted. Public access areas shall be posted at 500 feet intervals at those access areas more than 500 feet wide. Signs shall be a minimum of 8 ½ x 11 inches in size, and be made of a durable

weather-resistant, white material. The sign will say "Imidacloprid will be applied for burrowing shrimp control on [date] on commercial shell fish beds. Do not Fish, Crab or Clam within one-quarter mile of the treated area. The location of the treated area will be included on the sign.

- The sign will include lettering shall be in bold black type with the word "WARNING" or "CAUTION" at least one-fourth (1/4) of an inch high. Signs shall be posted so they are secure from the normal effects of weather and water currents, but cause no damage to private property. Signs shall be posted at least 2 days prior to treatment and shall remain for at least 30 days after treatment.

SPRAY DRIFT MANAGEMENT:

Avoiding spray drift at the application site is the responsibility of the applicator. The interaction of many equipment-and-weather-related factors determines the potential for spray drift. The applicator and the entity authorizing spraying are responsible for considering all these factors when making decisions.

To minimize spray drift, the applicator should be familiar with and take into account the following drift reduction advisory information. Additional information may be available from state enforcement agencies or the Cooperative Extension on the application of the product.

The best drift management strategy and most effective way to reduce drift potential are to apply large droplets that provide sufficient coverage and control. Applying larger droplets reduces drift potential, but will not prevent drift if applications are made improperly, or under unfavorable environmental conditions (see WIND, TEMPERATURE AND HUMIDITY, and TEMPERATURE INVERSIONS.

CONTROLLING DROPLET SIZE

- Volume – Use high flow rate nozzles to apply the highest practical spray volume. Nozzles with higher rated flows produce larger droplets.
- Pressure – Do not exceed the nozzle manufacturer's recommended pressures. For many nozzle types, lower pressure produces larger droplets. When higher flow rates are needed, use higher flow rate nozzles instead of increasing pressure.
- Number of Nozzles – Use the minimum number of nozzles that provide uniform coverage.
- Nozzle Orientation – Orienting nozzles so that the spray is released parallel to the airstream produces larger droplets than other orientations and is recommended practice. Significant deflection from the horizontal will reduce droplet size and increase drift potential.
- Nozzle Type – Use a nozzle type that is designed for the intended application. With most nozzle types, narrow spray angles produce larger droplets. Consider using low-drift nozzles. Solid stream nozzles oriented straight back produce the largest droplets and the lowest drift. Do not use nozzles producing a mist droplet spray.

APPLICATION HEIGHT

Making applications at the lowest possible height (helicopter, ground driven spray boom) that is safe and practical reduces exposure of droplets to evaporation and wind.
ground) upwind. Swath adjustment distance should increase with increasing drift potential (higher wind, smaller droplets, etc.).

WIND

Drift potential is lowest between wind speeds of 3-10 mph. However, many factors, including droplet size and equipment type, determine drift potential at any given speed. Application should be avoided below 3 mph due to variable wind direction and high inversion potential. NOTE: Local terrain can influence wind patterns. Every applicator should be familiar with local wind patterns and how they affect spray drift.

TEMPERATURE INVERSIONS

Drift potential is high during a temperature inversion. Temperature inversions restrict vertical air mixing, which causes small suspended droplets to remain in a concentrated cloud, which can move in unpredictable directions due to the light variable winds common during inversions. Temperature inversions are characterized by increasing temperatures with altitude and are common on nights with limited cloud cover and light to no wind. They begin to form as the sun sets and often continue into the morning. Their presence can be indicated by ground fog; however, if fog is not present, inversions can also be identified by the movement of smoke from a ground source or an aircraft smoke generator. Smoke that layers and moves laterally in a concentrated cloud (under low wind conditions) indicates an inversion, while smoke that moves upward and rapidly dissipates indicates good vertical air mixing.

AERIAL APPLICATION METHODS AND EQUIPMENT HELICOPTERS ONLY

Water Volume: Use 2 or more gallons of water per acre. The actual minimum spray volume per acre is determined by the spray equipment used. Use adequate spray volume to provide accurate and uniform distribution of spray particles over the treated area and to avoid spray drift.

Managing spray drift from aerial applications: Applicators must follow these requirements to avoid off-target drift movement: 1) boom length – the distance of the outmost nozzles on the boom must not exceed ¾ the length of the rotor, 2) nozzle orientation – nozzles must always point backward parallel with the air stream and never be pointed downwards more than 45 degrees, and 3) application height – without compromising helicopter safety, applications should be made at a height of 10 feet or less above the crop canopy or tallest plants. Applicators must follow the most restrictive use cautions to avoid drift hazards, including those found in this labeling as well as applicable state and local regulations and ordinances.

GROUND APPLICATION (BROADCAST)

Water Volume: Use 5 or more gallons of water per acre. The actual minimum spray volume per acre is determined by the spray equipment used. Use adequate spray volume to provide accurate and uniform distribution of spray particles over the treated area and to avoid spray drift.

Spray tank should have constant agitation to assure adequate mixing of product.

AERIAL APPLICATIONS

All precautions should be taken to minimize or eliminate spray drift. Helicopters can be used to apply PROTECTOR 2F; however, DO NOT make applications by helicopter unless appropriate buffer zones can be maintained to prevent spray drift out of the target area, or when spray drift as a result of helicopter application can be tolerated. Aerial equipment designed to minimize spray drift, such as a helicopter equipped designed to minimize spray drift, such as a helicopter equipped with a MicrofoilTM boom, Thru-ValveTM boom or raindrop nozzles, must be used and calibrated. Except when applying with a Microfoil boom, a drift control agent may be added at the recommended label rate. To avoid drift, applications should not be made during inversion conditions, when winds are gusty or any other conditions which allow drift. Side trimming is not recommended with PROTECTOR 2F unless death of treated tree can be tolerated.

GROUND APPLICATIONS
Low Volume
Use equipment calibrated to deliver 5 to 20 gallons of spray solution per acre.

For low volume, selected proper nozzles to avoid over-application. Proper application is critical to ensure desirable results.

Restrictions During Temperature Inversions
Because the potential for spray drift is high during temperature inversions, do NOT make air applications during temperature inversions.

Mixing and Loading Requirements

The use of a properly designed and maintained containment pad for mixing and loading of any pesticide into application equipment is recommended. If containment pad is not used, maintain a minimum distance of 25 feet between mixing and loading areas and potential surface to groundwater conduits such as field sumps, uncased well heads, sinkholes, or field drains.

STORAGE AND DISPOSAL

Do not contaminate water, food, or feed by storage or disposal.

Pesticide Storage: Store in a cool, dry place and in such a manner as to prevent cross contamination with other pesticides, fertilizers, food, and feed. Store in original container and out of reach of children, preferably in a locked storage area. Handle and open container in a manner as to prevent spillage. If the container is leaking or material spilled for any reason or cause, carefully dam up spilled material to prevent runoff. Refer to Precautionary Statements on label for hazards associated with the handling of this material. Do not walk though spilled material. Absorb spilled material with absorbing type compounds and dispose of as directed for pesticides below. In spill or leak incidents, keep unauthorized people away.

Pesticide Disposal: Wastes resulting from the use of this product may be disposed of at an approved waste disposal facility.

CONTAINER DISPOSAL [HANDLING]:

For containers smaller than 5 gallons: Nonrefillable container: Do not reuse or refill this container. Triple rinse as follows: Empty the remaining contents into application equipment or a mix tank and drain for 10 seconds after the flow begins to drip. Fill the container 1/4 full with water and recap. Shake for 10 seconds. Pour rinsate into application equipment or a mix tank or store rinsate for later use or disposal. Drain for 10 seconds after the flow begins to drip. Repeat this procedure two more times. Then offer for recycling or reconditioning, or puncture and dispose of in a sanitary landfill, or by other procedures approved by State and local authorities. Plastic containers are also disposable by incineration, or, if allowed by State and local authorities, by burning. If burned, stay out of smoke.

Nonrefillable Containers Larger than 5 Gallons: Nonrefillable container. Do not reuse or refill this container. Offer for recycling if available. Triple rinse or pressure rinse container (or equivalent) promptly after emptying.

Triple rinse as follows: Empty the remaining contents into application equipment or a mix tank. Fill the container 1/4 full with water. Replace and tighten closures. Tip container on its side and roll it back and forth, ensuring at least one complete revolution, for 30 seconds. Stand the container on its end and tip it back and forth several times. Turn the container over onto its other end and tip it back and forth several times. Empty the rinsate into application equipment or a mix tank or store rinsate for later use or disposal. Repeat this procedure two more times.

Pressure rinse as follows: Empty the remaining contents into application equipment or a mix tank and continue to drain for 10 seconds after the flow begins to drip. Hold container upside down over application equipment or mix tank or collect rinsate for later use or disposal. Insert pressure rinsing nozzle in the side of the container, and rinse at about 40 psi for at least 30 seconds. Drain for 10 seconds after the flow begins to drip.

This product is registered by the Willapa-Grays Harbor Oyster Growers Association, P.O. Box 3, Ocean Park, WA 98640

Appendix B

Bird Checklists of the United States:
Willapa National Wildlife Refuge (USFWS 1991)

The U.S. Geological Survey (USGS), Northern Prairie Wildlife Research Center[1] maintains Bird Checklists of the United States that are grouped by geographic area. The checklist area for Willapa National Wildlife Refuge and the Columbia River Estuary includes: Willapa Bay and adjacent habitats west of Highway 101 and south of Highway 105, plus the Long Beach Peninsula; the Columbia River from Puget Island to the Pacific Ocean; and the Julia Butler Hansen Refuge for the Columbia whitetailed deer. The list of bird species reproduced below has been extracted from that source for only those sightings in Willapa Bay, the Long Beach Peninsula and the Columbia River, west on the Astoria-Megler Bridge.

Seasons

Spring	March through May
Summer	June through August
Fall	September through November
Winter	December through February

Relative Abundance

a – abundant	Species that are very numerous
c – common	Species that are nearly certain to be seen
u – uncommon	Species that are present but not certain to be seen
o – occasional	Species that are seen several time/year or locally
r – rare	Species seen at intervals of 2 to 5 years
*	Known to nest within the checklist area

Common Names	**Seasonal Observations**			
	Spring	**Summer**	**Fall**	**Winter**
LOONS				
Red-throated loon	c	-	c	c
Pacific loon	c	r	c	u
Common loon	c	r	c	u
GREBES				
Pied-billed grebe*	u	u	u	u
Horned grebe	c	r	c	c
Red-necked grebe	r	-	o	o
Western grebe	a	u	a	a

1 The Northern Prairie Wildlife Research Center (NPWRC) is one of 18 science and technology centers within the USGS Biological Resources Discipline (BRD). The NPWRC is administratively positioned in the Central Region of the United States, and geographically located in the northern Great Plains. The main campus is in Jamestown, North Dakota. The mission of NPWRC is to provide the scientific information needed to conserve and manage the national's biological resources, with an emphasis on the species and ecosystems of the nation's interior.

Common Names	Seasonal Observations			
	Spring	Summer	Fall	Winter
FULMARS, PETRELS AND SHEARWATERS				
Northern fulmar	-	r	r	u
Pink-footed shearwater	-	-	r	-
Sooty shearwater	u	c	a	-
Short-tailed shearwater	-	-	-	o
Fork-tailed storm petrel	-	-	r	-
Leach's storm petrel*	-	-	r	-
PELICANS AND CORMORANTS				
Brown pelican	o	c	c	-
Double-crested cormorant*	c	c	c	c
Brandt's cormorant*	c	c	c	c
BITTERNS, HERONS AND EGRETS				
American bittern*	o	u	u	o
Great blue heron*	c	c	c	c
Great egret	o	-	o	-
Cattle egret	-	-	r	-
Green heron	r	r	r	-
WATERFOWL				
Tundra swan	-	-	u	u
Trumpeter swan	-	-	u	u
Greater white-fronted goose	o	-	o	o
Snow goose	o	-	o	o
Ross' goose	r	-	-	-
Emperor goose	r	-	o	r
Brant	a	o	c	c
Canada goose*	a	c	a	a
Wood duck*	u	u	u	-
Green-winged teal	c	r	c	c
Mallard*	c	c	c	c
Northern pintail	u	r	a	c
Blue-winged teal	u	r	u	-
Cinnamon teal*	u	u	u	-
Northern shoveler	u	r	u	o
Gadwall	u	r	u	u
Eurasian wigeon	-	-	o	o
American wigeon	c	r	a	c
Canvasback	u	-	u	u
Ring-necked duck	u	-	u	u
Tufted duck	-	-	-	r
Greater scaup	u	-	u	u
Lesser scaup	c	-	c	c
Harlequin duck	r	-	r	r
Oldsquaw	o	-	r	o
Black scoter	u	-	u	u

Common Names	Seasonal Observations			
	Spring	Summer	Fall	Winter
Surf scoter	c	o	c	c
White-winged scoter	c	o	c	c
Common goldeneye	u	-	u	c
Barrow's goldeneye	r	-	-	r
Bufflehead	c	-	c	c
Hooded merganser*	u	o	u	u
Common merganser*	c	u	u	u
Red-breasted merganser	c	r	c	c
Ruddy duck	o	-	u	u
VULTURES				
Turkey vulture	u	u	u	r
OSPREY, KITES, EAGLES AND HAWKS				
Osprey*	u	u	u	r
White-tailed kite	o	u	o	o
Bald eagle*	u	u	u	u
Northern harrier*	c	c	c	c
Sharp-shinned hawk	u	r	u	u
Cooper's hawk	u	r	u	u
Northern goshawk	r	-	r	r
Red-tailed hawk*	c	c	c	c
Rough-legged hawk	u	-	u	u
FALCONS				
American kestrel	u	r	u	u
Merlin	u	-	u	u
Peregrine falcon	u	-	u	u
Gyrfalcon	-	-	r	r
GALLINACEOUS BIRDS				
Ring-necked pheasant*	u	u	u	u
Blue grouse*	u	u	u	r
Ruffed grouse*	u	u	u	u
Wild turkey	r	r	r	r
Northern bobwhite*	u	u	o	o
RAILS				
Virginia rail*	u	u	u	r
Sora	r	-	r	-
American coot	u	-	u	c
PLOVERS				
Black-bellied plover	c	u	a	c
American golden plover	r	r	u	r
Snowy Plover*	u	u	u	r
Semipalmated plover	c	c	c	r

Common Names	Seasonal Observations			
	Spring	Summer	Fall	Winter
Killdeer*	u	u	c	u
OYSTERCATCHERS				
American oystercatcher*	u	u	u	-
SHOREBIRDS				
Greater yellowlegs	c	u	c	c
Lesser yellowlegs	-	-	r	-
Willet	r	-	o	o
Wandering tattler	u	o	u	-
Spotted sandpiper	u	o	u	-
Whimbrel	c	o	c	-
Long-billed curlew	u	-	u	o
Bar-tailed godwit	-	-	o	-
Marbled godwit	u	o	u	r
Ruddy turnstone	c	o	c	r
Black turnstone	u	u	u	u
Surfbird	c	r	c	r
Red knot	c	-	u	-
Sanderling	a	c	a	c
Semipalmated sandpiper	o	r	-	-
Western sandpiper	a	a	a	c
Least sandpiper	c	c	a	u
Pectoral sandpiper	-	-	c	-
Sharp-tailed sandpiper	r	-	u	-
Dunlin	a	u	a	a
Stilt sandpiper	-	-	r	-
Ruff	-	-	r	-
Short-billed dowitcher	a	a	c	-
Long-billed dowitcher	u	r	c	u
SNIPE				
Common snipe	c	r	c	u
PHALAROPES				
Wilson's phalarope	-	-	r	-
Red-necked phalarope	u	o	u	-
Red phalarope	r	r	o	-
JAEGERS				
Parasitic jaeger	r	r	u	-
GULLS AND TERNS				
Bonaparte's gull	c	u	c	r
Heermann's gull	o	c	c	-
Mew gull	c	r	c	c
Ring-billed gull	c	u	c	u

Common Names	Seasonal Observations			
	Spring	Summer	Fall	Winter
California gull	c	u	a	u
Herring gull	-	-	-	r
Thayer's gull	-	-	-	r
Western gull*	c	c	c	c
Glaucous-winged gull*	c	c	c	c
Black-legged kittiwake	u	r	u	u
Sabine's gull	r	r	r	-
Caspian tern*	c	c	c	-
Common tern	u	r	u	-
Arctic tern	r	-	r	-
SEABIRDS				
Common murre	u	c	c	u
Pigeon guillemot*	c	c	u	r
Marbled murrelet*	u	u	u	u
Ancient murrelet	-	-	r	r
Cassin's auklet	-	-	r	r
Rhinoceros auklet	o	u	o	o
Tufted puffin	o	u	o	o
Horned puffin	-	-	-	o
DOVES				
Rock dove*	u	u	u	u
Band-tailed pigeon*	c	c	c	-
Mourning dove	r	r	r	-
OWLS				
Barn owl*	u	u	u	u
Western screen owl*	u	u	u	u
Great horned owl*	u	u	u	u
Snowy owl	-	-	-	r
Northern pygmy owl*	u	u	u	u
Burrowing owl	r	-	r	r
Barred owl*	u	u	u	u
Long-eared owl	r	-	r	r
Short-eared owl	u	o	u	u
Northern saw-whet owl*	u	u	u	u
GOATSUCKERS				
Common nighthawk*	r	u	u	-
SWIFTS				
Vaux's swift*	c	c	c	-
HUMMINGBIRDS				
Anna's hummingbird	-	-	-	r
Rufous hummingbird*	a	a	o	r

Common Names	Seasonal Observations			
	Spring	Summer	Fall	Winter
KINGFISHERS				
Belted kingfisher*	u	u	u	o
WOODPECKERS				
Red-breasted sapsucker	u	-	u	u
Downy woodpecker*	u	u	u	u
Hairy woodpecker*	u	u	u	u
Northern flicker*	c	c	c	c
Pileated woodpecker*	u	u	u	u
FLYCATCHERS				
Olive-sided flycatcher*	c	c	o	-
Western wood-pewee*	u	u	o	-
Willow flycatcher*	u	u	o	-
Pacific-slope flycatcher*	c	c	u	-
LARKS				
Horned lark*	u	u	u	o
SWALLOWS				
Tree swallow*	c	c	u	o
Violet-green swallow*	c	c	u	o
Northern rough-winged swallow*	u	u	o	-
Cliff swallow*	c	c	o	-
Barn swallow*	c	a	o	-
JAYS, MAGPIES AND CROWS				
Gray jay	o	o	o	o
Stellar's jay*	u	u	c	u
American crow*	c	c	c	c
Common raven*	u	u	u	u
CHICKADEES AND TITMICE				
Black-capped chickadee*	c	c	c	c
Chestnut-backed chickadee*	c	c	c	c
BUSHTITS				
Bushtit*	o	r	o	o
NUTHATCHES				
Red-breasted nuthatch	u	r	u	u
CREEPERS				
Brown creeper*	u	u	u	u

Common Names	Seasonal Observations			
	Spring	Summer	Fall	Winter
WRENS				
Bewick's wren*	u	u	u	u
Winter wren*	c	c	c	c
Marsh wren*	c	c	c	c
KINGLETS, BLUEBIRDS AND THRUSHES				
Golden-crowned kinglet*	c	c	c	c
Ruby-crowned kinglet*	c	r	c	u
Western bluebird	r	-	r	-
Mountain bluebird	r	-	r	-
Townsend's solitaire	o	r	r	-
Swainson's thrush*	c	c	u	-
Hermit thrush	u	-	u	u
American robin*	c	c	c	c
Varied thrush*	c	u	c	c
WAGTAILS AND PIPITS				
American pipit	-	-	o	-
WAXWINGS				
Cedar waxwing*	u	c	u	r
SHRIKES				
Northern shrike	o	-	u	u
STARLINGS AND MYNAS				
European starling*	c	c	c	c
VIREOS				
Solitary vireo*	r	-	r	-
Hutton's vireo*	u	u	u	u
Warbling vireo*	u	u	o	-
Orange-crowned warbler*	c	c	u	-
Yellow warbler*	u	u	r	-
Yellow-rumped warbler*	c	u	u	c
Black-throated gray warbler	c	c	u	-
Townsend warbler	c	-	u	u
Hermit warbler	r	r	-	-
Palm warbler	-	-	r	r
MacGillivray's warbler	r	r	-	-
Common yellowthroat*	c	c	u	-
Wilson's warbler	c	c	u	-
TANAGERS				
Western tanager*	u	u	o	-

Common Names	Seasonal Observations			
	Spring	Summer	Fall	Winter
GROSBEAKS AND BUNTINGS				
Black-headed grosbeak*	u	u	r	-
TOWHEES AND SPARROWS				
Rufous-sided towhee*	u	u	c	c
Chipping sparrow	r	-	r	-
Savannah sparrow*	c	c	u	-
Fox sparrow	u	-	u	u
Song sparrow*	c	c	c	c
Lincoln's sparrow	r	-	r	-
White-throated sparrow	o	o	-	-
Golden-crowned sparrow	c	-	c	c
White-crowned sparrow*	c	c	c	u
Dark-eyed junco*	c	c	c	c
Lapland longspur	r	-	c	r
Snow bunting	-	-	o	o
BLACKBIRDS, MEADOWLARKS, ORIOLES				
Red-winged blackbird*	c	c	c	c
Western meadowlark*	u	u	u	u
Yellow-headed blackbird	r	-	-	-
Brewer's blackbird*	c	c	u	u
Brown-headed cowbird*	c	c	u	r
FINCHES				
Purple finch*	c	c	u	u
House finch*	c	c	c	c
Red crossbill*	u	c	u	u
Common redpoll	-	-	-	r
Pine siskin*	c	o	c	c
American goldfinch*	u	c	c	r
WEAVER FINCHES				
House sparrow*	c	c	c	c

Birds of Willapa Bay and Grays Harbor (WDF and WDOE, June 1985).

Explanation of Symbols

Breeding: * - (after species name) Known to breed regularly within Willapa Bay or Grays Harbor.

References: - Wahl, R. and R. Paulson. 1981. A Guide to Bird Finding in Washington. Whatcom Museum Press, Bellingham, WA.
- Willapa Bay National Wildlife Refuge Checklist and Widrig, R. 1980. The Birds and Plants of Long Beach Peninsula.

Habitats: SW - open salt water
SS - sandy shore
FW - fresh water (including marsh and shore)

Abundance: (in columns under Habitats and Seasons)
A - abundant
C - common; often seen or heard in appropriate habitats
U - uncommon; usually present but not seen or heard on every visit to appropriate habitats
R - rare; present in appropriate habitats only in small numbers and seldom seen or heard

Seasons: S - Spring F - Fall
S - Summer W - Winter

	Habitats			Seasons			
	SW	SS	FW	S	S	F	W
GAVIIDAE							
Common Loon	C		U	C	C	C	C
Arctic Loon	C		R	C	U	C	U
Red-throated Loon	C			C	U	R	C
PODICIPEDIDAE							
Red-necked Grebe	C		U	U		U	U
Horned Grebe	C		U	C	R	C	C
Western Grebe	C		C	A	U	A	A
Pied-billed Grebe	U		C	U	U	U	U
PROCELLARIIDAE							
Sooty shearwater	C			U	C	A	
PELECANIDAE							
Brown Pelican	R				R	U	
PHALACROCORACIDAE							
Double-crested Cormorant	C		U	C	C	C	C
Brandt's Cormorant	C			C	C	C	C
Pelagic Cormorant	C			C	C	C	C
ARDEIDAE							
Great Blue Heron		C	C	C	C	C	C
Great Common Egret	U			R		R	
American Bittern			C	R	R	U	R
ANATIDAE							
Whistling Swan			C			C	C
Trumpeter Swan						C	C
Canada Goose	U		C	A	C	A	C
Brant	C			C		U	C
White-fronted Goose	U		R	U		U	R
Snow Goose				R		R	R
Mallard	C		C	C	C	C	C
Gadwall	U		C	C	R	C	C
Pintail	C		C	C	U		C
Green-winged Teal	C		C	C	U	C	U
Cinnamon Teal	R		C	R		R	R
European Widgeon	R		R	R		R	R
American Widgeon	C		C	C	R		C
Shoveler	C		C	U	R	U	C
Redhead	R		C			R	U
Ring-necked Duck	R		C	U		C	U
Canvasback	C		C	C		C	C
Greater Scaup	C		C	C	U	C	C
Lesser Scaup	C		C	U	R	U	U
Common Goldeneye	C		C	U		U	C
Barrow's Goldeneye	C		C	R		R	R
Bufflehead	C		C	C	R	C	A
Oldsquaw	U		R	U	R	R	U
White-winged Scoter	C		R	C	U	A	A
Surf Scoter	C		R	C	U	C	A
Common Scoter	U			U	R	U	U
Ruddy Duck	U		C	U	R	U	U
Hooded Merganser	R		U	U	R	U	U
Common Merganser	U		U	U	U	U	C
Red-breasted Merganser	C		R	C	U	C	C
ACCIPITRIDAE							
Sharp-shinned-Hawk				U		U	C
Cooper's Hawk				U	U	U	C
Red-tailed Hawk				U	U	C	C
Bald Eagle		C		U	U	U	U
Marsh Hawk			C	U	U	C	C
PANDIONIDAE							
Osprey		U	U		U		
FALCONIDAE							
Peregrine Falcon		R		U		U	R
Merlin Pigeon Hawk				U		U	U
American Kestrel				U		U	R
GRUIDAE							
Sandhill Crane			U			R	

	Habitats			Seasons			
	SW	SS	FW	S	S	F	W
RALLIDAE							
Virginia Rail			C	U	U	U	U
American Coot	C	C		U	R	U	U
HAEMATOPODIDAE							
Black Oystercatcher					R		R
CHARADRIIDAE							
Semipalmated Plover		C	R	C	C	C	R
Snowy Plover		U		U	U	U	R
Killdeer		U	C	U	U	C	U
American Golden Plover		U	R	R	R	U	R
Black-bellied Plover		C	U	C	C	C	C
Surfbird				U	R	U	R
Ruddy Turnstone		U	R	U		U	R
Black Turnstone		U		U		U	C
SCOLOPACIDAE							
Common Snipe		U	C	C	R	C	U
Long-billed Curlew		R	R	U	U	U	R
Whimbrel		C	R	C	C	C	
Spotted Sandpiper		C	C	U	R	U	
Wandering Tattler				U	U	U	
Willet		R	R	R	R	U	R
Greater Yellowlegs		C	C	C	U	C	U
Lesser Yellowlegs		U	C	C	U	C	C
Red Knot		C	R	C	U	U	
Sharp-tailed Sandpiper		R		R		U	
Pectoral Sandpiper		C	C			C	
Baird's Sandpiper		U	C	R	R	U	
Dunlin		C	R		U		
Short-billed Dowitcher		C	R	U		U	
Long-billed Dowitcher		C	C		U		
Western Sandpiper		C	C		C		
Buff-breasted Sandpiper		R			R	R	
Marbled Godwit		R	R	R		U	
Sanderling		C	U	C	U	C	
Least Sandpiper		C	C		U		
PHALAROPODIDAE							
Red Phalarope	U	R		R		R	
Wilson's Phalarope		U	C	R			
Northern Phalarope	C	U	C	U		U	
STERCORARIIDAE							
Parasitic Jaeger	C				R	U	U

	Habitats			Seasons			
	SW	SS	FW	S	S	F	W
LARIDAE							
Glaucous Gull	R	R	R	U	U		U
Glaucous-winged Gull	C	C	U	C	U	C	C
Western Gull	C	C		C	U	C	C
Herring Gull	C	C	U	C	U	C	
Thayer's Gull	C	C		U		U	U
California Gull	C	C	C	U	C	C	U
Ring-billed Gull	U	U	C	C	U	C	C
Mew Gull	C	C	U	C	R	C	C
Bonaparte's Gull	C	C	C	C		C	U
Heermann's Gull	C	C		U	U	C	C
Black-legged Kittiwake	C			U		C	U
Common Tern	C	C		R	U	C	
Arctic Tern	U	R		R		U	
Caspian Tern	U	U	U	U		U	
ALCIDAE							
Common Murre	C			C	U	C	
Pigeon Guillemot	C			C	U	C	
Marbled Murrelet	C			R			R
Rhinoceros Auklet	C			R			R
STRIGIDAE							
Gread Horned Owl				C	C	C	C
Short-eared Owl				U	U	U	U
ALCEDINIDAE							
Belted Kingfisher		C	C	C	C	C	C
CORVIDAE							
Common Raven			C	R	R	R	R
Crow - Common and Northwestern		C	C	C	C	C	C

Appendix C

Benthic Invertebrate and Finfish Species Inventory
Willapa Bay and Grays Harbor (WDF and WDOE, June 1985).

CTENOPHORA
- Nuda
  - Beroe sp. ?

NEMERTEA
- Enopia
  - Heteronemertea
    - Amphiporus sp. 1 (imparispinosis?)
    - Amphiporus sp. 2
    - Paranemertes sp.

ACANTHOCEPHALON
- Found in fish stomachs (starry flounder)
- Found attached to Corophim stimpsoni

ANNELIDA
- Oligochaeta
  - Tubificidae
    - Peloscolex gabriellae
  - Enchytraeida
    - Enchytraeus sp. 1
    - Enchytraeus sp. 2
  - Naididae
    - Naididae sp. 1
  - Polychaeta
    - Arenicolidae
      - Abarenicola pacificia
    - Ampharetidae
      - Amphicteis mucronata
      - Anobothrus gracilis
    - Capitellidae
      - Capitella capitata
      - Capitellid '6'
      - Heteromastus filiformis
      - Mediomastus californiensis
      - Notomastus tenuis
    - Cirratulidae
      - Cirratulus sp.
    - Goniadidae
      - Glycinde armigera
    - Nephtyidae
      - Nephtys caecoides
      - Nephtys ferruginea
    - Nereidae
      - Nereis brandti
      - Nereis sp.
      - Nereis vexillosa
      - Nereis virens
    - Orbiniidae
      - Haploscoloplos sp.
      - Scolopolos armiger
    - Ophelidae
      - Armandia bioculata
      - Ophelia assimilis
    - Phyllodocidae
      - Eteone longa
    - Polynoidae
      - Harmothoe imbricata
      - Hesperonoe complanata
    - Sabellidae
      - Fabricia sabella
      - Manayunkia sp.
    - Sigalionidae
      - Pholoe minuta
    - Spionidae
      - Polydora ligni
      - Pseudopolydora kempi japonica
      - Pygospio elegans
      - Pygospio sp.
      - Rhyncospio arenicola
      - Spio filicornis
      - Spiophanes sp.
      - Streblospio benedicti
    - Syllidae
      - Brania brevipharyngea
      - Sphaerosyllis pirifera
      - Syllis sp.
      - Trypanosyllis sp.
      - Unidentified Syllidae

MOLLUSCA
- Pelecypoda
  - Eulamellibranchia
    - Cardiidae
      - Clinocardium nuttallii
    - Mactridae
      - Tresus capax
    - Myidae
      - Mya arenaria
      - Cryptomya californica
    - Ostreidae
      - Crassostrea gigas
    - Solenidae
      - Siliqua patula
    - Tellinidae
      - Macoma inconspicua
      - Macoma nasuta
      - Tellina nuculoides (salmonea)
    - Veneridae
      - Protothaca staminea
      - Tapes japonica
      - Saxidomas giganteus
  - Filibranchia
    - Mytellidae
      - Modiolus rectus
      - Mytilus californianus
      - Mytilus edulis
- Gastropoda
  - Nacticidae
    - Polinices draconis
  - Nassariidae
    - Nassarius perpingus

ECHINODERMATA
- Asteroidea
  - Pisaster ochraceus

ARTHROPODA
- Crustacea
  - Ostracoda
    - Unidentified ostracod
  - Copepoda
    - Clausidium vancouverensis
    - Diaptemous sp.
  - Cirripedia
    - Thoracica
      - Balanus glandula
      - Lepas anatifera
    - Rhizocephala
      - Unidentified genus: Parasictic on Corophium
      - Unidentified genus: Parasictic on Callianassa
      - May be Ellobiopsid
  - Malacostraca
    - Pericarida
      - Mysidaces
        - Archaeomysis grevnitzskii
        - Mysis oculata?
        - Neomysis mercedis
    - Cumacea
      - Eudorella sp.
      - Eurodorella sp.
      - Diastylis sp.
      - Lamprops, Hemilamprops, or Mesoprops sp.
      - Leptocuma sp.
      - Tanaidaces
        - Leptochelia savignyi
        - Pancolus californiensis

Isopoda
Valvifera
Idotea (Idotea) fewkesi
Idotea (Idotea) refescens
Idotea (Penidotea) resecata
Idotea (Penidotea) wosnesenskii
Saduria entomon
Flabellifera
Aegidae sp.
Cirolana kincaidi
Gnorismosphaeroma oregonensis
Epicaridea
Argeia pugettensis
Bopyrus sp.
Oniscoidea
Lygidia palsaii
Amphipoda
Gammaridea
Allorchestes angusta
Amphithoe sp.
Anisogammarus confervicolus
Ceradocus spinicaudus
Corophium acherusicum
Corophium oaklandense
Corophium spinicorne
Corophium stimpsoni (later identified as C. salmonis)
Dogielinotus loquax
Eohaustorius sp.
Hyale ancepts
Mandibulophoxus gilesi
Orchestia transkiana
Orchestoidea pugettensis
Orchomene pacifica
Paraphous milleri
Photis brevipes
Pontogeneia inermis
Caprellidea
Caprella borealis
Caprella californica
Caprella incisa
Eucarida
Decapoda
Natantia
Caridea
Crangonidae
Crangon alba
Crangon franciscorum
Crangon nigricauda
Reptantia
Astacura
Thallasinoidea
Callianassidae
Callianassa californiensis
Upogebia pugettensis
Brachyura
Brachygnatha
Brachyrhyncha
Cancer magister
Cancer oregonensis
Cancer productus
Hemigrapsus nudus
Hemigrapsusregonensis
Insecta
Collembola
Arthropleona
Anurida Maritima
Diptera
Aphrosylus sp.
Saunderia sp.
HEMICHORDATA
Enteropneusta
Unidentified genus

SOURCE: Albright and Rammen 1976.

Appendix D

Fish Species Composition, Grays Harbor (WDF and WDOE, June 1985).

Petromyzontidae - lampreys
- *Pacific lamprey - Lampetra tridentata

Squalidae - dogfish sharks
- Spiny dogfish - Squalus acanthias

Rajidae - skates
- Big skate - Raja binoculata

Acipenseridae - sturgeons
- White sturgeon - Acipenser transmontanus
- Green sturgeon - Acipenser medirostris

Clupeidae - herrings
- American shad - Alosa sapidissima
- Pacific herring - Clupea harengus pallasi
- Pacific sardine - Sardinops sagax

Engraulidae - anchovies
- Northern anchovy - Engraulis mordax

Salmonidae - salmon, trout, and char
- Chum salmon - Oncorhynchus keta
- Coho salmon - Oncorhynchus kisutch
- Chinook salmon - Oncorhynchus tshawytscha
- Cutthroat trout - Salmo clarki
- Steelhead trout - Salmo gairdneri
- Dolly Varden - Salvelinus malma

Osmeridae - smelts
- Surf smelt - Hypomesus pretiosus
- Longfin smelt - Spirinchus thaleichthys
- *Eulachon - Thaleichthys pacificus

Cyprinidae - minnows
- *Peamouth - Mylocheilus caurinus
- Northern squawfish - Ptychocheilus oregonensis

Gadidae - codfishes
- Pacific tomcod - Microgadus proximus

Atherinidae - silversides
- Topsmelt - Atherinops affinis affinis

Gasterosteidae - sticklebacks
- Threespined stickleback - Gasterosteus aculeatus

Syngnathidae - pipefishes
- Bay pipefish - Syngnathus griseolineatus

Embiotocidae - surfperches
- Redtail surfperch - Amphistichus rhodoterus
- Shiner perch - Cymatogaster aggregate
- Striped seaperch - Embiotoca lateralis
- Walleye surfperch - Hyperprosopon argenteum
- Silver surfperch - Hyperprosopon ellipticum
- White seaperch - Phanerodon furcatus
- Pile perch - Rhacochilus vacca

Pholidae - gunnels
- Saddleback gunnel - Pholis ornata

Ammodytidae - sand lances
- Pacific sand lance - Ammodytes hexapterus

Gabiidae - gobies
- Arrow goby - Clevelandia ios

Hexagrammidae - greenlings
- Kelp greenling - Hexagrammos decagrammus
- Mask greenling - Hexagrammos octogrammus
- Lingcod - Ophiodon elongatus

*Scorpaenidae - rockfishes
- Black rockfish - Sebastodes melanops

Cottidae - sculpins
- *Prickly sculpin - Cottus asper
- Pacific staghorn sculpin - Leptocottus armatus
- Padded sculpin - Artedius fenestralis
- Buffalo sculpin - Enophrys bison
- Cabezon - Scorpaenichthys marmoratus

Stickaeidae - pricklebacks
- Snake prickleback - Lumpenus sagitta

Agonidae - poachers
- Sturgeon poacher - Agonus acipenserinus
- Wartysea poacher - Occa verrucosa

Cyclopteridae - lumpfishes and snailfishes
- Blacktail snail fish - Careproctus melanurus

Bothidae - lefteyed flounders
- Pacific sanddab - Citharichthys sordidus

Pleuronectidae - righteyed flounders
- English sole - Parophrys vetulus
- Starry flounder - Platichthys stellatus
- Sand sole - Psettichthys melanosticus

DEPARTMENT OF ECOLOGY
Toxics Cleanup Program

April 7, 2015

TO: Barry Rogowski, Toxics Cleanup Program (TCP), HQ

FROM: Jason Landskron, P.E., Toxics Cleanup Program (TCP), SWRO

SUBJECT: Willapa Grays Harbor Oyster Growers Association (WGHOGA) NPDES Permit – 2014 Benthic Data Report Review

Thank you for the opportunity to review the 2014 data report on imidacloprid effects in Willapa Bay.[1] Imidacloprid is being proposed for application in intertidal areas within Willapa Bay and Grays Harbor as a method to control burrowing shrimp (ghost shrimp, *Neotrypaea californiensis;* and mud shrimp, *Upogebia pugettensis*) which interfere with oyster production in the estuaries. Experimental use of imidacloprid has been allowed under the current NPDES permit (WA-0040975).

The draft Sampling and Analysis Plan (SAP) for this study was submitted to Ecology on July 7, 2014.[2] The draft SAP was approved by Ecology on July 15, 2014.[3] Imidacloprid treatment of the applicable plots occurred on July 28, 2014 resulting in fieldwork being completed on July 27, August 11, and August 25, 2014 for the benthic invertebrate collection tasks. A total of 431 acres of imidacloprid (registered as Protector 2F, 0.5 lb a.i./ac, liquid formulation) were treated in Willapa Bay and 96.9 acres were treated in Grays Harbor for experimental use in 2014. An additional 13.2 acres was treated with the granular form of imidacloprid (registered as Protector 0.5G, 0.5 lb a.i./ac) in Willapa Bay.

This review provides technical analysis and discussion of the data provided. Further, the focus of this review is on imidacloprid effects to the benthic invertebrate community and to assess regulatory compliance with the Sediment Management Standards (SMS)[4] and Sampling Analysis Plan Appendix (SAPA)[5] where applicable. Other data presented in the draft data report not specifically addressing the benthic invertebrate component of the study, were not considered in this review but may be discussed in other Ecology memos or publications.

This review was not completed with the consultation of a benthic toxicologist or statistician. The intent of this review is to assess whether impacts to benthic invertebrates have occurred as the

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[1] Hart Crowser 2015. *2014 Field Investigations. Experimental Trials for Imidacloprid Use in Willapa Bay. Willapa Bay, Washington.* Submitted February 2, 2015. Revised March 18, 2015, April 3, 2015, and April 6, 2015.

[2] Hart Crowser 2014. *Sampling and Analysis Plan. Experiment Trials for Imidacloprid Use in Willapa Bay. Willapa Bay, Washington.* Submitted July 7, 2014.

[3] Ecology 2014. *Willapa Grays Harbor Oyster Growers Association (WGHOGA) (NPDES Permit WA-0040975) – Approval of Sampling and Analysis Plan for 2014 Experimental Trials of Imidacloprid for the Control of Burrowing Shrimp.* July 15, 2014.

[4] Washington State Sediment Management Standards, WAC 173-204, Ecology publication 13-09-055. Amended February 2013. https://fortress.wa.gov/ecy/publications/SummaryPages/1309055.html

[5] Ecology 2008. *Sediment Sampling and Analysis Plan Appendix: Guidance on the Development of Sediment Sampling and Analysis Plans Meeting the Requirements of the Sediment Management Standards (Chapter 173-204 WAC).* Revised April 2008. https://fortress.wa.gov/ecy/publications/summarypages/0309043.html

result of imidacloprid application for specific metrics identified as requiring site-specific analysis from the statistical analysis provided within the data report. Additionally Ecology will assess whether the study conforms to the established study design utilized in 2011 and 2012.

The 2014 field study focused on north-central Willapa Bay in a region known as Stony Point. Similar to prior studies, the control and treatment plots were not equivalent pre-treatment. Eight of the 18 metrics analyzed required a site-specific analysis to assess potential impacts of imidacloprid application. Upon further review of those metrics requiring site-specific analysis, it appears that the effects of imidacloprid cannot be discerned from seasonality and site variation or that relative recovery is occurring within the 14-day period between the treatment date and first round of samples.

The 2014 data report is approved. The following pages summarize Ecology's interpretation and analysis of the 2014 draft data report and accompanying data. If you have questions about Ecology's review, please email me at jala461@ecy.wa.gov or call me at (360) 407-6388.

Benthic Evaluation and Design Basis

As Washington State lacks promulgated numerical standards for imidacloprid in sediment, direct biological observation is the only means available to assess the health of the benthic community in Willapa Bay and Grays Harbor as a result of imidacloprid application. The following sub-sections summarize the general biological study design used to assess the imidacloprid field trials of 2011, 2012, and 2014, and provide a generalized basis for utilizing the design in Willapa Bay and Grays Harbor. This same study design was used in the 2014 trials and is currently proposed as the monitoring design framework for the draft NPDES permit.

The Sediment Management Standards give Ecology the authority to regulate discharges that impact sediment quality. Ecology has authority to evaluate any new or existing discharge to determine the potential that the discharge will cause a violation of the applicable SMS.[6] If a discharge has potential to violate the SMS, Ecology has authority to stipulate permit terms and conditions or modify permits authorizing discharges to surface waters of the state of Washington.[7] The SMS have two levels of protection described in the regulation:

1. Sediment Quality Standards (SQS) correspond to a "no effects" level.
2. Sediment Impact Zone Maximum (SIZmax) correspond to the maximum "minor effects" level.

Discharges that are demonstrated to meet the SQS level of protection (have no effect on human health or biological resources) are considered to meet the SMS without further permit terms and conditions. Discharges that are demonstrated to have minor effects to the benthic community may be permitted if they meet the conditions of a Sediment Impact Zone (SIZ), and a SIZ is

[6] WAC 173-204-400 (4) (5)
[7] WAC 173-204-400(8)

authorized in their permit. A discharge that has more than minor effects (exceeds SIZmax) would not be permitted.

Sediment Quality Standards (SQS) correspond to no effects on sediment quality. The SQS correspond to sediment quality that will result in no adverse effects, including no acute or chronic adverse effects on biological resources and no significant health risk to humans. For non-Puget Sound marine sediments, Ecology shall determine on a case-by-case basis the criteria, methods, and procedures necessary to meet the intent of the chapter.[8] Another part of the rule also states Ecology's authority to make appropriate sediment management decisions on a case-specific basis using best professional judgment and latest scientific knowledge for cases where the standards of this chapter are reserved or standards are not available.[9] The SMS further defines "no adverse effects" as no acute or chronic adverse effect to biological resources as measured by a statistically and biologically significant response relative to reference in any appropriate biological test as defined in WAC 173-204-200(3).[10]

If a discharge has any minor adverse effect, a Sediment Impact Zone (SIZ) can be authorized. The intent of the rule is to eliminate a SIZ whenever practicable. Ecology shall consider the relationship between environmental effects, technical feasibility, and cost in determining whether it is practicable to minimize and/or eliminate a SIZ.[11] The areal extent of the SIZ must be kept to the minimum practicable surface area.

The effect on biological resources within a SIZ must not be greater than "minor adverse effects", referred to as the SIZmax criteria. For non-Puget Sound marine sediment, Ecology shall determine, using best professional judgment and latest scientific knowledge, on a case-by-case basis, the criteria, methods, and procedures necessary to meet the intent of this chapter.[12] "Minor adverse effects" is defined as a level of effects that includes:

- An acute or chronic adverse effect to biological resources as measured by a statistically and biologically significant response relative to reference in no more than one appropriate biological test as defined in WAC 173-204-200(3).[13]

OR

- A statistically and biologically significant response that is significantly elevated relative to reference in any appropriate biological test defined in WAC 173-204-200(3).[14]

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[8] WAC 173-204-320(1)(c)
[9] WAC 173-204-110(6)
[10] WAC 173-204-200(16)
[11] WAC 173-204-410(1)(b)
[12] WAC 173-204-420 (1)(b) & WAC 172-204-110 (6)
[13] "Appropriate biological tests" means only tests designed to measure directly, or through established predictive capability, biologically significant adverse effects to the established or potential benthic or aquatic resources at a given location, as determined by rule by the department. WAC 173-204-200 (3).
[14] WAC 172-204-200 (15)

Puget Sound Marine Criterion for Benthic Community

The Puget Sound Marine Criterion in the Sediment Management Standards is not directly applicable to Willapa Bay and Gray's Harbor as these embayments are not located in Puget Sound. However, the criterion was considered, along with recent scientific literature, in developing the approach for interpreting the non-Puget Sound marine narrative criteria in Willapa Bay.

The Puget Sound marine criterion for benthic community includes the following metrics:

- Polychaete abundance
- Mollusk abundance
- Crustacean abundance

The Puget Sound Marine criterion for benthic community requires that the data for these metrics from the area in question or "test plot" be compared to a control or reference plot which is known to be unaffected by contaminants. If one of the Puget Sound metrics on the test site is decreased by more than 50% compared to the control site, and is statistically different than the control site, this would constitute a "minor effect"[15]. If two or more of the Puget Sound metrics are decreased by more than 50% compared to the control site, and are statistically different than the control site, this would constitute a "major effect" for the test location.[16]

For this application of imidacloprid in Willapa Bay and Gray's Harbor, Ecology staff began developing the metrics and data analysis methods for interpretation in 2009, before any data were collected. After a review of the existing Puget Sound criterion, the scientific literature, and internal discussion, Ecology staff recommended an approach that combined recent scientific thinking and the Puget Sound criterion. Several references have evaluated benthic community metrics and concluded that taxonomic richness of certain groups of benthic organisms can be used to evaluate the health of the benthic community.[17,18] For this application, taxonomic richness (number of different species or taxa present) is used in addition to abundance (number of organisms) for the three taxonomic groups listed in the Puget Sound marine criterion – Polychaetes, Molluscs, and Crustaceans.

Ecology has stated in previous memos that the benthic community metrics that it will use to consider impacts include:

- Crustacean abundance and taxonomic richness
- Polychaete abundance and taxonomic richness
- Mollusk abundance and taxonomic richness

[15] WAC 173-204-320 (3) (c)
[16] WAC 173-204-420 (3) (c) (iii)
[17] Striplin Environmental Associates, Inc (1999) *Puget Sound Reference Value Project Task 3: Development of Benthic Effects Sediment Quality Standards*. Submitted to Washington State Department of Ecology, April 1999. Ecology Publication No. 99-09-001.
[18] Weisberg, S.B., B. Thompson, J.A. Ranasingh, D.E. Montagne, D.B. Cadien, D.M. Dauer, D. Dierner, J. Oliver, D.J. Reish, R.G. Velarde, J.Q. Word. (2008) *The Level of Agreement Among Experts Applying Best Professional Judgment to Assess the Condition of Benthic Infaunal Communities*. Ecological Indicators 8, 389-394.

For these metrics, Ecology will be looking for a 50% reduction compared to a control or reference site, consistent with the Puget Sound marine criteria. If the permittee chooses to report other metrics, they may be considered as additional information in the site-specific assessment. These metrics describe the recommendation for measuring the magnitude of the impact from pesticides, but would still need to be considered within the context of how large of an area is affected (aerial extent) and how long the impact lasts (duration) to evaluate whether the impacts exceed "minor effects" on sediment quality.

Data Analysis

The following describes Ecology's approach for data analysis that the permittee shall use for interpreting the benthic data.

Ecology has stated that the benthic community metrics that it will use to consider impacts include:

- Crustacean abundance
- Crustacean taxonomic richness
- Polychaete abundance
- Polychaete taxonomic richness
- Mollusk abundance
- Mollusk taxonomic richness

Ecology has indicated that for each metric, if the mean of a test site is 50% less than the mean of the control site, and the treatment mean is significantly less than the control using statistical comparisons, it will be considered an effect for that metric. In cases where the control and treatment sites are not equivalent prior to treatment, or if data are not normally distributed, alternative methods are described below.

Because benthic invertebrates have high seasonal variability, comparison of the treatment site to a control or reference site is critical for interpreting the data. The treatment and control sites should be chosen carefully to ensure that they have similar characteristics and location so that they are likely to have similar benthic communities. Characteristics such as elevation, grain size, and vegetation may affect the benthic community. As part of the statistical analysis, the control and treatment sites will be sampled and analyzed prior to any pesticide application to determine if they have similar metrics.

Ecology acknowledges that in a dynamic estuary, there can be spatial variability such that the control site and test sites have some differences that are not related to the treatment. These can affect the subsequent tests that compare the mean values between the two sites. In consideration of this, Ecology has determined some alternative approaches for statistical comparison may be warranted in such a case. However, Ecology reserves the right to review the characteristics of the control and test sites, and determine whether they are matched well enough to continue with the data analyses. If Ecology determines that the sites are substantially different, then comparison of the data from the test and control sites may not be appropriate. Every effort should be made to match sites with similar characteristics to minimize the risk that the data will not be suitable for comparison of sites.

Figure 1 outlines the process for statistical analysis of the benthic data. The top section of the flow diagram shows the statistical test to determine whether the treatment sites and control site are similar prior to any treatment. Depending on the outcome of that test, different tests may be used on the post-treatment benthic community data. Figure 1 has letters in the diagram that correspond to different tests that are used depending on whether the treatment and control sites are equivalent prior to treatment (A), the control site metric is substantially more than the treatment site metric (B), or the control site metric is substantially less than the treatment site metric (C). Note that for a particular site, there may be a mix of A, B, and C outcomes for the 6 different metrics evaluated. For example, the treatment site may be equivalent to the control site for Crustacean abundance, but have less Polychaete abundance and more Mollusk abundance than the control site.

A summary of the flow diagram is provided below. Additional information detailing the statistical methods used in this analysis, including alternative statistical methods to deal with non-normalized data or data where the treatment plots do not match the control, are provided in previous memos issued by Ecology.

- Pre-treatment test. An equivalence test will be performed on the pre-treatment data to determine if the treatment site mean is significantly ($\alpha = 0.05$) within 25% of the control site mean for all of the metrics.

- (A) Control and treatment are equivalent. If the control site and treatment site are equivalent prior to treatment, the control site will automatically be considered an appropriate match. Then the post-treatment data for that metric will have up to two tests. The metric shall be considered to have an effect if both conditions are true:
  1. The treatment site mean is significantly less than the control site mean (one-tailed α = 0.05).
  2. The treatment site mean is less than 50% of the control site mean. This may be considered as "passing" or is not an effect if the ratio of treatment mean over control mean is greater than or equal to 50%. ($T/C \geq 0.5$)

- (B) Treatment is less than Control metric. If the treatment site mean is less than the control site mean prior to treatment, Ecology will review the characteristics of the site and determine if the sites are appropriately matched and the data analysis can proceed. Then the post-treatment data will be evaluated using the same tests as described in (A). However, if the treatment mean is significantly less than the control mean, and the ratio of the treatment to control mean is less than 0.5 – it is possible that the lower treatment means are due to the spatial variability that was identified prior to treatment. In this case, Ecology will also consider how the ratio of the mean (treatment/control mean) changes between pre-treatment and post-treatment. If the post-treatment ratio is stable or increasing compared to pre-treatment data, that metric will not be considered to have an effect.

- (C) Control is less than Treatment metric. If the treatment site mean is greater than the control site mean prior to treatment, Ecology will review the characteristics of the site and determine if the sites are appropriately matched and the data analysis can proceed. If Ecology determines that the data analysis can proceed, the focus will be on evaluating the ratio of treatment to control site mean and comparing them pre- and post-treatment. If the post-treatment ratio (treatment/control mean) is stable or increasing compared to pre-treatment data, that metric will not be considered to have an effect.

If the treatment and control sites are different prior to treatment, and the post-treatment evaluations do not pass the evaluations described above, Ecology will make a site-specific determination on whether there is an effect. Ecology will consult a benthic ecologist to review the benthic community data in detail to provide insight on the benthic community response at the treatment sites.

In cases where the control and treatment sites are different prior to any imidacloprid application, it is more complicated to determine effects from treatment from natural variability. In these cases, Ecology will look at trends over time and comparisons between the control and treatment sites. In pathways B and C, there is no pathway that results in "effect", only in site-specific analysis. In the case of declining trends post treatment that are greater on the treatment site than the control, Ecology staff will do a more in-depth analysis of the data and make a determination whether there is an effect on the treatment site.

It is important to distinguish that this study design is only intended to assess the magnitude of relatively short term acute impacts of imidacloprid on the benthic community and is meant to comply the state's Sediment Management Standards. The measurement endpoint for each examined metric is mortality; chronic or sub-lethal impacts on the benthic community are not evaluated by this study design nor is the ecosystem health beyond the benthos of the plot being treated.

Power Analysis

When performing statistical tests, it is important to have enough samples to be able to detect a difference between the plots. If there is a lot of variability in the data and not enough samples, it is possible that a difference does exist between the plots but the sampling was not sufficient to detect it. Therefore, Ecology requires that the number of samples collected shall be sufficient to determine a 50% reduction compared to the control, for the mean of each of the 6 metrics listed above with an alpha of 0.05 and a power of 80%. When developing a sampling plan, the number of samples needed to have sufficient power can be estimated by performing a power analysis based on the variability of data collected in previous seasons. Any additional samples per plot, beyond the minimum required, would further strengthen the statistical power of the analysis. Unfortunately a power analysis can only be completed after the field study occurs and therefore can only inform future sampling events.

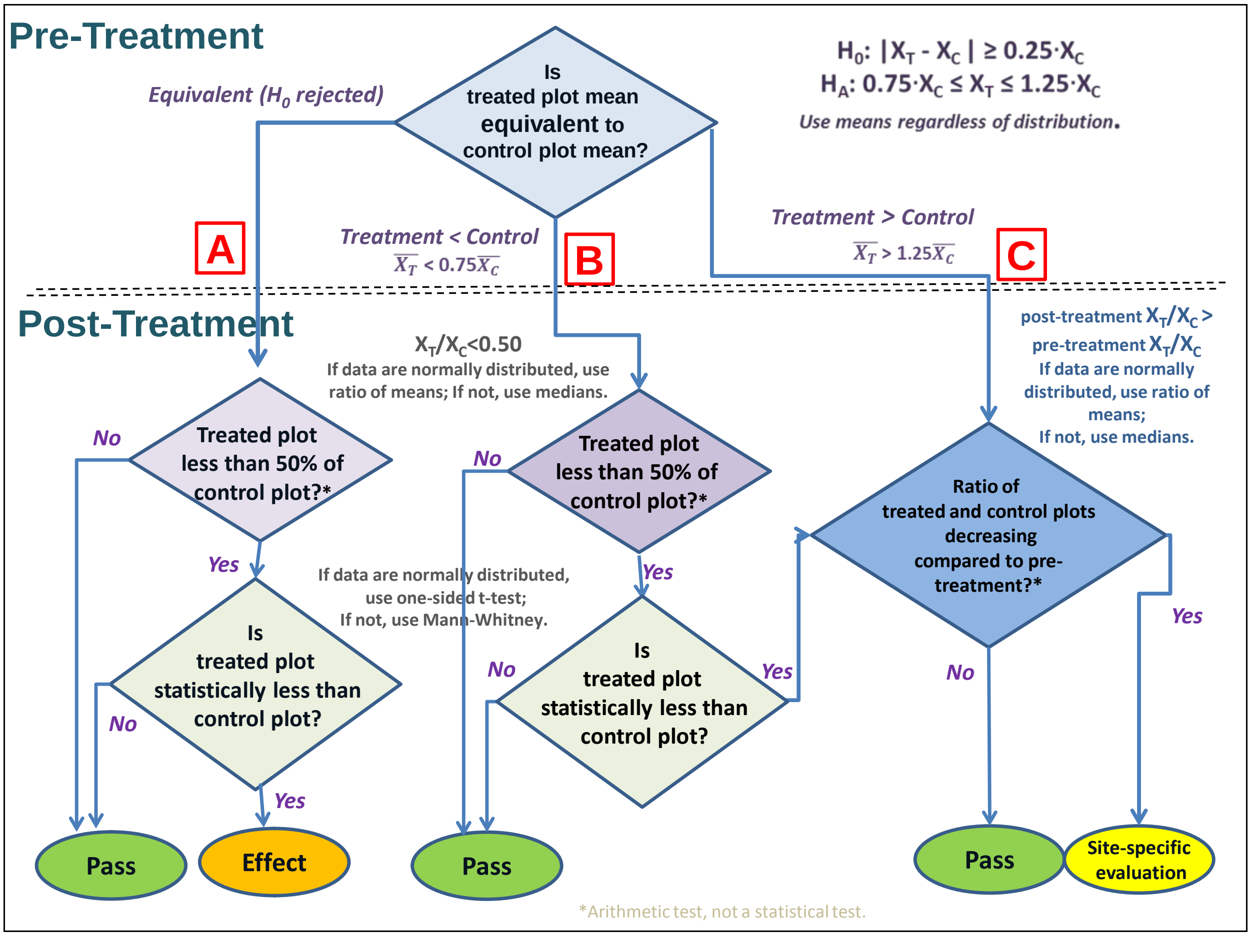

Figure 1: Decision flow chart for data analysis of benthic invertebrate data on imidacloprid treatment sites, as compared to an unaffected control site.

Previous Studies

Field trials using imidacloprid to control burrowing shrimp were completed in 2011 and 2012. The study design and interpretation of results were conducted with the assistance and oversight of TCP staff and followed the general study design described above. Below is a short summary of the results of each study. For additional information, refer to the official Ecology review of each study.

2011 Field Trials[19]

The SAP for the 2011 field trials was submitted to Ecology on July 7, 2011 but was not approved. However, WGHOGA chose to carry out the treatment and benthic sampling without an Ecology approved SAP. Even though the SAP had not been approved by Ecology, the sampling design, described above, was incorporated into the study and thus, the collected benthic data was interpreted using the mutually agreed upon procedures.

[19] Landskron 2014. *Willapa Grays Harbor Oyster Growers Association (WGHOGA) (NPDES Permit WA-0040975) – 2011 Benthic Data Report Review.* TCP Memo to Derek Rockett, Water Quality Program/SWRO. June 24, 2014.

The 2011 study focused on two specific areas of Willapa Bay including Cedar River, located in the northern end of the bay, and Bay Center, located in the north-central portion of the bay. The Cedar River study site consisted of one plot treated with the liquid imidacloprid formulation (Nuprid, currently registered as Protector 2F) and one control plot. The control and treatment plots were not equivalent pre-treatment for many of the metrics. The results of the Cedar River site show that the treatment site decreased 60 to 86% in crustacean abundance and decreased 55 to 72% in polychaete abundance at 14 and 28 days after treatment (DAT), compared to the control plot which increased 44 to 75% in polychaetes abundance and increased (-3%) to 42% in crustacean abundance. Based upon the required site-specific analysis, TCP determined that the imidacloprid application caused an exceedance of the minor adverse effects threshold per the SMS for both polychaete and crustacean abundance at 14 and 28 days on the Cedar River plot. Benthic recovery to pre-treatment abundance levels was not observed during the study period.

While there are many variables which could have contributed to the negative decline in abundance of crustaceans and polychaetes at the Cedar River site, Ecology concluded that the application of imidacloprid was the primary cause. One site feature in particular, the Total Organic Carbon (TOC) percentage of the sediment, was significantly elevated at the Cedar River site compared to any other site where benthic testing occurred including 2012 and 2014 studies. Hence, Ecology suggested that TOC may play an important factor in determining negative effects of imidacloprid application to the benthic communities. Ecology recommended additional studies of TOC, particularly the persistence of imidacloprid in high TOC environments.

The Bay Center site consisted of two treatment plots (one Nuprid plot and one granular imidacloprid formulation (Mallet, currently registered as Protector 0.5G) plot) and one control plot. The control and treatment plots were not equivalent pre-treatment for 48% of the metrics examined. However, based on the results of the site-specific analysis, effects of imidacloprid treatment were not discernible from seasonality and site variation or that relative recovery had occurred within the 14-day period between the treatment and first round of samples. Decreasing trends in polychaete abundance on the Nuprid and Mallet plots were also seen in the control. Similarly, these trends can also be seen in the crustacean abundance. Further, much of the data of each metric falls within the same or overlapping statistical interquartile range. TCP determined that the benthic community at the Bay Center site had recovered by day 14 and that the field trial at Bay Center would meet the SMS regulatory requirements if a NPDES permit were issued, provided other conditions were met.[20]

2012 Field Trials

The SAP for these studies was submitted to Ecology on June 4, 2012 and conditionally approved in a memo from Ecology on June 22, 2012. An addendum to the SAP to address the benthic invertebrate study was submitted to Ecology on July 6, 2012 and was conditionally approved in a memo from Ecology on July 20, 2012. The data report was submitted to Ecology on May 15, 2013, and a subsequent revision with corrections and clarifications was submitted on June 27,

[20] WAC 173-204-410

2013. TCP provided a review memo[21] on July 30, 2013 which requested changes to the document, including clarifications, additional information, and references to be cited for certain sections of the draft report. Ecology received a revised draft report on the 2012 imidacloprid data on April 21, 2014 and completed an addendum review on June 5, 2014.[22]

In 2012, benthic data was collected on 40 acres of imidacloprid treated beds in Bay Center and Leadbetter. While site variability with regard to the benthic community was high, resulting in many metrics on the treatment plots not matching control plots, imidacloprid impacts to benthic communities appeared to be minor based on the Sediment Management Standards regulatory framework and Ecology's site-specific analysis of the data. The treated plots appeared to recolonize with benthic invertebrates within 14 days, so that imidacloprid effects after 14 days could not be discerned from natural variability on the plots.

Neither the 2011 field report nor 2012 field report received Ecology approval for various reasons. As such, Ecology considers these submittals by WGHOGA draft or otherwise incomplete.

2014 Field Trial Results

The 2014 benthic invertebrate community data were collected on 1 treatment plot and 1 control in north-central Willapa Bay, referred to as the Stony Point site throughout the remainder of this review. Benthic data was also collected from the neighboring Coast Seafood's plot (with corresponding control plot) but this data was not supplied to Ecology. Imidacloprid was applied to the treatments plot at a rate of 0.5 pounds per acre of the active ingredient. The Stony Point treatment site is located north and slightly east of Stony Point, Willapa Bay in an area of high flushing and low organic content (mostly sandy) sediments, typical of central Willapa Bay. The control plot for the Stony Point treatment plot was located in Bay Center, approximately 5 miles to the southwest. The reason for this large separation between the 2 plots was due to the difficulty finding a control plot with similar characteristics that was distanced from other treated plots during the experimental trial.

The treatment plot cluster (consisting of plots B17, B18, B19, B23, B152) was approximately 50 acres in size (all owned by Taylor Shellfish Co.) with an adjoining 40 acre plot (B22 #12) also treated with imidacloprid (owned by Coast Seafoods Co.).[23] Per the Ecology SAP approval letter, the benthic study was mostly focused on the 50 acre Taylor Shellfish plot cluster. Further, Ecology approved that a 10-acre sub-plot within the 50 acre treatment plot could be used to gather all sediment and benthic sample as long as the sub-plot was representative of the overall

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[21] Podger 2013. *Willapa Grays Harbor Oyster Growers Association (WGHOGA) (NPDES Permit WA-0040975) – Draft Field Investigation 2012 Experimental Trails for Imidacloprid Use in Willapa Bay.* TCP Memo to Derek Rockett, Water Quality Program/SWRO. July 30, 2013.
[22] Rogowski 2014. *Willapa Grays Harbor Oyster Growers Association (WGHOGA) (NPDES Permit WA-0040975) – Draft Field Investigation 2012 Experimental Trails for Imidacloprid Use in Willapa Bay.* TCP Memo to Rich Doenges, Water Quality Program/SWRO. June 5, 2014.
[23] WGHOGA 2014. *2014 Annual Report. Management of Burrowing Shrimp on Commercial Shellfish Beds. Willapa-Grays Harbor Oyster Growers Association.* Submitted November 26, 2014.

50-acre treatment plot. Figure 2 (Appendix A) depicts the entire 90 acre treatment study area and location of sample stations used in the benthic analysis.

Ecology requested that the purpose of the 2014 benthic study was to evaluate recovery of an imidacloprid treated commercial bed at a larger scale than previously studied. Objectives included a study of a very large treatment plot as well as a study area positioned in a high density of treated beds in order to evaluate potential impacts in these commercial scenarios in central Willapa Bay where the majority of historical shrimp control has occurred. The 2014 study location meets these objectives.

However, as stated in Ecology's 2014 SAP approval memo[3], an additional objective of the 2014 field studies was to assess potential impacts to a commercial bed treated with imidacloprid in an area of low hydraulic flushing and high TOC. WGHOGA stated that they did not have the resources to study 2 treatment plots during 2014 and elected not to study the second set of objectives. Ecology stated in the approval memo that we would only "issue a defensible SIZ for geographic areas of pesticide application where the data is available to support a SIZ, and shows acceptable recovery of the benthic community." Based upon the available data at the time, TCP recommended that the southern portion of Willapa Bay be excluded from the SIZ in the draft NPDES permit until studies are provided that are representative of the conditions in southern Willapa Bay, show acceptable recovery, and qualify for SIZ coverage.

The 2014 study used a matrix sample core layout consisting of 24 sample stations on the control plot and 22 sample stations on the treatment plot. Samples were collected from each plot on three different dates: 1 day prior to treatment, 14 days after treatment (DAT), and 28 DAT. The data report indicates that benthic samples were collected at 56 DAT but this data was not supplied to Ecology. Each sample used a 10.2-cm internal diameter corer and advanced to 10-cm depth. Samples were collected during periods of low tide when the plots were accessible.

While 22 sample stations were established on the treatment plot, only 16 were sampled at all time series. Dr. Steve Booth (Pacific Shellfish Institute) stated in a personal communication that this was due to complications and site heterogeneity of the plot including the presence of shells, oyster long lines, and limited time before the incoming tide to reestablish the gridded sample array. The following site-specific evaluation focuses primarily on the 16 sample cores in common in order to make a meaningful comparison between cores unless otherwise noted. The data tables and figures presented in the 2014 data report represent all cores sampled. Additionally, all core data was used in the data report to perform the pathway analysis (Figure 1 and Appendix B) and make general conclusions on whether data 'passed' or required site-specific evaluation. Ecology believes that the original evaluation using all core data remains valid, as comparisons are only made using means or medians of data, where the additional would only strengthen the validity of the results. Further, in my review, I found no significant differences between the 16 core data set and the 22 core data set for any of the metrics reviewed.

Benthic Invertebrate Results

The 2014 benthic invertebrate data from the treatment plot was compared to the control plot for absolute abundance and taxonomic richness of three taxonomic groups: polychaetes, crustaceans, and mollusks (total of 6 metrics per sample). An additional metric, Shannon Wiener Diversity Index, was provided to Ecology. While diversity is not an official metric evaluated by Ecology, the additional information is appreciated and is incorporated in this review. The Shannon Wiener Diversity Index is a calculated result, based upon taxonomic richness and species abundance, which is used in many biological studies to track species assemblages over time.

The benthic data were compared prior to treatment to determine if the control and treatment plots were equivalent and which decision flow path would be used (Figure 1). Then the plots were compared 14 DAT and 28 DAT. There were 12 metrics evaluated from the 2014 data (18 if counting diversity). These are shown in Table 1 and again in Appendix B. Ten of the 18 (56%) metrics passed the comparison to the control, meaning benthic recolonization had occurred and that there was no discernible effect of imidacloprid to the benthic community at 14 DAT or 28 DAT as defined by the study design. The remaining 8 metrics required Ecology's site-specific evaluation due to significant differences between the control and treatment plots, which are evaluated in the next sections of this memo. In cases where the control and treatment metric were statistically equivalent, all metrics passed.

Table 1: End-Point Summary

Date	Comparison Failure	Comparison Pass	Site-Specific Evaluations Required	Sites Not Applicable to Endpoint Comparison	Total
Stony Point Treatment Site					
14 DAT	0	5	4	0	9
28 DAT	0	5	4	0	9

Table 2 shows all metrics requiring site-specific evaluation. A total of 8 of 18 metrics required Ecology to perform a site-specific evaluation based on the flow chart. Only the metrics of particular interest or concern are described in detail below. However all metrics requiring further evaluation were fully assessed in this analysis.

Table 2: Stony Point Site-Specific Evaluations

Date	Treatment Type	Taxon	Metric	Pre-treatment equivalence (Path to site specific eval)
Stony Point Treatment Site				
14 DAT	Protector 2F (Liquid)	Mollusks	Richness	C → Treatment Plot greater than control prior to treatment
14 DAT	Protector 2F (Liquid)	Mollusks	Diversity	C → Treatment Plot greater than control prior to treatment
14 DAT	Protector 2F (Liquid)	Crustaceans	Abundance	C → Treatment Plot greater than control prior to treatment
14 DAT	Protector 2F (Liquid)	Crustaceans	Diversity	C → Treatment Plot greater than control prior to treatment
28 DAT	Protector 2F (Liquid)	Mollusks	Diversity	C → Treatment Plot greater than control prior to treatment
28 DAT	Protector 2F (Liquid)	Mollusks	Abundance	C → Treatment Plot greater than control prior to treatment
28 DAT	Protector 2F (Liquid)	Mollusks	Richness	C → Treatment Plot greater than control prior to treatment
28 DAT	Protector 2F (Liquid)	Crustaceans	Diversity	C → Treatment Plot greater than control prior to treatment

In all cases requiring further evaluation, the treatment plot metric was greater than the control prior to treatment (path 'C' on the statistical decision tree).

Site Specific Evaluation

Site Characteristics

The Stony Point site is located approximately 1.5 miles northeast of a landmark feature of Willapa Bay called Stony Point. The site resides along southern edge the main Willapa River channel and approximately 0.75 miles from the shoreline to the south. The site is located proximal to the mouth of Willapa Bay and as such is expected to receive a high degree of tidal flushing and dilution capacity (see Neil Banas (2005)[24] dissertation which describes a hydrodynamic flow model of the estuary). The total organic carbon content of the study treatment plot was 0.790% as measured at one location on the plot. The adjacent Coast Seafoods plot TOC was 0.179%. Both plots were predominately sand with lesser quantities of silt and clay.

The data report does not provide treatment or control plot characterization data such as elevation, vegetation type, vegetation distribution or lack thereof for the plot on average or for individual sample stations. This data would typically be required for a site-specific evaluation. However, on July 30, 2014, two days after imidacloprid treatment, Ecology and WGHGOA representatives performed a site walk of both the Taylor Shelfish plots and Coast Seafoods plot. Based on my own observations, and photo log (Appendix C), the Taylor plots consisted of intermittent patches of native eelgrass (Zostera marina) and bare sand. The neighboring Coast Seafoods plot consisted primarily of Japanese eelgrass (Zostera japonica). The elevation of the Taylor plots also appeared to be slightly lower in elevation as more tidepools were present on the plot than on the neighboring plot. Walking conditions on both plots was relatively easy suggestive of a high sand content. Additionally, I observed ghost shrimp in various stages of tetany (paralysis) resting on the surface as well as several crab.

As discussed in the data report, the control plot (paired to the prior treatment study plot) "was covered with a homogenous 80 to 100 percent cover of native eelgrass (*Zostera marina*). There was slightly more woody debris at the control plot than the treatment plot, as a few rotting logs were present."

Metric Evaluation

In general, the majority of the metrics had overlapping interquartile ranges. The following statistics are of particular interest due to either metrics falling outside of the interquartile range or trending sharply opposite to the control plot. Appendix B shows community composition and general trend figures.

Polychaetes

As described in the data report and shown in Appendix B, all polychaete metrics resulted in a 'pass' based on the study design. No site-specific evaluation is required. In Appendix B, all polychaete data is depicted graphically for reference. Table 3 below quantifies select polychaete taxa abundances.

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[24] Banas, Neil S. *Dynamics of Willapa Bay, Washington. Links to the Coastal Ocean, Tidal Dispersion, and Oyster Carrying Capacity.* University of Washington PhD Dissertation. 2005.

Table 3: Select Polychaete Abundance by Taxa

2014 Stony Point Polychaete Abundance	Control Plot					Treatment Plot				
	Average Counts			% Diff to 1DBT		Average Counts			% Diff to 1DBT	
Animal Species/Group	1DBT	14DAT	28DAT	14DAT	28DAT	1DBT	14DAT	28DAT	14DAT	28DAT
Sphaerosyllis californiensis	30.2	20.7	35.5	-31%	18%	20.9	18.5	21.3	-11%	2%
Rhynchospio glutaea	29.1	24.3	21.4	-16%	-26%	13.1	10.3	11.9	-21%	-9%
Capitella capitata - Cmplx	10.0	12.0	7.9	20%	-21%	2.8	0.9	1.1	-68%	-61%
Polydora cornuta	3.8	4.3	3.3	13%	-13%	4.9	31.7	38.6	547%	688%
Pseudopolydora kempi	1.9	1.7	2.0	-11%	5%	2.8	5.9	5.2	111%	86%
Pseudopolydora paucibranchiata	3.1	3.0	3.1	-3%	0%	5.8	23.3	25.2	302%	334%
Scoloplos armiger	5.6	3.7	3.3	-34%	-41%	0.3	0.1	0.1	-67%	-67%
Streblospio benedicti	3.5	4.3	5.3	23%	51%	7.6	6.3	6.6	-17%	-13%
Armandia brevis	4.1	2.0	8.0	-51%	95%	3.3	3.3	11.6	0%	252%
Mediomastus californiensis	12.3	14.1	9.8	15%	-20%	23.0	18.4	18.4	-20%	-20%
Tharyx parvus	71.9	72.3	69.7	1%	-3%	41.4	28.3	40.8	-32%	-1%
			Total Abundance (all species):	**-6%**	**0%**			**Total Abundance (all species):**	**12%**	**40%**

Mollusks

A total of five metrics required site-specific evaluation of Mollusks at the Stony Point. These included richness and diversity at 14DAT and abundance, richness, and diversity at 28DAT. In Appendix B, all Mollusk data is depicted graphically for reference. The following table quantifies Mollusk abundances for several taxa.

Table 4: Select Mollusk Abundance by Taxa

2014 Stony Point Mollusk Abundance	Control Plot					Treatment Plot				
	Average Counts			% Diff to 1DBT		Average Counts			% Diff to 1DBT	
Animal Species/Group	1DBT	14DAT	28DAT	14DAT	28DAT	1DBT	14DAT	28DAT	14DAT	28DAT
Clinocardium nuttali	0.5	0.4	0.9	-20%	80%	2.9	3.6	3.6	24%	24%
Macoma nasuta	0.3	0.6	0.6	100%	100%	0.9	0.1	0.6	-89%	-33%
Macoma sp - JUV	4.6	4.1	4.1	-11%	-11%	4.5	6.1	5.3	36%	18%
Sphenia ovoidea	0.2	0.1	0.3	-50%	50%	0.8	0.2	0.1	-75%	-88%
Mytilid sp - JUV	1.6	1.8	1.8	13%	13%	1.3	2.1	5.9	62%	354%
Myid sp - JUV	1.7	1.8	2.6	6%	53%	3.9	8.8	9.5	126%	144%
			Total Abundance (all species):	**-4%**	**16%**			**Total Abundance (all species):**	**10%**	**38%**

The Stony Point treatment plot was significantly more abundant for Mollusks than the control plot as well as containing a different community composition. The mean abundance and species composition on the control plot remained relatively consistent during the study period. On the treatment plot, the mean abundance increased 10% at 14DAT and increased 38% by 28DAT, relative to 1 day before treatment (DBT). Relative changes in species richness and diversity are bulleted below.

- At 14DAT, mollusk mean species richness decreased 22% on the treatment plot (control decreased 2%) relative to 1DBT.
- At 28DAT, mollusk mean species richness decreased 7% on the treatment plot (control increased 7%) relative to 1DBT.
- At 14DAT, mollusk mean diversity decreased 21% on the treatment plot (control increased 5%) relative to 1DBT.
- At 28DAT, mollusk mean diversity decreased 9% on the treatment plot (control increased 13%) relative to 1DBT.

With the exception of mollusk richness and diversity at 14DAT, box plot trends remained within the interquartile range or followed a trend similar to the control plot. During this study mollusks were low in abundance, often averaging less than one per core sample. As a result, small changes in animals collected per core result in large relative percentage changes as evident in the above table. For example, *Macoma nasuta* (bent nose clam) decreased 89% 14DAT on the treatment plot while increasing 100% on the control plot. The size of the animal (typically 3-6cm) relative to the sample core size (10.2cm) likely explains this variability. This is typical of other mollusk bivalves as well, making assessments of the impact due to imidacloprid near impossible given the current data set and core size used. A larger sample core size and/or many more samples are required to make a valid assessment when the species size is significant compared to the core size.

Even though the treatment plot exhibits increased mean abundance and decreased richness and diversity, seasonality, site variability, and 14-day recolonization are likely responsible for the differences observed and any impacts due to imidacloprid treatment are masked by variability in the data.

<u>Crustaceans</u>
A total of three crustacean metrics required site-specific evaluation at the Stony Point site. These included abundance and diversity and 14DAT and diversity at 28DAT. In Appendix B, all crustacean data is depicted graphically for reference. The following table quantifies crustacean abundances for several taxa.

Table 5: Select Crustacean Abundance by Taxa

2014 Stony Point Crustacean Abundance	**Control Plot**					**Treatment Plot**				
	Average Counts			% Diff to 1DBT		Average Counts			% Diff to 1DBT	
Animal Species/Group	1DBT	14DAT	28DAT	14DAT	28DAT	1DBT	14DAT	28DAT	14DAT	28DAT
Order Cumacea	27.8	27.9	32.0	0%	15%	101.3	70.9	105.8	-30%	4%
Suborder Gammaridea	6.6	16.3	26.3	147%	298%	13.5	15.3	24.1	13%	79%
Suborder Caprellidea	12.5	30.1	26.7	141%	114%	9.6	9.5	91.9	-1%	857%
Family Corophidea	112.0	134.3	123.3	20%	10%	139.8	207.4	283.8	48%	103%
Order Isopoda	0.3	0.3	7.3	0%	2333%	0.6	1.1	2.3	83%	283%
Class Ostracoda	1.0	4.1	4.4	310%	340%	1.4	0.8	1.6	-43%	14%
Order Harpacticoid	28.8	70.0	38.7	143%	34%	160.6	167.3	365.9	4%	128%
	Total Mean Abundance (all Crustaceans):			**32%**	**21%**	**Total Mean Abundance (all Crustaceans):**			**8%**	**96%**

The treatment plot had a higher mean abundance than the control plot for crustaceans prior to treatment as well as throughout the study period. By 28DAT the treatment plot abundance was nearly double that from 1DBT. The control plot did not reciprocate these abundance trends. Relative changes in species richness and diversity are bulleted below.

- At 14DAT, Crustacean mean abundance on the treatment plot increased 8% (control increased 32%) relative to 1DBT.
- At 14DAT, Crustacean mean diversity on the treatment plot decreased 8% (control increased 8%) relative to 1DBT.
- At 28DAT, Crustacean mean diversity on the treatment plot decreased 2% (control increased 10%) relative to 1DBT.

Most of the species on the treatment plot were observed to increase by 14DAT although at a ratio lower than the control plot. However, by 28DAT the crustacean population had increased nearly 81%. These changes were typically plot-wide and not specific to a specific core or region on the plot. Further, the community composition was similar across the study period for both the treatment and control plots. The treatment plot was primarily composed of order *Harpacticoida* followed by family *Corophidea* and order *Cumacea* representing a combined 84% of the crustacean population at 1DBT. By 14DAT this ratio was 86% and then 81% by 28DAT. Suborder *Caprellidea* had a large upsurge in population by 28DAT increasing nearly 10 times its initial population during the study period. The reasons for the large population increase at 28DAT of both Caprellidea and the crustaceans as a whole is unknown. Seasonality, site variability, and 14-day recolonization are likely responsible for the differences observed and any impacts due to imidacloprid treatment are masked by variability in the data.

Conclusions

The 2014 Stony Point control and treatment plots were not equivalent pre-treatment for 8 of the 18 metrics analyzed. Upon further review of those metrics requiring site-specific analysis, it appears that the effects of imidacloprid cannot be discerned from seasonality and site variation or that relative recovery or recolonization is occurring within the 14-day period between the treatment date and first round of samples. Much of the data of each metric falls within the same or overlapping statistical interquartile range of the box plots.

To date, all but one of the study locations have occurred in areas of low total organic carbon (less than 1% TOC) or high oceanic flushing. In these areas, which represent a large proportion of Willapa Bay, the data suggest that the benthic community has a high recolonization potential in response to imidacloprid applications to control burrowing shrimp and would fulfill the requirement of the SMS under a Sediment Impact Zone, should one be permitted in a Final NPDES permit, provided all other requirements of the SMS are met (AKART, BMPs, etc.).

In the one study location of elevated TOC (Cedar River, 2011), an impact to the benthic community, attributed to the imidacloprid application, was observed. There are many variables to explain why an effect was observed at Cedar River and not in other areas of Willapa Bay, but based on the information collected thus far and literature review of the properties of imidacloprid, the degree of oceanic flushing, distribution of sediment grain size, and total organic carbon content are the most likely reasons for the variable degree of imidacloprid toxicity observed. Physical plot specific variables such as vegetation cover, elevation, and community composition also profoundly influence discerning impacts to the benthic community from a control. Further, seasonality (specifically when the plots are treated) likely plays a role of when the benthic community may be more susceptible to imidacloprid toxicity. Seasonable variables include freshwater inputs, breeding cycles of particular creatures, water temperature, and tidal cycles.

The results of the Cedar River study concluded that the minor adverse effects threshold of the SMS was exceeded. Based on the studies conducted to date, I recommend the use of imidacloprid to control burrowing shrimp be restricted to areas of Willapa Bay and Grays Harbor where studies have shown adequate recovery of the benthic community within the 14-day recovery period after application.

Ecology Approval of 2014 Data Report

In general, I concur with the conclusions stated in the data report and recommend agency approval. Central Willapa Bay appears to be highly productive and capable of rapid recolonization or recovery of the benthic community in response to a temporary disturbance, as long as the persistence of the applied pesticide is brief. Based on the studies conducted to date, the sandy and well-flushed sediments of central Willapa Bay have been demonstrated to fit this characterization.

Deviations from SAP and Additional Comments

The data report notes 2 deviations from the 2014 approved SAP:

1. "Pre- and post-treatment sediment and sediment porewater samples were not collected from the control sites for the Taylor and Coast treatment sites.
2. Pre-treatment sediment and sediment porewater samples were not collected from the Taylor and Coast treatment sites."

Both of these conditions were required in the SAP as they add to the integrity of the sample design and minimize assumptions made to the benthic communities prior to treatment. Were these plots already in a depressed state or not? The answer to that question could greatly alter the conclusions that could be derived. Based on the Annual Operations Report prepared for 2013 and prior, I believe it is safe to assume that the plots in question were not exposed to imidacloprid in the past several years. However, in 2013, Carbaryl was applied to 24.5 acres directly on the 2014 treatment study area (Taylor plots B17 and B18).[25] Reference to this fact should be made in the data report. I am unsure why these same plots were selected to be treated in 2 consecutive years, albeit with a different chemical. I am also unsure of how this may have

[25] WGHOGA 2013. *Willapa-Grays Harbor Oyster Growers Association 2013 Annual Report for Burrowing Shrimp Control.* Submitted November 27, 2013.

affected the 2014 study results, if at all. Regardless, Ecology should have been notified of these deviations as they occurred and not just noted in the data report.

Sample Core Locations
The data report states that "Sample stations with an elevation or vegetation that were not characteristic of 80 percent of the rest of the plot were not sampled. The nearest area that was more characteristic of the entire plot was sampled instead."

During the July 30, 2014 onsite inspection, Dr. Kim Patten (WSU) stated that the approved treatment sub-plot was not appropriate for study as it covered too many site features (eelgrass cover, shell, sediment types, channels, intertidal pools). As a result of this, Dr. Patten stated that the benthic samples would likely contain significant inter-sample variability and lose statistical power, confounding interpretation of results. Depending on the benthic habitat at a particular sample location, a different benthic community would exist. During discussions in the field, Ecology agreed with this assessment. Dr. Patten therefore proposed an alternate benthic study plot in the adjacent treatment area (Coast Seafoods). Ecology did not have adequate justification to approve the SAP amendment. In response to Ecology's denial of WGHOGA's proposal to deviate from the SAP, Dr. Patten moved the benthic sample stations to areas of the approved treatment plot less prone to variability, specifically to areas of eelgrass (majority *Zostera Marina*), in order to minimize potential sample variance (see Photo 1, Appendix C). He stated that the chosen control plot conditions were still similar to the treatment plot.

In Ecology's approval memo, TCP requested that the 10 acre sub-plot being sampled be representative of the overall commercial plot and contain as many samples as necessary to achieve statistical power to detect a 50% difference between the study plot and the control. Changing the sub-plot location on the approved plot to an area of eelgrass in order to reduce variability does not technically meet the objectives of the SAP. TCP required that the sub-plot be representative of the overall commercial plot, inclusive of the plot's variable features where possible. Studying a specific feature (e.g. eelgrass cover) on that sub-plot does not meet this goal. While Dr. Patten is correct in stating that reducing the chance of inter-sample variability could strengthen the statistical power of the results, the goal of the SAP was to study the effects of application in a dense area of treated commercial plots to address scale-up in central Willapa Bay. Both Ecology and Dr. Patten agreed that a typical commercial plot consists of a high degree of variability, especially at commercial-scale acreages, and that finding a control plot with comparable features is difficult.

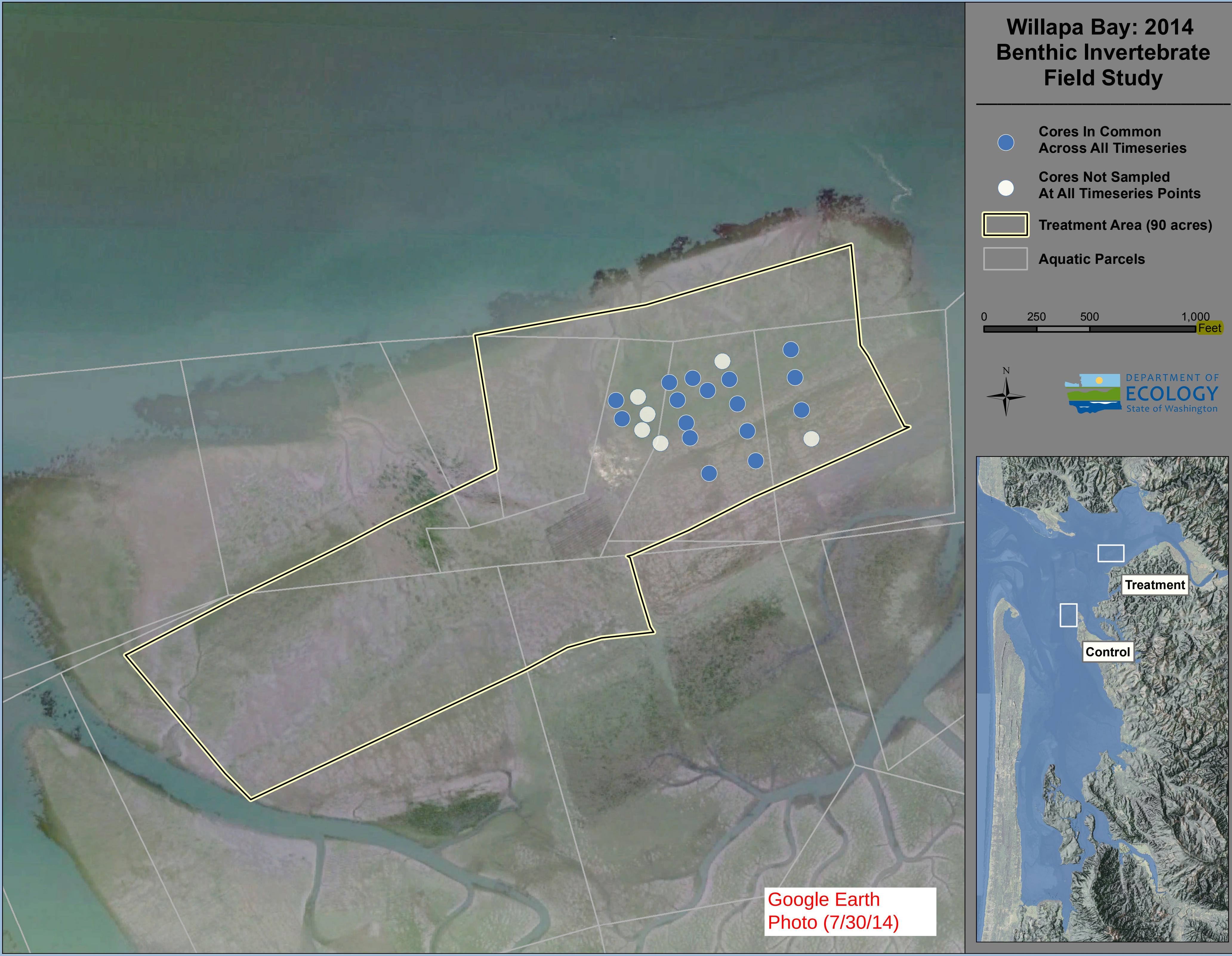
The best means to reduce statistical variability is to increase the sample size, not physically reduce variables by elimination. By constraining the study location to specific site features, the overall study objectives become more focused. Instead of studying the 'effects of imidacloprid on a commercial plot' we are studying the 'effects of imidacloprid on a commercial plot in areas of eelgrass cover'.

The statistically based study design and data analysis process incorporated years of work and collaboration between Donna Podger (Ecology), Russ McMillan (Ecology), Lorraine Reed (TerraStat), and Steve Booth (Pacific Shellfish Institute). It anticipates the potential for site variability and inability for a study plot to match a control which is why there are site-specific evaluation end-points in the data analysis decision tree. The only alternative to this site-specific analysis approach was to disregard data and possibly the entire study if the study plot was too variable and did not statistically match the control. Thus further studies would be required. This would be an expensive and time consuming process. Both the 2011 and 2012 studies resulted in numerous study metrics requiring site-specific evaluation and Ecology did not expect 2014 would be different.

cc: Rich Doenges, WQ SWRO
Derek Rockett, WQ SWRO
Deborah Cornett, WQ SWRO
Barry Rogowski, TCP HQ
Jason Landskron, P.E., TCP SWRO

Appendix A

Study Map


Willapa Bay: 2014
Benthic Invertebrate
Field Study
Cores In Common
Across All Timeseries
Cores Not Sampled
At All Timeseries Points
Treatment Area (90 acres)
Aquatic Parcels
0
250
500
1,000
Feet
N
DEPARTMENT OF
ECOLOGY
State of Washington
Treatment
Control
Google Earth
Photo (7/30/14)

Appendix B

Benthic Pathway Analysis Table

&

Benthic Analysis Figures

(16 Cores in Common)

Table provided by Hart Crowser (2014 Data Report)

Table 17 – Summary table of data and analysis. Pre-treatment comparisons of mean or median (bolded) values of Absolute Abundance, Taxonomic Richness, and Shannon-Weiner Diversity of three primary taxonomic groups for equivalence between the plot to be treated and the control plot resulted in different pathways of analysis for post-treatment comparisons (from Table 15)*

		Pre-treatment (July 27)								14 DAT (August 11)							28 DAT (August 25)						
		Mean or Median [a] Value						T/C [d]		Normal	Mean or Median				Ratio		Nor	Mean or Median				Ratio	
Taxon	Metric	Treated	Control	Treated	Control	Equiv [b]	Path [c]	Means	Medians	Dist [e]	Treated	Control	T/C	Sig [f]	Test [g]	Conclusion [h]	Dist	Treated	Control	T/C	Sig	Test	Conclusion
Polychaetes	Abundance	17212	23603	**19461**	**22889**	No	B	0.73	**0.85**	Yes	20413	22261	0.92	none	no	PASS	No	**23684**	**22399**	1.06	none	no	PASS
	Richness	14.4	17.1	**15.0**	**17.5**	Yes	A	0.84	**0.86**	No	**15.0**	**17.0**	**0.88**	none	no	PASS	Yes	16.1	17.0	0.95	none	no	PASS
	Diversity	1.93	1.96	**1.89**	**1.94**	Yes	A	0.98	**0.98**	Yes	1.99	1.97	1.01	none	no	PASS	No	**2.11**	**2.06**	**1.02**	none	no	PASS
Mollusks	Abundance	2419	1132	**2448**	**1102**	No	C	2.14	**2.22**	No	**2754**	**857**	**3.21**	none	no	PASS	No	**2509**	**1163**	**2.16**	none	yes	SSE
	Richness	5.6	3.5	**6.0**	**4.0**	No	C	1.61	**1.50**	No	**4.0**	**3.5**	**1.14**	none	yes	SSE	No	**4.0**	**3.5**	**1.14**	none	yes	SSE
	Diversity	1.49	0.98	**1.52**	**1.06**	No	C	1.52	**1.44**	Yes	1.21	1.03	1.18	none	yes	SSE	Yes	1.32	1.11	1.19	none	yes	SSE
Crustaceans	Abundance	53156	38030	**46389**	**29559**	No	C	1.40	**1.57**	No	**42411**	**46328**	**0.92**	none	yes	SSE	No	**78580**	**45104**	1.74	none	no	PASS
	Richness	7.3	6.1	**7.0**	**6.0**	No	C	1.20	**1.17**	No	**7.0**	**6.0**	**1.17**	none	no	PASS	No	**7.0**	**6.0**	**1.17**	none	no	PASS
	Diversity	1.43	1.18	**1.45**	**1.18**	No	C	1.21	**1.22**	Yes	1.29	1.28	1.01	none	yes	SSE	Yes	1.39	1.29	1.08	none	yes	SSE

Notes:

* Depending on the pathway, comparisons of mean values (for data that fit a normal distribution) or median values (for data that did not) at 15 and 30 days after treatment depended on the whether to ratio of values from the treated compared to the control plot was < 0.5 or was <, >, or = to the corresponding pre-treatment ratio and resulted in a conclusion of no effect (PASS) or for subsequent Site Specific Evaluation (SSE)

[a] Means for data that fit a normal distribution; medians for data that does not

[b] Results of pre-treatment equivalence tests (Table 15).

[c] Pathway to analysis and impact assessment (Figure 7; Table 15).

[d] Ratio of value on treated plot (T) relative to value on control plot (C).

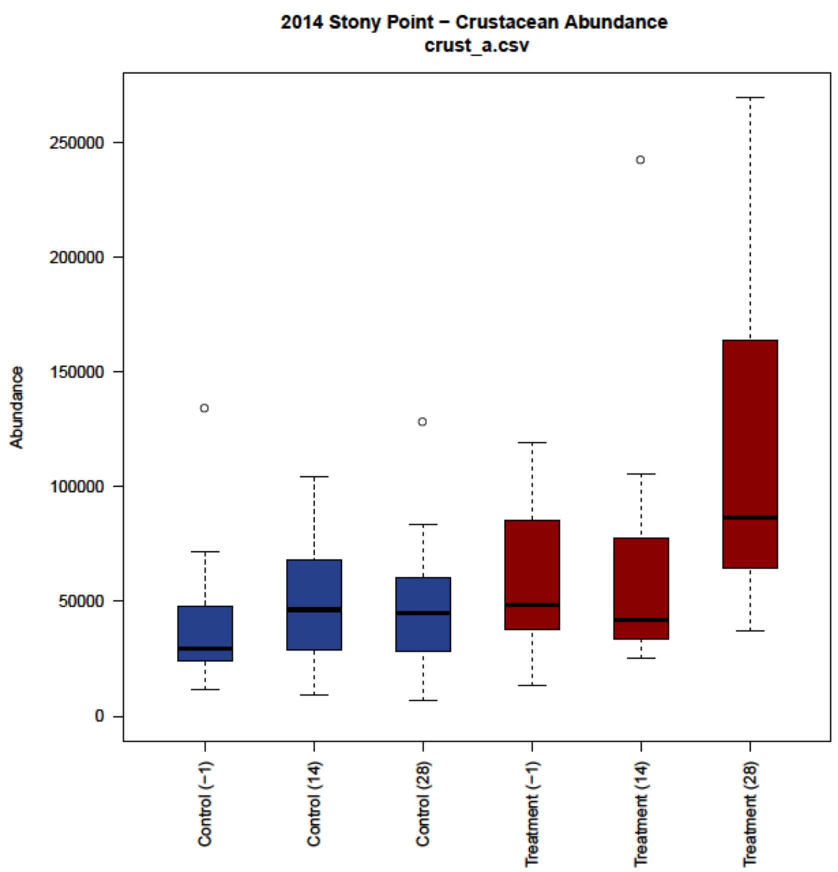
[e] Data fit a normal distribution (Yes) or not (No) according to Shapiro-Wilk test (Table 16).

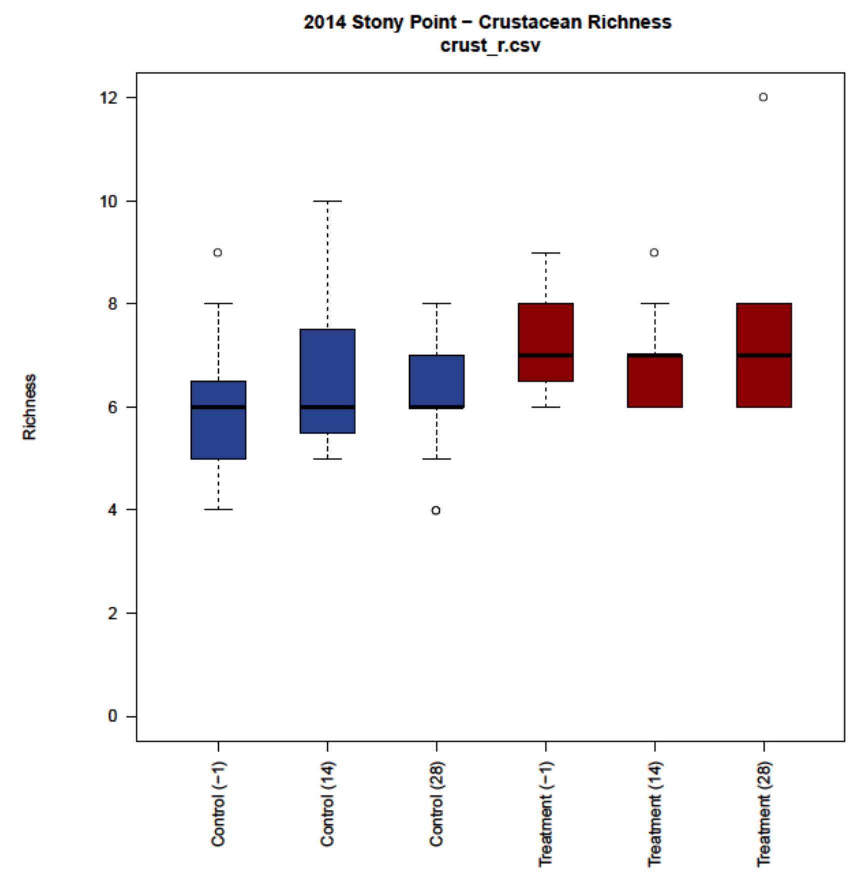
[f] T/C from treated plot significantly lower than T.C from control plot (s) or not (ns); none, not required according to assessment pathway (Figure 7).

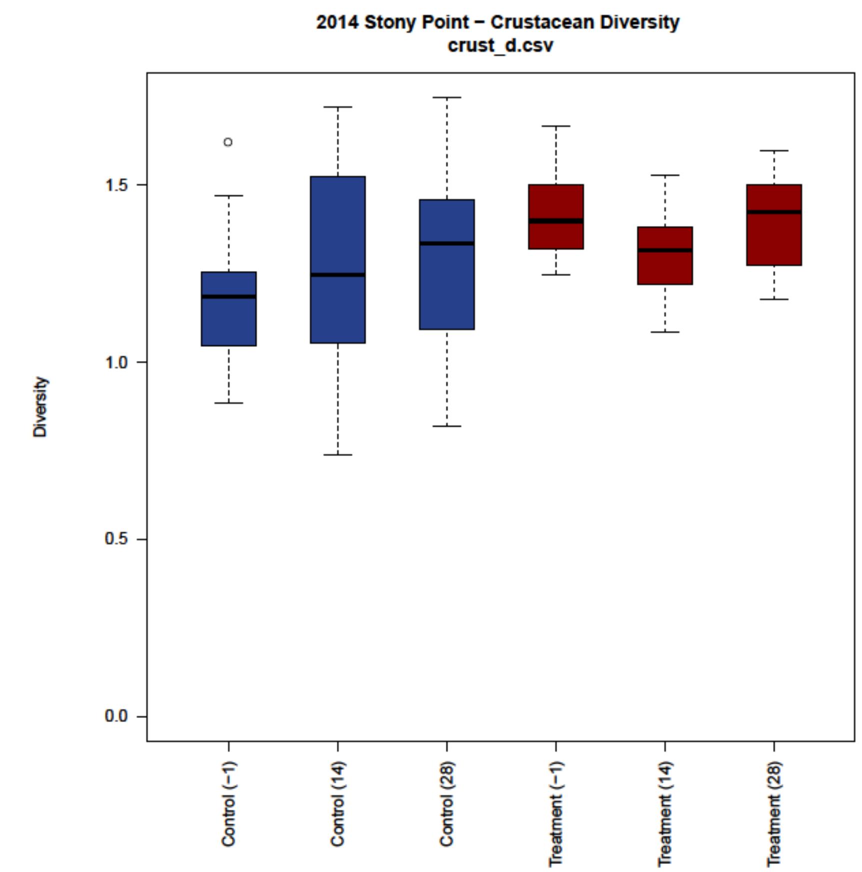
[g] T/C from treated plot < ½ T/C from control plot.

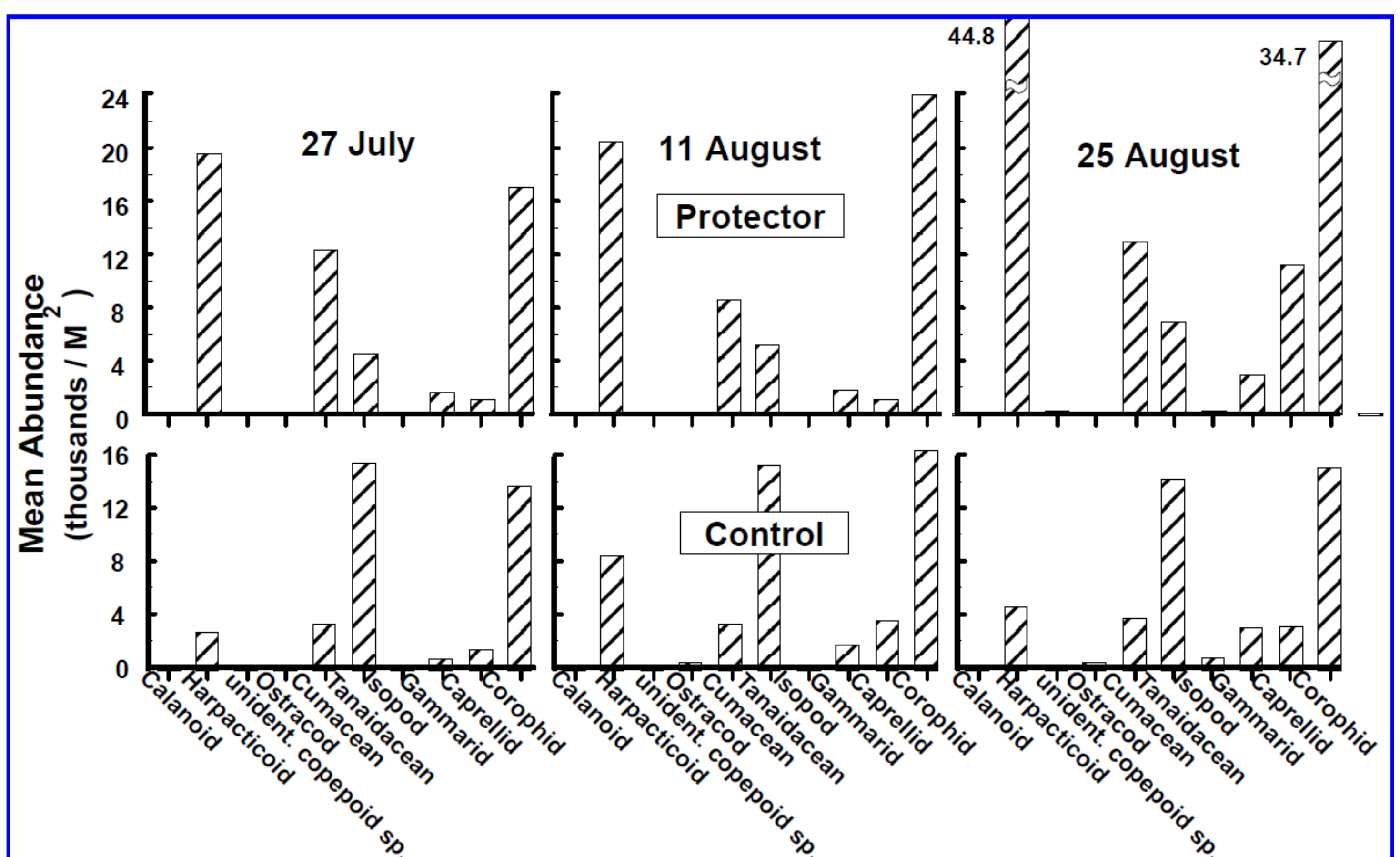
[h] Conclusion of assessment from impact; (PASS, no impact; SSE, Site-Specific Evaluation Required before final Conclusion.

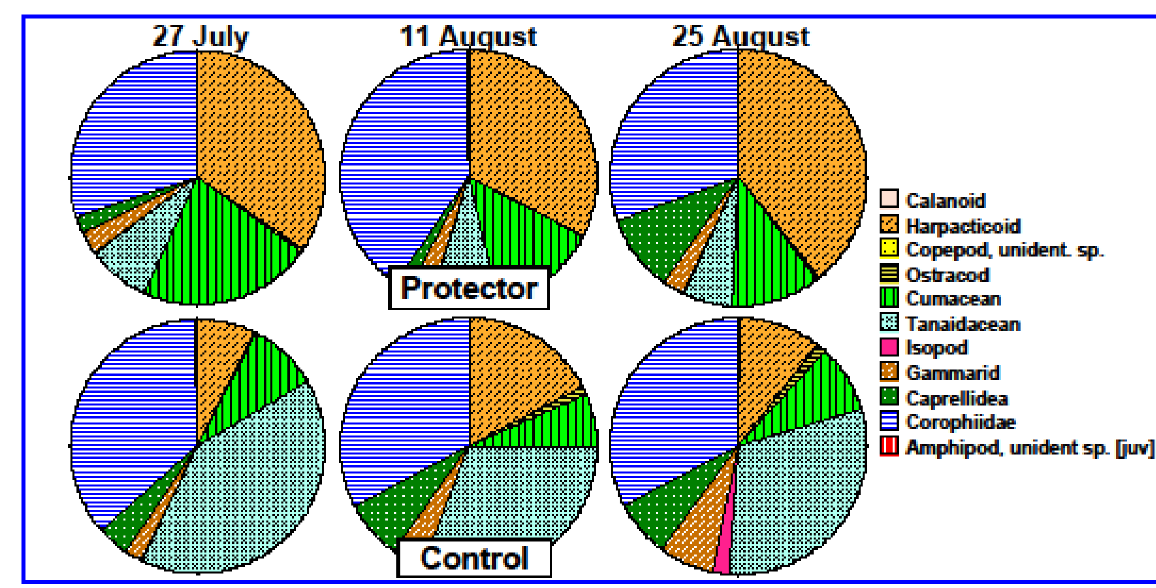
2014 Field Trials – Stony Point
Crustaceans



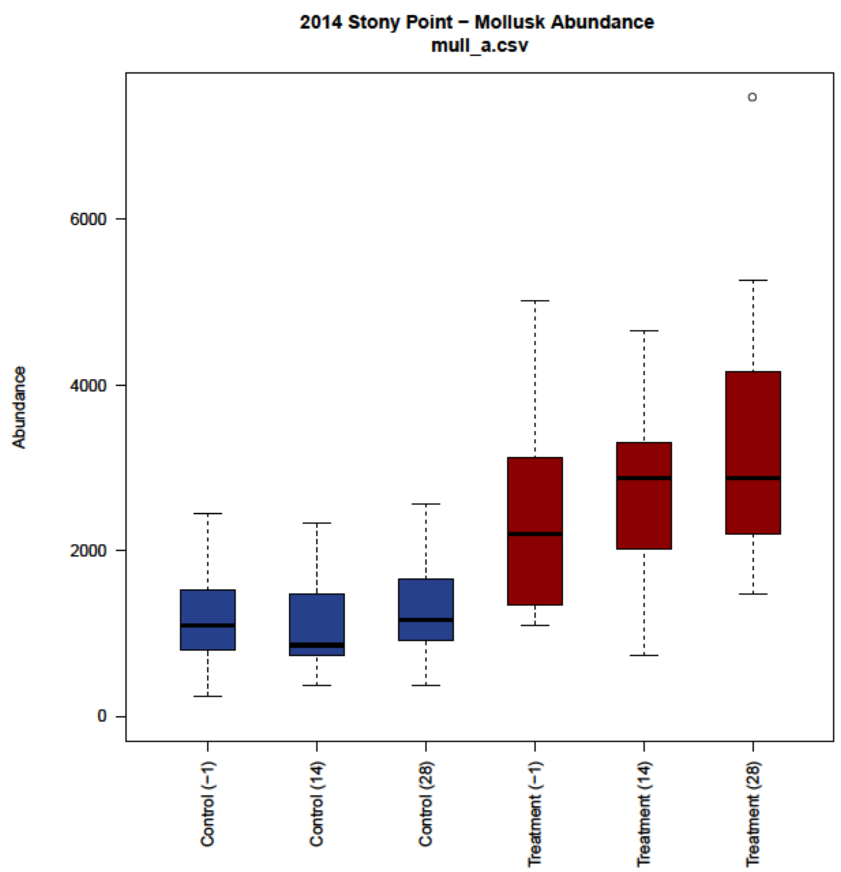


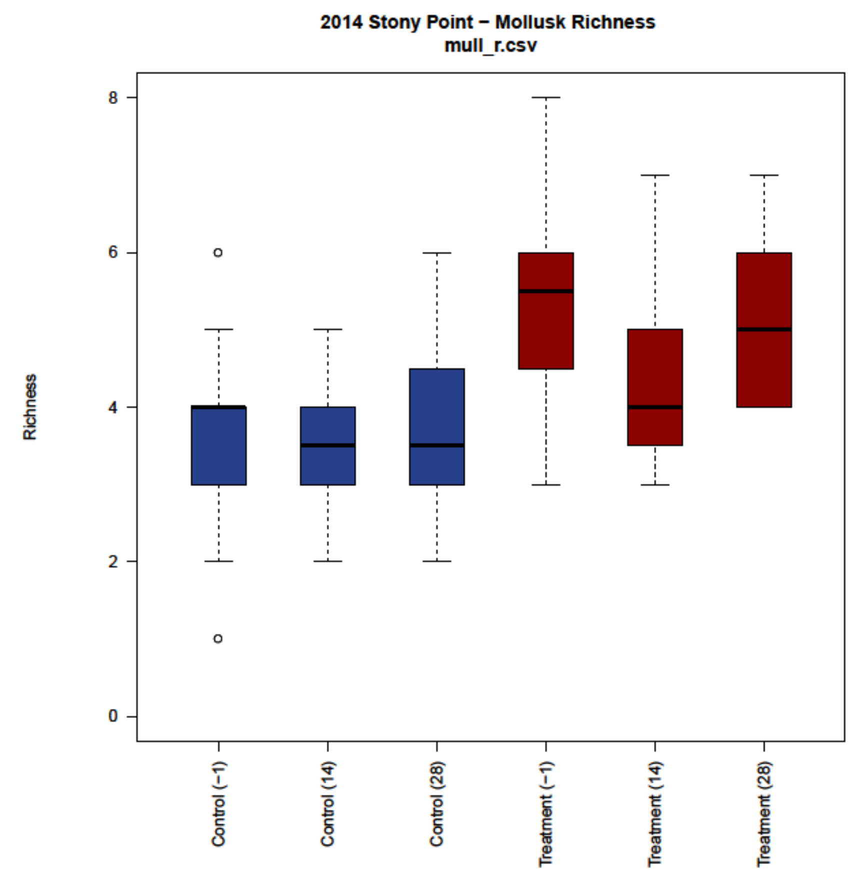


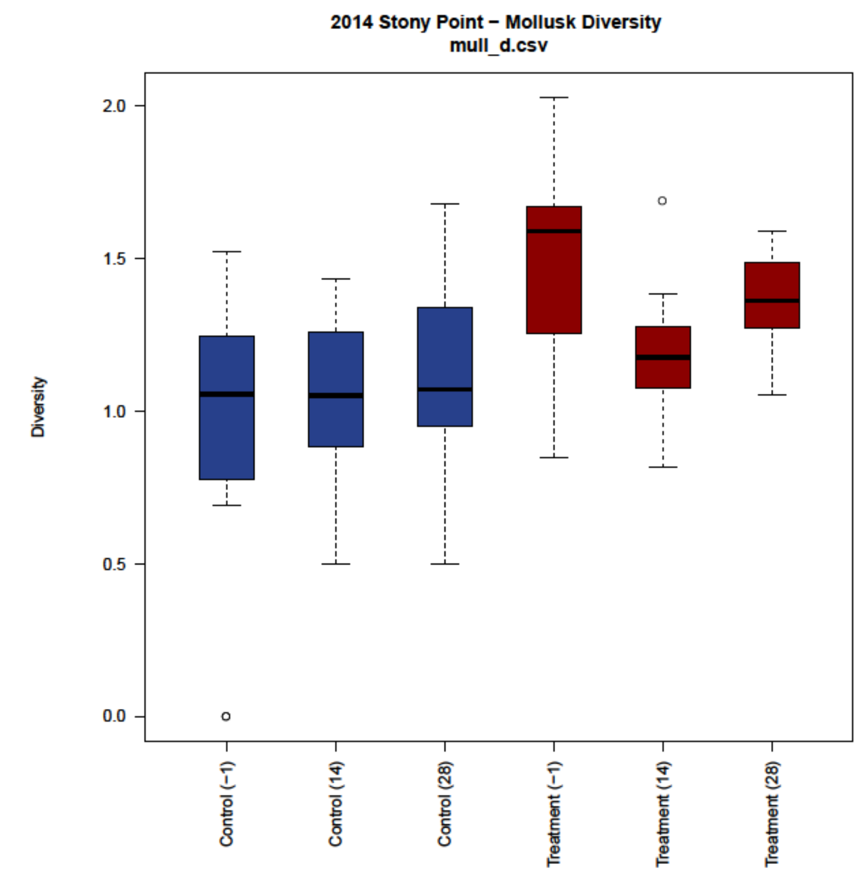


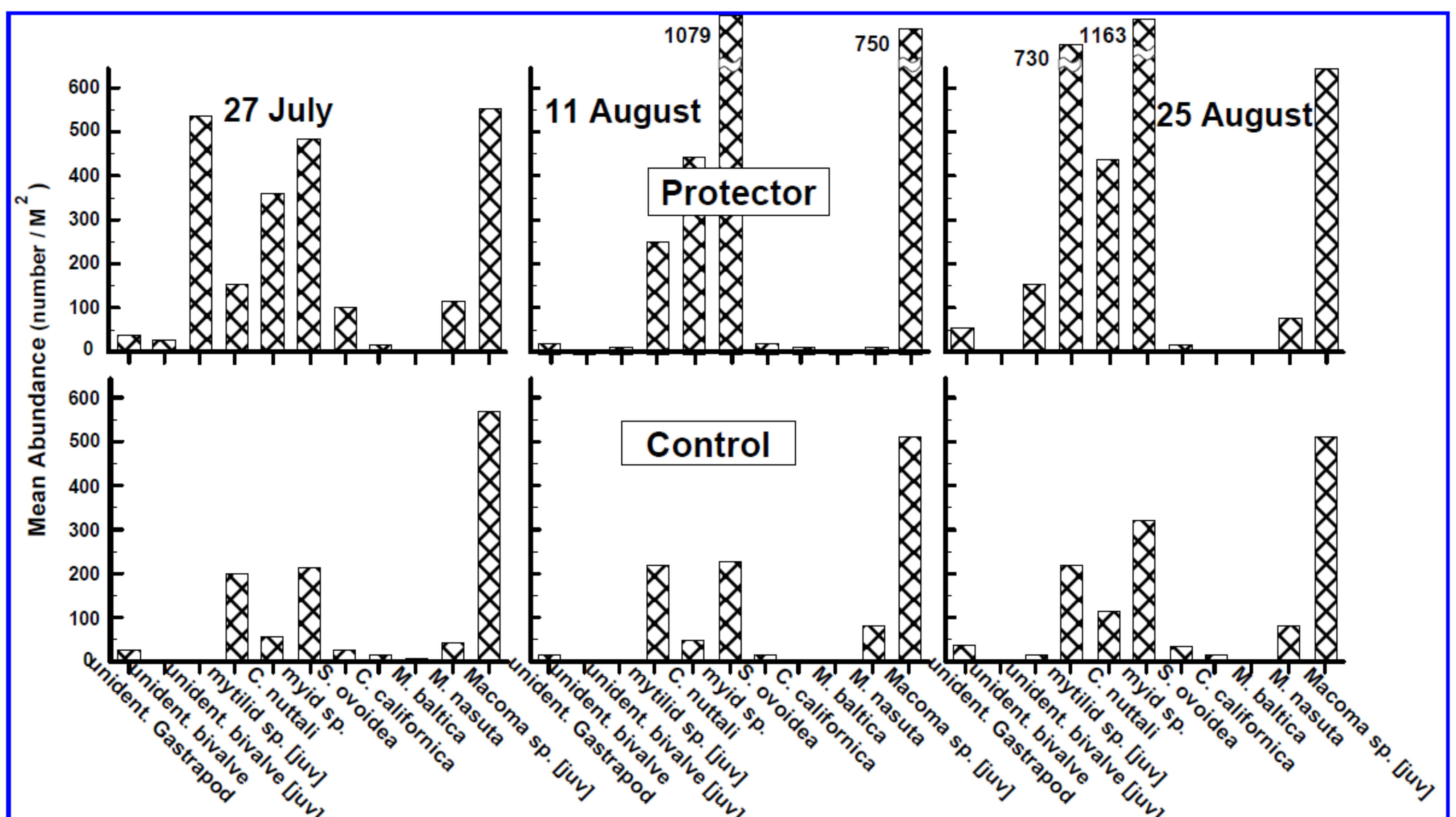


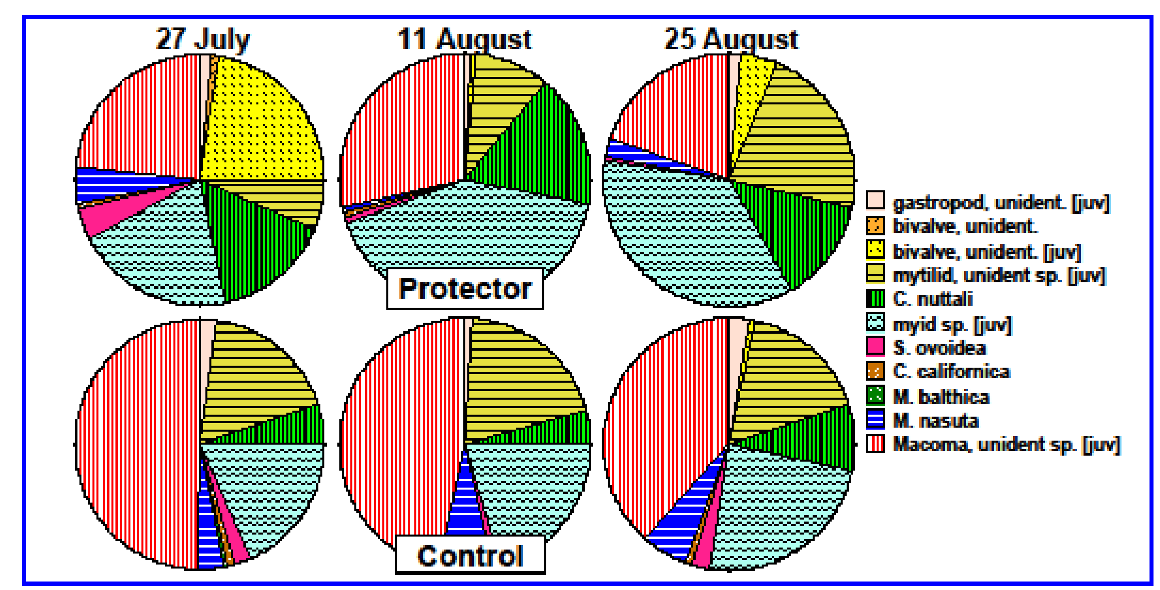
2014 Field Trials – Stony Point
Mollusks



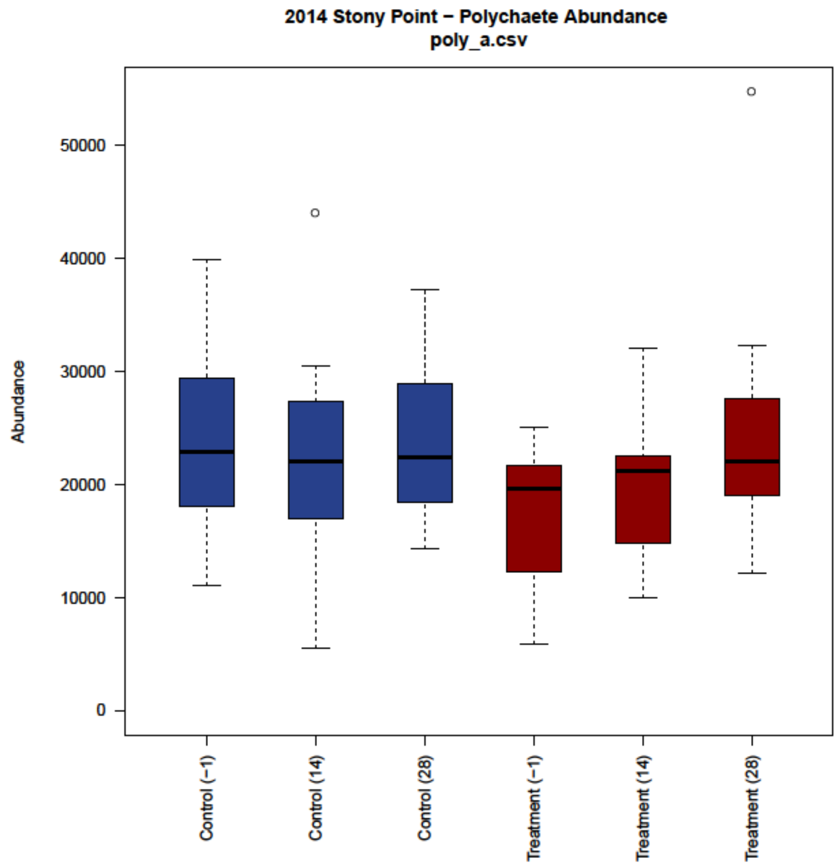


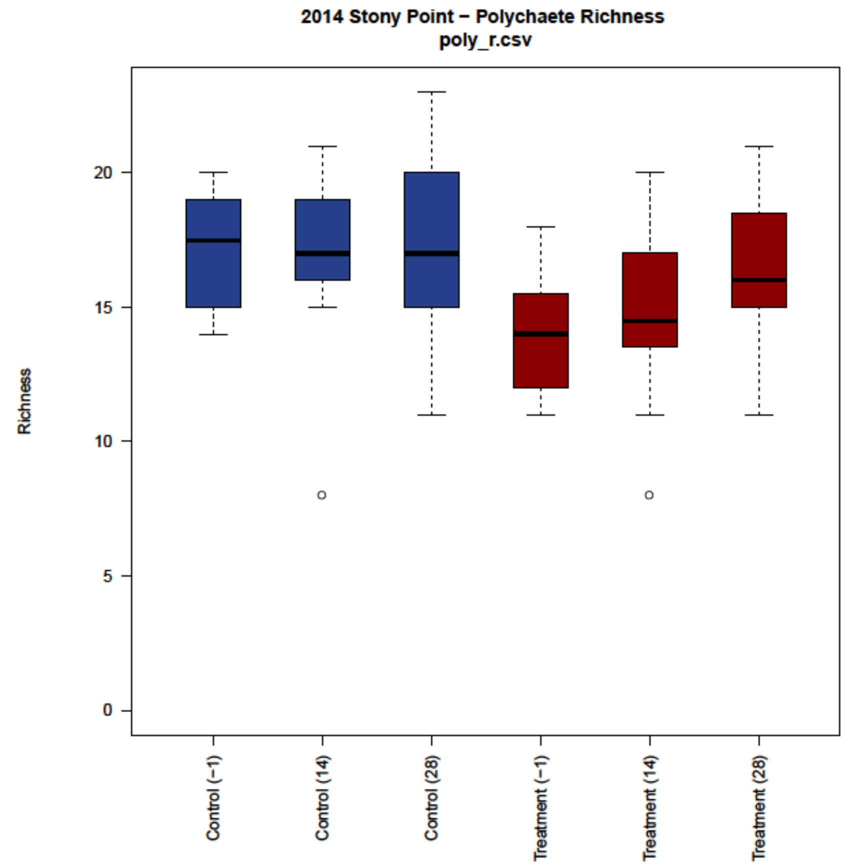


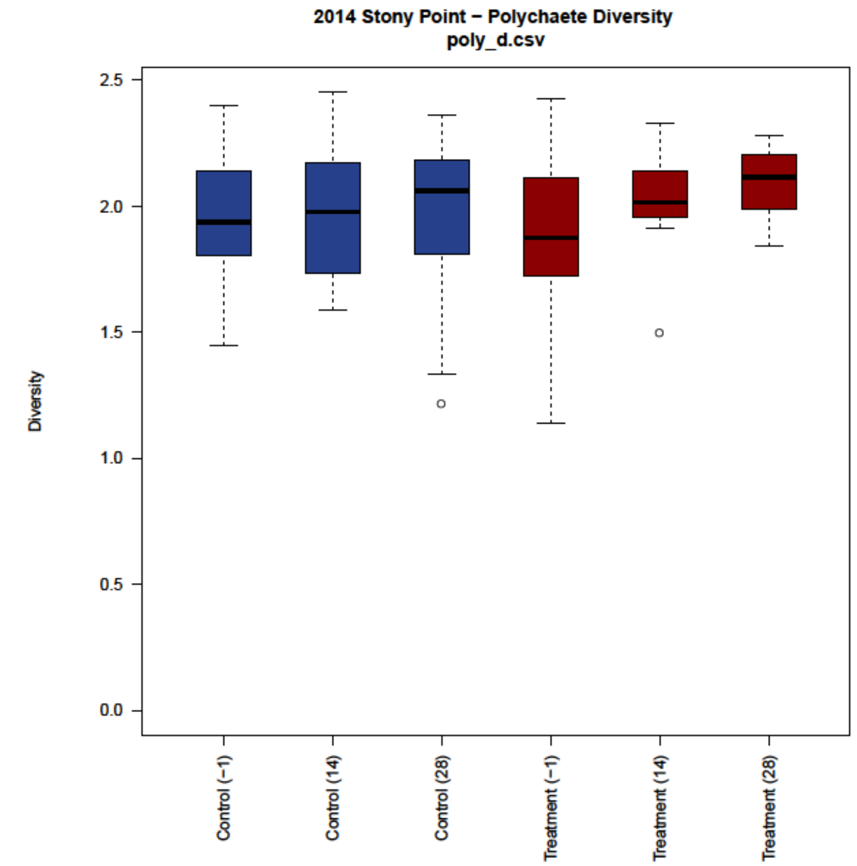


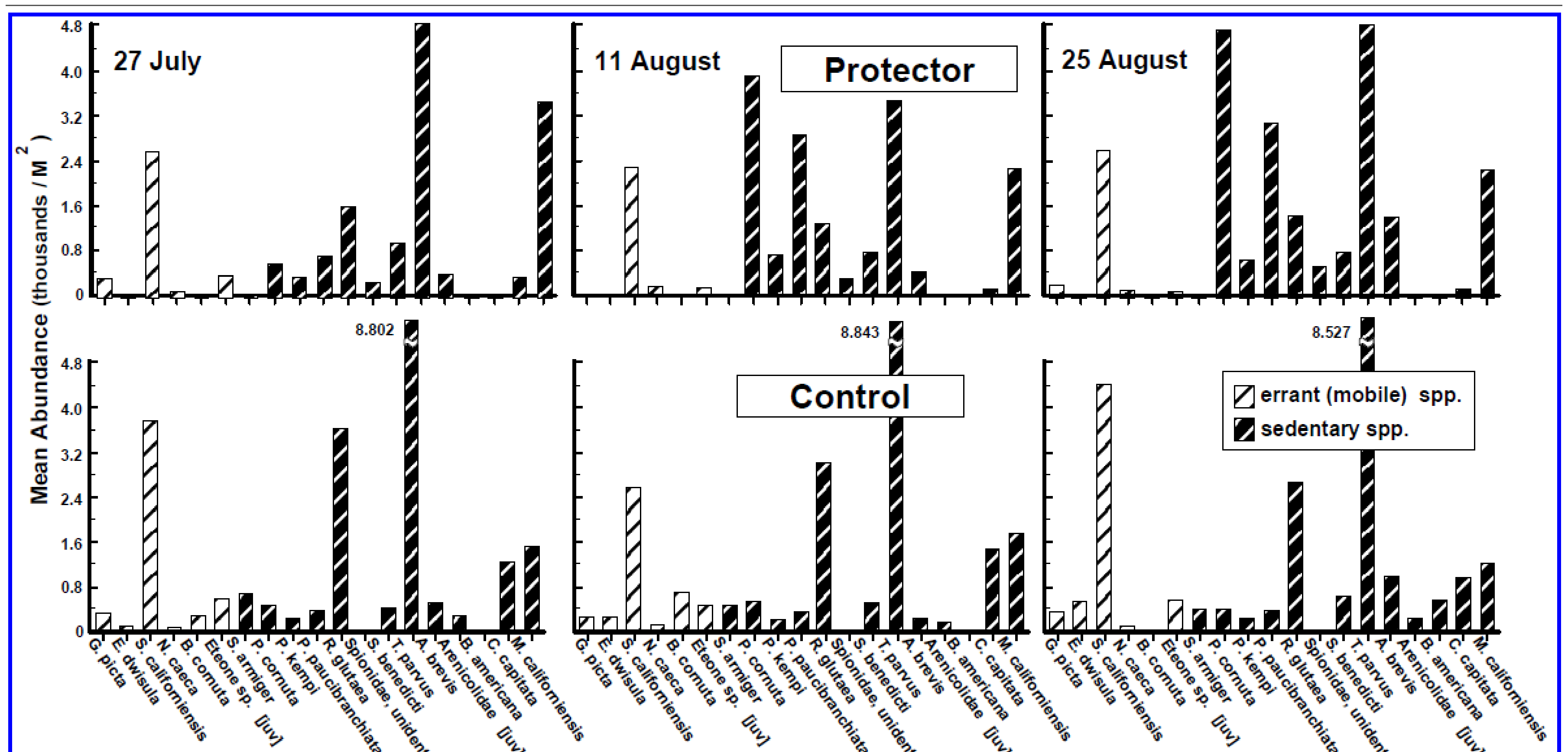


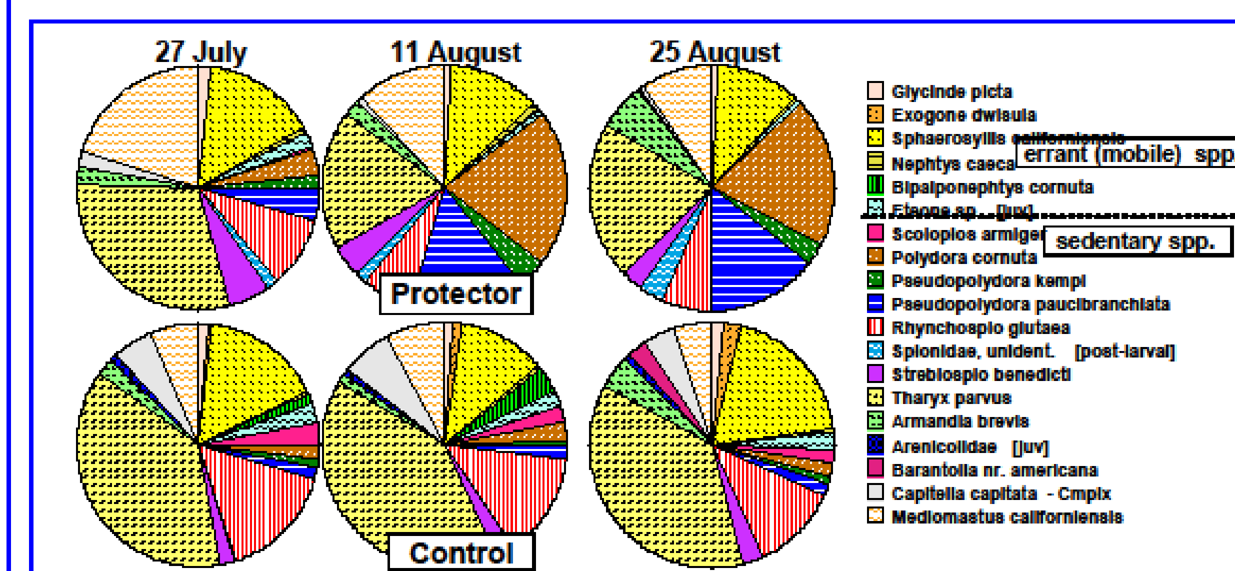
2014 Field Trials – Stony Point
Polychaetes











Appendix C

Site Photo Log

(7/30/14)

Selected Site Photos from 7/30/14 Field Walk

Photo 1: Approved (Taylor) Benthic Study Plot Looking East (white post is a sample station), eelgrass is Zostera marina

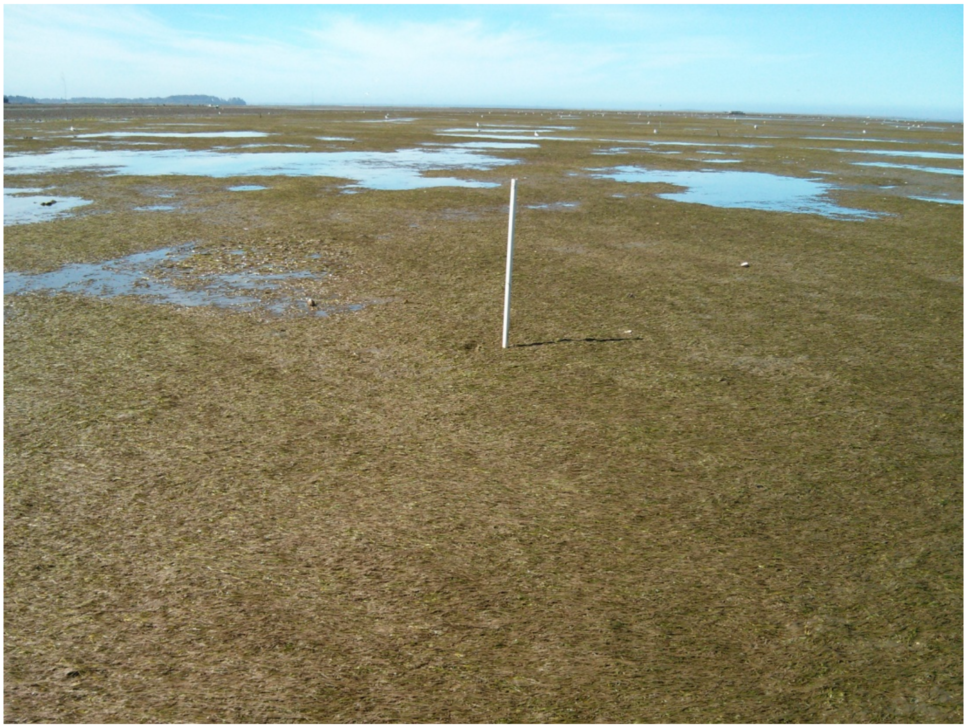


Photo 2: Coast Seafoods Benthic Study Plot Looking West (white post is a sample station), eelgrass is Zostera japonica

Photo 3: Approved (Taylor) Benthic Study Plot Looking North (Sand and Silt with minor channel)

Photo 4: Transition between Zostera japonica (left) and Zostera marina (right). Standing between Coast and Taylor plots.


Photo 5: Ghost shrimp (*Neotrypaea californiensis*) in tetany (Taylor plot)


Photo 6: Longline oyster culture method (Taylor plot)

Appendix D

Summary Statistics on Data Sets

(16 Cores in Common)

Stony Point

Crustaceans – Abundance

control1	control2	control3	nuprid1	nuprid2	nuprid3
Min. : 11628	Min. : 9302	Min. : 6977	Min. : 13219	Min. : 25092	Min. : 37332
1st Qu.: 25153	1st Qu.: 29039	1st Qu.: 28886	1st Qu.: 39076	1st Qu.: 34027	1st Qu.: 64994
Median : 29559	Median : 46328	Median : 45104	Median : 48286	Median : 41799	Median : 86536
Mean : 38030	Mean : 50204	Mean : 46150	Mean : 58461	Mean : 63250	Mean :114466
3rd Qu.: 47552	3rd Qu.: 67472	3rd Qu.: 59119	3rd Qu.: 81334	3rd Qu.: 75857	3rd Qu.:154712
Max. :134394	Max. :104039	Max. :128029	Max. :119094	Max. :242350	Max. :269400
			NA's :8	NA's :8	NA's :8

Crustaceans – Diversity

control1	control2	control3	nuprid1	nuprid2	nuprid3
Min. :0.885	Min. :0.739	Min. :0.818	Min. :1.247	Min. :1.082	Min. :1.175
1st Qu.:1.045	1st Qu.:1.058	1st Qu.:1.101	1st Qu.:1.321	1st Qu.:1.222	1st Qu.:1.286
Median :1.185	Median :1.246	Median :1.334	Median :1.398	Median :1.315	Median :1.423
Mean :1.179	Mean :1.277	Mean :1.294	Mean :1.427	Mean :1.307	Mean :1.395
3rd Qu.:1.247	3rd Qu.:1.509	3rd Qu.:1.446	3rd Qu.:1.483	3rd Qu.:1.378	3rd Qu.:1.492
Max. :1.620	Max. :1.718	Max. :1.745	Max. :1.664	Max. :1.528	Max. :1.595
			NA's :8	NA's :8	NA's :8

Crustaceans – Richness

control1	control2	control3	nuprid1	nuprid2	nuprid3
Min. :4.000	Min. : 5.000	Min. :4.000	Min. :6.000	Min. :6.000	Min. : 6.000
1st Qu.:5.000	1st Qu.: 5.750	1st Qu.:6.000	1st Qu.:6.750	1st Qu.:6.000	1st Qu.: 6.000
Median :6.000	Median : 6.000	Median :6.000	Median :7.000	Median :7.000	Median : 7.000
Mean :6.083	Mean : 6.625	Mean :6.292	Mean :7.375	Mean :6.938	Mean : 7.312
3rd Qu.:6.250	3rd Qu.: 7.250	3rd Qu.:7.000	3rd Qu.:8.000	3rd Qu.:7.000	3rd Qu.: 8.000
Max. :9.000	Max. :10.000	Max. :8.000	Max. :9.000	Max. :9.000	Max. :12.000
			NA's :8	NA's :8	NA's :8

Stony Point

Mollusks – Abundance

control1	control2	control3	nuprid1	nuprid2	nuprid3
Min. : 244.8	Min. : 367.2	Min. : 367.2	Min. :1102	Min. : 734.4	Min. :1469
1st Qu.: 826.2	1st Qu.: 734.4	1st Qu.: 948.6	1st Qu.:1408	1st Qu.:2111.4	1st Qu.:2326
Median :1101.6	Median : 856.8	Median :1162.8	Median :2203	Median :2876.4	Median :2876
Mean :1132.2	Mean :1086.3	Mean :1310.7	Mean :2371	Mean :2616.3	Mean :3267
3rd Qu.:1499.4	3rd Qu.:1468.8	3rd Qu.:1621.8	3rd Qu.:3091	3rd Qu.:3243.6	3rd Qu.:3917
Max. :2448.0	Max. :2325.6	Max. :2570.4	Max. :5018	Max. :4651.2	Max. :7466
			NA's :8	NA's :8	NA's :8

Mollusks – Diversity

control1	control2	control3	nuprid1	nuprid2	nuprid3
Min. :0.0000	Min. :0.5000	Min. :0.5000	Min. :0.849	Min. :0.816	Min. :1.055
1st Qu.:0.7997	1st Qu.:0.8882	1st Qu.:0.9543	1st Qu.:1.284	1st Qu.:1.074	1st Qu.:1.290
Median :1.0550	Median :1.0505	Median :1.0695	Median :1.588	Median :1.175	Median :1.363
Mean :0.9772	Mean :1.0272	Mean :1.1084	Mean :1.486	Mean :1.181	Mean :1.360
3rd Qu.:1.2295	3rd Qu.:1.2470	3rd Qu.:1.3088	3rd Qu.:1.657	3rd Qu.:1.264	3rd Qu.:1.473
Max. :1.5230	Max. :1.4320	Max. :1.6770	Max. :2.026	Max. :1.687	Max. :1.591
			NA's :8	NA's :8	NA's :8

Mollusks – Richness

control1	control2	control3	nuprid1	nuprid2	nuprid3
Min. :1.000	Min. :2.000	Min. :2.000	Min. :3.000	Min. :3.00	Min. :4.000
1st Qu.:3.000	1st Qu.:3.000	1st Qu.:3.000	1st Qu.:4.750	1st Qu.:3.75	1st Qu.:4.000
Median :4.000	Median :3.500	Median :3.500	Median :5.500	Median :4.00	Median :5.000
Mean :3.458	Mean :3.375	Mean :3.708	Mean :5.438	Mean :4.25	Mean :5.062
3rd Qu.:4.000	3rd Qu.:4.000	3rd Qu.:4.250	3rd Qu.:6.000	3rd Qu.:5.00	3rd Qu.:6.000
Max. :6.000	Max. :5.000	Max. :6.000	Max. :8.000	Max. :7.00	Max. :7.000
			NA's :8	NA's :8	NA's :8

Stony Point

Polychaetes – Abundance

	control1	control2	control3	nuprid1	nuprid2	nuprid3
Min.	11016	5508	14321	5875	9914	12118
1st Qu.	18237	17105	18482	12821	15177	19094
Median	22889	22032	22399	19584	21175	22032
Mean	23603	22261	23501	17365	19385	24357
3rd Qu.	28274	27295	28274	21389	22521	27234
Max.	39902	44064	37209	25092	32069	54712
NA's				8	8	8

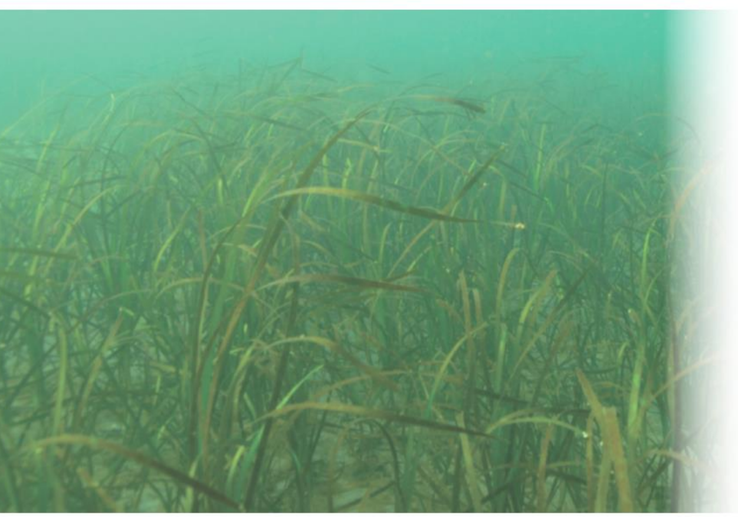
Polychaetes – Diversity

	control1	control2	control3	nuprid1	nuprid2	nuprid3
Min.	1.448	1.589	1.216	1.138	1.497	1.842
1st Qu.	1.806	1.745	1.840	1.738	1.960	2.019
Median	1.937	1.976	2.062	1.877	2.016	2.115
Mean	1.962	1.967	1.975	1.885	2.031	2.097
3rd Qu.	2.133	2.160	2.177	2.114	2.134	2.205
Max.	2.398	2.452	2.362	2.427	2.331	2.280
NA's				8	8	8

Polychaetes – Richness

	control1	control2	control3	nuprid1	nuprid2	nuprid3
Min.	14.00	8.00	11.00	11.00	8.00	11.00
1st Qu.	15.00	16.00	15.00	12.00	13.75	15.00
Median	17.50	17.00	17.00	14.00	14.50	16.00
Mean	17.08	17.21	17.04	14.00	14.69	16.38
3rd Qu.	19.00	19.00	20.00	15.25	17.00	18.25
Max.	20.00	21.00	23.00	18.00	20.00	21.00
NA's				8	8	8






FINAL

2014 Field Investigations

Experimental Trials for Imidacloprid Use in Willapa Bay

Willapa Bay, Washington

Prepared for

Willapa Grays Harbor Oyster Growers Association

April 6, 2015
12733-02

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Prepared by

Hart Crowser, Inc.

Jeffrey C. Barrett, PhD
Regional Manager

Adrienne Stutes
Marine Scientist

190 W Dayton Street, Suite 201
Edmonds, WA 98020
Fax 425.778.9417
Tel 425.775.4682

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Willapa Bay, Washington

1.0 INTRODUCTION AND BACKGROUND INFORMATION

Within Willapa Bay, ghost shrimp (*Neotrypaea californiensis*) and mud shrimp (*Upogebia pugettensis*), collectively referred to as burrowing shrimp, are disruptive to commercial shellfish culture and have historically been controlled with the carbamate insecticide carbaryl (Sevin® 80 WSP) to improve harvest rates. As part of an ongoing Integrated Pest Management Program, the neonicotinoid insecticide imidacloprid (1-[(6-chloro-3-pyridinyl)methyl]-N-nitro-2-imidazolidinimine) in liquid (Nuprid® 2F) and granular (Mallet® 5G) formulations has been under investigation as a replacement for carbaryl in Willapa Bay and Grays Harbor, Washington. Experimental applications have been used to study efficacy, environmental fate and persistence, and the potential for effects on non-target organisms. In 2013, the US Environmental Protection Agency (EPA) issued imidacloprid pesticide registrations to the Willapa Bay/Grays Harbor Oyster Growers Association (WGHOGA). Imidacloprid has been registered as Protector 2F (liquid) and Protector 0.5G (granular). These designations will be used throughout the remainder of this report, except when specifically referring to previous studies that used Nuprid or Mallet.

In spring 2014, WGHOGA presented the Washington Department of Ecology with a Sampling and Analysis Plan (SAP) intended to guide field studies related to the use of imidacloprid to control burrowing shrimp in Willapa Bay. The scope of the experimental field trials was to describe the magnitude, extent, and duration of impacts from imidacloprid that could be associated with commercial use for the control of burrowing shrimp, and compliance with the Sediment Management Standards (WAC 173-204-200). Results will be used to support a registration and State National Pollutant Discharge Elimination System (NPDES) permit for the control of burrowing shrimp with imidacloprid in Willapa Bay and Grays Harbor.

This report presents the results of the experimental field trials conducted by a team of scientists from Washington State University and Pacific Shellfish Institute, directed at quantifying the concentrations, transport, and biological effects of imidacloprid sprayed in intertidal environments in Willapa Bay, Washington. Field sampling and analyses were carried out in general accordance with the Sampling and Analysis Plan (SAP) dated July 7, 2014 (Hart Crowser 2014).

Parts of the text, as well as tables and figures, were provided by Dr. Kim Patten and his team at Washington State University (Patten 2015) and by Dr. Steve Booth and his team at Pacific Shellfish Institute (Booth et al. 2015).

Components of the study included:

- Measurement of pre- and post- treatment water column concentrations of imidacloprid;

- Measurement of whole sediment imidacloprid concentrations;
- Measurement of sediment porewater imidacloprid concentrations;
- Observational megafauna surveys;
- Evaluation of the efficacy of imidacloprid in controlling burrowing shrimp; and
- Evaluation of the effects of imidacloprid on benthic invertebrate communities.

1.1 Site Setting and History

Indigenous people have collected shellfish in Willapa Bay for thousands of years. Oysters and clams have been farmed in Willapa Bay since about 1849. Willapa Bay and Grays Harbor are currently home to thousands of acres of commercial oyster and clam beds. Burrowing shrimp disrupt commercial shellfish culture by destabilizing the sediments on commercial shellfish beds, causing significant mortality and reduced growth rates. This threatens the viability of the entire commercial shellfish industry on the coast of Washington State. As part of an ongoing integrated pest management program, imidacloprid has been under investigation as a potential replacement for carbaryl, a carbamate insecticide that has been used to control burrowing shrimp in Willapa Bay and Grays Harbor for more than 60 years.

Research on imidacloprid as a control agent for burrowing shrimp on commercial shellfish beds in Willapa Bay and Grays Harbor has been ongoing since 2008. From 2008 to 2012, several large-scale trials were conducted. Results of the 2010 trials featured both small (< 0.1 acre) and large (> 1 acre) plots, while the 2012 trials featured large plots between 7 and 10 acres in size. Trials in 2012 were conducted under an Ecology approved SAP. Trials prior to 2012 were not conducted under an Ecology-approved SAP. Scientists from the University of Washington, Washington State University, and the Pacific Shellfish Institute have participated in all field trials, data analysis, and interpretation. Scientists from Hart Crowser participated in the 2012 study.

The trials conducted between 2010 and 2012 generally indicated that the granular and liquid forms of imidacloprid applied at 0.5 pounds (lbs) active ingredient per acre (a.i./ac) were moderately to highly effective in reducing burrowing shrimp densities. These studies included sampling and analysis of imidacloprid in the water column, sediment porewater, whole sediments, and eelgrass, as well as studies of the impact to the epibenthic and benthic invertebrates. The 2014 studies added to the previous work to better define the efficacy, fate and transport, and effects on non-target organisms of imidacloprid applications to oyster and clam beds in Willapa Bay and Grays Harbor (Figure 1). The 2014 field studies were conducted on larger plots (> 50 acres) than all previous studies. Given future commercial scale applications of imidacloprid may occur on larger plots and in growing areas with multiple commercial shellfish beds undergoing treatment, the 2014 field studies were designed to test whether environmental effects of spraying such plots were substantively different that results from tests in prior years on plots of 10 acres or less and in areas with multiple imidacloprid-treated shellfish beds.

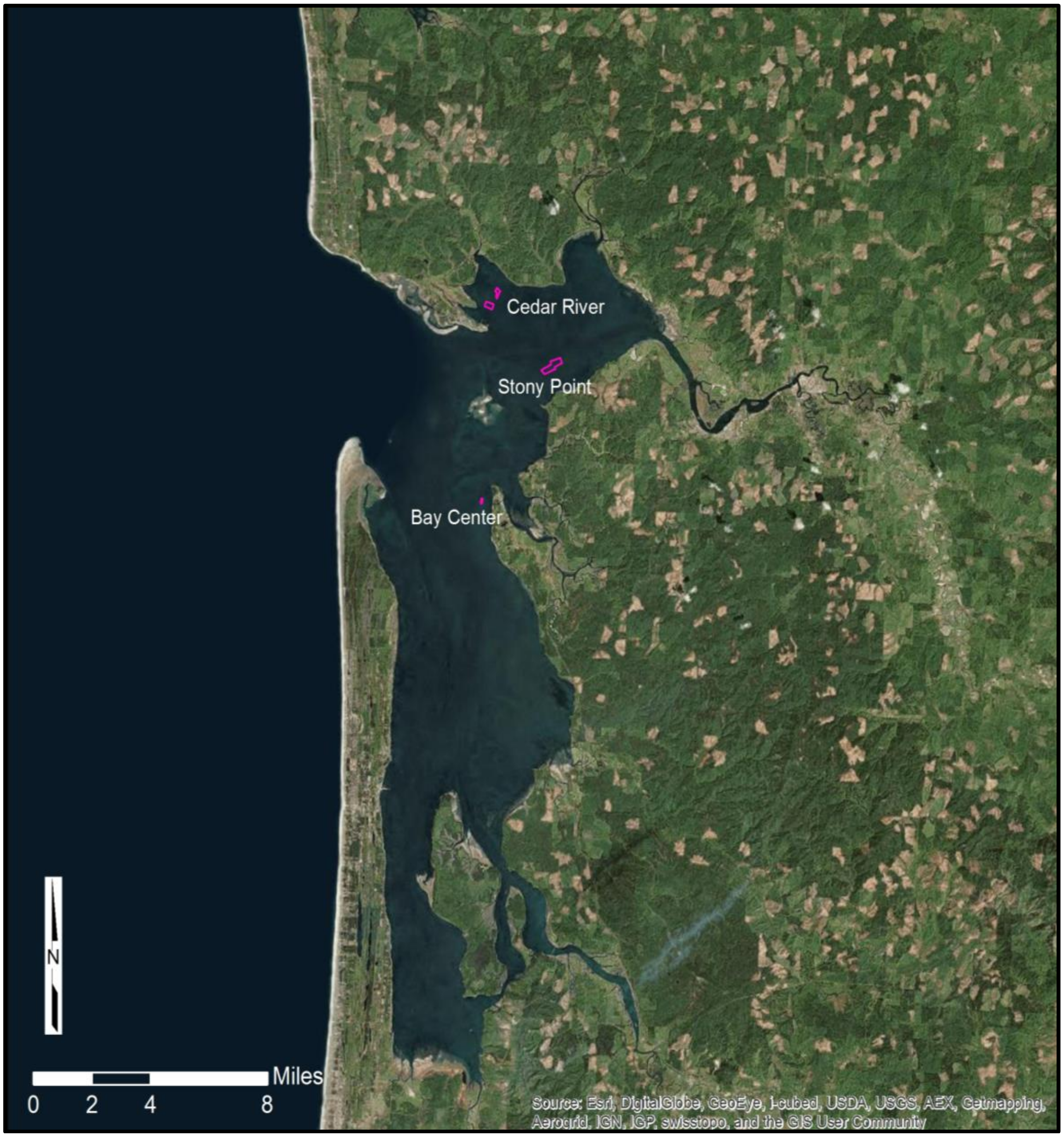


Figure 1 – Vicinity Map of Willapa Bay

1.2 Summary of Previous Studies

Large-scale trials using imidacloprid in Willapa Bay and Grays Harbor were conducted in 2008 through 2012 under Federal and State Experimental Use Permits. The 2008 and 2009 trials investigated the efficacy of a flowable formulation of imidacloprid, Nuprid® 2F (Nuprid; Nufarm Americas Inc., Burr Ridge, IL) and a granular material, Mallet® 0.5G (Mallet; Nufarm Americas Inc.).

In early 2010, both large (> 1 acre) and small (< 0.1 acre) plots were used for trial applications, with Nuprid at 2.0 lb a.i./ac and Mallet at 0.5 lbs a.i./ac on 10-acre plots. Data were collected for water column, porewater, and whole sediment concentrations of imidacloprid, as well as studies of impacts of imidacloprid application to epibenthic and benthic invertebrates, salmonids, and green sturgeon.

Additional studies were conducted in 2011 and 2012, using application rates of 0.5 lbs a.i./ac for both Nuprid and Mallet. Data were collected for efficacy against burrowing shrimp, impacts to Dungeness crab and epibenthic and benthic invertebrates, and on concentrations of imidacloprid in eelgrass (*Zostera marina*) and in the water column, sediment porewater and whole sediment. In 2012, data were also collected on the imidacloprid degradation product, imidacloprid-olefin.

1.3 Data Gaps

Results of previous experimental trials indicate that imidacloprid has a limited impact on epibenthic and benthic invertebrates when experimental plots are approximately 10 acres in size. Although a majority of future commercial treatments of imidacloprid (assuming regulatory approval for such use is ultimately given) will be on plots of about 10 acres in size or less, WGHOGA also expects to treat plots of larger sizes (e.g., 20 acres or more). Accordingly, Ecology recommended that an additional trial on larger plots be conducted in 2014. Similarly, whereas past studies utilized treatment and control plots that were widely separated from one another (i.e., > 500 meters), commercial applications of imidacloprid will, in some cases, involve spraying of individual plots that are in closer proximity to one another (i.e., < 500 meters). Accordingly, Ecology recommended that, if feasible, the treatment plot in 2014 should be located in the vicinity of other plots that are sprayed at the same time. These 2014 studies included sampling of water, sediment, sediment porewater, and invertebrates, with the goal of evaluating imidacloprid concentrations on the day of treatment in water and sediment, persistence in and partitioning between sediment porewater and whole sediment, and biological effects on non-target invertebrate species.

2.0 FIELD SAMPLING METHODS

2.1 Deviations from the 2014 SAP

Deviations from the Ecology-approved SAP for the imidacloprid investigation are summarized below and are discussed in more detail in the applicable report sections.

- Pre- and post-treatment sediment and sediment porewater samples were not collected from the control sites for the Taylor and Coast treatment sites.
- Pre-treatment sediment and sediment porewater samples were not collected from the Taylor and Coast treatment sites.

These deviations were due to an unfortunate oversight by the field crews conducting the monitoring. Given the substantial physical distance between treatment and control sites and the absence of previous imidacloprid use at the treatment plots, there is no reason to believe that the samples, if taken, would have contained imidacloprid residues.

2.2 Study Site Selection and Sample Location Control

2.2.1 Study Site Selection

Criteria for the selection of the study site included ownership by a member of the WGHOGA, adequate densities of burrowing shrimp, a large plot located near other beds scheduled for commercial treatment, plus topography and substrate/vegetation composition that could be matched by another untreated plot that would serve as a control. Researchers spent four days surveying all potential sites, but could not identify a single plot that could fully meet all requirements. However, a 35-acre site in the Stony Point growing area (spread over parcels B17, 18, 19, 23, and 152) was selected as the best option as a treatment site and was proposed to and accepted by Ecology for inclusion in the 2014 Sample and Analysis Plan (SAP). While laying out a 10-acre internal sample grid at two weeks before the proposed treatment date, surveyors discovered that the site was heterogeneous. Given concerns about the logistics of sampling this heterogeneous site, WGHOGA, the investigators, and Hart Crowser discussed moving the treatment plot to an adjacent, more homogenous parcel, B22 #12. Ecology concluded that sampling of the original plot should proceed. However, the sampling effort was expanded to include both sites, as well as the small buffer located between the sites. The entire area was therefore treated (a total of 90 acres) by helicopter with Protector 2F at 0.5 lb a.i./ac on July 26 (Figure 1, Stony Point).

A portion of the 90-acre treatment plots were treated with carbaryl in 2013. Carbaryl residues were not tested for (such testing is not part of the SAP), but also are not expected given the rapid decline in sediment concentration of carbaryl after application. By extension, no residual effects on the invertebrates were expected on the treatment plots. This was corroborated by similarity of the treatment plots to the controls in the T = 0 invertebrate samples.

The control site was selected to have similar elevation, vegetation, and substrate, but was also distant enough from the treated site so as to receive no exposure to imidacloprid. The closest site to meet these criteria was located just to the southwest of the Bay Center Peninsula, some five miles distant (Figure 1, Bay Center). The control site was covered with a homogenous 80 to 100 percent cover of native eelgrass (*Zostera marina*). There was slightly more woody debris at the control plot than the treatment plot, as a few rotting logs were present.

The selected treatment plots are surrounded with water on a rising tide (e.g., effectively acting as higher elevation islands). This condition makes the sites less desirable for measuring imidacloprid transport off of treatment plots than locations where the rising tide follows a more or less linear path from low elevation to high elevation areas. Accordingly, to test off-site transport of imidacloprid in water over long distances, a second pair of sites in the Cedar River area were chosen for the collection of water samples (Figure 1, Cedar River).

2.2.2 Sample Location Control

Plot boundaries were delineated using handheld global positioning system (GPS) units and marked with stakes. Location sampling points for water and sediment were guided by criteria set forth within the SAP and marked in the same way. Some of the sample locations and waypoints are approximate due to either the limitations of the GPS units used or human error while collecting these waypoints.

2.3 Transect and Sampling Point Layout

The Stony Point treatment site consisted of several treatment plots that totaled to approximately 90 contiguous acres. These plots included a cluster of plots owned by Taylor Shellfish (~50 acres total) and one 40-acre plot owned by Coast Seafoods. These plots were all sprayed with Protector 2F, for a total of 90 acres of treated land. Two corresponding control plots were located in Bay Center, one to match the characteristics of each treatment site. The treatment and control plots were far apart due to the necessity of finding suitably comparable control plots. Two smaller plots (~10 acres) located in the Cedar River area were also sprayed with Protector 2F and had a limited sampling array to monitor off-plot flow of imidacloprid on the first rising tide.

Table 1 (attached) and Figures 2 through 5 detail the location of all sampling points within the study plots. Sampling points were primarily located within the treatment and control plots and along transects designed to capture imidacloprid movement off the plots. Table 2 (attached) shows the environmental characteristics of the sediment sampling stations. During the August 25 sample period, the following were measured for the benthic invertebrate sampling stations: (1) species and average percent cover of vegetation (*Zostera marina*, *Z. japonica*, or algae [mostly floating mats of *Ulva lactuca*]); and (2) depth (cm) and average percent cover of water at each sample point and the surrounding 2-meter (m) diameter area (Table 3; attached). The morning low tide on that date was +0.3 feet. Tidal heights were + 0.2 feet on July 31 and –0.7 feet on August 11, respectively, but the amount of standing water was about the same despite these small differences in tidal elevation (Dr. Steve Booth, PSI, personal communication). The control plot was fairly uniform with 70 to 90 percent *Z. marina,* and mostly dry throughout the sample periods, except for one low area (Table 3). Further site characterization data can be found in Tables 12 through 14 (attached).

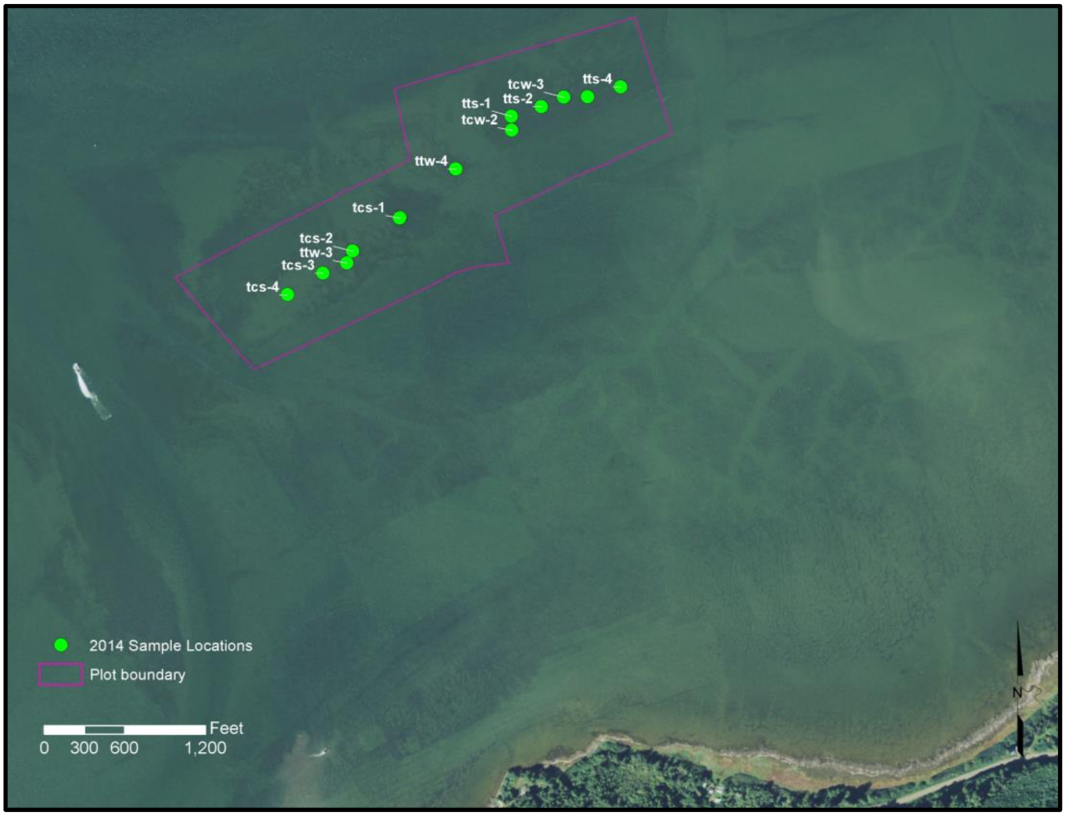


Figure 2 – Sample locations at Stony Point

Figure 3 – Sample locations at Bay Center

Figure 4 – Sample locations at Cedar River – Coast

Figure 5 – Sample locations at Cedar River – Nisbet

2.4 Water Column Sampling

Water samples were collected for analysis of imidacloprid within and adjacent to the treated plots according to the conceptual plan presented within the SAP. Water column samples were collected on the first incoming tide following treatment (approximately 2 hours after treatment). A total of five water samples were collected approximately two hours following treatment at the Stony Point site. Three were taken on the Taylor plot and two were taken on the Coast plot. At this site, the treatment plot flooded from all directions into the center of the plot; therefore, the samples were taken from the convergence zone as shown in Figure 2, just at the time of convergences.

Because the Stony Point treatment plots are surrounded with water on a rising tide, it was not possible to collect water samples at large distances (e.g., > 100 m) from the plot. Accordingly, water quality sampling was conducted at a second pair of sites in the Cedar River area that were subject to commercial level spraying of the liquid formulation of imidacloprid (i.e., Nuprid). At one of the Cedar River locations water samples were taken at the following distances: 0 m, 55 m, 110 m, 220 m, 440 m, and 665 m (Figure 5). The sample transect was determined based on the movement of dye markers in the water column at the time of sampling. At the second Cedar River location, water samples were taken at 0 m and 753 m (Figure 4). An intermediate sample location was not taken because of unsafe conditions due to a rapidly rising tide.

For the control plots, two water samples were collected from each control plot one day prior to spraying, and one water sample was collected from the Coast control plot one day post-treatment, after the rising tide partially inundated the area to ensure imidacloprid had not migrated to the site from treatment areas.

Water samples were collected passively by allowing the incoming tide to flood a sample bottle buried in the sediment. Inundation sample bottles (125-mL amber glass) were buried upright with the mouth of the bottle 5 cm above the sediment surface. As the tide rose the sample bottles filled, beginning with the sampling points of lowest elevation. As soon as each individual bottle was filled, the bottle was sealed, removed from the sediment, and stored according to general sample handling procedures. The screening values and practical quantitation limits (PQL) are presented in Table 4.

The 3.7 micrograms per liter (µg/L) screening level for surface water is a conservative concentration based upon EPA guidance (EPA 1985) that recommends an operational water quality criterion equal to one-tenth the LC50 for the most sensitive organism. A literature review conducted as part of the 2012 SAP that was reviewed and approved by Ecology concluded the most sensitive organism relevant to invertebrates in Willapa Bay and Grays Harbor was a crustacean, mysid shrimp, with an LC50 of 37 µg/L (although some insect sensitivities may be higher, insects are rare or absent in the estuary). This LC50 value is based on a 96-hour exposure test using a constant concentration of imidacloprid. The epibenthic and benthic organisms in the imidacloprid treatments outlined in this SAP, by contrast, will be exposed to water-based concentrations of imidacloprid for at most a few hours as the incoming and outgoing tides first dilute and then wash away imidacloprid. Thus, the use of one-tenth of a 96-hour LC50 for the most sensitive taxon tested is a conservative screening level for potential, surface water impacts to invertebrates.

Table 4 – Screening values for imidacloprid concentrations (ppb) utilized for each matrix collected

Matrix	Screening Values	Practical Quantitation Limit
Water	3.7 µg/L	0.04 µg/L
Whole Sediment	6.7 µg/L	6.7 µg/L
Sediment Porewater	0.6 µg/L	0.04 µg/L

2.5 Sediment and Sediment Porewater Sampling

Sediment samples were collected for analysis of imidacloprid within the Stony Point treatment and control areas according to the conceptual plan presented in the SAP, with two exceptions. First, pre-treatment samples were not taken from the treatment plots. Second, pre- and post-treatment sediment samples were not collected from the Taylor control plot, and post-treatment sediment samples were not taken from the Coast control plot. These deviations were due to a misunderstanding by the science team (K. Patten, WSU, personal communication). Given the substantial physical distance between treatment and control sites and the absence of previous imidacloprid use at the treatment plots, there is no reason to believe that the samples, if taken, would have contained imidacloprid residues. In addition, both the treatment and control plots were sampled for surface water concentrations of imidacloprid pre-treatment, and imidacloprid was not detected in any surface water samples. Sediment samples were collected in four locations on the Taylor treatment plot and four locations on the Coast treatment plot. One pre-treatment sediment sample was also taken from the Coast control plot.

Four sediment samples for extraction of porewater were collected from each treatment plot at low tide on Days 1, 14, and 28 after treatment. Sediment cores collected after Day 1 were rotated clockwise in cardinal directions and offset 1 meter from the original sample point. For example, the Day 14 samples were collected 1 meter east of the Day 1 samples, the Day 28 samples were collected one meter south of the Day 1 samples, etc.

Whole sediment concentrations of imidacloprid were determined for the same sites and dates as for sediment porewater. Accordingly, all whole sediment samples included sufficient volume to allow for laboratory testing of both whole sediment and sediment porewater from the same sample.

2.5.1 Collection and Processing of Sediment Samples

Whole sediment and sediment porewater samples both began as a sample of sediment collected from the study area with a chemically clean sediment coring device. The coring device was designed to collect a sample 7 centimeters (cm) in diameter and 10 cm in depth. The device was a modified, semi-transparent, Nalgene 500 milliliter (mL) HDPE bottle with the bottom removed and a vent hole drilled into the top shoulder of the bottle. All coring devices were new, chemically cleaned at point of manufacture, and not re-used.

To remove a sediment core, the device was inserted into the sediment to a depth of 12–15 cm, the vent covered with a gloved finger to create a vacuum, and the core pulled from the surrounding sediment. The device was then inverted and the vent opened to allow any standing water that existed above the sediment to drain. Once drained, the device was righted and the sediment core allowed to slip until the surface of the sediment core was in alignment with a mark placed on the side of the device 10 cm from the bottom. A clean plastic knife was used to cut away all sediment collected deeper than 10 cm (the portion hanging below the bottom edge of the device), and finally the core was allowed to slip out of the device into the sample container without being touched.

Two sediment cores were collected at each sampling point to ensure sufficient sediment porewater could be extracted from whole sediments. Additional cores were taken to ensure sufficient volume for testing of both whole sediment and sediment porewater on the treatment plot. Samples were placed in 1-liter (L), wide-mouth HDPE bottles and in a cooler on ice, and then transported to the laboratory under chain of custody.

Whole sediment samples were not frozen. In the laboratory, each sediment sample was homogenized, and then split into one sample for analysis of whole sediment, and a second sample underwent porewater extraction for analysis of sediment porewater. Sediment was placed in a disposable, sterile 500-mL Millipore Steritop® 0.22-micron filtration unit. Vacuum was applied and the porewater extracted and collected into individual, clean 125-mL amber glass bottles. Samples were placed on wet ice or refrigerated (< 4° C) until being shipped to Pacific Agricultural Laboratory (PAL, the analytical lab for all sediment and water samples) for analysis. All normal handling precautions to guard against cross contamination between samples were taken. All materials and supplies utilized throughout the porewater extraction process were disposable and replaced between each sample. All samples were managed such that time out of refrigerated storage space was minimized. Each sample was removed from cold storage immediately before extraction, kept on wet ice while being processed, and then returned to cold storage immediately after processing. Samples were later removed for packaging and shipment to PAL under methods described above. Typical time spent out of controlled temperature for any one sample as a result of processing and packaging procedures was approximately 5–10 minutes. Control samples were systematically stored and packaged separately when possible, and processed first. All whole sediment samples were analyzed within the 7-day holding time or stored at 4° C until analyzed. All porewater samples were extracted within the 7-day holding time and the extracted porewater was either analyzed within 7 days or stored at 4° C until analyzed.

All sediment and sediment porewater samples that were collected were analyzed by PAL and the results included the measured imidacloprid level, or where not detected, the practical quantitation limit for the laboratory tests. These quantitation limits are 0.04 µg/L for sediment porewater, and 6.7 µg/kilogram (kg) for whole sediment (Table 4).

Screening values for sediment and sediment porewater are 6.7 µg/kg and 0.6 µg/L, respectively (Table 4). Since sediment imidacloprid concentrations are at least somewhat persistent, and therefore can produce toxicity from chronic exposure, the screening level was developed differently than for surface water. Toxicity studies on mysid shrimp were again used, but compared to the LC50, the 0.6 µg/L screening level for sediment porewater is a more conservative concentration based on the No

Observed Effect Concentration (NOEC) in 21-day toxicity studies (Ward 1991). Due to their sensitivity to imidacloprid, the sediment porewater screening level was chosen, even though mysid shrimp live within the water column rather than the sediment. Based on toxicity studies for benthic arthropods that actually live in sediments, a NOEC screening concentration up to 6 µg/L could be supported, indicating that the screening level for sediment porewater is, as with surface water, a conservative screen of potential effects of imidacloprid on invertebrates.

The 6.7 µg/kg limit for whole sediment is equal to the PQL for imidacloprid as reported by the Pacific Agricultural Laboratory, the lab that processed all samples (Steve Thun, Laboratory Director, personal communication).

2.5.1.1 Sediment Texture

Sediment texture analysis was conducted on all treatment and control plots at the center of the plots. Sediment was collected under the same sampling procedures described for sediment imidacloprid analyses and came from the pooled sediment samples that were also used for whole sediment and sediment porewater analysis. Samples for texture analysis were collected one day before treatment. Once collected, the samples were handled according to the SAP sample storage, transport, and custody requirements. Analytical Resources Inc. (ARI) analyzed the samples using the ASTM D422 methodology.

2.6 Efficacy Sampling

Details on protocols for application, data collection, and analysis are contained within the SAP. Five locations were selected by WSU for assessment of efficacy. Within each of these locations, efficacy assessments were made across different sediments and vegetation coverage. On most of these beds, there were no reliable pre-count data available. In these situations, comparisons were made along the edges, both inside and outside the treatment zone, in locations where burrowing shrimp densities were high enough to provide reliable efficacy estimates. Burrowing shrimp density was assessed using 0.25-square-meter (m^2) quadrats. For each assessment area, data were collected from 20 to 100 quadrats.

The growers also assessed efficacy, using slightly different methods. Prior to spraying, pre-treatment surveys were conducted to assess shrimp populations during the weeks of May 18 to June 13. Due to multiple delays, treatments were not conducted until the end of the summer tide series beginning July 26 through August 13, 2014. Post-treatment effects (change in burrow counts) were assessed starting one day after treatment and will be completed when sufficiently low tides allow for safe access. Percent control was based on the change in burrow density. During each survey, observer's recorded the date of site visit, burrow counts, bed number, location (GPS coordinates), shrimp species present, seagrass presence, and time. Observations were made regarding the presence of burrowing shrimp fecal pellets to confirm that the observed burrows contained burrowing shrimp. Additional confirmation of shrimp species and presence was obtained using a shrimp suction gun at a minimum of three locations along each transect.

The entire bed perimeter (7 m on the inside and 7 m on the outside) was assessed for epibenthic megafauna (Dungeness crab and fish).All affected megafauna species were counted around the perimeter. Affected species were those exhibiting any signs of tetany, or that were dead by any cause, directly or indirectly related to the treatment (e.g., bird predation of tetany-affected crab). Any additional affected species from within the treated bed were also noted.

2.7 Epibenthic and Benthic Invertebrate Sampling

2.7.1 Sample Design

Twenty-two sample stations were distributed within a 10 acre internal sample grid within the treated plot and 24 sample stations were distributed with the control plot (Figure 6). At all locations, sample stations were comprised of 1-m-diameter circles identified with labeled 2-foot-long PVC pipes pushed into the substrate. A single quadrant was sampled at each sample date. Sample stations with an elevation or vegetation that were not characteristic of 80 percent of the rest of the plot were not sampled. The nearest area that was more characteristic of the entire plot was sampled instead. Most anomalous samples were taken at the first two sample events, before eelgrass became uniformly distributed over the plots. At the later sample dates, floating algae sometimes became wrapped around the PVC pipe, forming a mat approximately a quarter of a meter in diameter. These areas were not sampled and the algae were removed.

Benthic and epibenthic invertebrates were sampled at 1 day before treatment (DBT) and at 14, 28, and 56 days after treatment (DAT).

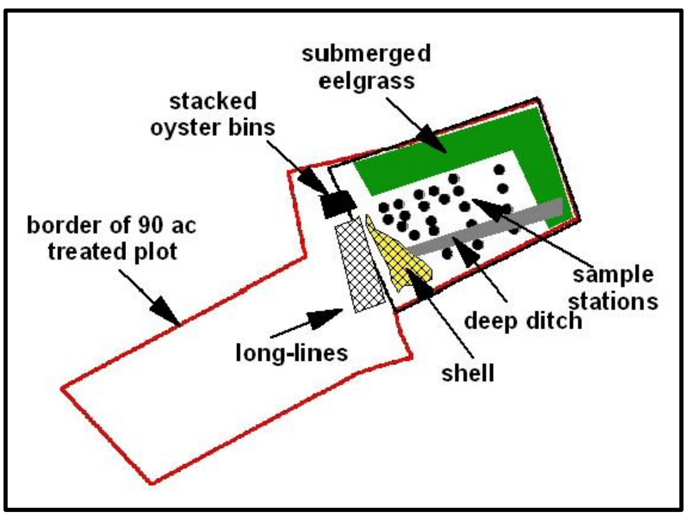


Figure 6 – Schematic of the Stony Point treatment plot

2.7.2 Field Procedures

Invertebrates were sampled using a 10.2-cm internal diameter corer to a depth of 10 cm. At the treatment plot, cored samples and identification labels were placed inside 1-gallon Ziploc® storage bags, carried to standing water on the south side of the plot and sieved through 0.5-mm mesh. At the control plot, each sample was sieved in nearby standing water immediately after collection. Each sample and an internal label was placed in a plastic jar which was also labeled on the outside. Samples were transported in coolers to the shore within 3 hours where they were fixed in 10 percent buffered formalin. After at least two weeks, samples were re-sieved through a 100-micrometer (µm) mesh sieve using freshwater, transferred to 70 percent isopropyl alcohol, stained with rose Bengal, and stored until identified and counted.

Invertebrates were sorted from bits of algae, eelgrass, and debris by Pacific Shellfish Institute (PSI) temporary workers. Polychaetes were identified and enumerated by Ruff Systematics, Inc. Crustaceans and mollusks were identified and enumerated by PSI staff. Organisms were identified to the lowest taxonomic level possible. Samples from 56 DAT were not processed.

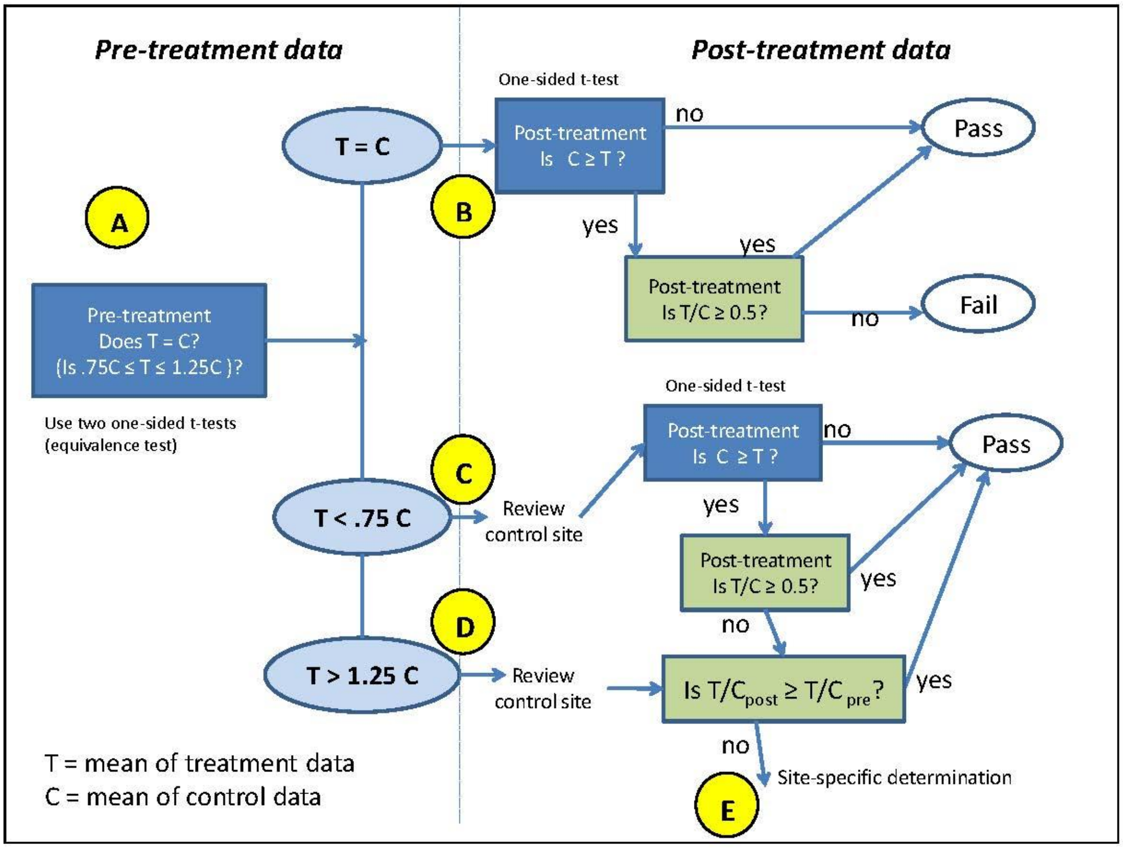
2.7.3 Sample Analysis

In general, imidacloprid effects were assessed for nine endpoints (absolute abundance, taxonomic richness, and Shannon diversity for each of three primary taxonomic groups: polychaetes, mollusks, and crustaceans) by comparisons on the treated plot to the same endpoint in the control plot at 14 and 28 DAT. Ecology required analyses of 6 endpoints: abundance and taxonomic richness of the 3 primary taxonomic groups, but the additional information on the Shannon Diversity Index is provided for Ecology to consider in their review.

Ecology has previously determined that an effect will be considered to have occurred if the value of an endpoint from data in the treated plot is 50 percent less and significantly different (α=0.05) than its value from data in the control plot (i.e., the "50 percent test"). This is consistent with the Sediment Management Standards Puget Sound marine criteria for benthic abundance (WAC 173-204-320(3)(c)), although these standards do not apply to Willapa Bay.

Some of the specific statistical tests conducted on the invertebrate data were confounded by dissimilar endpoint levels between the treatment and control plots prior to treatment, which resulted in a multipart analysis structure. During development of the SAP for the 2012 studies, Ecology hired an outside statistical consultant, Lorraine Read, to review the proposed statistical analyses, and to make recommendations. These recommendations have been incorporated into the statistical tests and interpretations included in this field report. The general guidelines for assessment of effects, were described in a memo from Ecology on July 20, 2012, and are presented in Figure 7.

Values of the endpoints in the study plots were statistically compared before treatment (1 DBT) to test for relative equivalence of invertebrate endpoints before applications of imidacloprid occurred. Non-equivalent endpoint values in the treated and control plots before treatment could confound post-treatment comparisons of the treated and control plots. In instances where treatment and control sites are not equivalent, Ecology has established guidelines to assess potential effects that include changes in the proportions of endpoint values on treated relative to control plots between pre- and post-sample dates. Ecology also indicated they would consider other site-specific factors to determine potential effects when treated and control plots were not equivalent before treatment.



Note: The left side shows a statistical test to determine if the test and control sites are similar prior to treatment. The right side shows analysis of the post-treatment data. Blue boxes denote statistical tests that consider variability. Green boxes denote simple arithmetic comparisons.

Figure 7 – Flow diagram for statistical analysis of benthic community data

2.7.4 Pre-treatment Equivalence

Each endpoint was examined for pre-treatment equivalence between treated and control plots using an Equivalence Test with the following hypotheses:

null hypothesis of H_0: $|\mu_T - \mu_C| > \delta$

alternative hypothesis H_A: $-\delta \le \mu_T - \mu_C \le \delta$,

where μ_T and μ_C are the population means from plots to be treated and control plots, respectively and δ is an equivalence margin. The Equivalence Test can be done using two one-sided t-tests (TOST), or a confidence interval approach. The null hypothesis (H_0) for the equivalence test assumes that the means of two populations are not equivalent and must be “proven” equivalent within an equivalence margin, δ. This is in contrast to the null hypothesis for the standard two sample t-test which assumes that two populations are equal and must be “proven” unequal. The stringency of demonstrating statistical equivalence with this approach depends on the size of delta: a larger delta makes it easier to demonstrate equivalence than a smaller delta.

For these tests, δ was assigned as 25 percent of the mean value of the control plot. Accordingly, the null and alternate hypotheses for the TOST approach were:

$$H_{01}: \mu_T < 0.75\mu_C \text{ vs. } H_{A1}: \mu_T \geq 0.75\mu_C$$

$$H_{02}: \mu_T > 1.25\mu_C \text{ vs. } H_{A2}: \mu_T < 1.25\mu_C,$$

where μ_T is the population mean on the plot to be treated and μ_C is the population mean on the control plot. Each of these tests is assessed at a significance level of $\alpha = 0.05$.

The TOST analysis is equivalent to a $100(1 - 2\alpha)$ percent confidence interval on the difference of means, and requires that the confidence interval is completely contained within ± 25 percent of the control mean. The rejection region (where statistical equivalence is concluded) occurs when the lower limit of the 90 percent confidence interval on the $(\mu_T - \mu_C)$ is greater than $-0.25\,\bar{x}_C$ AND the upper limit of the same confidence interval is less than $+0.25\bar{x}_C$. The means μ_T and μ_C are the means from the treated and control plot, as above and $\mu_T - \mu_C$ is the difference of the means.

2.7.5 Post-treatment Assessment of Endpoint Values

Results of the pre-treatment equivalence tests directed the post-treatment assessment of endpoint values for potential effects of imidacloprid application on invertebrates along 3 alternative pathways, as shown in Figure 7.

If treated and control endpoints were equivalent pre-treatment (Figure 7 Path A), then post-treatment effects were assessed by both:

- Direct comparison of the values of each endpoint on treated and control plots to determine if there is a 50 percent reduction relative to the control value at each post-treatment sample date, and
- A one-tailed t-test that the mean on the treated plot was lower than the mean on the control plot ($\alpha = 0.05$).

If both conditions are true, then an impact was considered to have occurred. This resulted in statistical significance ($\alpha = 0.05$; i.e., a ratio of means or medians that was less than 50 percent, indicating a reduction in the treatment plot of more than 50 percent of the control plot).

If treated and control endpoints were not equivalent prior to treatment because the endpoint mean from the plot to be treated was lower than the endpoint mean from the control plot (Figure 7, Path B), then the assessment for a potential post-treatment effect was conducted by:

- Direct comparison of the endpoint value from treated and control plots to determine if there is a 50 percent reduction relative to the control value;
- A one-tailed t-test that the mean on the treated plot was lower than the mean on the control plot ($\alpha = 0.05$); and

- A potential comparison of change in the ratio of the value on the treated bed relative to its value on the control bed between pre- and post-treatment sample dates depending on the outcome of the first two tests.

If treated and control endpoints were not equivalent pre-treatment because the endpoint value from the plot to be treated was higher than the value from the control plot (Figure 7, Path C), then the ratios of values from the treated plot relative to the control plot were compared between pre- and post-treatment sample dates.

Instances of pre-treatment non-equivalence could require the examination of site-specific information and other ancillary data, such as shifts in the taxonomic composition of invertebrate assemblages.

2.7.6 Parametric vs. Non-parametric Analyses

Parametric statistical analyses require that the data being assessed conform to a normal distribution, either in their original form, or following transformation (e.g., to logarithms or square roots).

The distribution of each endpoint at each study area and sample interval was assessed to as to whether or not it conformed to a normal distribution using the pooled mean residuals of the Protector 2F vs. control comparison and associated Shapiro-Wilk statistic. A significant statistic ($p < 0.05$) rejected the null hypothesis that the data fit a normal distribution. Data that fit a normal distribution were also tested for homogeneity using a Levene's test ($\alpha = 0.05$).

T-statistics for the TOST approach, or related confidence intervals for the difference of means required that data conform to a normal distribution or otherwise be estimated using a bootstrap technique (bias-corrected and accelerated confidence intervals [BCa] with 5,000 sample iterations). Bootstrap techniques repeatedly select cases (with replacement) from the sample to create a surrogate population from which the statistic and its uncertainty, are calculated.

If post-treatment data conformed to a normal and homogenous distribution, then treatment and control plots were compared using normal parametric statistics (comparison of means using Student's one-sided t-test where appropriate). If post-treatment data were normally distributed but not with a homogenous distribution, then treatment and control plots were compared using comparisons of means, but the t-statistic and associated degrees of freedom were computed using a formula for separate variances (Welche's t-test). If post-treatment data did not fit a normal distribution, then treatment and control plots were compared using comparison of ranked means using the Mann-Whitney U test. Significance level for all tests was 0.05.

For the direct comparison of endpoint values on treated and control plots, means or medians were used depending on the data distribution. If the data were normally distributed, the mean value of each plot was used to determine whether a 50 percent reduction had occurred on the treated plot relative to the control plot. If the data were not normally distributed, the median value of each plot was used to determine whether a 50 percent reduction had occurred on the control plot relative to the treated plot.

2.7.7 Taxonomic Composition of Invertebrate Assemblages

To determine the potential effect of imidacloprid exposure on individual taxa, and to assess the importance of site-specific influences, the taxonomic community composition of the assemblages of benthic and epibenthic organisms (polychaetes, mollusks, and crustaceans) was examined at each treatment plot and sample date by reviewing the absolute abundances and proportional abundances of most taxa. Rare polychaete taxa were excluded from this graphics-oriented analysis to simplify the analysis. The excluded taxa were: polychaetes with an overall proportional abundance (all plots and sample dates) of < 0.5 percent and crustaceans < 0.4 percent, except for Calanoid copepods (0.11 percent).

3.0 CHEMICAL ANALYSIS RESULTS

3.1 Data Quality Review Summary

Data quality is indicated by assessing the data's precision, accuracy, representativeness, comparability, and completeness. Overall, the data quality objectives as set forth in the SAP were achieved, and the data for this project are acceptable for use.

3.2 Water Column Chemical Analysis Results

Water column sample results are detailed in Table 5, and graphically in Figures 8 through 11.

Imidacloprid was detected in on-site water samples taken approximately 2 hours after treatment at the Taylor and Coast treatment sites, on the incoming tide. Imidacloprid concentrations ranged from 280 to 1,600 parts per billion (ppb) in these samples.

Imidacloprid was detected in samples from the Cedar River treatment sites, with a maximum of 290 ppb on the Nisbet plot and 230 ppb on the Coast plot. Off-plot imidacloprid concentrations ranged from 0.55 ppb at 55 m to below the PQL at 665 m at the Nisbet plot. The imidacloprid concentration at 753 m away from the Coast plot was 0.054 ppb on the first incoming tide after treatment.

Table 5 – Imidacloprid concentrations (ppb) in water samples from all sites, treatments, and sampling points analyzed in 2014

Matrix	Site	Treatment	Sampling Day	Sampling Point	Imidacloprid (ppb)
Water	Bay Center - Taylor	Control	Pre-Spray	C-2-27	ND
Water	Bay Center - Taylor	Control	Pre-Spray	C-2-26	ND
Water	Stony Point	Protector 2F	Spray Day	TT2	1000
Water	Stony Point	Protector 2F	Spray Day	TT3	1600
Water	Stony Point	Protector 2F	Spray Day	TT4	180
Water	Bay Center - Coast	Control	Pre-Spray	C-1-27	ND
Water	Bay Center - Coast	Control	Spray Day	C-1-28	ND
Water	Bay Center - Coast	Control	Pre-Spray	C-1-26	ND

Matrix	Site	Treatment	Sampling Day	Sampling Point	Imidacloprid (ppb)
Water	Stony Point	Protector 2F	Spray Day	TC3	920
Water	Stony Point	Protector 2F	Spray Day	TC2	280
Water	Cedar River – Coast	Protector 2F	Spray Day	CRw-0	230
Water	Cedar River – Coast	Protector 2F	Spray Day	CRw-SH	0.054
Water	Cedar River - Nisbet	Protector 2F	Spray Day	Nw-0	290
Water	Cedar River - Nisbet	Protector 2F	Spray Day	Nw-62	0.55
Water	Cedar River - Nisbet	Protector 2F	Spray Day	Nw-125	0.14
Water	Cedar River - Nisbet	Protector 2F	Spray Day	Nw-250	ND
Water	Cedar River - Nisbet	Protector 2F	Spray Day	Nw-500	0.066
Water	Cedar River - Nisbet	Protector 2F	Spray Day	Nw-SH	ND

Figure 8 – Imidacloprid concentrations in surface water at Stony Point

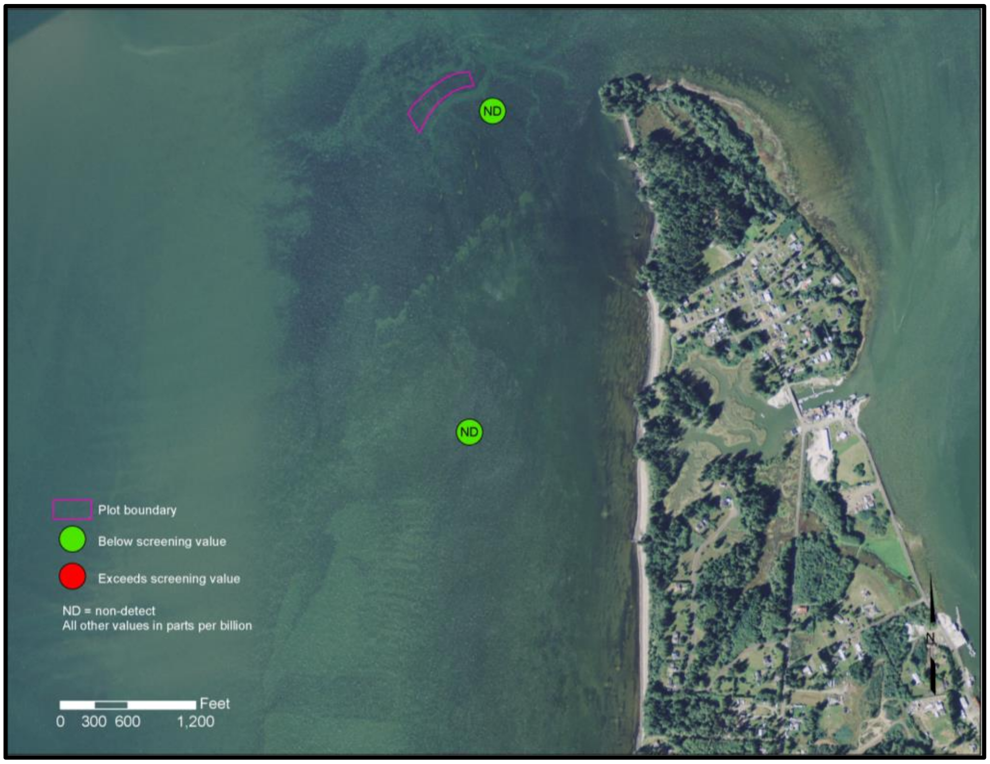


Figure 9 – Imidacloprid concentrations in surface water at Bay Center

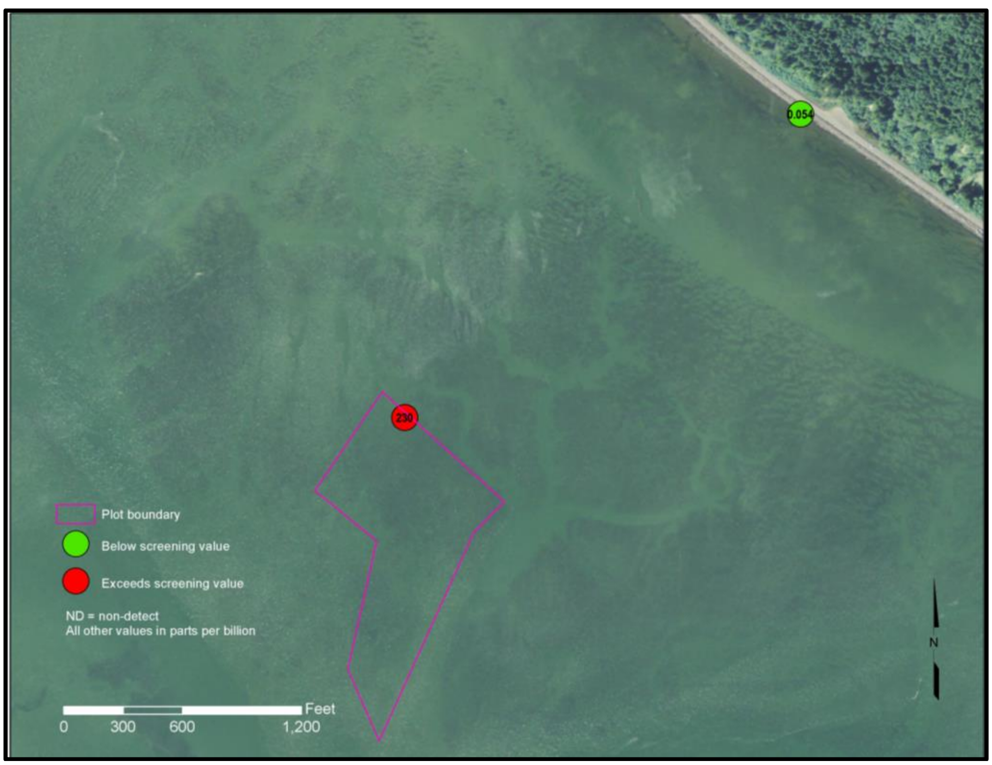


Figure 10 – Imidacloprid concentrations in surface water at Cedar River – Coast

Figure 11 – Imidacloprid concentrations in surface water at Cedar River – Nisbet

3.3 Sediment and Sediment Porewater Chemical Analysis Results

Imidacloprid concentrations in whole sediments are detailed in Table 6. Concentrations in sediment porewater are given in Table 7.

The range of imidacloprid concentrations in whole sediments one day post-treatment on the treated beds ranged from 64 ppb on the Taylor plot to 20 ppb on the Coast sites (Table 6). By 14 days post-treatment, concentrations on the Taylor site had fallen to a maximum of 18 ppb, while the maximum concentration on the Coast plot was 12 ppb. On Day 28, one sampling point on the Taylor plot had a concentration of 12 ppb imidacloprid in the whole sediment; however, imidacloprid was undetectable in whole sediments at all other sampling points on the treated plots.

The range of imidacloprid concentrations in sediment porewater one day post-treatment on the treated beds ranged from 100 ppb on the Coast plot to 4.7 ppb on the Taylor plot (Table 7). By 14 days post-treatment (the next sampling interval), imidacloprid concentrations in sediment porewater were reduced, with all concentrations below 1.0 ppb, with the exception of one sampling point on the Coast plot, which had a concentration of 3.1 ppb. This decreasing trend in imidacloprid concentrations continued on day 28, with the highest concentration (1.2 ppb) found on the Coast plot.

Table 6 – Imidacloprid concentrations (ppb) in whole dry sediment from all sites, treatments, days post-treatment, and sampling points analyzed in 2014

Matrix	Site	Treatment	Sampling Day	Sampling Point	Imidacloprid (ppb)
Sediment	Stony Point	Protector 2F	1	TTS-1	57
Sediment	Stony Point	Protector 2F	14	TTS-1	18
Sediment	Stony Point	Protector 2F	28	TTS-1	12
Sediment	Stony Point	Protector 2F	1	TTS-2	59
Sediment	Stony Point	Protector 2F	14	TTS-2	14
Sediment	Stony Point	Protector 2F	28	TTS-2	ND
Sediment	Stony Point	Protector 2F	1	TTS-3	50
Sediment	Stony Point	Protector 2F	14	TTS-3	ND
Sediment	Stony Point	Protector 2F	28	TTS-3	ND
Sediment	Stony Point	Protector 2F	1	TTS-4	64
Sediment	Stony Point	Protector 2F	14	TTS-4	6.8
Sediment	Stony Point	Protector 2F	28	TTS-4	ND
Sediment	Stony Point	Protector 2F	1	TCS-1	29
Sediment	Stony Point	Protector 2F	14	TCS-1	ND
Sediment	Stony Point	Protector 2F	28	TCS-1	ND
Sediment	Stony Point	Protector 2F	1	TCS-2	20
Sediment	Stony Point	Protector 2F	14	TCS-2	ND
Sediment	Stony Point	Protector 2F	28	TCS-2	ND
Sediment	Stony Point	Protector 2F	1	TCS-3	29
Sediment	Stony Point	Protector 2F	14	TCS-3	ND
Sediment	Stony Point	Protector 2F	28	TCS-3	ND
Sediment	Stony Point	Protector 2F	1	TCS-4	27
Sediment	Stony Point	Protector 2F	14	TCS-4	12
Sediment	Stony Point	Protector 2F	28	TCS-4	ND
Sediment	Bay Center - Coast	Control	Pre-Spray	C-1-28	ND

Table 7 – Imidacloprid concentrations (ppb) in sediment porewater from all sites, treatments, days post-treatment, and sampling points analyzed in 2014

Matrix	Site	Treatment	Sampling Day	Sampling Point	Imidacloprid (ppb)
Sediment	Stony Point	Protector 2F	1	TTS-1	9
Sediment	Stony Point	Protector 2F	14	TTS-1	0.77
Sediment	Stony Point	Protector 2F	28	TTS-1	0.56
Sediment	Stony Point	Protector 2F	1	TTS-2	13
Sediment	Stony Point	Protector 2F	14	TTS-2	0.62
Sediment	Stony Point	Protector 2F	28	TTS-2	0.11
Sediment	Stony Point	Protector 2F	1	TTS-3	9
Sediment	Stony Point	Protector 2F	14	TTS-3	0.17
Sediment	Stony Point	Protector 2F	28	TTS-3	0.18
Sediment	Stony Point	Protector 2F	1	TTS-4	4.7
Sediment	Stony Point	Protector 2F	14	TTS-4	0.2
Sediment	Stony Point	Protector 2F	28	TTS-4	0.12
Sediment	Stony Point	Protector 2F	1	TCS-1	15
Sediment	Stony Point	Protector 2F	14	TCS-1	0.087
Sediment	Stony Point	Protector 2F	28	TCS-1	0.15
Sediment	Stony Point	Protector 2F	1	TCS-2	18
Sediment	Stony Point	Protector 2F	14	TCS-2	0.13
Sediment	Stony Point	Protector 2F	28	TCS-2	0.31
Sediment	Stony Point	Protector 2F	1	TCS-3	22
Sediment	Stony Point	Protector 2F	14	TCS-3	0.31
Sediment	Stony Point	Protector 2F	28	TCS-3	0.43
Sediment	Stony Point	Protector 2F	1	TCS-4	100
Sediment	Stony Point	Protector 2F	14	TCS-4	3.1
Sediment	Stony Point	Protector 2F	28	TCS-4	1.2

3.3.1 Sediment Characterization

Sediment texture analysis was conducted on the two treatment and control plots. Tables 8 and 9 present the results of sediment grain size analysis and total organic carbon (TOC). Table 8 shows that the sediment at all sites was predominately sand (averages range from 88 to 97 percent), with small amounts of silt (2.4 to 7.7 percent) and clay (1.8 to 3.7 percent) making up the rest of the sediment. The results shown in Table 9 indicate that the treatment and control sites were relatively similar with respect to TOC and total solids. At all sites, TOC ranged from 0.18 to 0.79 percent while total solids ranged from 71.7 to 78.8 percent. The relationship between texture and organic carbon and binding of imidacloprid to sediments is discussed in a subsequent section of this report.

Table 8 – Sediment texture based on grain size (percent retained, Plumb 1981) for treatment plots in 2014 (n = 1 for all sites and treatments)

Site	Treatment	Year	Sand	Silt	Clay	Total Fines
Taylor Treated	Protector 2F	2014	88.3	7.7	3.7	11.4
Taylor Control	Control	2014	88.2	7.3	4.1	11.6
Coast Treated	Protector 2F	2014	95.4	2.7	1.8	4.4
Coast Control	Control	2014	97.4	< 2.4	< 2.4	2.4

Notes:
Sand = percent retained within 63 microns and passing through 2,000 microns
Silt = percent retained within 2 microns and passing through 63 microns
Clay = percent passing through a screen of 2 microns
The percent of sample retained in sieves greater than 4,750 microns was less than 0.1 percent.

Table 9 – Total solids and TOC for all treatment plots in 2014

Site	Year	Treatment	Day	Total Solids (%)	TOC (%)
Taylor Treated	2014	Protector 2F	1	74.70	0.79
Taylor Control	2014	Control	28	71.69	0.679
Coast Treated	2014	Protector 2F	1	78.75	0.179
Coast Control	2014	Control	28	73.48	0.193

3.5 Megafauna Sampling Results

The numbers of affected Dungeness crab varied with size class and location (Table 10). Observations were taken 24 hours after treatment. The average across all sites and treatments was 2 affected crab per acre. In total, 137 crab were potentially affected by spraying imidacloprid on a 90-acre plot at Stony Point. The number of dead and tetany affected crab was higher in the area outside the buffer around the spray zone than on the edge of the spray zone (Table 10). The crab likely prefer these slightly deeper areas; therefore, affected crab may have moved off-plot following application, or some crab may have been affected for reasons other than imidacloprid exposure. No additional crab were observed within the treated zone; however, an extensive meter-by-meter survey was not conducted throughout the entire 90 acre plot. These affected crab numbers indicate those found on the perimeter of the plot only.

Table 10 – Summary of total affected crab inside and outside a 7-meter perimeter of the treated area at the Stony Point site in 2014

Crab Size Class (carapace length, in inches)	Outside edge of spray zone			Inside edge of spray zone		
	Alive	Tetany	Dead	Alive	Tetany	Dead
< 2	1	4	7	0	1	10
2–3	1	8	20	0	3	18
3–4	0	9	22	2	7	12
4–5	0	5	2	0	7	2
> 5	0	0	0	0	0	0
Total	2	26	51	2	18	42

Note: Observations were recorded one day after treatment

3.6 Efficacy Sampling Results

WSU monitored efficacy on the treatment and control plots. Assessments of efficacy were based on the availability of tides and time. Comparisons were made along the edges, both inside and outside the treatment zone, in locations where burrowing shrimp densities were high enough to provide reliable efficacy estimates. The mean burrow density and percent control for each sediment/vegetation condition within each site are provided in Table 11. Efficacy ranged from 27 percent to 97 percent, with most sites showing efficacy levels in excess of 60 percent. Efficacy estimates were lower in areas of vegetation coverage, likely because in areas of thick eelgrass, the burrows were too obscure to obtain reliable counts. Accordingly, these sites tended to be avoided during the assessment. This skew in sampling sites may mean these results are an over-estimate of real field efficacy across all field conditions. The data indicate that, although good control was obtained in many locations, additional work will need to be done to better understand the variables affecting efficacy.

Table 11 – Summary of efficacy data from 2014 imidacloprid trials monitored by WSU*

Site	Sediment/ vegetation type	Mean # burrow/ 0.25m^2			% control
		Before inside	After inside	After outside	
Taylor plot, Protector 2F	Bare sand		6.3	28.9	80
	Sand w/ thick *Zostera japonica*		21.3	29.1	27
A 40, Protector 2F	Sand, bare		1.6	22.7	93
	Sand, medium *Zostera marina*		0.9	9.11	90
	Silty sand, bare		4.2	16.5	68
	Sandy silt, bare		1.7	61	97
	Silty sand, w/ thick *Zostera marina*		6	15.3	61

Site	Sediment/ vegetation type	Mean # burrow/ $0.25m^2$			% control
		Before inside	After inside	After outside	
	Silty sand, w/ medium *Zostera marina*		2	7.2	72
A 101, Protector 2F	Silt, bare	43	13		69
	Silt, mixed bare w/ patchy *Zostera marina*	21.7	7.1		81
B 197, Protector 2F	Sand, bare		5.3	27.8	81
	Sand, medium to thick *Zostera marina*		3.2	8.1	61
B111, Mattle	Silty sand	13.7	8.4		39

WGHOGA also assessed efficacy in 2014 on some of the treated shellfish beds. The overall reduction in burrow counts ranged from 20 percent to 97 percent (Tables 12, 13, and 14; attached). Efficacy varied widely depending on shellfish bed characteristics. Shrimp control ranged from a 41 percent to a 74 percent reduction in burrow counts in areas with *Zostera marina* cover. Bare sandy/silty sediment showed the greatest efficacy with percent control ranging from 49 percent to 97 percent.

Efficacy monitoring is ongoing to collect data from beds not yet monitored or that produced confounding results. The remaining sites are scheduled to be sampled in the spring of 2015, as there are insufficient daylight low tides during the fall and winter months of late 2014 and early 2015 to permit surveys. To ensure quality data, future surveys will compare shrimp densities inside vs. outside the treatment area during each site visit. Monitoring will also focus on visible adult burrows, thus avoiding potential bias created by juvenile shrimp recruitment. The remaining sites to be monitored and proposed sampling dates are presented in Table 14 (attached).

3.7 Epibenthic and Benthic Invertebrate Sampling Results

3.7.1 Species Lists

Organisms were identified to a total of 79 taxa: 44 to species, 15 to genus, 4 to family, 1 to suborder, 2 to infra-order, 9 to order, and 4 to class (Table 15; attached). Individuals from Classes Enteropneusta, Nemertea, and Oligochaeta were identified and counted but discarded from all subsequent analyses as they are not members of the three primary taxonomic groups as specified by the SAP for statistical analysis.

3.7.2 Pre-treatment Equivalence

Three of the nine pre-treatment endpoint data sets conformed to a normal distribution (Table 16), so most pre-treatment equivalence tests required a bootstrap estimation of the confidence interval of the standardized difference between the mean on the treated plot and the mean on the control plot.

Only two of the nine pre-treatment comparisons of means on plots to be treated with Protector 2F and means from their respective control plot were equivalent, leading to pathway A in the subsequent assessment for effects from imidacloprid as in Figure 7 and Table 17. There were six comparisons where the endpoint mean from the plot to be treated was not equivalent to, and higher than, the mean from the corresponding control plot (e.g., LCL($\bar{x}_T$ - $\bar{x}_C$) < -0.25$\bar{x}_C$), as in Figure 7, Path C. The pre-treatment comparison of polychaete abundance followed Path B, where means from the plot to be treated were not equivalent to, and lower than, the mean from the corresponding control plot (e.g., UCL($\bar{x}_T$ - $\bar{x}_C$) > +0.25$\bar{x}_C$).

Table 16 – Shapiro-Wilk statistic and associated significance level (Sig.) for mean pooled residuals computed for each of nine endpoints from at one day before treatment

Group	$\bar{x}$ Residual	statistic	d.f. [a]	p [b]	Normal Dist. [c]
Polychaetes	Abundance	.984	45	.763	yes
	Richness	.942	45	.025	no
	Diversity	.976	45	.475	yes
Mollusks	Abundance	.962	45	.140	yes
	Richness	.950	45	.049	no
	Diversity	.935	45	.014	no
Crustaceans	Abundance	.861	45	.000	no
	Richness	.950	45	.049	no
	Diversity	.974	45	.400	no

[a] degrees of freedom
[b] probability
[c] data is normally distributed if p>0.05

Table 17 – Results of equivalence tests on pre-treatment mean values for the nine primary endpoints based on 3 metrics: abundance, richness, and diversity for each of 3 taxonomic groups: polychaetes, mollusks, and crustaceans using the confidence interval approach of a two one-sided t-test (TOST) of equivalence

Group	Metric	Control			Protector				
		$\bar{x}_C$ [a]	$0.25\bar{x}_C$ [b]	N [c]	LCL_{STDF} [d]	UCL_{STDF} [e]	d.f. [f]	Equiv [g]	Path [h]
Polychaetes	Abundance	23602.6	5900.6	24	2897.7 [NB]	9884.2	43	No	B
	Richness	17.1	4.27	24	1.59	3.73	43	Yes	A
	Diversity	1.96	0.49	24	-0.11 [NB]	0.17	43	Yes	A
Mollusks	Abundance	1132.2	283.0	24	-1710.0 [NB]	-863.3	43	No	C
	Richness	3.46	0.86	24	-2.72	-1.48	43	No	C
	Diversity	0.98	0.24	24	-0.67	-0.34	43	No	C
Crustaceans	Abundance	38030.4	9507.6	24	-29148.0	-1177.6	43	No	C
	Richness	6.08	1.52	24	-1.76	-0.64	43	No	C
	Diversity	1.18	0.29	24	-0.33 [NB]	-0.17	43	No	C

[a] $\bar{x}_C$, mean of values from control plot
[b] $0.25\bar{x}_C$, mean of values from control plot * 0.25
[c] N, sample size
[d] LCL_{STDF}, lower confidence limits (90%) of mean standardized difference between values from treated and control plots
[e] UCL_{STDF}, upper confidence limits (90%) of mean standardized difference between values from treated and control plots
[f] d.f., degrees of freedom
[g] Equivalent, (Yes, values are equivalent, No, values are not equivalent)
[h] Path, pathway towards assessment of impact, as in Figure 7
[NB] No Bootstrap; confidence limits were not estimated by bootstrap (BCa; N = 5,000; α = 0.05)

3.7.3 Post-treatment Comparison of Means or Medians

Only seven of the 18 data sets from the post-treatment sample intervals conformed to a normal distribution (Table 18). Further analysis of those sets required comparison of the medians from treated and control plots to evaluate ratios and use of the non-parametric Mann-Whitney U test (α = 0.05) for statistical comparisons.

Table 18 – Shapiro-Wilk statistic and associated significance level (p) for mean pooled residuals computed for each of nine endpoints from experimental plots at 14 and 28 days after treatment (August 11 and August 25)

Sample Date	Group	$\bar{x}$ Residual	Statistic	d.f.[a]	p [b]	Normal Dist.[c]
August 11	Polychaetes	Abundance	.972	46	.321	yes
		Richness	.945	46	.029	no
		Diversity	.983	46	.723	yes
	Mollusks	Abundance	.934	46	.012	no
		Richness	.889	46	.000	no
		Diversity	.981	46	.648	yes
	Crustaceans	Abundance	.769	46	.000	no
		Richness	.929	46	.008	no
		Diversity	.987	46	.866	yes
August 25	Polychaetes	Abundance	.937	46	.016	no
		Richness	.968	46	.243	yes
		Diversity	.926	46	.006	no
	Mollusks	Abundance	.900	46	.001	no
		Richness	.892	46	.000	no
		Diversity	.988	46	.902	yes
	Crustaceans	Abundance	.921	46	.004	no
		Richness	.899	46	.001	no
		Diversity	.982	46	.701	yes

[a] degrees of freedom
[b] probability
[c] data is normally distributed if p > 0.05.

The two endpoint means that were equivalent pre-treatment (Polychaete richness and diversity), and so required post-treatment assessment that directly compared the mean on the treated plot to 50 percent of the mean on the control plot (e.g., the 50 percent test; Figure 7, Path A), resulted in 4 post-treatment comparisons. In each case, the treated plot mean or median did not have a 50 percent reduction compared to the control plot and therefore "passed" Ecology's guideline (Table 19; attached).

The single assessment that followed Path B (where the pre-treatment endpoint mean from the plot to be treated was not equivalent to, and lower than, the mean from the corresponding control plot according to the equivalence test) resulted in two post-treatment comparisons. In both of those assessments (polychaete abundance at 14 and 28 DAT), the post-treatment plot mean or median did not have a 50 percent reduction compared to the control plot, and therefore "passed" Ecology's guideline.

The six pre-treatment comparisons that lead to Path C (pre-treatment comparisons with an endpoint mean from the plot to be treated that was not equivalent to, and higher than, the mean from the corresponding control plot) resulted in 12 post-treatment comparisons. Since the control was higher than the treatment plots prior to any treatment, the main test is whether the T/C ratio decreased post-treatment compared to pre-treatment. Four of the 15 post-treatment comparisons had ratios that were not lower than the pre-treatment and therefore “passed” Ecology’s guidelines. The remaining eight endpoints will be examined further by Ecology to determine if any site-specific characteristics, life-history traits, or other ecological interactions that might have affected them aside from imidacloprid.

The ratio of median mollusk abundance from the Protector 2F plot relative to the mean from the control plot was higher at 14 DAT than at pre-treatment, but only slightly lower at 28 DAT than at pre-treatment (2.16 compared to 2.22). Median taxonomic richness of mollusks on the treated relative to the control plot was also slightly lower at both post-treatment dates (1.14 for both dates compared to 1.50 before treatment), but these values were low to begin with (6 and 4).

The ratio of median crustacean abundance on the treated relative to the control plot was lower at 14 DAT compared to pre-treatment (0.92 compared to 1.57) but the ratio was much higher at 28 DAT than before treatment (1.74 compared to 1.57). These trends result from the sizable increase of crustacean abundance on the treated plot over the course of the month-long study relative to the much slower increase on the control plot.

Although no statistical tests were required for any of the post-treatment assessments, results of the appropriate test (t-test for data that conform to a normal distribution, Mann-Whitney U test for data that does not), including associated means and standard errors or median and mean rank, are presented for further clarity (Table 20).

Table 20 – Mean and standard error ($\bar{x}$ ± S.E.) or median and mean rank (m, R)* of Absolute Abundance, Taxonomic Richness, and Shannon-Weiner Diversity of three primary taxonomic groups in plots treated with 0.5 lb a.i./ac flowable imidacloprid (Protector 2F) compared to mean values in untreated (control) plots on the day before (–1) and at 14 and 28 days after treatment (DAT)**

Taxon	DAT	Treatments	Abundance	Richness	Diversity	N
Polychaetes	-1	Protector 2F	17,211.6 ± 1,249.0 ne	15.0 (15.9) s	1.93 ± 0.07 e	21
		Control	23,602.6 ± 1,606.3	17.5 (29.2)	1.96 ± 0.05	24
	14	Protector 2F	20,412.8 ± 1,164.7 ns	15.0 (21.8) s	1.99 ± 0.04 ns	22
		Control	22,261.3 ± 1,649.1	17.0 (25.1)	1.97 ± 0.05	24
	28	Protector 2F	23,684.2 (23.8) s	16.1 ± 0.6 ns	2.11 (25.7) ns	22
		Control	22,399.0 (23.2)	17.0 ± 0.7	2.06 (21.5)	24
Mollusks	-1	Protector 2F	2,418.8 ± 236.6 ne	6.0 (32.1) ns	1.06 (32.0)ns	21
		Control	1,132.2 ± 112.8	4.0(15.0)	1.52 (15.2)	24
	14	Protector 2F	2,754.0 (32.3) s	4.4 ± 0.2 s	1.21 ± 0.05 s	22
		Control	856.8 (14.1)	3.4 ± 0.2	1.03 ± 0.05	23
	28	Protector 2F	2,509.2 (32.6) s	4.0 (29.9) s	1.32 ± 0.03 s [W]	22
		Control	1,162.8 (15.2)	3.5 (17.6)	1.11 ± 0.06	24
Crustaceans	-1	Protector 2F	46,389.2 (19.6) ns	7.0 (29.5) s	1.45 (32.1) s	21
		Control	29,559.4 (26.9)	6.0 (17.3)	1.18 (15.0)	24
	14	Protector 2F	42,411.3 (24.0) ns	7.0 (26.2) ns	1.29 ± 0.04 ns	22
		Control	46,328.0 (23.0)	6.0 (21.0)	1.28 ± 0.06	24
	28	Protector 2F	78,580.2 (30.6) s	6.0 (26.9) ns	1.39 ± 0.03 ns [W]	22
		Control	45,104.0 (17.0)	7.0 (20.4)	1.29 ± 0.05	24

* Significance tests did not figure in the assessment for potential impact in cases where UCL($\bar{x}_T$ - $\bar{x}_C$) was higher than +0.25$\bar{x}_C$ pre-treatment (Figure 7, Path C), but they were included in the interests of comprehensiveness and clarity
** Mann-Whitney test for significance presented here for pre-treatment data that did not fit a normal distribution; test for equivalence for data that did not fit a normal distribution was bootlegged TOST test (Table 17)
e/ne/s/ns Letter "e" following lower values indicate values from comparative plots were equivalent on -1 DAT according to the tests above (Table 17). Letter "ne" indicates values were not equivalent. Letter "s" indicates value from treated plot was significantly different than value from control plot. Letters "ns" indicate value was not significantly different (Student's1-tailed t-test, Welches 1-tailed t-test [indicated by W], or Mann-Whitney 1-tailed U test [α = 0.05])

3.7.4 Shifts in the Taxonomic Composition of Species Assemblages

Proportional abundances of the 19 most common polychaetes were fairly consistent both between the treatment and control dates and among sample dates (Figure 12). The proportions were remarkably consistent at the control plot, especially for *Tharyx parvus*, *Sphaerosyllis californiensis*, and *Rhynchospio glutaea*. *Tharyx parvus* was also the dominant polychaete at the treatment plot on all three sample dates, but *Polydora cornuta* and *Pseudopolydora paucibranchiata* were proportionally more abundant at 14 and 28 DAT compared to the pre-treatment sample date. This shift in proportional abundance is a result of an increase in abundance of these two species in the treated plot, rather than a loss of other species (Figure 13). Many polychaetes that belonged to either subclass

Errantia (mobile species) or Sedentaria (sedentary) were more abundant after treatment in the treated plot. The polychaete *P. cornuta* was seven times as abundant at the treated plot at both post-treatment sample dates compared to before treatment and *P. paucibranchiata* also increased by a factor of four. Neither of these species increased by much at the control plot. Polychaete richness was also greater in the treatment plot after treatment than before. The proportions of juvenile polychaetes were likewise very similar both between the treatment and control plot and among all sample dates (Figure 14). Proportionally more juveniles were found in the treatment plot at 28 DAT compared to both before treatment and 14 DAT.

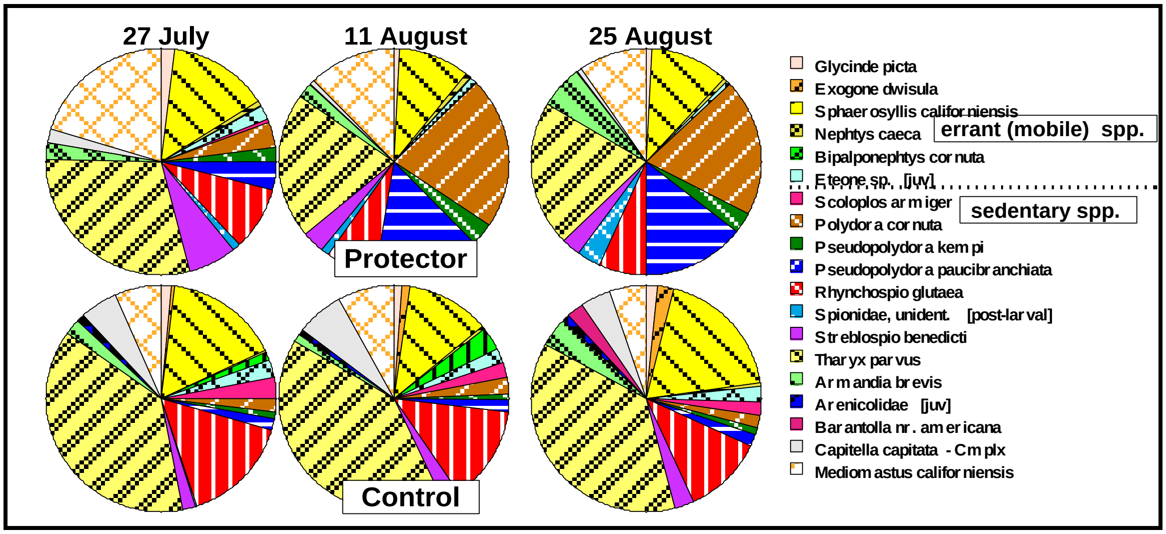


Figure 12 – Proportional abundance of 19 of 54 polychaetes at the Protector-treated and control plots before treatment (July 27) and at 14 and 28 days after treatment (11 August, 25 August)

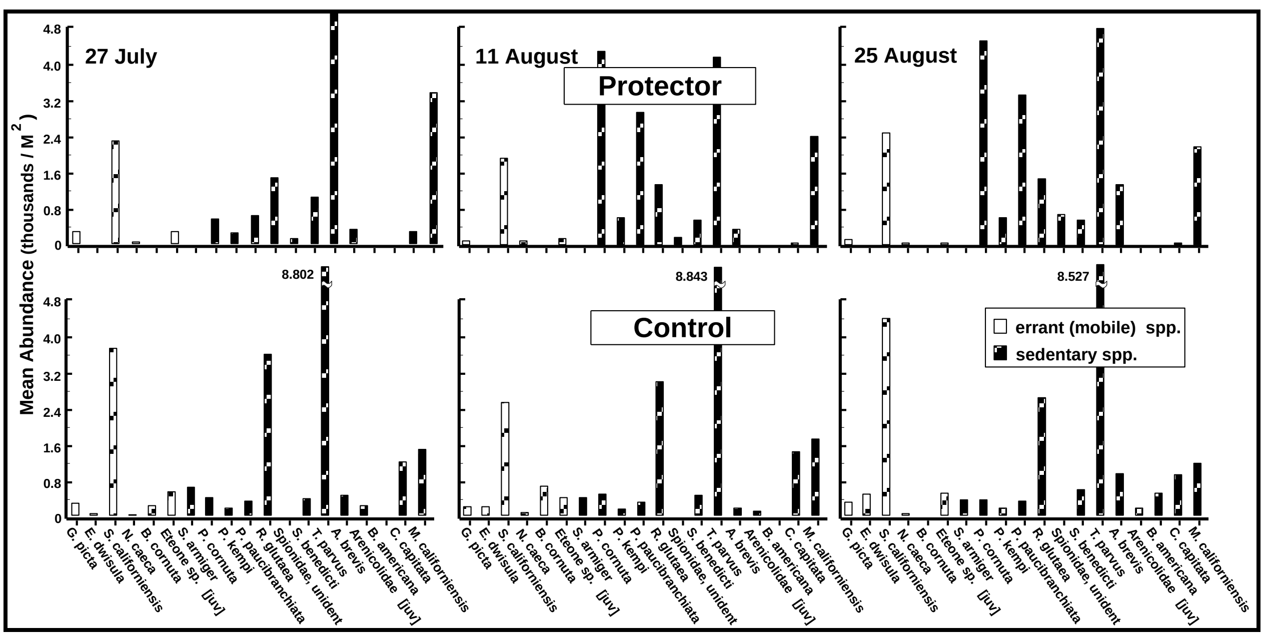


Figure 13 – Mean abundances of 19 most common of 54 polychaetes at the Protector-treated and control plots before treatment (27 July) and at 14 and 28 days after treatment (11 August, 25 August)

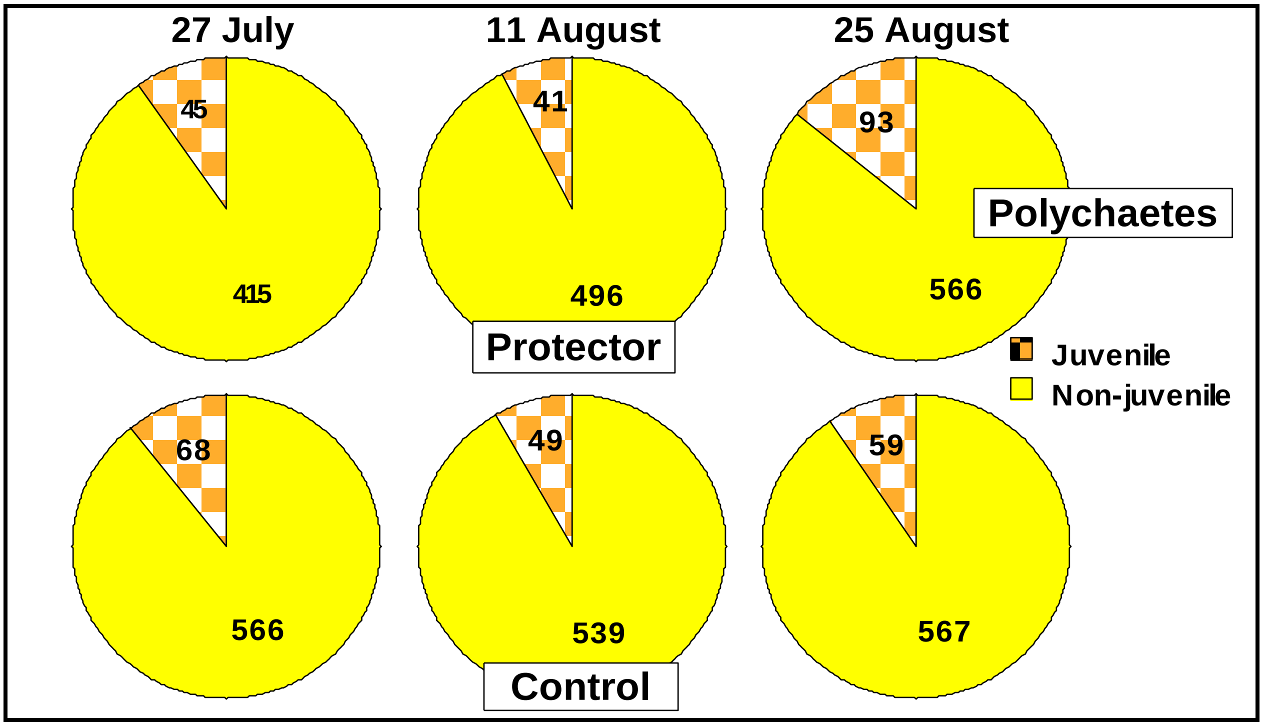


Figure 14 – Proportions of juvenile polychaetes at the Protector-treated and control plots before treatment (27 July) and at 14 and 28 days after treatment (11 August, 25 August)

Proportional abundance of mollusks were slightly different between the plot treated with Protector 2F and the control plot at the pre-treatment sample date, but fairly consistent among all three sample dates at each plot, especially the control (Figure 15). Most mollusks, but especially the juvenile bivalves, were much more abundant at the treatment plot after treatment than at the control. At the treatment plot, five of the 11 mollusks identified and counted were more abundant at 14 DAT than pre-treatment. This was particularly true for very small juvenile mytilid and Macoma species (Figure 16). At the control plot, juvenile Macoma species were less abundant at both post-treatment sample dates than at pre-treatment. Proportions of juvenile mollusks were slightly greater at the control plot than the treatment plot both pre-treatment and at 14 DAT (Figure 17). At the treatment plot, the proportion of juveniles was slightly greater at 28 DAT compared to pre-treatment, whereas the proportion was lower at 28 DAT compared to pre-treatment at the control plot.

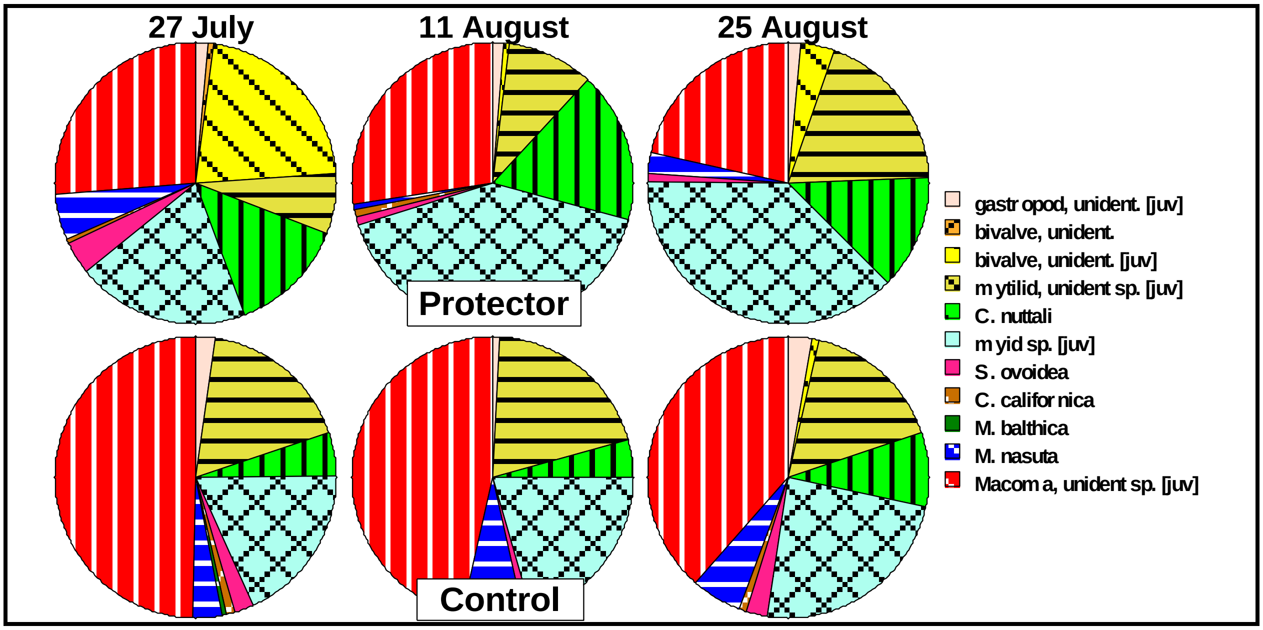


Figure 15 – Proportional abundance of mollusks at Protector-treated and control plots before treatment (27 July) and at 14 and 28 days after treatment (11 August, 25 August)

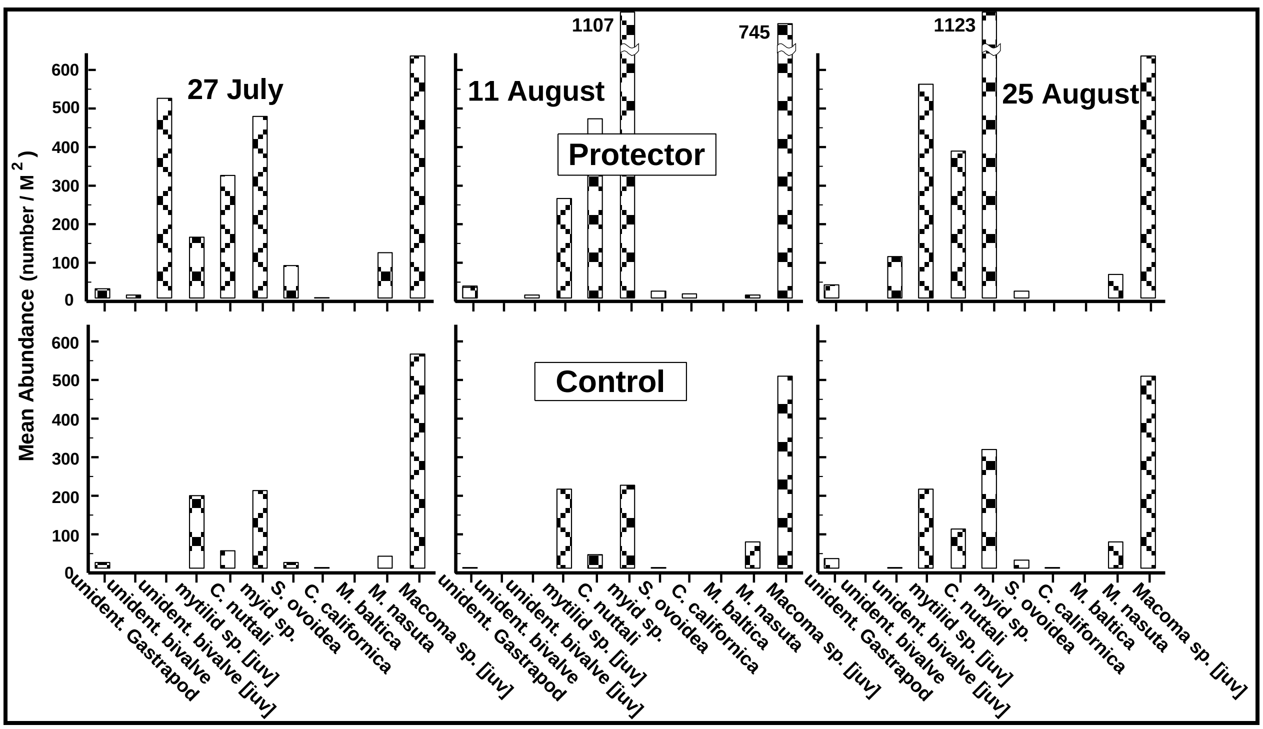


Figure 16 – Mean abundance of mollusks at the Protector-treated and control plots before treatment (27 July) and at 14 and 28 days after treatment (11 August, 25 August)

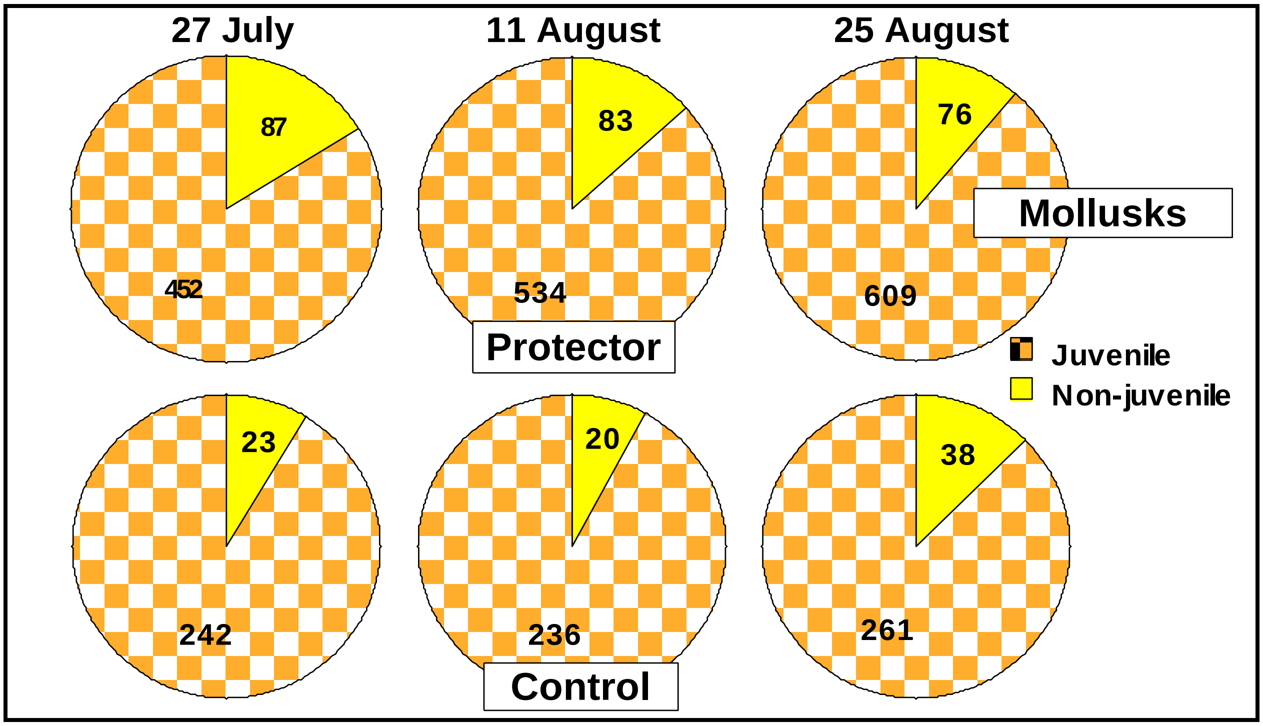


Figure 17 – Proportions of juvenile mollusks at the Protector-treated and control plots before treatment (27 July) and at 14 and 28 days after treatment (11 August, 25 August)

The proportional abundances of crustaceans also differed somewhat between plots, but were fairly consistent among sample dates at each plot (Figure 18). Corophids, harpacticoids, and to a lesser degree, cumaceans, dominated the treatment plot in fairly consistent proportions among all sample dates. Harpacticoids and tanaidaceans dominated the control plot in proportions that were also consistent among sample dates. Corophids and harpacticoids were more abundant at 14 DAT than before treatment and even more so at 28 days after treatment (Figure 19). Harpacticoids in particular were nearly twice as abundant at 28 DAT as before treatment. At the control plot, harpacticoids were 3 times more abundant at 14 DAT than before treatment, but only about 1.7 times as abundant at 28 days after compared to before treatment. Corophids were about as abundant at 28 DAT as before at the control plot, while they continued to be more abundant at 28 DAT than before treatment. The proportion of juvenile crustaceans was smaller at both the treatment and the control plot than it was for both polychaetes and mollusks. The proportion declined in both plots across sample dates as abundance of harpacticoids, corophids, and tanaidaceans increased (Figure 20).

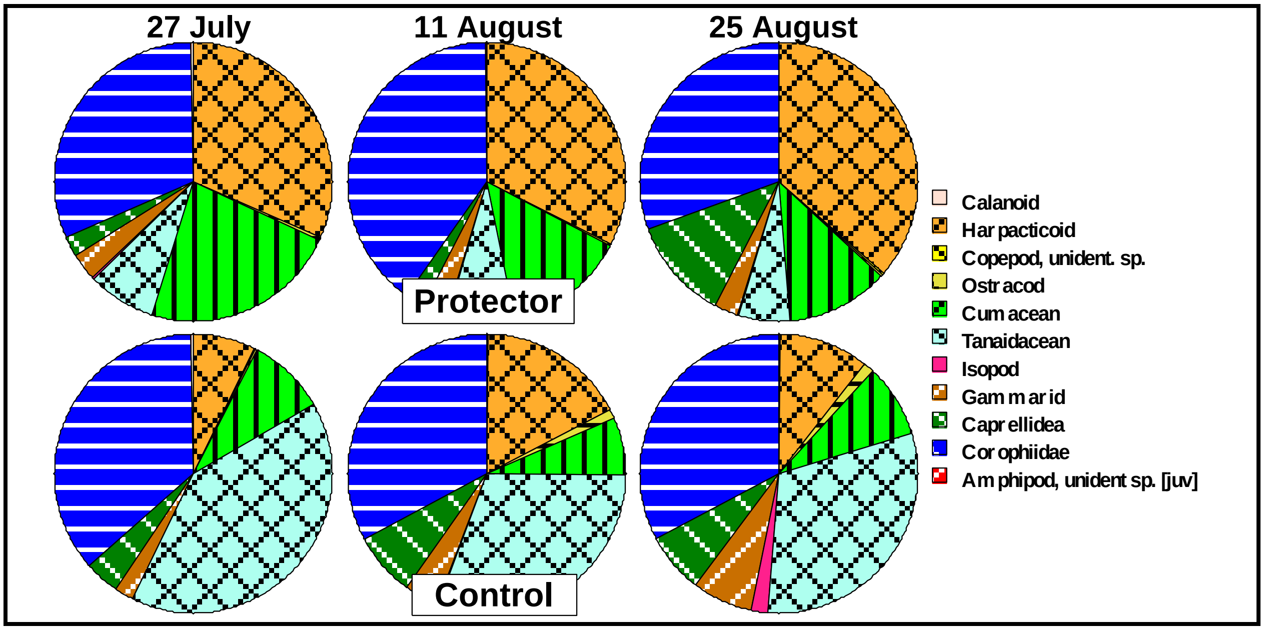


Figure 18 – Proportional abundance of 11 of 14 crustaceans at Protector-treated and control plots before treatment (27 July) and at 14 and 28 days after treatment (11 August, 25 August)

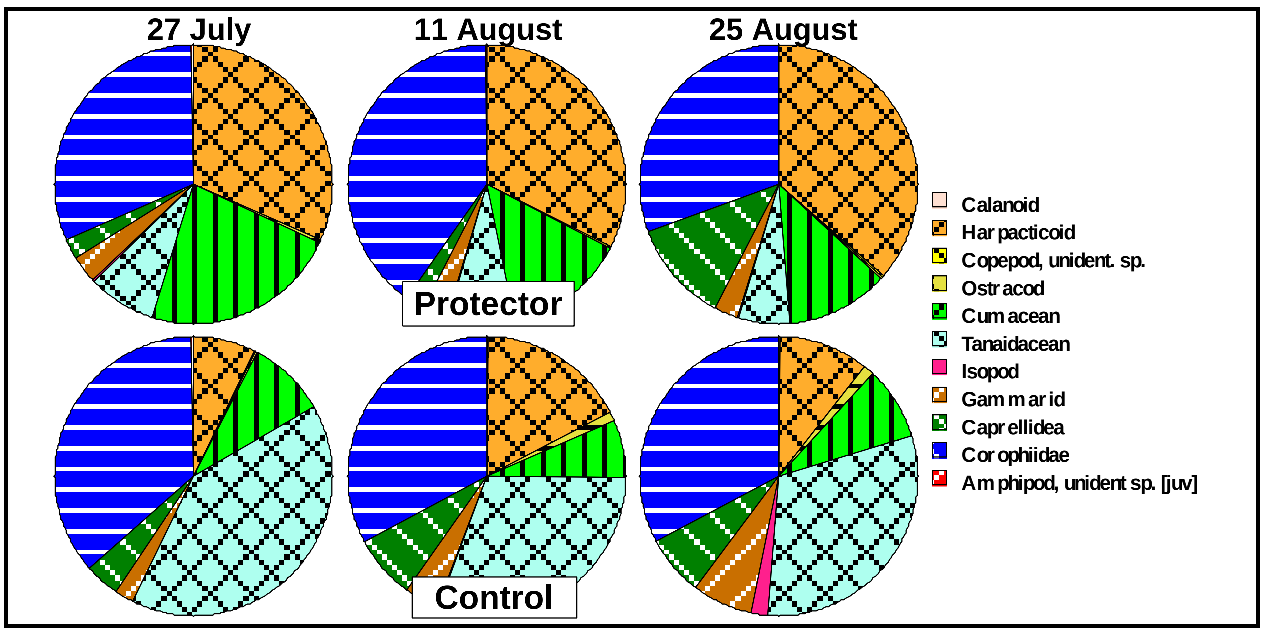


Figure 19 – Mean abundances of 11 of 14 crustaceans at the Protector-treated and control plots before treatment (27 July) and at 14 and 28 days after treatment (11 August, 25 August)

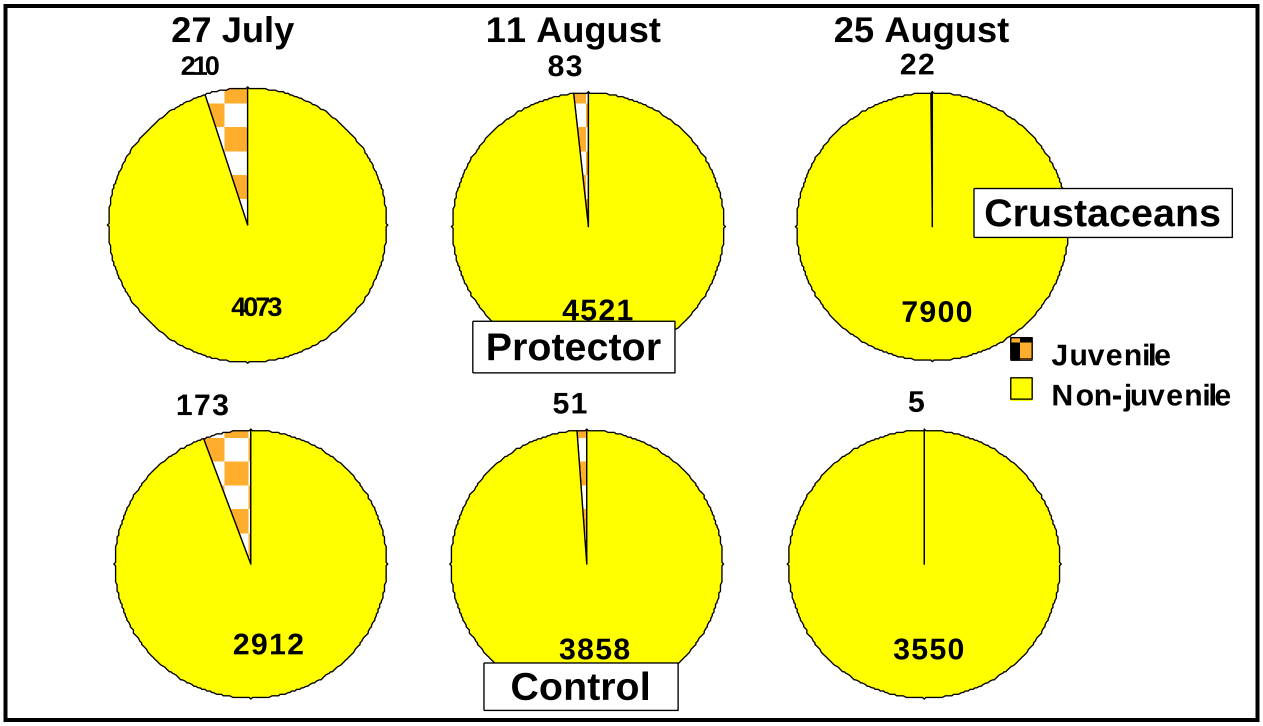


Figure 20 – Proportions of juvenile crustaceans at the Protector-treated and control plots before treatment (27 July) and at 14 and 28 days after treatment (11 August, 25 August)

4.0 SUMMARY

4.1 Imidacloprid Concentrations Across Sites and Matrices

The treatment plots chosen for these experimental trials were a good test of what could be expected when spraying large areas of commercial shellfish beds. The surface water, whole sediment, and sediment porewater samples were taken on both the Taylor and Coast plots, despite only the Taylor plot being part of the Ecology-approved SAP. Using the samples from both treatment plots allows for a better understanding of the impacts of treating large areas (> 10 acres) with imidacloprid.

The treatment plots chosen in Stony Point were not appropriate for determining off-plot movement of imidacloprid after spraying due to the wetting patterns and elevations on these plots. However, the treatment plots chosen in the Cedar River area offered a good test of off-plot movement of water, despite being separated from all other analyses from the Stony Point plots.

A total of 68 samples were analyzed for imidacloprid across the treatment and control plots. Of these analyses, 72 percent resulted in concentrations of imidacloprid above the limit of quantification (PQL = 0.04 ppb), with a maximum detection of 1,600 ppb for one surface water sample.

4.2 Imidacloprid Concentrations in Surface Waters

The surface water data indicate a strong pattern of high on-plot and low off-plot concentrations of imidacloprid during the first rising tide after treatment. The Stony Point surface water data indicate that all on-plot surface water samples collected during the first rising tide after treatment were well above the screening value of 3.7 ppb. Imidacloprid was not detected in the single water sample taken at the Coast control plot on the first rising tide after treatment, indicating that the control plots were not impacted by spraying imidacloprid on the nearby treatment plots. Neither was there any detection in the control plot in samples collected during the other commercial treatment applications that were prior to the Stony Point application.

Imidacloprid was detected off-plot at both of the Cedar River sites; however, in all cases, the concentrations of imidacloprid off-plot were well below the screening value of 3.7 ppb, despite the 0 m samples having imidacloprid concentrations above the screening value (230 and 290 ppb). Thus, off treatment areas appear to have been exposed to levels of imidacloprid below levels likely to produce biological effects, especially given the short time of exposure as the rising tide diluted waters flowing off the plots. At the Nisbet treatment plot, imidacloprid was undetectable at 655 m from the treatment plot and at the Coast plot, the imidacloprid concentration was very low (0.054 ppb) at 782 m from the treatment plot. These results show that tidal dilution results in very low or undetectable concentrations in areas located at moderate distance from the areas that were spayed. Collectively, and as expected, the results for imidacloprid in surface waters are consistent with results found in previous years' studies of off-plot movement of imidacloprid.

4.3 Imidacloprid Concentrations in Whole Sediments and Porewater

Imidacloprid concentrations in whole sediments were initially high and well above the screening value of 6.7 ppb. This was followed by a rapid drop-off of imidacloprid concentrations by 14 days post-treatment, and further declines with non-detect values by 28 days post treatment. The range of imidacloprid concentrations in whole sediment 1 day post-treatment was similar across the treatment plots. Concentrations 1 day post-treatment ranged from 27 to 64 ppb. By Day 28, all except one sampling point had dropped to undetectable concentrations of imidacloprid. The exception (TTS-1) had an imidacloprid concentration of 12 ppb. As in prior studies, the drop off in whole sediment imidacloprid samples appears to be approximately exponential over the period samples.

Imidacloprid concentrations in the sediment porewater samples were also initially high and well above the screening value of 0.6 ppb imidacloprid. The range of imidacloprid concentrations in sediment porewater 1 day post-treatment was relatively similar across the treatment plots, ranging from 4.7 to 100 ppb. By 14 days post-treatment, imidacloprid concentrations were reduced. By Day 28, concentrations at all sampling points except one were reduced to below the screening level of 0.6 ppb. One sample at the Coast treatment plot had an imidacloprid concentration of 1.2 ppb at 28 days post-treatment.

As with the whole sediments, there was a rapid drop-off of imidacloprid concentrations in sediment porewater by 14 days post-treatment and most samples had concentrations below the screening level by 28 days post-treatment. Again, the decline appeared to follow an approximately negative exponential relationship over time.

4.4 Grain Size and TOC Concentrations

Grain size and TOC concentrations were similar between paired treatment and control plots, but differed between treatment plots and between control plots. The Taylor treatment plot (and its corresponding control plot) had slightly lower compositions of sand and slightly higher concentrations of TOC compared to the Coast treatment plot. Grain size composition and TOC concentrations are similar to those found in previous studies.

4.5 Megafauna Summary

The results of the megafauna surveys indicate effects on crabs both inside and outside the edge of the spray area. The density of crabs exhibiting tetany and/or dead crabs was higher than observed in previous years. This may indicate an increased effect on crabs due to the larger area sprayed. However, due to the large size of the treated areas, it was impossible to collect data for the entire site as was done in previous years. Instead, observations were focused in zones most likely to contain affected crab, along the edge of the treated area which was lower and contained more *Z. marina*. Additional observations in subsequent years should be made before impacts to crab can be considered conclusive.

4.6 Efficacy Summary

In general, the efficacy study indicated good results of using imidacloprid to control burrowing shrimp on shellfish beds, particularly in areas with low densities of eelgrass. However, efficacy was variable across treatment plots. Efficacy ranged from 27 to 97 percent in the assessments conducted by both WSU and WGHOGA. The efficacy of imidacloprid appears to be dependent upon factors such as sediment type and the presence/absence of seagrass and its corresponding percent cover. Although the efficacy results indicate that imidacloprid is a good tool for reducing burrowing shrimp populations, more work is needed to confirm the role of site characteristics such as sediment type and eelgrass cover on efficacy.

4.7 Effects of Imidacloprid on Epibenthic and Benthic Invertebrates

Invertebrate results of this study supplement the two primary conclusions that were also present in previous studies:

- Estuarine epibenthic and benthic invertebrates were similar on the treatment and control plots following imidacloprid treatment.
- Assemblages of benthic and epibenthic invertebrates in Willapa Bay vary considerably in space and time.

The lack of significant differences between the treatment and control plots following application may be due to imidacloprid having a limited effect, to recolonization following treatment, or to some combination of the two factors. The 2014 study, while supporting prior work, was also specifically designed to evaluate imidacloprid treatment of a much larger area than those of previous years (90 acres versus ~10 acres). In addition, this study featured an imidacloprid treatment to a commercial oyster bed in a major growing area in Willapa Bay where several other commercial beds were also treated.

Due to sometimes non-equivalent levels of endpoints prior to treatment, assessments for potential impacts from imidacloprid involves three separate pathways.

The means of two endpoints (abundance and richness of polychaetes) were equivalent on both plots before treatment and so followed a pathway that compared the post-treatment value at the treated plot to 50 percent of the post-treatment value at the control plot. In both of these cases, the value at the treated plot was greater than 50 percent of the control value and so passed the assessment. In fact, the values of both endpoints at the treated plot were greater than 100 percent of the values on the control plot at both 14 and 28 days after treatment. In all previous studies a conclusion of "pass" was also reached for tests where the endpoints were equivalent before treatment.

When the mean endpoints were not equivalent before treatment, and instead the mean at the treatment plot was lower than on the control plot before treatment (second analysis pathway), both comparisons (polychaete abundance at 14 and at 28 days after treatment) directly passed without the need for a site-specific evaluation. In all previous studies a "pass" conclusion was also reached in 23 out of 26 comparisons for this assessment pathway.

In a third assessment pathway (when mean endpoints on the treatment and control plots were not equivalent before treatment and the mean on the treatment plot was greater than on the control plot), 4 out of 8 comparisons directly resulted in a pass, but site specific evaluation was required for the other 8 comparisons. In previous studies, 9 out of 44 such comparisons directly resulted in a "pass" conclusion, 35 out of the 44 comparisons needed a site-specific evaluation, and 3 assessments could not be completed due to zero values on one or other of the plots. Thirty of the 35 site-specific comparisons featured mollusk endpoints, which were confounded by other factors (see below) and also by very low values. In fact, three of the mollusk assessments could not be completed due to values of zero on one or other of the plots. At least three of the crustacean assessments following this pathway that required a site-specific comparison were eventually passed via the site specific evaluation, while two did not pass.

Assessments of the higher treatment relative to control pre-treatment endpoint means scenario are also complicated by what might cause that ratio to decline post treatment. In this study, the primary reason for that decline was due to an increase in post-treatment endpoint values at the control plot while the complimentary endpoint values at the treatment plot increased only moderately or even declined slightly. Abundance of crustaceans, primarily harpacticoids, but also other taxa, was a case in point. However, by 28 days after treatment, both harpacticoids and corophids had increased tremendously at the treated plot compared to the control plot. This was a common scenario in previous studies as well.

To summarize, a site-specific evaluation can be challenging to interpret. It involves examining the relationship of particular species, in addition to a comprehensive taxon such as a class, as they relate to not only conditions on-site at the time of sampling, but also off-site at other times of the year. The evaluation, in short, is ecological, rather than merely quantitative.

In this study, the sometimes tremendous increase in abundance of benthic and epibenthic invertebrates at the treatment plot is in accordance with the incredible productivity of the Stony Point growing area. The entire area, including Ellen Sands which neighbors to the west, is shallow and waters warm quickly during the summer low tides. The North, Cedar, and Willapa Rivers, as well as the Pacific Ocean, deliver nutrients. Many commercial oyster beds, like the study site, are located up to a mile from shore and currents feed it from all sides. The currents also likely colonize the area with estuarine invertebrates. These include both early life-stages, such as the post-larval unidentified spionid polychaete species (Figure 13) that were fairly abundant on the treatment plot, but also new harpacticoid and other copepod recruits. The higher abundance of juvenile mollusks at the treatment plot at 28 days after treatment compared to before indicates that they may have either been newly recruited during the study or were not impacted by imidacloprid.

The Stony Point growing area also has a moderately silty substrate that is prime habitat for many polychaetes. *Polydora*, *Pseudopolydora*, and other spionid species especially prefer silty/muddy habitats (Eugene Ruff, Ruff Systematics, personal communication). Spionids are also sedentary species; it is highly likely that many of the non-post larval and non-juvenile individuals that were sampled at the treatment plot were extant during the entire month-long study and were not impacted by imidacloprid.

As in previous studies, mollusks generally showed few differences in control and treatment plot results following imidacloprid exposure, but associated endpoints were difficult to assess. In addition to unequivalent pre-treatment values on the treated plots relative to the control plots, the hard calcareous shells of mollusks are much slower to degrade than the soft bodies of polychaetes and crustaceans. Accordingly, it is more difficult to determine whether individuals that were sampled were dead or alive at the time of collection. This has a limited effect on the ability to interpret the effects of imidacloprid, however, because relatively few mollusks were enumerated in this study, likely due to bioturbation by both burrowing shrimp and polychaetes.

This study corroborates other studies that demonstrate the ability of estuarine epibenthic and benthic invertebrate communities to withstand disturbance. Estuarine environments are volatile by nature. Conditions change not only seasonally, but daily as tides come and go, changing not only water levels, but also substantially changing the temperature. Estuarine epibenthic and benthic invertebrates are well adapted to these seasonal and transitory changes. As noted above for crustaceans, they are highly prolific, fecund, and produce multiple generations per year. Most are very mobile, with pelagic juvenile life stages that move not only within an estuary, but among estuaries via ocean currents. Abundances sometimes seemed exorbitant; with counts of nearly 160,000 harpacticoid individuals in a single sample from the treatment plot, an abundance equivalent to nearly 640 billion per acre. This ability to withstand disturbance is an important element in explaining the consistent pattern of this and previous studies that find imidacloprid consistently passes the tests for effects on invertebrates.

Very high neighboring abundances and rapid recruitment and colonization make estuarine invertebrate populations able to withstand disturbances such as storms, flooding tides, and applications of imidacloprid. Exposure time to imidacloprid is limited, as concentrations of imidacloprid in porewater declined precipitously after treatment as demonstrated in both this and previous studies; exposure to benthic organisms is short. Other benthic organisms could potentially avoid exposure by burrowing or by some other behavior. Laboratory studies also demonstrate that mortality-inducing levels of imidacloprid are generally at least an order of magnitude higher than the exposures resulting from field applications.

In this regard, burrowing shrimp, because of their tunneling, may be particularly susceptible to imidacloprid; following exposure, burrowing shrimp enter a state of constant muscular stimulation, or tetany, which causes them to cease burrow maintenance, resulting in burrow collapse, and eventually to suffocation of the shrimp (Grue 2013). Targeted action on burrowing shrimp arguably makes imidacloprid an ideal chemical control for use on oyster and clam beds in Willapa Bay and Grays Harbor, particularly in comparison to chemicals that produce direct mortality in a broad cross-section of the invertebrate community of these estuaries.

5.0 REFERENCES

Booth, Steven R., B. Hudson, A. Suhrbier, K. Patten, J. Barrett, and A. Stutes 2015. Impact of imidacloprid on epibenthic and benthic invertebrates: 2014 studies to describe the Sediment Impact Zone (SIZ) related to imidacloprid treatments to manage burrowing shrimp. Report submitted to Washington Department of Fish & Wildlife.

Grue, Christian 2013. Survival of ghost shrimp in sediments exposed to imidacloprid in the laboratory: Implications for control of shrimp on oyster beds in Willapa Bay, WA. Presentation to Pacific Coast Shellfish Grower's Association Annual Conference, Sun River, OR. Oct 2, 2013.

Hart Crowser 2014. Draft Sampling and Analysis Plan. Experimental Trials for Imidacloprid Use in Willapa Bay. Willapa Bay, Washington. Prepared for Willapa Grays Harbor Oyster Growers Association. July 7, 2014.

Patten, K. 2015. Progress Report to WDFW – Investigation of the use of Imidacloprid for Burrowing Shrimp Management in Bivalve Aquaculture in Willapa Bay, Washington: 1) Impacts on Megafauna, Epibenthic and Benthic Organisms and 2) Persistence and Spatial Distribution of Imidacloprid within the Sediment Impact Zone. Report submitted to Washington Department of Fish & Wildlife.

TABLES

Table 1 – Latitude and longitude of all sampling points utilized within the study

(see Figures 2 through 5 for reference*)

Site	Treatment	Sampling Point	Latitude	Longitude
Bay Center	Control for Taylor	1 – sediment & water	46.635821	-123.964280
Bay Center	Control for Coast	2- sediment & water	46.623160	-123.960000
Stony Point	Treated – Taylor	1 - sediment	46.69.193	-123.916690
Stony Point	Treated – Taylor	2- sediment	46.692150	-123.915820
Stony Point	Treated – Taylor	3- sediment	46.692392	-123.914459
Stony Point	Treated – Taylor	4- sediment	46.692624	-123.913485
Stony Point	Treated – Taylor	2- on-site water	46.690798	-123.918275
Stony Point	Treated – Taylor	3- on site water	46.691639	-123.916669
Stony Point	Treated – Taylor	4 - on-site water	46.692362	-123.915162
Stony Point	Treated – Coast	1 - sediment	46.689750	-123.919880
Stony Point	Treated – Coast	2- sediment	46.689030	-123.921230
Stony Point	Treated – Coast	3- sediment	46.688550	-123.922080
Stony Point	Treated – Coast	4- sediment	46.688080	-123.923110
Stony Point	Treated – Coast	2- on-site water	46.688764	-123.921367
Stony Point	Treated – Coast	3- on site water	46.689632	-123.919737
Cedar River	Treated – Coast	1- off-site water (0 m)	46.723430	-123.960104
Cedar River	Treated – Coast	2- off-site water (782 m – shore)	46.727866	-123.952402
Cedar River	Treated – Nesbitt	1- offsite water (0 m)	46.717239	-123.968340
Cedar River	Treated – Nesbitt	2- offsite water (55 m)	46.717515	-123.969041
Cedar River	Treated – Nesbitt	3- offsite water (110 m)	46.717643	-123.969769
Cedar River	Treated – Nesbitt	4- offsite water (220 m)	46.718370	-123.976730
Cedar River	Treated – Nesbitt	5- offsite water (440 m)	46.718000	-123.973950
Cedar River	Treated – Nesbitt	6- offsite water (655 m – shore)	46.718494	-123.976780
Stony Point	Treated – Taylor	Benthic Invertebrates	46.6916800	-123.9173200
Stony Point	Treated – Taylor	Benthic Invertebrates	46.691754	-123.916840
Stony Point	Treated – Taylor	Benthic Invertebrates	46.6919120	-123.9174530
Stony Point	Treated – Taylor	Benthic Invertebrates	46.6919710	-123.9170350
Stony Point	Treated – Taylor	Benthic Invertebrates	46.6921750	-123.9164570
Stony Point	Treated – Taylor	Benthic Invertebrates	46.6920950	-123.9157310
Stony Point	Treated – Taylor	Benthic Invertebrates	46.6924840	-123.9154790
Stony Point	Treated – Taylor	Benthic Invertebrates	46.6922460	-123.9160260
Stony Point	Treated – Taylor	Benthic Invertebrates	46.6922500	-123.9153360
Stony Point	Treated – Taylor	Benthic Invertebrates	46.6926720	-123.9142030
Stony Point	Treated – Taylor	Benthic Invertebrates	46.6923100	-123.9140960
Stony Point	Treated – Taylor	Benthic Invertebrates	46.6919380	-123.9151640

Site	Treatment	Sampling Point	Latitude	Longitude
Stony Point	Treated – Taylor	Benthic Invertebrates	46.6915930	-123.9149520
Stony Point	Treated – Taylor	Benthic Invertebrates	46.6912110	-123.9147720
Stony Point	Treated – Taylor	Benthic Invertebrates	46.6910200	-123.9156370
Stony Point	Treated – Taylor	Benthic Invertebrates	46.6916630	-123.9161070
Stony Point	Treated – Taylor	Benthic Invertebrates	46.6914690	-123.9160230
Stony Point	Treated – Taylor	Benthic Invertebrates	46.6913860	-123.9165730
Stony Point	Treated – Taylor	Benthic Invertebrates	46.6915500	-123.9169310
Stony Point	Treated – Taylor	Benthic Invertebrates	46.691952	-123.916293
Stony Point	Treated – Taylor	Benthic Invertebrates	46.691531	-123.913742
Stony Point	Treated – Taylor	Benthic Invertebrates	46.691896	-123.913951
Stony Point	Control	Benthic Invertebrates	46.63571	-123.967
Stony Point	Control	Benthic Invertebrates	46.63592	-123.967
Stony Point	Control	Benthic Invertebrates	46.63612	-123.967
Stony Point	Control	Benthic Invertebrates	46.63629	-123.967
Stony Point	Control	Benthic Invertebrates	46.63645	-123.966
Stony Point	Control	Benthic Invertebrates	46.63665	-123.966
Stony Point	Control	Benthic Invertebrates	46.63672	-123.966
Stony Point	Control	Benthic Invertebrates	46.63679	-123.965
Stony Point	Control	Benthic Invertebrates	46.63663	-123.965
Stony Point	Control	Benthic Invertebrates	46.63647	-123.965
Stony Point	Control	Benthic Invertebrates	46.63641	-123.965
Stony Point	Control	Benthic Invertebrates	46.63655	-123.966
Stony Point	Control	Benthic Invertebrates	46.63646	-123.966
Stony Point	Control	Benthic Invertebrates	46.63629	-123.966
Stony Point	Control	Benthic Invertebrates	46.6361	-123.966
Stony Point	Control	Benthic Invertebrates	46.63627	-123.966
Stony Point	Control	Benthic Invertebrates	46.6361	-123.966
Stony Point	Control	Benthic Invertebrates	46.63594	-123.966
Stony Point	Control	Benthic Invertebrates	46.63571	-123.967
Stony Point	Control	Benthic Invertebrates	46.63591	-123.967
Stony Point	Control	Benthic Invertebrates	46.6357	-123.967
Stony Point	Control	Benthic Invertebrates	46.63546	-123.967
Stony Point	Control	Benthic Invertebrates	46.63526	-123.967
Stony Point	Control	Benthic Invertebrates	46.63551	-123.967

*Note: Sampling points are approximate due to either the limitations of the GPS units used or human error while collecting these waypoints.

Table 2 – Sediment sampling station characteristics

Company	Sampling Station	Sampling Date 8/11/2014 Water depth at sample time (cm)	Sampling Date 8/11/2014 Eelgrass cover (%)	Sampling Date 8/25/2014 Water depth at sample time (cm)	Sampling Date 8/25/2014 Eelgrass cover (%)	Approx. tidal height (feet)
Taylor	TTS-1	2	10% *Z. marina*	1.5 cm	30% *Z. marina*, 3% *Z. japonica,* 10% macro algae	0.5
Taylor	TTS-2	0	35% *Z. marina*	0	10% *Z. marina*, 0% *Z. japonica*	1
Taylor	TTS-3	3	10% *Z. marina*	3	20% *Z. marina,* 0% *Z. japonica*	1.5
Taylor	TTS-4	1	0% *Z. marina*	0	5% *Z. marina*, 0% *Z. japonica*	2
Coast	TCS-1	0	100% *Z. japonica*; minor anoxia	<0.5 cm	10% *Z. marina*	2.3
Coast	TCS-2	0	25% *Z. japonica*; minor anoxia	<0.5 cm	35% *Z. marina*	2.3
Coast	TCS-3	0	50% *Z. japonica*; minor anoxia	<0.5 cm	10 % *Z. marina*	2
Coast	TCS-4	2	0% *Z. japonica*; no anoxia	<0.5 cm	0% *Z. marina* and *Z. japonica*	1.5

Table 3 – Benthic invertebrate sampling station characteristics

Sample Point	Percent *Zostera marina*	Percent *Zostera japonica*	Percent algae	Percent Bare	Percent Water	Water Depth (cm)	100 Percent mud
Taylor 2	90				100	2	
Taylor 3	90				100	2	
Taylor 4	90				100	2	
Taylor 8	50				20	4	
Taylor 8.5	80				85	1	
Taylor 9	0				0	0	yes
Taylor 10	20				10	0.5	
Taylor 11	90				100	2	
Taylor 12	80				85	1	
Taylor 13	0		0		0	0	yes
Taylor 14	0		90		10	0.5	
Taylor 15	70				90	1	
Taylor 15.5	90				100	1	
Taylor 16	60				100	1	
Taylor 17	0		0		0	0	yes
Taylor 18	0				0	0	
Taylor 19	85				100	2	
Taylor 20	90				100	2	
Taylor 22	40				100	0.5	
Taylor 23	80				100	0.5	
Taylor 24	40				100	2	
Taylor 25	90				100	2	
Taylor 26	70				80	0.5	
Taylor 27	90				100	2	
Taylor 28	70				9	1	
Control 1	80	5		20	10	0.2	
Control 2	70		20	20	40	0.2	
Control 3	80		70	0	10	0.2	
Control 4	85		30	10	10	0.2	
Control 5	90		20	10	10	0.2	
Control 6	40		30	40	0		
Control 7	85		20	10	10	0.2	
Control 8	95		50	0	10	0.2	
Control 9	80		30	5	20	1	
Control 10	90		30	2	5	0.2	
Control 11	95		40		15	1	
Control 12	95		40	0	20	0.5	

Sample Point	Percent *Zostera marina*	Percent *Zostera japonica*	Percent algae	Percent Bare	Percent Water	Water Depth (cm)	100 Percent mud
Control 13	80	10		20	10	0.2	
Control 14	100			5	95	0.2	
Control 15	5	40		30	30	1	
Control 16	15	25	30	60	15	0.5	
Control 17	85	10		30	70	0.5	
Control 18	40	20	5	40	70	1	
Control 19	10	5	5	90	30	0.5	
Control 20	95		10		90	1	
Control 21	15	20	10	85	0		
Control 22	15	15		90	10	0.5	
Control 23	30	40	5	30	100	1	
Control 24	10	10		90	10	0.5	

Table 12 – Efficacy results comparing pre- versus post-treatment shrimp burrow counts on treated beds

Company Name	Bed	Elevation	Size (ac)	Shrimp Species	Soil Type	Seagrass Presence	Pre-Treatment		Post-Treatment		Percent Control
							Inspection Date	Burrow Count m^2	Inspection Date	Burrow Count m^2	
Coast Seafoods Co.	Cedar River	-0.5	20	Mud/Ghost	sand, mud	scattered	5/28/2014	55.0	8/27/2014	43.5	20.9%
G.A. & Lila L. Wiegardt	E249	2.5	5	Ghost	sand, mud	japonica	5/23/2014	12.8	8/28/2014	4.4	65.6%
Heckes Clams Inc.	E78	2.0	20	Ghost	sand, silt, mud	japonica	5/22/2014	14.4	8/25/2014	2.6	81.9%
Jambor Oyster LLC.	B199 B287 B312	-0.5	17.9	Ghost	sand, silt	scattered	5/28/2014	30.6	8/26/2014	20.6	32.7%
Nisbet Oyster Co.	A-41	0.5	27.4	Mud/Ghost	mud, silt	scattered	5/28/2014	21.4	8/27/2014	7.6	64.5%
R&B Oyster Co.	B313 B332	1.0	20	Ghost	sand	none	5/30/2014	23.8	8/26/2014	16.8	29.4%
Wiegardt & Sons	C-89 C-90 C-91	1.0	40	Mud	mud	japonica	5/22/2014	17.6	10/10/2014	5	71.6%
	D51	1.0	15	Mud/Ghost	sand, mud	japonica	5/26/2014	18.4	11/4/2014	14.4	21.7%
Willapa Fish & Oyster Inc.	B197	0.0	15	Mud/Ghost	sand	scattered	5/30/2014	58.0	8/27/2014	13.8	76.2%

Note: Efficacy surveys were conducted by WGHOGA.

Table 13 – Intensive efficacy surveys by WSU comparing pre- versus post-treatment, adjacent burrow density and habitat types within treatment beds

Company Name	Bed	Elevation	Size (ac)	Shrimp Species	Soil Type	Seagrass Presence	Physical Description	Inside Pre-Treatment Area		Outside Treatment Area		Inside Post-Treatment Area		Percent Control
								Inspection Date	Burrow Count 1/4 m2	Inspection Date	Burrow Count 1/4 m2	Inspection Date	Burrow Count 1/4 m2	
Nisbet Oyster Co.	A-41	0.50	27.4	Mud, Ghost	mud, silt	scattered	NE Corner, Bare sediment	8/13/2014	41.2	8/27/2014	46.9	8/27/2014	1.7	96.1%
							NW Corner	8/14/2014	20.9	8/27/2014	21.4	8/27/2014	2.6	87.5%
							Northern Edge, Bare Sediment	nc	nc	8/27/2014	11.6	8/27/2014	5.9	49.1%
							North Edge Middle, 50 to 80% Zostera marina	nc	nc	8/27/2014	15.3	8/27/2014	6.1	60.1%
							South Edge, Zostera marina and Oysters	nc	nc	8/27/2014	6.0	8/27/2014	1.8	70.0%
							East Edge Middle, Soft Sand 50% Zostera marina	nc	nc	8/27/2014	9.1	8/27/2014	0.9	90.1%
							East Edge Middle	nc	nc	8/27/2014	22.8	8/27/2014	1.6	93.0%
Willapa Fish & Oyster Inc.	B197	0.00	15.0	Mud, Ghost	sand	scattered	NE Corner, 40 to 60% Zostera marina	nc	nc	8/27/2014	7.0	8/27/2014	4.1	41.4%
							Northern Line Central, no Zostera marina	nc	nc	8/27/2014	35.0	8/27/2014	5.7	83.7%
							NE, 70 to 80% Zostera marina cover	nc	nc	8/27/2014	7.7	8/27/2014	2.9	62.3%
							NW Edge, High Ground Thick Zostera japonica	nc	nc	8/27/2014	9.6	8/27/2014	2.5	74.0%
							West NW Corner/Edge, All Bare Sand	nc	nc	8/27/2014	23.5	8/27/2014	5.5	76.6%
							SW Corner Edge, Sandy	nc	nc	8/27/2014	24.9	8/27/2014	4.8	80.7%
Coast Seafoods Co.	Cedar River	-0.5	20.0	Mud, Ghost	sand, mud	scattered	SE Edge, Thick Burrowing Shrimp, No Zostera marina, Bare Silt	8/13/2014	43.0	8/27/2014	53.0	8/27/2014	2.3	95.7%
							NE Corner Between Vegetation Spots	nc	nc	8/27/2014	21.7	8/27/2014	7.1	67.3%
	B-22 # 12	-0.5	40.0	Mud, Ghost	sand, mud	scattered	NW Edge	nc	nc	8/26/2014	35.9	8/26/2014	1.8	95.1%
							Very Most NE Edge	nc	nc	8/26/2014	49.3	8/26/2014	15.1	69.4%
							North Edge, 50 to 80% Zostera japonica cover	nc	nc	8/26/2014	29.1	8/26/2014	21.3	26.8%
Taylor Shellfish Co.	B17, B18, B19, B23, B152	0.0	50.0	Ghost	sand, mud	scattered	SW Border Mid Way	nc	nc	8/26/2014	14.3	8/26/2014	5.0	65.0%
							SW Border North Edge	nc	nc	8/26/2014	16.1	8/26/2014	3.3	79.8%

Table 14 – Sites remaining to be sampled and tentative sampling dates

Company Name	Bed	Elevation	Size (ac)	Shrimp Species	Soil Type	Seagrass Presence	Inside Treatment Area		Outside Treatment Area		Percent Control
							Inspection Date	Burrow Count 1/4 m^2	Inspection Date	Burrow Count 1/4 m^2	
Northern Oyster Co.	E-215	0.0	15	Ghost	sand	moderate	3/24/2015		3/24/2015		
	E-6/E-5	-1.0	15	Ghost	sand	moderate	3/24/2015		3/24/2015		
Bay Center Mariculture	B-67	0.0	7	Mud/Ghost	sandy	scattered	3/23/2015		3/23/2015		
Coast Seafoods Co.	NCP # 3 NCP # 5	-1.0	25	Mud/Ghost	sand, mud	none	4/20/2015		4/20/2015		
	Grass Cr # 3 Grass Cr # 3a Grass Cr # 4a	-1.2	30	Ghost	sand, mud	none	4/20/2015		4/20/2015		
	Grass Cr # 8 Grass Cr # 9 Grass Cr # 11	-1.2	25	Ghost	sand, mud	none	4/20/2015		4/20/2015		
	Swan # 3	-1.2	10	Mud/Ghost	sand, mud	none	4/20/2015		4/20/2015		
	Swan # 5a	-1.2	10	Mud/Ghost	sand, mud	none	4/20/2015		4/20/2015		
	Damon Pt # 3 Damon Pt # 5	-0.5	20	Mud/Ghost	sand, mud	none	4/20/2015		4/20/2015		
	B 148 # 1-2	-0.5	24	Mud/Ghost	sand, mud	none	4/20/2015		4/20/2015		
	GB 39 # 1 GB 39 # 2	-1.0	20	Mud/Ghost	sand	none	4/21/2015		4/21/2015		
Markham Oyster Inc.	Dart North	0.0	10.8	Ghost	sand, mud	none	4/20/2005		4/20/2005		
Stony Point Oyster Co.	B-44	0.0	5	Ghost	mud	moderate	3/23/2015		3/23/2015		
Taylor Shellfish Co.	B114	1.0	35.6	Mud/Ghost	sand, silt, mud	none	3/23/2015		3/23/2015		

Table 15 – List of 79 taxa identified and enumerated from all samples at both the treated and control plots, 2014

Taxon	No.
Phylum Annelida	
Class Polychaeta	
Sub-Class Errantia	
Order Eunicida	
Family Dorvilleidea	
Dorvillea annulata	01
Order Phyllodocida	
Family Polynoidea	
Harmothoe imbricata	02
Family Goniadidae	
Glycinde picta	03
Family Chrysopetalidae	
Paleanotus bellis	04
Family Hesionidae	
Micropodarke dubia .	05
Microphthalmus sp.	06
Family Nereididae	
Neanthes limnicola	07
Neanthes virens	08
Neanthes sp. [juv]	09
Nereis vexillosa	10
Nereis sp. [juv]	11
Platynereis bicanliculata	12
Platynereis sp. [juv]	13
Family Syllidae	
Exogone dwisula	14
Sphaerosyllis californiensis	15
Sphaerosyllis sp. N-1	16
Syllides minutes	17
Syllides sp. [juv]	18
Family Nephtyidae	
Nephtys caeca	19
Nephtys sp. indet. (juv)	20
Bipalponephtys cornuta	21
Family Phyllodocidae	
Eumida longicornuta	22
Eumida sp. [juv]	23
Eteone californica	24
Eteone fauchaldia	25
Eeone sp. (juv)	26
Phyllodoce hartmanae	27
Phyllodoce sp.	28
Sub-Class Sedentaria	
Order Orbiniida	
Family Orbiniidae	
Paraonella platybranchia	29
Scoloplos armiger	30
Scoloplos sp. (juv)	31
Order Sabedellida	
Family Oweniidae	
Owenia sp.	32
Order Spionida	
Family Spionidae	
Dipolydora quadrilobata	33
Polydora cornuta	34
Pseudopolydora kempi	35
Pseudopolydora pauci-branchiata	36
Pygospio californica	37
Rhynchospio glutaea	38
Scolelepis squamata	39
Spionidae unident (post-larval	40
Spiophanes norrisi	41
Spiophanes sp. [juv]	42
Streblospio benedicti	43
Order Terebellida	
Family Terebellidae	
Poycirrus sp.	44
Order Cirratulida	
Family Cirratulidae	
Tharyx parvus	45
Order Opheliida	
Family Opheliidae	
Armandia brevis	46
Order Capitellida	
Family Arenicolidae (juv)	47
Family Capitellidae	
Barantoall nr. americana	48
Capitella capitata - complex.	49
Heteromastus filiformis	50
Notomastus tenuis	51
Notomastus sp. [juv]	52
Mediomastus californiensis	53
Family Maldanindae	
Sabaco elongatus	54
Phylum Mollusca	
Class Gastropoda	
Unidentifed [juv]	55
Class Bivalvia	
Unidentified [adult]	56
Unidentified [juv]	57
Subclass Heterodonta	
Family Mytilidae	
Unidentified Mytilid [juv]	58
Family Cardiidae	
Clinocardium nuttali	59
Family Myidae	
Unidentifed Myid [juv]	60
Sphenia ovoidea	61
Cryptomya californica	62
Family Tellinidae	
Macoma balthica	63
Macoma nasuta	64
Macoma sp. [juv]	65
Phylum Arthropoda	
Sub Phylum Crustacea	
Class Copepoda	
Order Calanoida	66
Order Harpacticoida	67
Order Cyclopoida	68
Unidentified copepod	69
Class Ostracoda	
Order Ostracoda	70
Class Malacostraca	
Order Cumacea	71
Order Tanaidacea	72
Order Isopoda	73
Order Amphipoda	
Suborder Gammaridea	74
Suborder Corophidea	
Infraorder Capreillida	75
Infraorder Corophida	76
corophid egg	77
Unidentified amphipod [juv]	78
Order Decapoda	79

Table 19 – Summary table of data and analysis. Pre-treatment comparisons of mean or median (bolded) values of Absolute Abundance, Taxonomic Richness, and Shannon-Weiner Diversity of three primary taxonomic groups for equivalence between the plot to be treated and the control plot resulted in different pathways of analysis for post-treatment comparisons (from Table 17)*

		Pre-treatment (July 27)								14 DAT (August 11)							28 DAT (August 25)						
		Mean or Median [a] Value						T/C [d]		Normal	Mean or Median				Ratio		Nor	Mean or Median				Ratio	
Taxon	Metric	Treated	Control	Treated	Control	Equiv [b]	Path [c]	Means	Medians	Dist [e]	Treated	Control	T/C	Sig [f]	Test [g]	Conclusion [h]	Dist	Treated	Control	T/C	Sig	Test	Conclusion
Polychaetes	Abundance	17212	23603	**19461**	**22889**	No	B	0.73	**0.85**	Yes	20413	22261	0.92	none	no	PASS	No	**23684**	**22399**	1.06	none	no	PASS
	Richness	14.4	17.1	**15.0**	**17.5**	Yes	A	0.84	**0.86**	No	**15.0**	**17.0**	**0.88**	none	no	PASS	Yes	16.1	17.0	0.95	none	no	PASS
	Diversity	1.93	1.96	**1.89**	**1.94**	Yes	A	0.98	**0.98**	Yes	1.99	1.97	1.01	none	no	PASS	No	**2.11**	**2.06**	**1.02**	none	no	PASS
Mollusks	Abundance	2419	1132	**2448**	**1102**	No	C	2.14	**2.22**	No	**2754**	**857**	**3.21**	none	no	PASS	No	**2509**	**1163**	**2.16**	none	yes	SSE
	Richness	5.6	3.5	**6.0**	**4.0**	No	C	1.61	**1.50**	No	**4.0**	**3.5**	**1.14**	none	yes	SSE	No	**4.0**	**3.5**	**1.14**	none	yes	SSE
	Diversity	1.49	0.98	**1.52**	**1.06**	No	C	1.52	**1.44**	Yes	1.21	1.03	1.18	none	yes	SSE	Yes	1.32	1.11	1.19	none	yes	SSE
Crustaceans	Abundance	53156	38030	**46389**	**29559**	No	C	1.40	**1.57**	No	**42411**	**46328**	**0.92**	none	yes	SSE	No	**78580**	**45104**	1.74	none	no	PASS
	Richness	7.3	6.1	**7.0**	**6.0**	No	C	1.20	**1.17**	No	**7.0**	**6.0**	**1.17**	none	no	PASS	No	**7.0**	**6.0**	**1.17**	none	no	PASS
	Diversity	1.43	1.18	**1.45**	**1.18**	No	C	1.21	**1.22**	Yes	1.29	1.28	1.01	none	yes	SSE	Yes	1.39	1.29	1.08	none	yes	SSE

Notes:

* Depending on the pathway, comparisons of mean values (for data that fit a normal distribution) or median values (for data that did not) at 15 and 30 days after treatment depended on the whether to ratio of values from the treated compared to the control plot was < 0.5 or was <, >, or = to the corresponding pre-treatment ratio and resulted in a conclusion of no effect (PASS) or for subsequent Site Specific Evaluation (SSE)

[a] Means for data that fit a normal distribution; medians for data that does not

[b] Results of pre-treatment equivalence tests (Table 17).

[c] Pathway to analysis and impact assessment (Figure 7; Table 17).

[d] Ratio of value on treated plot (T) relative to value on control plot (C).

[e] Data fit a normal distribution (Yes) or not (No) according to Shapiro-Wilk test (Table 18).

[f] T/C from treated plot significantly lower than T.C from control plot (s) or not (ns); none, not required according to assessment pathway (Figure 7).

[g] T/C from treated plot < ½ T/C from control plot.

[h] Conclusion of assessment from impact; (PASS, no impact; SSE, Site-Specific Evaluation Required before final Conclusion.

INDIVIDUAL NPDES PERMIT FOR THE CONTROL OF BURROWING SHRIMP USING IMIDACLOPRID ON COMMERCIAL SHELLFISH BEDS IN WILLAP BAY AND GRAYS HARBOR

Addendum to the Fact Sheet

Appendix F: Response to Comments

April 8, 2015

SUMMARY OF KEY PERMIT CHANGES

This is a summary of the changes made to the Individual NPDES Permit for the Control of Burrowing Shrimp Using Imidacloprid on Commercial Shellfish Beds in Willapa Bay and Grays Harbor in response to the public comments received between October 24 and December 8, 2014. In finalizing this permit, the Washington State Department of Ecology (Ecology) considered all of the public comments received during the public comment period, and comments received during oral testimony at the public hearing held in South Bend Washington on December 2, 2014.

Due to extensive comments regarding the monitoring requirements in the draft permit Ecology has made the following changes:

- Ecology has removed the requirement to sample for porewater. Whole sediment, water, and benthic sampling will provide the information that is needed in order to evaluate the environmental effects of imidacloprid in Willapa Bay and Grays Harbor.

- Based on data collected in previous studies, sixteen core samples per monitoring plot is sufficient to meet the statistical power requirement for the majority of the monitoring metrics. Therefore, the power requirement will not be included in the final permit. Sample numbers may be adjusted in the future based on monitoring data acquired during the duration of the permit.

- The Department of Ecology included the Ocean Park boat basin and vicinity (approximately 300 acres) in the sediment impact zone for central Willapa Bay. Several commentors noted that this is an area of economic importance for the staging of seed oysters prior to the movement to other areas of the bay for fattening. As part of the SIZ this area will be included in the general monitoring requirements.

COMMENTS AND RESPONSES

Ecology published a draft Individual Permit for the Control of Burrowing Shrimp using Imidacloprid on Commercial Shellfish Beds in Willapa Bay and Grays Harbor on October 24, 2014 for public comment. The public comment period ended December 8, 2014 at 5:00 p.m. During the comment period, Ecology conducted a public workshop and hearing in South Bend. Ecology also accepted public comments via letter and email.

Ecology considered all comments in preparing the final permit. The response to comments documents Ecology's response to each commenter and any changes to the permit that resulted from the comments. Each comment has been paraphrased to clarify the concern that Ecology is responding to. Full text of all comments received by Ecology can be found at: http://www.ecy.wa.gov/programs/wq/pesticides/imidacloprid/index.html or by contacting Derek Rockett at: derek.rockett@ecy.wa.gov, or (360) 407-6697. Comments on the Draft Environmental Impact Statement (DEIS) are summarized in Appendix F of the Final EIS.

1. Association of Washington Business (Housekeeper)
   Comment: Support of a permit to include southern Willapa Bay and limited monitoring, with an emphasis on the economic benefit of aquaculture.

   Response: Currently, Southern Willapa Bay is excluded for treatment under the draft permit for the following reasons:
   1. Possible persistence of the pesticide due to the presence of sediments with a high total organic content, which can increase the potential for persistence.
   2. Concerns about the lower flushing rate of the tidal cycle in this portion of the bay, which could increase persistence of the pesticide.

   The WGHOGA has the opportunity during the permit cycle to provide information that supports treatment in Southern Willapa Bay by providing applicable information. Southern Willapa Bay may receive treatment under the experimental use section of the permit if the treatment meets the intent of this section, which is to conduct research in order to obtain information.

   Monitoring requirements for this permit are based on the Sediment Management Standards and the obligation of the Washington State Department of Ecology (Ecology) to protect water quality.

2. Association of Washington Business (Johnson)
   Comment: Support of a permit to include southern Willapa Bay and limited monitoring, with an emphasis on the economic benefit of aquaculture.

   Response: Refer to response #1.

3. Audubon Society (Bayard)

   Comment: Concern regarding the potential effects of burrowing shrimp control and imidacloprid application on the Grays Harbor and Willapa Bay estuarine ecosystems, and uncertainties surrounding the fate of imidacloprid in the marine aquatic environment.

   Response: Monitoring studies have been done to understand the fate of imidacloprid in the marine aquatic environment. These studies are discussed in FEIS 2.8.3.5. Additionally, the permit requires annual monitoring of water, sediment, and benthic invertebrates.

   If any exceedances of minor adverse effects are confirmed during monitoring, Ecology will require adaptive management measures (which could include timing of imidacloprid application, changing areas to be sprayed, changing buffer zones around application, changing concentration or improving best management practices) with the permittee to reduce adverse effects. The probable likely net impact from these adaptive management measures will be to restrict spraying in areas where exceedances of minor adverse effects have occurred.

Comment: Concern for bird species.

Response: Concentrations of imidacloprid below 150 milligrams per kilogram (mg/kg) are generally non-toxic to most birds (Gervais et al. 2010), with a low of 15 mg/kg direct application found toxic to the gray partridge (Mineau and Palmer 2013). Similarly, CSI (2013) found imidacloprid application was unlikely to adversely affect birds in Willapa Bay or Grays Harbor based on an application concentration of approximately 3.34 mg/kg22. The flowable form of imidacloprid disperses in water, and granular application dissolves in shallow water. Although crustaceans and molluscs uptake imidacloprid during exposure (Frew 2013), they do not bioaccumulate imidacloprid in their tissues, minimizing potential exposure to foraging shorebirds. Red knot and other shorebirds that feed in and around shellfish beds could come in contact with low concentrations of granular imidacloprid immediately following an application. Peak abundance for red knot and many shorebirds occurs in April and May. (FEIS 3.2.5.3)

Granular-form applications of imidacloprid on commercial shellfish beds (mudflats) could result in an opportunity for birds to be exposed to this chemical through ingestion of the solid form, but direct exposure would be limited since application techniques flush birds from the site, and imidacloprid dissolves readily in water. This limited period of potential exposure would be interrupted when the mudflats became inundated by the incoming tide. CSI (2013) found imidacloprid toxicity exposure for snowy plover to have a low likelihood of indirect effects, and concluded that it would be unlikely to have adverse effects. ”Flowable”-form applications of imidacloprid would avoid exposure time for birds (Giddings et al. 2012). (FEIS 3.2.5.3)

Aerial dispersal of imidacloprid is limited by spray drift management techniques which will minimize potential exposure to non-target species. Aerial applications are permitted only when wind speeds are less than ten miles per hour. Therefore aerial applications would be unlikely to adversely affect bird populations within Willapa Bay or Grays Harbor.

Additionally, the potential for direct exposure of either pesticide to birds would be limited since application techniques by helicopter or hand-held equipment tend to flush birds from the target area (personal communication with Dr. Kim Patten). (FEIS 2.9)

Comment: Request to discuss Important Bird Areas.

Response: Important Bird Areas are now discussed in FEIS 3.2.5.

Comment: Request integration or recent advances in the published literature about both the short and long-term effects of imidacloprid into the FEIS.

Response: Ecology has relied on the best available science and has required monitoring to ensure compliance with the Sediment Management Standards (WAC 173-204) and the Water Quality Standards (WAC 173-201A).

This permit may be modified, revoked and reissued, or terminated if a determination that the permitted activity endangers human health or the environment, or contributes to water quality standards violations and can only be regulated to acceptable levels by permit modification or termination.

Comment: Although it appears from the evidence presented in the DEIS that imidacloprid uptake by eelgrass is minimal, there seems to be enough uncertainty about the transport and long-term accumulation of imidacloprid in the sediments of these two sites that a greater understanding of the potential uptake by zooplankton and micro and macro-algae, both within and outside of the pesticide application area should be considered.

Response: Imidacloprid would be applied on selected commercial shellfish beds in-water during out-going tides or on exposed mudflats, when densities of zooplankton would be low due to limited water depth. Imidacloprid breaks down rapidly in water and has a low volatilization potential in air, minimizing potential adverse effects on zooplankton in Willapa Bay or Grays Harbor (Gervais et al. 2010). (FEIS 3.2.5.3)

Limited information is available regarding imidacloprid impacts to marine vegetation. The results of field studies conducted during one season to evaluate uptake in eelgrass tissues showed limited uptake by eelgrass, and imidacloprid was undetectable after 14 days. In addition, imidacloprid is an acetylcholinase inhibitor and plants do not have a biochemical pathway involving acetylcholinase. Therefore, it is unlikely that imidacloprid would adversely affect eelgrass or other marine vegetation. (FEIS 3.2.4)

6.4.2 Algae
No studies were available to assess the toxicity of imidacloprid to marine algae. However, freshwater data indicate that algae are at least three orders of magnitude less sensitive to imidacloprid than many insect and crustacean species (CCME 2007). (CSI 2013, page 26)

6.4.3 Aquatic macrophytes
As discussed in Sections 6.4.2, imidacloprid is an insecticide and has low toxicity to plants. In field trials, Patten et al. (2011b) reported that eelgrass became established quickly on bare plots treated with 0.4 and 0.5 lb a.i./acre, indicating that eelgrass is capable of rapid growth when burrowing shrimp are reduced. Although no other studies of imidacloprid toxicity to aquatic macrophytes were available, it can be concluded that

imidacloprid use on shellfish beds will not have adverse effects on aquatic macrophytes. (CSI 2013, page 26)

Comment: The timing of the proposed imidacloprid application is between April 15 and December 15. Because shorebird numbers peak from mid-April through early May during spring migration, and waterfowl return to the estuaries in October, we request that if alternative 3 is approved, the timeframe for imidacloprid application be limited to May 15-September 15.

Response: The WGHOGA has requested an opportunity to apply in spring and fall to evaluate increased efficacy at times of the year other than summer. Some of the variables associated with seasonal application include vegetative cover, burrowing shrimp life stages, dissolved oxygen, and water temperature. These could all affect efficacy. If negative effects on birds is observed due to treatments, the permit allows for adaptive management through the Annual Operations Plan and windows of treatment could be incorporated. Permit timing is consistent with the FIFRA Registrations which allow applications during the period between April 15 and December 15.

Comment: The DEIS contends that burrowing shrimp are present at high densities at these sites, but no formal assessment of the burrowing shrimp population, including potential drivers for population growth, are given. If burrowing shrimp populations are indeed substantially higher than "normal," it is important to understand if other human pressures are driving this trend, or whether high densities of burrowing shrimp are the result of natural phenomena.

Response: Studies are ongoing to increase understanding of burrowing shrimp populations. Additionally, Dr. Dumbauld's most recent studies regarding burrowing shrimp recruitment are referenced in the Final Environmental Impact Statement and can be found in FEIS 3.1.

Comment: The DEIS contends that a reduction in burrowing shrimp will yield beneficial impacts to eelgrass and other aspects of the invertebrate biodiversity. We find this purported benefit quite puzzling, since the Willapa/Grays Harbor Oyster Growers Association (WGHOGA) recently applied for and received a permit to control non-native eelgrass using the herbicide imazamox. Is there any information available on whether the suppression of burrowing shrimp will result in new areas on non-native eelgrass (Zostera japonica) growth? The idea that imidacloprid use to suppress burrowing shrimp populations will result in greater biodiversity is completely at odds with the biological outcomes observed in the published literature.

Response: Increased densities of burrowing shrimp could result in decreased biodiversity and increased sedimentation (Dumbauld and Wyllie-Echeverria 1997; Colin et al. 1986). High densities of burrowing shrimp have been associated with lower numbers of Dungeness crab, oysters, and other shellfish due to competitive exclusion and habitat modification caused by the shrimp (Doty et al. 1990; Brooks 1995; Dumbauld and Wyllie- Echeverria 1997). (FEIS 3.2.5.3)

Comment: What is the current profile of fungicides, pesticides, and fertilizer contamination in Grays Harbor and Willapa Bay, and how does this vary over the course of the proposed imidacloprid application period? Have the analyses of the potential toxic effects of imidacloprid taken this information into account?

Response: Please refer to the 303d listings available at the following link http://www.ecy.wa.gov/programs/wq/303d/index.html.

Comment: Application of imidacloprid in the estuarine environment appears to be a fairly unusual use of the insecticide. The DEIS states that WGHOGA 2011 field trials testing the efficacy, environmental fate and transport, and biological effects of imidacloprid did not have an Ecology-approved Sampling and Analysis plan, although 2012 field trials did. Nevertheless, one year of preliminary field data combined with one year of more rigorous data should not take precedence over the peer-reviewed research. Until a rigorous assessment of imidacloprid in the estuarine environment is available, Ecology should use a precautionary approach and apply conservative estimates of imidacloprid toxic effect thresholds and transport rates, as are reported in the peer-reviewed literature. This includes recommended ecological thresholds for imidacloprid at below 0.2 µg/L for acute exposure and 0.035 µg/L for long-term chronic exposure. The imidacloprid levels reported in the 2013 Risk Assessment are considerably higher (acute 0.35 µg/L to 4,200 µg/L; chronic: 0.4 µg/L), which poses an unacceptable risk to the benthic environment of Willapa Bay and Grays Harbor.

Response: Different environments may have different variables affecting the threshold and transport rates of imidacloprid. The Draft Permit requires continued studies to continue evaluation of imidacloprid in both Willapa Bay and Grays Harbor. These studies along with best available science are being used by Ecology to apply adaptive management regarding imidacloprid applications. In 2014 monitoring studies were done at a commercial scale and the results are included in FEIS Appendix E.

Washington State currently has not promulgated any regulatory standards for imidacloprid in either surface waters or sediments. Therefore, permit monitoring utilizing direct biological observation of benthic organisms is the only means Ecology has to verify compliance with the Sediment Management Standards (WAC 173-204) and assess the health of the benthic community throughout the term of the permit. Sampling and analysis costs of biological monitoring typically greatly exceed the costs of measuring a chemical concentration. Ecology strives to maintain a balance between monitoring benefits and monitoring cost, and believes that the proposed monitoring plan is a precautionary yet feasible solution.

4. Board of Pacific County Commissioners (Rogers, Wolfe, Ayers)
   Comment: Support of a permit.

   Response: Comment noted.

5. Coalition of Coastal Fisheries (Fricke)
   Comment: Support of a permit with emphasis on the benefits of the habitat provided by shellfish beds

   Response: Comment noted.

6. Coalition to Protect Puget Sound Habitat (Laura Hendricks)
   Comment: We strongly oppose the issuance of a permit and application for a SIZ due to concern for pollinators and aquatic invertebrates.

   Response to concern for pollinators: Scoping comments received from local area scientific experts report that pollinators do not use the tideflats, and spray drift management techniques required by the Federal registrations for imidacloprid are sufficiently protective (personal communications received from Ed Darcher, Pacific County *Spartina* Coordinator since 1996, February 6, 2014; and Dr. Kim Patten, WSU Pacific County Extension Director, various dates). There are no flowering plants (other than eelgrass) on commercial shellfish beds as these are inundated twice daily by tides. Of the approximately 3,000 bee hives imported in June each year to pollinate cranberries at the south end of Willapa Bay, a few of these are located approximately 0.5 mile (2,640 feet) from the nearest commercial shellfish beds. The closest cranberry farm in Grays Harbor is approximately 1.5 miles from a commercial shellfish beds. The remaining 98 percent of the colonies are located 6 miles or more from the nearest shellfish beds (see FEIS Chapter 3, Section 3.2.5). The conditional FIFRA Registrations issued for the use of imidacloprid products at the proposed rate of 0.5 lb active ingredient per acre indicate that this would be below concentrations that would impact honey bees (USEPA 2013b). Further, in the professional opinion of the WSDA, Special Pesticide Registration Program Coordinator (Erik Johansen), there is no risk to bees from the application of imidacloprid (either granular or flowable formulation) to tidal flats. Implementing appropriate spray drift management techniques for the flowable formulation of imidacloprid, and maintaining an adequate buffer between the imidacloprid treatment area and blooming plants (as proposed by WGHOGA) would mitigate potential risk to bees (personal communication with Erik Johansen,WSDA, March 19, 2014). (FEIS 1.7)

   Additionally, the FIFRA Registrations for the granular and flowable formulations of imidacloprid (Protector 0.5G and Protector 2F, respectively) include the following spray drift management requirements (USEPA 2013a and 2013b):
   • Drift potential is lowest between wind speeds of 3 to 10 mph. Average wind speed at the time of application shall not exceed 10 mph to minimize drift to adjacent shellfish and water areas when either Protector 0.5G or 2F is applied by air. Further, aerial applications shall not occur during gusty conditions, or during temperature inversions. Temperature inversions begin to form as the sun sets and often continue into the morning.
   • Applications of imidacloprid shall be made at the lowest possible height (helicopter, ground, or barge) that is safe to operate and that would reduce exposure of the granules to wind.

• When applications of Protector 0.5G (the granular formulation) are made crosswind, the applicator must compensate for displacement by adjusting the path of the application equipment upwind. Swath adjustment distance should increase with increasing drift potential.
• Helicopters used to apply Protector 2F (the flowable formulation) should be equipped to minimize spray drift. The best drift management strategy and most effective way to reduce drift potential is to apply large droplets that provide sufficient coverage and control. Droplet size can be controlled by using high flow-rate nozzles, selecting the number and type of nozzles, nozzle orientation, and controlling pressure appropriate for the nozzle type.

Response to concern for aquatic invertebrates: The Sediment Impact Zone requires that impacts to benthic invertebrates do not exceed minor adverse effects. Sampling has been done in 2011, 2012 and 2014 to study these effects. The FEIS describes the results of these studies in section 2.8.3.5.

Sampling studies indicate the minor adverse effects threshold will not be exceeded in the area designated by Ecology as a SIZ. Ecology is requiring sampling and analysis under this permit to ensure that minor adverse effects to sediments and the benthic community do not occur. If any exceedances of minor adverse effects are confirmed during monitoring, Ecology will require adaptive management measures (which could include timing of imidacloprid application, changing areas to be sprayed, changing buffer zones around application, changing concentration or improving best management practices) with the permittee to reduce adverse effects. The probable likely net impact from these adaptive management measures will be to restrict spraying in areas where exceedances of minor adverse effects have occurred.

Field studies to date demonstrate that there is limited on-site impact to non-target aquatic invertebrates, and that this impact is transient. The use of efficient and accurate application methods over treated shellfish beds will mitigate impacts beyond the targeted areas. The strict specification on the accepted labeling, of rotating applications at least a year apart, will limit any effects to temporary and transient events. (CSI 2013, 8.11)

7. Columbia River Crab Fisherman's Association (Beasley)
   Comment: Support of a permit with an emphasis on the benefits of oyster beds on crab, water quality, the greater community, and the overall environment.

   Response: Comment noted.

8. Ocean Park Area Chamber of Commerce (Adams)
   Comment: We encourage you to expeditiously assist the shellfish industry in seeking appropriate solutions as part of their Integrated Pest Management program.

   Response: Comment noted.

9. Pacific Coast Shellfish Growers Association (Barrette)
   Comment: Support of a permit to include southern Willapa Bay and limited monitoring, with an emphasis on the economic benefit of aquaculture.

   Response: Refer to response #1.

10. Plauche & Carr LLP on behalf of the Willapa Bay Oyster Growers Association (WGHOGA)
    Comment: The letter submitted provided background information on the proposal with an emphasis on the benefits that shellfish aquaculture provides to the communities of Pacific County and Grays Harbor County.

    Response: Comment noted.

    Comment: The SIZ letter errs in failing to authorize a SIZ in southern Willapa Bay.

    Response: Refer to response #1.

    Comment: The “conditional” status of the Grays Harbor and northern Willapa Bay sediment impact zone (SIZ) authorizations should be removed.

    Response: The status of Grays Harbor and northern Willapa Bay will remain conditional. The Permit authorizes the SIZ and also provides a process to confirm the determination made by Ecology that for those areas the minor adverse effects threshold will not be exceeded. The additional SIZ conditions in Grays Harbor and northern Willapa Bay serve to emphasize the importance of gathering this information, to notify the oyster growers that management of this area is dependent upon collection of information to confirm the theory that application of imidacloprid does not exceed the minor adverse effects threshold outlined in the Sediment Management Standards (SMS), and to clarify the response of Ecology if the sampling results show an exceedance of the minor adverse effects threshold.

    Data has not been collected on the potential effects of imidacloprid application in Grays Harbor. The data collected to date for central Willapa Bay does not exceed the minor adverse effects threshold. Ecology has determined that extrapolating this data to Grays Harbor provides sufficient foundation to justify authorization of a SIZ, but extrapolating this data to Grays Harbor without confirmation sampling is inappropriate. Therefore Ecology is issuing a conditional SIZ, so there is a requirement to collect confirmational information for Grays Harbor. To the extent that the information shows an exceedance of the minor adverse effects threshold, it is clearly understood that Ecology may modify or rescind the permit and SIZ authorization.

A similar approach is being required for the northern Willapa Bay (Cedar River) area. Benthic tests conducted on experimental application of imidacloprid in 2011 in the Cedar River area exhibited more than a minor adverse effect based on Department of Ecology review. The specific reason(s) why the test exhibited more than a minor adverse effect is not known, and several variables could have affected the results. Since tests in northern Willapa Bay showed exceedances of minor adverse effect, the conditional status will remain and additional studies are required to begin in 2015. Based on the results, the conditional status may be lifted/changed/modified.

Comment: The Draft Permit monitoring requirements are unreasonable and must be revised.

Response: Regarding the sediment monitoring schedule.

a. Is required to verify imidacloprid application will not result in exceedances of the minor adverse effect threshold that ongoing monitoring for the entire span of the five year permit be required for both Grays Harbor and Willapa Bay. Although experimental trials have been conducted in Willapa Bay, ongoing full scale commercial application of 2000 acres per year over a five year period (as proposed in the permit) has not been conducted.
b. Requires sediment sampling for persistence beyond 28 days if results from the previous sampling event indicate it is necessary.
c. The Monitoring information supports adaptive management and changes to the spraying plan if necessary.

Response: Regarding the sediment benthic invertebrate monitoring.

Ecology has reviewed alternative proposals for sediment and benthic invertebrate monitoring. Ecology has found efficiencies which have reduced the estimated overall cost from over $1 million to approximately $500,000.

Comment: The maximum biological effects criteria in the Draft Permit are inappropriate and must be revised.

Response: Ecology recognizes WGHOGA's concerns about the use of the Puget Sound invertebrate maximum biological effects criteria. The Puget Sound Marine Criterion in the SMS is not directly applicable to Willapa Bay and Grays Harbor as these embayments are not located in Puget Sound. Ecology acknowledged that distinction, and determined that it was appropriate and justified for the agency to use the Puget Sound Marine Criterion, along with scientific literature, to develop an approach to interpret the non-Puget Sound marine narrative criteria in Willapa Bay (and by extension Grays Harbor). This approach combined recent scientific thinking and the Puget Sound criterion.

There is not adequate basis or rationale provided by WGHOGA to support Ecology deviating from the approach which the agency determined would best evaluate the health of the benthic community. In addition, adopting a different criteria at this stage would make results of the required future studies difficult to compare or interpret to previous data collected.

Comment: Propose that the Annual Operations Plan be submitted at least 14 days prior to the first treatment of the year instead of March 1st each year. This is because some of the growers may not know which beds they intend to treat by March 1st.

Response: The Annual Operations Plan may be revised/updated with justification.

Comment: The Willapa/Grays Harbor Oyster Growers Association request that GPS coordinates provided in the Annual Operations Plan be of the treated beds, not the precise area to be treated. This is because the precise area to be treated will depend on site specific conditions of the bed at the time of treatment.

Response: The Annual Operations Plan may be revised/updated with justification. It is understood that locations of acreage planned for treatment may change.

Comment: Provided appendices with the Integrated Pest Management Memorandum of Agreement, The Economic Impact of Shellfish Aquaculture in Washington, Oregon and California, and support from Hart Crowser, Inc. in support of previous comments.

Response: Information provided was informative.

11. Washington Farm Bureau (Stuhlmiller)
    Comment: Support of a permit to include southern Willapa Bay and limited monitoring, with an emphasis on the economic benefit of aquaculture.

    Response: Refer to response #1.

12. World Temperate Rainforest Network (Rasmussen)
    Comment: The World Temperate Rainforest Network would like to sign onto the attached comments submitted by the Xerces Society for Invertebrate Conservation.

    Response: Refer to response #13.

    Comment: The use of neonicotinoids is irresponsible given what we know about their tragic effect on honeybees.

    Response: Refer to response #6.

    Comment: Your proposal to use a pesticide that will impact invertebrates and reduce salmon that are eaten by orcas will mean more stress put on the orca population.

    Response: Imidacloprid would be unlikely to adversely affect salmonids or their critical habitat. (CSI 2013)

6.4.4 Fish
Eight laboratory toxicity studies of technical grade and formulations of imidacloprid on five species of marine/estuarine fish were identified by the search strategy described previously (Table 6.1). The studies ranged in length from 96 hours to 32 days. Imidacloprid has low toxicity to fish regardless of test species or duration. Toxicity studies on species that are resident in Willapa Bay and Grays Harbor indicate relatively low sensitivity to this product and reflect the results found with surrogate test organisms. (CSI 2013, page 26)

Additionally, with site specific information on spawning areas, it is possible to adjust treatment areas and timing through the Annual Operations Plan.

13. Xerces Society (Mazzacano)
Comment: The draft permit fails to confirm appropriate economic thresholds for burrowing shrimp.

Response: The economic threshold for burrowing shrimp has been included in the FEIS. Please refer to FEIS 1.4.

Comment: The draft permit fails to determine a method to accurately measure shrimp population density.

Response: Ecology is working with the WGHOGA in order to establish an appropriate method to ensure that shrimp burrows are accurately identified. However, burrow counts are used to determine the stability of the substrate and not the number of shrimp. Burrows are an indicator of shrimp density, related to effects on shellfish aquaculture.

Comment: The draft permit fails to institute integrated management methodologies in order to diminish reliance on a single control method.

Response: The draft permit will incorporate integrated pest management. Ecology is working with the WGHOGA and other agencies in order to revise and adapt IPM techniques.

Comment: Reference to “Worldwide Integrated Assessment on Systemic Pesticides” published in *Environmental Science and Pollution Research* with concern for non-target species and persistence.

Response regarding concern for non-target species: Balancing beneficial uses, Ecology recognizes that there could be limited impacts to non-target species and the permit conditions mitigate those potential impacts to the extent possible while still allowing for the beneficial use of shellfish aquaculture.

Ecology is requiring the best available testing and monitoring requirements from the SMS regulation to provide information about risks and potential effect to non-target benthic invertebrate species. To date experimental trials of imidacloprid have not shown significant impacts to non-target organisms. Sampling results have not exceeded the "minor adverse impacts" level in all but one sampling event. Testing data has shown that significant impacts have not been observed on the treated beds, and therefore won't be seen on or around the treated beds. (FEIS 2.8.3.5)

If any exceedances of minor adverse effects are confirmed during monitoring, Ecology will require adaptive management measures (which could include timing of imidacloprid application, changing areas to be sprayed, changing buffer zones around application, changing concentration or improving best management practices) with the permittee to reduce adverse effects. The probable likely net impact from these adaptive management measures will be to restrict spraying in areas where exceedances of minor adverse effects have occurred.

The potential effects of imidacloprid use for the control of burrowing shrimp in Willapa Bay and Grays Harbor have been studied extensively over the past six years. Studies have included investigations of chemical residues, laboratory and field toxicity using surrogate and local species, and biological field sampling under commercial use conditions. The overriding weight of evidence indicates that imidacloprid treatment will not significantly impact the endemic species or the ecology of these waters, and will not significantly impact human health. The use of imidacloprid in Willapa Bay and Grays Harbor will be limited in both timing and spatial scope. To reduce the impact of the burrowing shrimp species on shellfish production, these products will be used to treat targeted beds approximately once every 3 - 4 years on a rotating basis (although applications in consecutive years are allowed). Not all shellfish beds require treatment, dependent on the resident population of burrowing shrimp. There are approximately 45,000 acres of tidelands in Willapa Bay, with only 20% used for commercial shellfish (largely oysters and clams). In Grays Harbor, shellfish are grown commercially on only 3% of the 9,000 acres of tideland. These facts indicate that exposure will be significantly limited within the two water bodies. The Willapa Bay and Grays Harbor systems both experience significant flushing associated with daily tidal patterns, with major daily tidal fluctuations ranging between six and ten feet. This extensive water exchange is necessary for commercial shellfish production and provides several critical inputs into these environments. Tidal flows provide water dilution and movement, increasing opportunities for rapid dissipation of imidacloprid. Tidal changes also bring in water that is rich in nutrients and microorganisms, supporting more rapid metabolic breakdown of chemicals such as imidacloprid. This rapid breakdown and subsequent decline in concentrations is supported in multiple residue studies involving water and sediments associated with treated beds and adjacent channels. Based on these observations, exposures of non-target organisms to biologically active concentrations of imidacloprid would be significantly limited and brief. Numerous studies have been conducted on the effects of imidacloprid on estuarine and marine organisms. Results indicate that the majority of surrogate and endemic species are not sensitive to environmentally relevant concentrations of imidacloprid. This includes fish, mollusks, polychaetes and some crustaceans. Although there are some indications of toxicity to specific crustaceans, the impact is expected to be minor because of limited exposures and rapid re-colonization. Biological field trials were conducted on commercially treated oyster beds in Willapa Bay and Grays Harbor. Imidacloprid was found to have a limited impact on certain crustaceans on treated beds, although ecological indices showed minor, transient changes in the fauna on commercial oyster plots. Researchers believe that these data suggest a short-lived toxic effect on the most sensitive macro-invertebrates (primarily crustaceans) followed by a rapid recovery through product dissipation and re-colonization with tidal flushing. The proposed use of imidacloprid to treat burrowing shrimp in shellfish beds located in Willapa Bay and Grays Harbor is expected to have little or no impact on the local estuarine and marine species. (CSI 2013, page 7)

Response regarding concern for persistence: Persistence monitoring is an annual requirement in the permit.

Comment: The draft EIS has not provided sufficient information regarding the possible risks of imidacloprid. Therefore, Ecology has not justified the use of imidacloprid, especially on such an expanded acreage.

Response: A Risk Assessment was prepared for EPA prior to the registration of imidacloprid for use in Willapa Bay and Grays Harbor in order to control burrowing shrimp. Additionally, Ecology has developed an Environmental Impact Statement assessing potential impacts associated with imidacloprid applications in Willapa Bay and Grays Harbor, and the permit requires extensive monitoring.

This permit may be modified, revoked and reissued, or terminated if a determination that the permitted activity endangers human health or the environment, or contributes to water quality standards violations and can only be regulated to acceptable levels by permit modification or termination.

Comment: Larger studies should be done and included in the FEIS.

Response: Monitoring studies were done at a commercial rate in 2014 and showed that commercial applications in Willapa Bay did not violate that Sediment Management Standards. The final monitoring report is referenced in FEIS 2.8.3.5 and is in appendix E of the FEIS. Additionally, ongoing monitoring is a permit requirement.

Comment: Expresses the need to include specific elements in the Integrated Pest Management Program (IPM).

Response: Your suggestions are noted.

14. Gary Anderson

Comment: Has any effort been made to find a method of compaction to mechanically control burrowing shrimp?

Response: Various mechanical and non-chemical control methods have been tried as methods for controlling burrowing shrimp. These methods have either failed to control burrowing shrimp, are too impractical to implement on a commercial scale, or they significantly harm the shellfish crop and/or non-target species. Examples of these include sediment compaction, sediment alteration, and physical barriers. Therefore, IPM studies have shifted to a search for less toxic chemicals that are still effective at controlling burrowing shrimp. Imidacloprid has been identified through years of study and experimentation as a possible substitute for carbaryl.

A preliminary imidacloprid IPM Plan will be submitted to Ecology concurrent with issuance of the final NPDES permit. Growers propose to refine the imidacloprid IPM Plan over time based on what they learn from investigation and evidence gathered each year that applications are made (personal communication with WGHOGA, June 17, 2014). (FEIS 2.8.3.3)

Refer to FEIS Section 2.8.4 *Alternatives Considered and Eliminated from Detailed Evaluation*.

15. Bay Center Mariculture Co. (Wilson)

Comment: Informative comments on Dr. Wilson's background working within Willapa Bay, burrowing shrimp history, eelgrass, and their impacts to the environment. Dr. Wilson emphasized a need to maintain a healthy environment through an informed process.

Response: Comment noted.

Comment: Overall I think the serious damage to the nearshore habitat where the ghost shrimp take over, needs to be understood and proper actions taken to maintained at levels which do not eliminate valuable members of the biota. It seems regulations should be promulgated on the premise of helping maintain environmental productivity and not on how to keep control methods minimum or even eliminated because of perceived problems.

Response: Comment noted.

16. Ross Barkhurst

Comment: Concern for lack of WDFW and DNR input.

Response: WDFW and DNR both submitted comments. See comments and responses #46 and #47.

Comment: Concern for potential cumulative effects with imazamox.

Response: There are currently no known studies that address additive or synergistic effects of imidacloprid and imazamox. Imidacloprid and imazamox have completely different toxic modes of action; imidacloprid is a neonicotinoid insecticide that affects neural transmission in animals, and imazamox is an acetolactate synthesis (ALS) inhibitor which acts on a biochemical pathway that occurs in plants but not in animals. (FEIS 2.10.1)

Comment: Concern for salmon.

Response: Imidacloprid would be unlikely to adversely affect salmonids or their critical habitat. (CSI 2013)

6.4.4 Fish

Eight laboratory toxicity studies of technical grade and formulations of imidacloprid on five species of marine/estuarine fish were identified by the search strategy described previously (Table 6.1). The studies ranged in length from 96 hours to 32 days. Imidacloprid has low toxicity to fish regardless of test species or duration. Toxicity studies on species that are resident in Willapa Bay and Grays Harbor indicate relatively low sensitivity to this product and reflect the results found with surrogate test organisms. (CSI 2013, page 26)

Additionally, with site specific information on spawning areas, it is possible to adjust treatment areas and timing through the Annual Operations Plan.

Comment: Concern for avian species.

Response: Refer to response #3.

Comment: Concern for invertebrates.

Response: Refer to response #38.

Comment: Analysis and monitoring is prudent.

Response: Washington State currently has not promulgated any regulatory standards for Imidacloprid in either surface waters or sediments. Therefore, permit monitoring utilizing direct biological observation of benthic organisms is the only means Ecology has to verify compliance with the Sediment Management Standards (WAC 173-204) and assess the health of the benthic community throughout the term of the permit. Sampling and analysis costs of biological monitoring typically greatly exceed the costs of measuring a chemical concentration. Ecology strives to maintain a balance between monitoring benefits and monitoring cost, and believes that the proposed monitoring plan is a precautionary yet feasible solution.

Previous monitoring was done and is described in FEIS section 2.8.3.5.

Comment: Concern for Green Sturgeon.

Response: Refer to response #39.

17. Frank Bedell
Comment: Opposed to any application of pesticides/chemicals to Grays Harbor.

Response: Comment noted.

18. Jen-Jay, Inc. (Chris Betcher)
Comment: There needs to be other methods of mitigating for the detrimental effects of the native burrowing shrimp on the aquaculture of the non-native oysters and clams.

Response: The draft permit will incorporate integrated pest management. Ecology is working with the WGHOGA and other agencies in order to revise and adapt IPM techniques.

Comment: Opposed to the permit with concerns for pollinators.

Response: Refer to response #6.

Comment: Physical, not chemical, solutions to the problem need to be investigated.

Response: Refer to FEIS Section 2.8.4 *Alternatives Considered and Eliminated from Detailed Evaluation*.

19. Nancy Bischoff
Comment: As an owner of Willapa Bay land I do not want pesticides put into intertidal areas, the bay or onto the sediment lands.

Response: Comment noted.

20. Fritzi Cohen
Comment: I am totally opposed to this permit application and am in agreement with those critics who find the permit and sediment impact zone unsupported by scientific evidence.

Response: The Risk Assessment and Environmental Impact Statement both discuss the scientific literature and studies that were used to evaluate the proposal for the use of imidacloprid treatment to control burrowing shrimp. Additional monitoring will be required in the permit to further evaluate environmental impacts of imidacloprid applications.

This permit may be modified, revoked and reissued, or terminated if a determination that the permitted activity endangers human health or the environment, or contributes to water quality standards violations and can only be regulated to acceptable levels by permit modification or termination.

Comment: Request the information regarding the costs of past permits granted to the aquaculture industry and what the growers have paid. If an exemption regarding paying actual cost was determined I am asking that that information be provided, i.e. as to any legislation or policy that was developed to subsidize this permitting process.

Response: The Department of Ecology is proposing to provide approximately $200,000 from the State Toxics Control Account (STCA) to assist Washington State University with monitoring. The STCA is a fund established (RCW 70.105 D and RCW 82.21.030) from a thirty-three hundredths of one percent tax on hazard substances imported into Washington State. Monies from this account are commonly used to help fund important environmental projects or research.

Ecology is proposing to provide funding because we are interested in additional information about the effects of imidacloprid application in an estuary environment to be able to manage this practice.

Permits are not subsidized and the permittee is required to pay all statutory/regulatory fees associated with the permit.

Comment: Provided information on neonicotinoids from EARTH FOCUS and a link for additional information www.linktv.org/earthfocus or www.kcet.org/earth_focus.

Response: Comment noted.

21. Michael Goldberg
Comment: I am concerned about unmonitored potentially detrimental use of imidacloprid to oyster beds in Willapa Bay. This chemical can drift into other areas and may be harmful to human health.

Response: The proposed use of imidacloprid is not likely to result in adverse human health effects. Imidacloprid is not considered toxic to humans via dermal or inhalation exposure routes. It is designated an acute oral toxicant, but residues in fish and shellfish are below the detection limit and pose no threat even under conservative aggregate exposure scenarios. The subpopulations most vulnerable to dietary exposure— infants and children—are the least likely to consume high levels of fish and shellfish. This assessment also considered scenarios including population subgroups that are prone to higher levels of fish/shellfish consumption, but these did not alter the conclusions reached in this risk assessment. Applicators inherently face the possibility of acute exposure, particularly in the event of an accidental dose. The label instructions require that applicators wear protective equipment beyond US EPA Human Effects Division's (HED's) more conservative expectations (e.g. applicators of the granular formulation must wear dust masks during application). All of HED's applicator scenarios resulted in Margins of Exposure (MOEs) "not of concern," when applicators wore gloves. As the formulation labels restrict usage to a single application per year, there is no risk of chronic or subchronic exposure to handlers or other groups. (CSI 2013, page 8)

Under current labels, effects on human health as a result of residential, dietary, or occupational exposure appear to be low as a result of the low application rates relative to the toxicity of imidacloprid and to the rates and exposures generated from other registered uses. There is sufficient data on the chemistry, fate, toxicity, and exposure to conclude that adverse effects to human health due to imidacloprid are not expected if label directives are followed. (CSI 2013, page 76)

Additionally, the permit has monitoring requirements to further evaluate environmental impacts of imidacloprid applications, and Ecology staff will be monitoring applications to ensure permit compliance.

22. Daniel Graf
Comment: Opposed to the permit with concern for pollinators.

Response: Refer to response #6.

Comment: Opposed to the permit with concern for salmon.

Response: Imidacloprid would be unlikely to adversely affect salmonids or their critical habitat. (CSI 2013)

6.4.4 Fish
Eight laboratory toxicity studies of technical grade and formulations of imidacloprid on five species of marine/estuarine fish were identified by the search strategy described previously (Table 6.1). The studies ranged in length from 96 hours to 32 days. Imidacloprid has low toxicity to fish regardless of test species or duration. Toxicity studies on species that are resident in Willapa Bay and Grays Harbor indicate relatively low sensitivity to this product and reflect the results found with surrogate test organisms. (CSI 2013, page 26)

Additionally, with site specific information on spawning areas, it is possible to adjust treatment areas and timing through the Annual Operations Plan.

Comment: It's time we look at more sustainable practices, or we'll pay the consequences in food supply, and with our health, later.

Response: Comment noted.

23. Warren Huntsinger
Comment: Concern for long term effects.

Response: The Sediment Impact Zone requires that impacts to benthic invertebrates do not exceed minor effects. Sampling has been done in 2011, 2012 and 2014 to study these effects. The FEIS describes the results of these studies in section 2.8.3.5.

Sampling studies indicate the minor adverse effects threshold will not be exceeded in the area designated by Ecology as a SIZ. Ecology is requiring sampling and analysis under this permit to ensure that minor adverse effects to sediments and the benthic community do not occur. If any exceedances of minor adverse effects are confirmed during monitoring, Ecology will require adaptive management measures (which could include timing of imidacloprid application, changing areas to be sprayed, changing buffer zones around application, changing concentration or improving best management practices) with the permittee to reduce adverse effects. The probable likely net impact from these adaptive management measures will be to restrict spraying in areas where exceedances of minor adverse effects have occurred.

Field studies to date demonstrate that there is limited on-site impact to non-target aquatic invertebrates, and that this impact is transient. The use of efficient and accurate application methods over treated shellfish beds will mitigate impacts beyond the targeted areas. The strict specification on the accepted labeling, of rotating applications at least a year apart, will limit any effects to temporary and transient events. (CSI 2013, 8.11)

Comment: Concern for pollinators.

Response: Refer to response #6.

Comment: Suggest the stake culture instead of chemicals.

Response: Refer to response #26.

24. Jane Lindley

Comment: Opposed to the permit.

Response: Comment noted.

Comment: Concern for pollinators.

Response: Refer to response #6.

Comment: Concern for non-targeted marine life.

Response: Refer to response #13.

25. Kristen Long

Comment: Opposed to the permit with concern for non-target species.

Response: Refer to response #13.

26. Brent Naylor

Comment: Concern for long term effects.

Response: Refer to response #23.

Comment: Concern for breakdown products.

Response: Eight imidacloprid degradation products have been identified as a result of imidacloprid hydrolysis, photolysis, and soil and microbial degradation. Two of these degradation compounds, imidacloprid olefin, and 5-hydroxy imidacloprid were identified by EPA as being of interest due to potential toxicity. One of these degradates, imidacloprid-olefin, was analyzed during 2012 research efforts (Grue & Grassley 2013; Hart Crowser 2013). Of the samples analyzed for imidacloprid olefin concentrations, less than 20 percent resulted in detectable concentrations of imidacloprid-olefin and these ranged from 0.08 to 3.6 ppb. Imidacloprid-olefin was found in surface water, sediments, and sediment porewater; it was undetectable in eelgrass tissue. Despite numerous attempts, the necessary laboratory standards to test for 5-hydroxy imidacloprid could not be found or synthesized. Subsequent analysis suggests that this degradation product is likely unstable and has a very short half-life in the environment (Hart Crowser 2012). (FEIS 2.8.3.6)

Studies have shown that imidacloprid has eight degradation products as a result of hydrolysis, photolysis, and soil and microbial degradation. These degradation products include: imidacloprid-olefin, 5-hydroxyimidacloprid, imidacloprid-nitrosimine, imidacloprid-guanidine, imidacloprid-urea, 6-chloronicotinic acid, imidacloprid-guanidine-olefin, and acyclic derivative. The toxicity levels of all the degradation products are equal to or lower than the toxicity of the parent compound (SERA 2005). (FEIS 3.2.3.2)

Comment: Concern for pollinators.

Response: Refer to response #6.

Comment: There are alternatives such as stake culture.

Response: Commercial shellfish growers have been investigating alternative methods for burrowing shrimp control since the 1950s. These have included mechanical means, alternative shellfish culture methods, a variety of chemical applications, and biological controls, none of which has proven to be as effective, reliable, economical, or more species-specific than carbaryl or imidacloprid applications administered with adaptive management principles.

Some of the methods tried can be found in *An Updated Plan for Integrated Pest Management of Burrowing Shrimp on Commercial Shellfish Beds* (Booth 2010). Additionally, the FEIS discusses alternatives considered in section 2.8.4.

27. Kate O'Neal
    Comment: Opposed to the permit.

    Response: Comment noted.

28. Michael Parker
    Comment: Support of a permit to include southern Willapa Bay, with an emphasis on the economic benefit of aquaculture.

    Response: Refer to response #1.

29. Brian Sheldon
    Comment: Support of a permit to include southern Willapa Bay and limited monitoring, with an emphasis on the economic benefit of aquaculture.

    Response: Refer to response #1.

    Comment: Clarification of the submittal of the Sediment and Analysis Plan and the Sediment Data Report.

    Response: The permit states that the SAP will be submitted in the Annual Operations Plan (S4.D.) and that the Sediment Data Report will be submitted in the Annual Report (S4.E.).

30. Katherine Smith
    Comment: Support of a permit to include southern Willapa Bay and limited monitoring, with an emphasis on the economic benefit of aquaculture.

    Response: Refer to response #1.

    Comment: Shellfish farmers put significant resources toward protecting habitat and these actions should be considered an ecological public service.

    Response: Comment noted.

31. Keith Stavrum
    Comment: Opposed to the permit.

    Response: Comment noted.

32. Max Ventura
Comment: Please feel free to use my personal account after carbaryl exposure.

Response: Comment noted.

33. Larry Warnberg
Comment: The use of an aquatic pesticide to kill native shrimp to protect non-native oyster culture should not be permitted.

Response: Comment noted.

Comment: There is currently no reliable measure of shrimp density.

Response: Ecology is working with the WGHOGA in order to establish an appropriate method to ensure that shrimp burrows are accurately identified. Burrow count are used to determine the stability of the substrate and not the number of shrimp.

Comment: There are proven effective non-chemical alternatives available to shellfish growers.

Response: Commercial shellfish growers have been investigating alternative methods for burrowing shrimp control since the 1950s. These have included mechanical means, alternative shellfish culture methods, a variety of chemical applications, and biological controls, none of which has proven to be as effective, reliable, economical, or more species-specific than carbaryl or imidacloprid applications administered with adaptive management principles.

Comment: No published evidence supports the claim that shrimp populations have increased.

Response: Dr. Dumbauld's most recent studies are referenced in the Final Environmental Impact Statement and can be found in FEIS 3.1.

Some of the methods tried can be found in *An Updated Plan for Integrated Pest Management of Burrowing Shrimp on Commercial Shellfish Beds* (Booth 2010). Additionally, the FEIS discusses alternatives considered in section 2.8.4.

Comment: The time restriction is too wide. Spraying could occur right up to the moment the tide floods over a treated area, greatly increasing the risk of off-site drift with the current.

Response: Monitoring studies have been done to understand the fate of imidacloprid in the marine aquatic environment. These studies are discussed in FEIS 2.8.3.5.

Additionally, the permit requires annual monitoring of water, sediment, and benthic invertebrates.

If any exceedances of minor adverse effects are confirmed during monitoring, Ecology will require adaptive management measures (which could include timing of imidacloprid application, changing areas to be sprayed, changing buffer zones around application, changing concentration or improving best management practices) with the permittee to reduce adverse effects. The probable likely net impact from these adaptive management measures will be to restrict spraying in areas where exceedances of minor adverse effects have occurred.

This permit may be modified, revoked and reissued, or terminated if a determination that the permitted activity endangers human health or the environment, or contributes to water quality standards violations and can only be regulated to acceptable levels by permit modification or termination.

Comment: Who will pay for the permit, how much, and will the Growers again be exempted from paying the actual cost of developing and issuing the proposed permit?

Response: Permit coverage fees are set by rule and can be found in WAC 173-224-040.

Comment: I strongly support the restriction in the south half of Willapa Bay.

Response: Comment noted.

34. Carole Wiegardt
    Comment: Support of the permit with emphasis on economic, historical, and environmental reasons.

    Response: Comment noted.

35. Cris Wiegardt
    Comment: Support of the permit.

    Response: Comment noted.

36. Michael Williams
    Comment: Against the spraying of chemicals in Willapa Bay.

    Response: Comment noted.

37. Steve and Vicki Wilson
    Comment: Support of a permit to include southern Willapa Bay and limited monitoring, with an emphasis on the economic benefit of aquaculture.

Response: Refer to response #1.

38. Elise Wright
    Comment: Opposed to the permit.

    Response: Comment noted.

    Comment: Concern for consumers.

    Response: Refer to response #21.

    Comment: Concern for avian species.
    Response: Refer to response #3.

    Comment: Concern for invertebrates.

    Response: The Sediment Impact Zone requires that impacts to benthic invertebrates do not exceed minor effects. Sampling has been done in 2011, 2012 and 2014 to study these effects. The FEIS describes the results of these studies in section 2.8.3.5.

    Sampling studies indicate the minor adverse effects threshold will not be exceeded in the area designated by Ecology as a SIZ. Ecology is requiring sampling and analysis under this permit to ensure that minor adverse effects to sediments and the benthic community do not occur. If any exceedances of minor adverse effects are confirmed during monitoring, Ecology will require adaptive management measures (which could include timing of imidacloprid application, changing areas to be sprayed, changing buffer zones around application, changing concentration or improving best management practices) with the permittee to reduce adverse effects. The probable likely net impact from these adaptive management measures will be to restrict spraying in areas where exceedances of minor adverse effects have occurred.

    Field studies to date demonstrate that there is limited on-site impact to non-target aquatic invertebrates, and that this impact is transient. The use of efficient and accurate application methods over treated shellfish beds will mitigate impacts beyond the targeted areas. The strict specification on the accepted labeling, of rotating applications at least a year apart, will limit any effects to temporary and transient events. (CSI 2013, 8.11)

39. National Oceanic and Atmospheric Administration (Hooper)
    Comment: Believe that we should reduce the proposed acreage to 800 acres total because there are too many unknowns regarding impact to other aquatic and terrestrial biota.

    Response: Comment noted.

Comment: Request that the 2014 data report be available for public review and comment prior to permit issuance. Additionally, believe that the data from the report could have altered the subsequent FEIS and Fact Sheet and would result in sufficiently protected public aquatic resources.

Response: Ecology's evaluation and the report are in FEIS Appendix E.

Comment: Request data regarding recent burrowing shrimp recruitment from Dr. Dumbauld.

Response: Dr. Dumbauld's most recent studies are referenced in the Final Environmental Impact Statement in FEIS 3.1.

Comment: Request previous water quality monitoring reports.

Response: These reports have been sent to National Oceanic and Atmospheric Administration employee Thomas Hooper.

Comment: State that the burrowing shrimp are native to these waters and play an important role in the natural ecosystem.

Response: Refer to FEIS 3.1.

Comment: Concern for the green sturgeon.

Response: Toxicity studies on species that are resident in Willapa Bay and Grays Harbor indicate relatively low sensitivity to imidacloprid and reflect the results found with surrogate test organisms such as the white sturgeon.

6.4.4 Fish

Eight laboratory toxicity studies of technical grade and formulations of imidacloprid on five species of marine/estuarine fish were identified by the search strategy described previously (Table 6.1). The studies ranged in length from 96 hours to 32 days. Imidacloprid has low toxicity to fish regardless of test species or duration. Toxicity studies on species that are resident in Willapa Bay and Grays Harbor indicate relatively low sensitivity to this product and reflect the results found with surrogate test organisms. (CSI 2013, page 26)

Additionally, with site specific information on spawning areas, it is possible to adjust treatment areas and timing through the Annual Operations Plan.

This is listed as an uncertainty in the FEIS. (FEIS 1.7) Imidacloprid has a limited effect on large vertebrates, and only when high concentrations are ingested directly.

Imidacloprid applications would occur in shallow water or on exposed mudflats, when sturgeon are unlikely to be present over commercial shellfish beds. (FEIS 3.2.5.3)

Comment: Concern for impacts to a prey resource in the designated critical habit for green sturgeon.

Response: Imidacloprid applications would be unlikely to adversely affect green sturgeon foraging habitat due to the limited area where imidacloprid would be applied relative to the size of Willapa Bay and Grays Harbor. (FEIS 3.2.5.3)

Comment: Concern zooplankton.

Response: Imidacloprid would be applied on selected commercial shellfish beds in-water during out-going tides or on exposed mudflats, when densities of zooplankton would be low due to limited water depth. Imidacloprid breaks down rapidly in water and has a low volatilization potential in air, minimizing potential adverse effects on zooplankton in Willapa Bay or Grays Harbor (Gervais et al. 2010). (FEIS 3.2.5.3)

Comment: Concern for salmon and forage fish.

Response to concern for salmon: Imidacloprid would be unlikely to adversely affect salmonids or their critical habitat. (CSI 2013)

6.4.4 Fish

Eight laboratory toxicity studies of technical grade and formulations of imidacloprid on five species of marine/estuarine fish were identified by the search strategy described previously (Table 6.1). The studies ranged in length from 96 hours to 32 days. Imidacloprid has low toxicity to fish regardless of test species or duration. Toxicity studies on species that are resident in Willapa Bay and Grays Harbor indicate relatively low sensitivity to this product and reflect the results found with surrogate test organisms. (CSI 2013, page 26)

Additionally, with site specific information on spawning areas, it is possible to adjust treatment areas and timing through the Annual Operations Plan.

Response to concern for forage fish: It is unlikely that there would be adverse effects to forage fish or groundfish from imidacloprid in water (CSI 2013) due to dilution, adsorption onto sediment, and application during low tide conditions. Additionally, imidacloprid would be unlikely to have a significant adverse effect on forage fish or groundfish in Willapa Bay and Grays Harbor due to the relatively small proportion of tidelands within each estuary that would be treated for the control of burrowing shrimp.

Comment: Concern for persistence in sediments.

Response: Sediment monitoring will be required annually to identify any areas of persistence.

Comment: Concern that the Puget Sound regulations are sufficient.

Response: The Puget Sound Marine Criterion in the Sediment Management Standards (SMS) is not directly applicable to Willapa Bay and Gray's Harbor as these embayments are not located in Puget Sound. However, the criterion was considered, along with recent scientific literature, in developing the approach for interpreting the non-Puget Sound marine narrative criteria in Willapa Bay.

The SMS and the research and rationale developed and used that provide the basis for the SMS are the primary wealth of institutional knowledge and the best known, developed and utilized criteria for this type of proposal. There is not adequate basis or rationale provided to deviate from the protocols that have been used for many years, and in fact to do so may set a poor precedent and make results difficult to compare or interpret to previous data collected.

Comment: Gave opportunity for grants to encourage alternative practices.

Response: Ecology welcomes grant opportunities and will incorporate consideration of alternative practices during IPM.

40. Nisqually Tribe (Shotwell)
Comment: Support of a permit that allows for shrimp control for the entirety of Willapa and Grays Harbor.

Response: Comment noted. Refer to response #1.

41. Pacific County Commissioners (Rogers, Wolfe, Ayers)
Comment: Support of a permit.

Response: Comment noted.

42. Shoalwater Bay Tribe (Davis)
Comment: Concern for monitoring water quality away from the application site.

Response: There is required water quality monitoring away from the application site in order to monitor fate and transport. Refer to permit condition S4.A.

Comment: Concern for additive effects from multiple treatment areas.

Response: The permit requires persistence sampling every year. Refer to permit condition S4.F.

Comment: Concern for impact on marine fauna.

Response: Refer to response #13.

Comment: Concern for green sturgeon.

Response: Refer to response #39.

Comment: Concern for lack of information in a marine environment.

Response: The Risk Assessment and Environmental Impact Statement both discuss the scientific literature and studies that were used to evaluate the proposal for the use of imidacloprid treatment to control burrowing shrimp. Additional monitoring will be required in the permit to further evaluate environmental impacts of imidacloprid applications.

This permit may be modified, revoked and reissued, or terminated if a determination that the permitted activity endangers human health or the environment, or contributes to water quality standards violations and can only be regulated to acceptable levels by permit modification or termination.

43. United States Fish and Wildlife Service (USFWS) (Quackenbush on behalf of McReynolds)
Comment: There is not a current permit for the application of carbaryl to commercial shellfish beds in Willapa Bay and Grays Harbor.

Response: The individual permit for the control of burrowing shrimp using carbaryl on oyster beds in Willapa Bay and Grays Harbor remains in effect.

Comment: Support of the no action alternative.

Response: Comment noted.

Comment: Opposed to imidacloprid permit due to lack of scientific information regarding fate and transport, efficacy, persistence, and effects to non-target organisms. Believe that the research findings indicate that effects and damages will not be limited to the treatment sites.

Response: Refer to response #13.

Comment: Alternative methods should be given fair and equal consideration.

Response: The draft permit will incorporate integrated pest management. Ecology is working with the WGHOGA and other agencies in order to revise and adapt IPM techniques.

Comment: Question regarding recent recruitment.

Response: Dr. Dumbauld's most recent studies are referenced in the Final Environmental Impact Statement in FEIS 3.1.

Comment: Question regarding the burrowing shrimp threshold.

Response: The economic threshold for burrowing shrimp has been included in the FEIS. Please refer to FEIS 1.4.

Comment: Request results for 2014 field trials.

Response: Ecology's evaluation and the report are in FEIS Appendix E.

Comment: Concern regarding native predators of shrimp with specific concern for sturgeon.

Response: Refer to response #39.

Comment: USFW Service disagrees with the claim that shrimp control improves biodiversity.

Response: Increased densities of burrowing shrimp could result in decreased biodiversity and increased sedimentation (Dumbauld and Wyllie-Echeverria 1997; Colin et al. 1986). High densities of burrowing shrimp have been associated with lower numbers of Dungeness crab, oysters, and other shellfish due to competitive exclusion and habitat modification caused by the shrimp (Doty et al. 1990; Brooks 1995; Dumbauld and Wyllie- Echeverria 1997). (FEIS 3.2.5.3)

Comment: Do not support control of mixed beds of native and non-native eel grass.

Response: Imidacloprid is an acetylcholinase inhibitor and plants do not have a biochemical pathway involving acetylcholinase. Therefore, it is unlikely that imidacloprid would adversely affect eelgrass or other marine vegetation (FEIS Chapter 3, Section 3.2.4). (FEIS 1.7)

Imidacloprid applications are not intended to control eelgrass.

Comment: Do not agree that significant alterations to the bay wide ecosystem would occur without burrowing shrimp control. Chemical control methods represent an intrusive alteration and may have unintended consequences. Additionally, USFW Service disagrees that no significant adverse impacts would be expected with proposed alternative 2 or 3.

Response: Comment noted.

Comment: USFW Service believes that the proposed permit and SIZ cannot be implemented without significant adverse impacts.

Response: Comment noted.

Comment: USFW Service disagrees that a finding of no significant and adverse impact can be justified for plants.

Response: Limited information is available regarding imidacloprid impacts to marine vegetation. The results of field studies conducted during one season to evaluate uptake in eelgrass tissues showed limited uptake by eelgrass, and imidacloprid was undetectable after 14 days. In addition, imidacloprid is an acetylcholinase inhibitor and plants do not have a biochemical pathway involving acetylcholinase. Therefore, it is unlikely that imidacloprid would adversely affect eelgrass or other marine vegetation (FEIS Chapter 3, Section 3.2.4). (FEIS 1.7)

Comment: Disagrees with our description of bull trout presence in Willapa Bay and Grays Harbor.

Response: Comment noted.

Comment: Disagrees with our description of snowy plover distribution and habitat use.

Response: Comment noted.

Comment: Concern regarding ESA listed species and their critical area habitats.

Response: Issuance of this permit is not a Federal agency action subject to the ESA's consultation provisions.

Issuance of a NPDES permit by Ecology is not subject to ESA consultation with the National Marine Fisheries Service or the U.S. Fish and Wildlife Service. However, obtaining coverage under an NPDES Individual Permit does not exempt a permit holder from the "take" provisions of the ESA. "Take" means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or attempt to engage in such conduct with respect to a species listed under ESA (16 U.S. C. Section 1532 [19]). Potential impacts to species listed under the ESA are addressed in FEIS Chapter 3, Section 3.2.5.

Comment: The draft permit proposes inadequate treatment buffers.

Response: Permit buffers are consistent with criteria from EPA's registration.

Comment: Without a valid current incidental take permit or statement addressing the effects of this practice on listed species parties engaging in aquatic application of imidacloprid lack ESA coverage.

Response: Refer to the previous response regarding the Endangered Species Act.

Comment: Attachment B fails to identify the U.S. Department of the Interior U.S. Fish and Wildlife Service as a landowner.

Response: The referenced appendix was part of the application submitted by WGHOGA. Ecology recognizes the U.S. Department of the Interior U.S. Fish and Wildlife Service as a landowner.

Comment: Eelgrass represents a potentially significant exposure pathway for a variety of wildlife species.

Response: Limited information is available regarding imidacloprid impacts to marine vegetation. The results of field studies conducted during one season to evaluate uptake in eelgrass tissues showed limited uptake by eelgrass, and imidacloprid was undetectable after 14 days. In addition, imidacloprid is an acetylcholinase inhibitor and plants do not have a biochemical pathway involving acetylcholinase. Therefore, it is unlikely that imidacloprid would adversely affect eelgrass or other marine vegetation (FEIS Chapter 3, Section 3.2.4). (FEIS 1.7)

Comment: Concern for sub-lethal impacts

Response: There are approximately 45,000 acres of tidelands in Willapa Bay, with only 20% used for commercial shellfish (largely oysters and clams). In Grays Harbor, shellfish are grown commercially on only 3% of the 9,000 acres of tideland. Imidacloprid applications would only be on a small percentage of the water bodies, limiting exposure.

The permit would require annual monitoring and closure of the SIZ's to ensure recovery of the sediment and benthic organisms.

Comment: Concern for birds.

Response: Refer to response #3.

Comment: Without a valid, current incidental take permit or statement addressing the effects of this practice on listed species, parties engaging in aquatic application of imidacloprid lack ESA coverage.

Response: Refer to previous response regarding ESA coverage.

Comment: A decision to issue the permit and authorize SIZs while relevant and important data remain unavailable would be premature. We recommend that Ecology should continue limited field trials under the Experimental Use Permit. We do not support the issuance of an individual NPDES permit at this time and we oppose the authorization of SIZs in Willapa Bay and Grays Harbor.

Response: Commercial size monitoring studies conducted in 2014 support previous field trials and are referenced in FEIS section 2.8.3.5, and included in FEIS appendix E.

44. United States Department of Agriculture – Agriculture Research Service (Dumbauld)
Comment: DEIS reference on page 1-8 should be Dumbauld et al 2006 not Dumbauld et al 2001.

Response: This change was made in the FEIS.

Comment: Unclear why there is a difference between the description measures for Alternative 2- carbaryl and Alternative 3 –imidacloprid for NPDES permit requirements.

Response: Because this is a new use pattern for imidacloprid and less is known regarding its effects in this type of environment.

Comment: DEIS reference on page 2-29 should be Dumbauld et al 2001 not Dumbauld et al 1997.

Response: This change was made in the FEIS.

Comment: The McCauley et al reference is not in the literature cited.

Response: It is now cited in the FEIS.

Comment: Disagrees with the statement in the DEIS on page 2-29 that burrowing shrimp can be slow to recolonize.

Response: This has been removed from the FEIS.

Comment: Need to update statements about salmonid exposure to carbaryl.

Response: Waiting for studies.

Comment: DEIS page 2-55 should state red rock crabs instead of red crabs.

Response: This has been changed in the FEIS.

Comment: We now think that ghost shrimp can live up to 13 years.

Response: The FEIS states that ghost shrimp can live up to 13 years.

Comment: The statement citing McCrow about multiple broods (three to four) is unlikely.

Response: This has been deleted from the FEIS.

Comment: Mud shrimp do not necessarily delay reproduction until their third year.

Response: This has been deleted from the FEIS.

Comment: Post-larvae settle to the bottom in spring to early summer.

Response: The language in the FEIS has been changed to reflect this.

Comment: The last paragraph on page 3-4 cites Hosack et al 2006 for burrowing shrimp effects on eelgrass should be deleted.

Response: This has been deleted from the FEIS.

Comment: The depth range on page 3-27 is not accurate for Willapa Bay.

Response: This has been deleted from the FEIS.

Comment: The statement that "these population cycles have not been correlated to specific environmental or biological factors" is not true.

Response: This has been deleted from the FEIS.

Comment: What is the purpose of repeatedly monitoring the effects of imidacloprid applications?

Response: Ecology has developed a monitoring plan over the five year span of the permit to provide cost-effective monitoring. Ecology developed the first year of monitoring to provide the most information possible to be used to design the subsequent years of monitoring. Additional benthic analysis is being conducted every other year to provide a better time span for information collection. We agree that collecting the same information every year may be redundant. Hence the every other year approach. Water Quality data is being collected every year of the permit. Monitoring the effects of pesticide application needs to be completed on a regular basis.

45. Washington State Department of Agriculture (McLain)
    Comment: Multiple changes in language in the Fact Sheet and DEIS in order to provide clarity.

    Response: We agree with these changes in language. The Fact Sheet cannot be modified and the changes regarding the DEIS will be incorporated in the FEIS. Please refer to the comments from the Washington State Department of Agriculture for specifics, as the list of changes is numerous. Their comments can be found at http://www.ecy.wa.gov/programs/wq/pesticides/imidacloprid/commentsDec2014.html.

46. Washington State Department of Fish and Wildlife (Culver)
    Comment: Would like to see a sustainable ecologically base IPM plan.

    Response: The draft permit will incorporate integrated pest management. Ecology is working with the WGHOGA and other agencies to develop an IPM strategy.

    Comment: Concern for sublethal effects, trophic impacts, and bioaccumulation effects.

    Response: Limited information in marine environments is available regarding the possible sub-lethal effects of imidacloprid on non-target aquatic organisms. Ultimately, burrowing shrimp are controlled through sublethal effects. Review of future studies will be conducted to further determine the potential long-term sublethal effects of imidacloprid on animals in the aquatic environment.

7.4 Bioconcentration and bioaccumulation
Concentrations of imidacloprid in aquatic invertebrates and fish can be estimated assuming that tissue concentrations are in equilibrium with water concentrations. Imidacloprid has a low octanol-water partition coefficient (log Kow = 0.57), indicating a low potential for bioaccumulation. Indeed, because of the low log Kow, EPA has not required a bioconcentration study for imidacloprid. The log Kow is below the minimum value required for EPA's Kabam bioaccumulation model. Assuming that imidacloprid is taken up from the water column or interstitial water rapidly, an estimate of residue concentrations in fish and invertebrate tissues would be the same as the maximum concentration in the on-bed treated water,
470 μg/L (Table 7.5). (CSI 2013)

Comment: Concern for Dungeness crab and finfish.

Response: Imidacloprid applications at the permitted concentration of 0.5 lb active ingredient per acre would not cause direct mortality in Dungeness crab, fish, or birds (CSI 2013).

Comment: Concern for aerial drift with a preference for granular application because it is more strategic.

Response: FIFRA Registration spray drift management techniques would become conditions of the NPDES permit for the use of imidacloprid:

- Average wind speed at the time of application shall not exceed 10 mph when either Protector 0.5G or 2F is applied by air. Further, aerial applications shall not occur during gusty conditions, or during temperature inversions. Temperature inversions begin to form as the sun sets and often continue into the morning.
- Applications of imidacloprid shall be made at the lowest possible height (helicopter, ground or barge) that is safe to operate and that would reduce exposure of the granules to wind.
- When applications of Protector 0.5G (the granular formulation) are made crosswind, the applicator must compensate for displacement by adjusting the path of the application equipment upwind. Swath adjustment distance should increase with increasing drift potential.
- Helicopters used to apply Protector 2F should be equipped to minimize spray drift. The best drift management strategy and most effective way to reduce drift potential is to apply large droplets that provide sufficient coverage and control. Droplet size can be controlled by using high flow-rate nozzles, selecting the number and type of nozzles, nozzle orientation, and controlling pressure appropriate for the nozzle type.

Comment: They are not opposed although would like their concerns noted for the record.

Response: Comment noted.

47. Washington Department of Natural Resources (Niles)
Comment: DNR recognizes the need for the shellfish industry to control burrowing shrimp and supports their effort to do so in a responsible manner.

Response: Comment noted.

Comment: Burrowing shrimp are a food source for green and white sturgeon and gray whales.

Response: Comment noted.

Comment: We believe that the DEIS has not adequately addressed important considerations regarding the use of imidacloprid.

Response: The DEIS was written based on the best available science and the results of monitoring activities. Additionally, annual monitoring is required in the permit.

48. Washington State Long Beach Research and Extension Unit (Patten)
Comment: Provided information on tidal residence time in Willapa Bay.

Response: Ecology has reviewed Dr. Patten's comment and believes that tidal dilution and tidal residence time may be less of a factor on pesticide effect than total organic carbon content of sediments. Poor circulation is still a greater factor in southern Willapa Bay than in central and northern Willapa Bay and Grays Harbor. Ecology's position is that a combination of factors including potentially poorer dilution and higher TOC warrant a more conservative approach be taken toward pesticide application in southern Willapa Bay. This, coupled with limited data on southern Willapa Bay, all contribute to Ecology's decision to take a conservative approach towards managing this area.

Public Hearing Comments Transcribed in order presented.

49. Keith Stavrom
Comment: Concern for Willapa Bay and for the characterization that it is a chemical soup.

Response: Comment noted.

Comment: Concern for green sturgeon.

Response: Refer to response #39.

50. Terry Larson
    Comment: Against pesticides being sprayed in the water to control burrowing shrimp.

    Response: Comment noted.

    Comment: Would like us to be aware of elevated cancer in Grays Harbor and Pacific Counties and a potential connection to carbaryl.

    Response: Comment noted.

51. Larry Warnberg
    Comment: Has farmed oysters using off-bottom culture and believes that it is unnecessary and unwise for the growers to pursue this permit.

    Response: Comment noted.

52. Jacob Moore
    Comment: Concerned for the conditional zone in the northern part of Willapa Bay due to some really productive oyster beds bordered by some really intense ghost shrimp infestations. Additionally, emphasized his observations of beds with high shrimp populations having a reduction in biodiversity.

    Response: Refer to response #10.

53. Ross Barkhurst
    Comment: Does not feel that Ecology workshops serve their purpose.

    Response: Comment noted.

    Comment: Is concerned for fish and waterfowl.

    Response concerning fish: It is unlikely that there would be adverse effects to forage fish or groundfish from imidacloprid in water (CSI 2013) due to dilution, adsorption onto sediment, and application during low tide conditions. Additionally, imidacloprid would be unlikely to have a significant adverse effect on forage fish or groundfish in Willapa Bay and Grays Harbor due to the relatively small proportion of tidelands within each estuary that would be treated for the control of burrowing shrimp.

Response concerning waterfowl: Refer to response #3.

Comment: Believes that the monitoring is weak.

Response: Washington State currently has not promulgated any regulatory standards for Imidacloprid in either surface waters or sediments. Therefore, permit monitoring utilizing direct biological observation of benthic organisms is the only means Ecology has to verify compliance with the Sediment Management Standards (WAC 173-204) and assess the health of the benthic community throughout the term of the permit. Sampling and analysis costs of biological monitoring typically greatly exceed the costs of measuring a chemical concentration. Ecology strives to maintain a balance between monitoring benefits and monitoring cost, and believes that the proposed monitoring plan is a precautionary yet feasible solution.

54. Eric Hall

Comment: Support of issuing the permit to control burrowing shrimp in Willapa Bay and Grays Harbor. Emphasis on the economic input from the shellfish industry and the employment provided. Believes that it is highly critical to our farming operations, our business, and our employees, to have the ability to control burrowing shrimp on our shellfish beds.

Response: Comment noted.

55. Kim Patten

Comment: Does not think that it is acceptable to have exclusion or conditional zones because of high organic sediments and/or low flows within some parts of those areas.

Response: Refer to responses #1 and #10.

Comment: There needs to be a dialog with Ecology to look at the monitoring and what is needed to satisfy the Washington Administrative Codes yet still be practical, feasible, and technically cost effective.

Response: Washington State currently has not promulgated any regulatory standards for Imidacloprid in either surface waters or sediments. Therefore, permit monitoring utilizing direct biological observation of benthic organisms is the only means Ecology has to verify compliance with the Sediment Management Standards (WAC 173-204) and assess the health of the benthic community throughout the term of the permit. Sampling and analysis costs of biological monitoring typically greatly exceed the costs of measuring a chemical concentration. Ecology strives to maintain a balance between monitoring benefits and monitoring cost, and believes that the proposed monitoring plan is a precautionary yet feasible solution.

Monitoring requirements for this permit are based on the Sediment Management Standards and the obligation of the Washington State Department of Ecology (Ecology) to protect water quality.

Comment: Suggest that it may be better to look at benthic monitoring in 24 or 28 days as opposed to 14 days.

Response: Ecology has selected the 14 day time period to measure benthic communities as an appropriately conservative measurement time period based on the tidal patterns and sampling logistics.

56. Dick Sheldon

Comment: Provides history and states that the growers have dumped millions of dollars satisfying Department of Ecology demands and that the required studies have changed nothing.

Response: Comment noted.

57. Don Gillies

Comment: Commented in support of the permit. Thinks the no-control option did not address the impact of not controlling the shrimp fully and should be elaborated on.

Response: Comment noted.

Comment: Thinks that the monitoring seems too aggressive and could reproduce the same results year after year.

Response: Ecology has developed a monitoring plan over the five year span of the permit to provide cost-effective monitoring. Ecology developed the first year of monitoring to provide the most information possible to be used to design the subsequent years of monitoring. Additional benthic analysis is being conducted every other year to provide a better time span for information collection. We agree that collecting the same information every year may be redundant. Hence the every other year approach. Water Quality data is being collected every year of the permit. Monitoring the effects of pesticide application needs to be completed on a regular basis.

Comment: Believes that there should be further investigation regarding the theory that the sediments in southern Willapa Bay are true.

Response: Ecology agrees.

Comment: Would like everyone to be aware of the economic impact the shellfish industry has in Pacific County and Grays Harbor and that this is taken into account when decisions are made regarding the permit and the sediment impact zone evaluations.

Response: Comment noted. Refer to FEIS 2.6.

58. Kathleen Nisbet Moncy
Comment: Urges people to take a look at the economic impact that the loss of shellfish farming would have on Pacific County and the people that exist in it.

Response: Comment noted. Refer to FEIS 2.6.

Comment: Support of the issuance of the permit for shellfish farmers to be a viable part of a sustainable community, the environment, and the ecosystem in which they farm.

Response: Comment noted.

59. Westin Taylor
Comment: Discusses the economic value of shellfish farmers and the jobs that they provide.

Response: Comment noted.

60. Eric Petit
Comment: Discusses the need to have a chemical to control burrowing shrimp in order to sustain his farm and the people that work there. States that without a chemical to control burrowing shrimp what he has seen built up will go away.

Response: Comment noted.

61. Fritzi Cohen
Comment: Concern for the water in Willapa Bay, the oysters, and the people who consume these oysters, due to chemicals within Willapa Bay.

Response: Comment noted.

62. Brady Ingvall

Comment: Provides a history of the Burrowing Shrimp Committee, some of the methods tried to control burrowing shrimp, and the decision to use carbaryl.

Response: Comment noted.

Comment: Issuance of the permit would be a net positive, and not a negative.

Response: Comment noted.